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“UkrSGRI”

STATE GEOLOGICAL MAP OF UKRAINE

Scale 1:200 000

CARPATHIAN SERIES
MAP SHEET M-35-XXV (IVANO-FRANKIVSK)

EXPLANATORY NOTES

Editors: G.D.Dosyn, Yu.M.Veklych
Expert of Scientific-Editorial Council: V.V.Kuzovenko, SE "Zakhidukrgeologia"
English Translation (2008): B.I.Malyuk


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In the work, the geological data are summarized based on results of extended geological studies in the map sheet M-35-XXV (Ivano-Frankivsk) in the scale 1:200 000 conducted over 1999-2005. The Explanatory Notes contain description of stratigraphic units, tectonics of the region and history of its geological development as well as mineral resources and regularities in their distribution. In specific sections the general descriptions for geomorphology, relief-forming processes, hydrogeology and ecological state of geological environment are given; the Annexes include the lists of mineral deposits and occurrences as well as geological and archeological landmarks known over the map sheet territory.

The work is devoted to the wide range of specialists related to the geological sciences as well as businessmen dealing with mineral exploration and exploitation.

The set of maps can be used in the course of planning the geological exploration works in Carpathian region.

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Abbreviations used in the text

TC[I]T – Trans-Carpathian [Internal] Trough
GM-50 – Geological Mapping in the scale 1:50 000
EGSF-200 – Extended Geological Study of the Fields in the scale 1:200 000
GEE – Geological Exploration Expedition
SEP – Standard [vertical] Electric Profiling
IP – Induced Polarization
Derzhgeolkarta-200 – the State Geological Map in the scale 1:200 000
NAS - National Academy of Sciences of Ukraine
TAC – top admissible concentration
TAL – top admissible level
UISC – Ukrainian Inter-Ministry Stratigraphic Committee
OGA – Oil-Gas-Bearing Area
SSU – the State Standard of Ukraine
BCP – bulk contamination parameter

Drill-hole name abbreviations used in graphic supplements and explanatory notes to the map sheet M-35-XXV (Ivano-Frankivsk)

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INTRODUCTION

The territory of map sheet M-35-XXV (Ivano-Frankivsk) is defined by geographic coordinates 48°40'-49°20' N latitude and 24°00'-25°00' E longitude. In the administrative respect, most part of studied area belongs to Ivano-Frankivska Oblast. North-western and north-eastern parts (up to Dnister River valley) belong to Lvivska and Ternopilska Oblasts respectively. Major inhabited localities include Ivano-Frankivsk city – Oblast’s administrative center, the towns Galych, Dolyna, Kalush, Nadvирна – area centers connected with railroads and paved roads, and other inhabited sites which are connected by paved and dirt roads.

By the landscape features, the map sheet territory is divided into three parts. The south-western one differs in low- and medium-mountain relief of Ukrainian Carpathians. Its border with fore-maintains is expressed in clear erosion-tectonic ledge up to 200 m high. The landscape features in Carpathians are tightly related to geology reflected in the latitudinal-zoned setting of orographic elements. The system of sub-parallel ridges (Stinka, Grynkiv, Yavornyk, Sekhls) is oriented conformably to the strike of tectonic structures. The watershed altitudes change from 650 m close to the external margin of Carpathians, to 1350 m at the far south-western part of the territory. Maximum altitude of the territory – Verkhniy Sekhls Mountain attains 1356 m. The dense network of diverse-order streams does extensively erode the surface making combination of the flat watershed areas and deep steeply-banked valleys.

In the central part of the map sheet, from Carpathians to the Dnister River valley, the extensive hilly relief is developed with altitudes 300-500 m and relative heights up to 300 m. Here, the landscape comprises mainly continuous range of fluvial (alluvial and gully) terraces with the major one provided by Dnister River. Some flat watersheds observed along Carpathians comprise relic terraces of this river of Pliocene and Eo-Pleistocene age. Each right-bank-side Dnister River branch however does have own terrace complex which renews terrace relief of Dnister River. Numerous slides are developed over the valley slopes. In the Dnister River right-bank-side are also developed relatively large geomorphologic forms expressed in trough-like depressions known as low-lands – Kaluska, Ivano-Frankivska (Stanislavska), Striyska. They are formed with low terraces of Bystrytsya-Nadvirynska, Bystrytsya-Solotynska, Limnytsya, Svirzh, Stry rivers.

The north-eastern part of the territory, in the Dnister River left-bank-side, belongs to the margin of Podilske plateau which is also known as Opillya. Here the Dnister River valley comprises the major relief element. In the map sheet boundaries it is of trough-like asymmetric profile. The valley bottom is formed by the flood-land and two first over-flood terraces. The remnants of higher Middle Quaternary terraces are being traced over the right slope. In the left slope, the higher terraces are completely lacking and relief is extensively cut by trough-like valleys of Svirzh, Gnyla Lypa, Naraiivka and Gorozhanka rivers. The watersheds of these streams are mainly extended in the northern direction with flat surface cut by numerous gullies into separated hills comprising erosion remnants. Altitudes vary in the range 300-370 m and cutting depth of major streams attains 100 m.

The major river in Fore-Carpathians – Dnister – crosses over the territory and provides the border of its central and north-eastern parts. Right Dnister branches – Striy, Svirch, Limnytsya, Bystrytsya-Nadvirynska, Bystrytsya-Solotynska, are water-rich, with well-developed terraced valleys. Left branches do have low-terrace complex only. River network density is 0.7-1.4 km per square kilometer.

Climate is moderate-continental, with notable difference in the fore-mountains and mountains. January average temperature in the plain is -5°C, in the mountains -7°C; in July, these are +20°C and +15°C respectively. Annual average temperature is +10°C. Wind mode depends on directions of valleys and inter-river areas. In the winter, south-western wind direction predominates, and in the summer – western and north-western ones. In the fore-mountains amount of precipitates is 300-800 mm/year, in the mountains – 1000-1500 mm/year. Precipitate minimum falls to October-November, and maximum, mainly with rainfalls – to June-August.

The soil cover is developed over aeolian-eluvial (out-terrace inter-river areas, surface flattening), alluvial (terraces) and eluvial-deluvial (slopes) sediments. In the fore-mountains, mainly over aeolian and eluvial loams, the non-gruss and brown-earth, meadow, meadow-swamp and swamp soils are developed. On the steep (40-45°) slopes the soil cover is mainly lacking. The plants include mixed forests. In the mountains the vertical zoning is typical. In the range of 400-1000 m of altitude, the leaf forests are developed including beech, hornbeam and conifers. In the underbrush, raspberry, blackberry, hips are growing. The upper range (above 1000

1 In Ukraine, the “Oblast” comprises major territorial administrative unit. In total, Ukraine includes 25 Oblasts plus the Crimean Autonomic Republic. Each Oblast consists of some higher-order administrative units hereafter entitled as “area” (Translator note).
m) is formed with fir forest. In the fore-mountains, the oak, hornbeam, birch, asp, linden, wild cherry, in places fir and pine-tree are developed.

The country population is mainly composed of Ukrainian and stays mainly in the plain where population density exceeds 100 people per 1 km², in the mountains – 50 people per 1 km². The major business of inhabitants is agriculture. Industrial objects are concentrated in towns Ivano-Frankivsk, Kalush, Dolyna, Burshyn. By amount of bulk production (in Soviet times), the food industry was ranked first, then light industry, machinery, metal-processing. Economy of the mountain inhabitants is tightly related to the wood. It is being developed and primary processed but is strongly decreased in amount nowadays. In Dolyna town and Broshniv, Perepinske, Dzvynych villages the small wood-cutting and processing plants are in production.

In the studied territory, in the most extent in comparison to other areas of Western Ukraine, the major mineral deposits are concentrated which have been being mined for many years – natural gas (Dashavske deposit), oil, potassium salts (Kaluske deposit), native sulfur (Podorozhyanske deposit), as well as raw construction materials (gypsum, limestones, clays, sands, sandstones, gravel), of which significant part is out of production nowadays. Water supplying for inhabited locations and industrial objects is being mainly provided from the water-bearing complex confined to the flood-land and low-terrace alluvial sediments.

The territory encompasses the fragments of some major regions quite different in their geological history: the south-western margin of ancient Eastern-European Platform, the north-eastern part of young Western-European Platform, Fore-Carpathian Trough and Folded Carpathians. In the fore-mountains the natural outcrops of pre-Quaternary sediments are observed in the steep slopes of Dnister River and its major branches. At the watersheds these rocks are exposed in the quarries and are intersected by numerous drill-holes. The rocks of lower levels of sedimentary cover and basement are intersected by the single parametric boreholes. The mountains exhibit single-level structure. Here numerous natural outcrops are being traced mainly along stream courses and in places are observed in the narrow watersheds and steep slopes.

The principal information, provide the ground for design of M-35-XXV map sheet of Derzhgeolkarta-200 and explanatory notes, received from reports on geological mapping in the scale 1:50 000 performed by various authors in 1963-1990, as well as results of extended geological study over the territory in the scale 1:200 000, and Miocene salt-bearing molassa in the Ukrainian Peredkarpatty. Laboratory studies (spectral, spectral-gold-measuring, chemical, mineralogical analyses) during EGSF-200 were carried out by laboratories of Lvivska and Zakarpatska GEE and Crimean branch of UkrSGRI. Paleontological studies (micro-fauna and nano-plankton determinations) were done by specialist from Lvivske branch of UkrSGRI and Kyiv National University. Report on EGSF-200 was discussed and approved with the best score at the meeting of Scientific-Editorial Council of the State Geological Survey of Ministry of Environment Protection of Ukraine on October 12, 2005, protocol No. 160.

In the map preparation to publishing all remarks were taken into account provided by the report reviewer and then Derzhgeolkarta editor – G.D.Dosyn. The control-adjusting studies and field works were performed at the border of present map sheet with adjacent ones which have confirmed reliability of maps designed over EGSF-200. The “Geological map and map of mineral resources of pre-Quaternary units” is compiled by V.O.Vashchenko, S.M.Turchynova, I.I.Turchynov. The “Geological map and map of mineral resources of Quaternary sediments” is compiled by V.O.Vashchenko. He has drawn up “Introduction”, sections 1-5, and “Conclusions” of explanatory notes; S.M.Turchynova and I.I.Turchynov are the authors of sections 7 and 8, G.G.Polikha – sections 6 and 9. Text supplements are prepared by T.L.Evtushko and T.P.Lyakhova. Graphic materials and digital version of explanatory notes are prepared by V.O.Vashchenko and I.I.Turchynov. Scientific edition is provided for:

1. “Geological map and map of mineral resources of pre-Quaternary units” and most parts of explanatory notes - candidate of geological-mineralogical sciences G.D.Dosyn.

1. GEOLOGICAL STUDY DEGREE OF THE AREA

The map sheet territory comprises the counterpart of Western Ukrainian region which encompasses External Carpathians, Fore-Carpathian Trough, and margin of Eastern-European Platform. Since the area is rich in mineral resources including oil, gas, potassium salts etc., as compared to other Fore-Carpathian areas, it was extensively studied by several generations of geologists and geophysicists.

Geological studies in the late XIX – early XX centuries are summarized in the geological map in the scale 1:75 000 of “Galician Atlas” (1887-1907). In the studied area, designing of geological maps for particular sites and respective explanatory notes were performed by A.Alt, F.Benysh (1887), R.Zuber (1888), E.Dunikovskiy (1891), V.Teisseire (1900-1906), Ya. Lomnytskiy (1905). These authors created the basics for stratigraphy of molassa in Fore-Carpathians and flysch in Carpathians. And as far back as 1910-1930 geologists have applied the nappe concept of Carpathian structure in the given area, distinguishing some tectonic thrusts composed of the flysch and molassa sediments.

Since 1919 the large-scale (1:25 000 – 1:50 000) geological mapping and prospecting-exploration works have been being conducted in the region under leadership of V.Teisseire, B.Buyalskiy, E.Jablonskiy, G.Syzankur and others. Results of these works were released in the geological map of Eastern Carpathians in the scale 1:200 000 under leadership of K.Tolvynskiy (1927). In 1939, under edition of K.Tolvynskiy, the new map in the scale 1:200 000 was published covering Carpathians, Fore-Carpathians and platform margin. Various and diverse by content materials of geological studies over pre-war period were examined and re-appraised in details in the monograph “Geology and mineral resources in western regions of Ukraine” published in 1941 under edition of N.A.Bykhover.

In 1945, M.R.Ladyzhenskiy had designed the geological map in the scale 1:25 000 for the area of salt-bearing molassa in Fore-Carpathians and northern structures of External Carpathians. Later on, in monograph [31], this author had also provided detailed description of Fore-Carpathian Trough.

In 1946-1949 the Carpathian Expedition of Moscow Geological Exploration Institute under leadership of O.O.Bogdanov had carried out mapping in the scale 1:200 000 for Eastern Carpathians and Fore-Carpathian Trough. Specifically, O.V.Yuferev and D.P.Naydin were authors of maps for the sheet M-35-XXV (Stanislav). Results of medium-scale mapping were summarized in the book “Geology and mineral resources of Eastern Carpathians” (1953).

During after-war works, Fore-Carpathian Trough was established as the syncline-like structure where V.I.Slavin [41] distinguished three portions – platform and orogenic limbs and central part. However, most authors that time have accepted concept of O.O.Bogdanov [4] who had defined two parts in Fore-Carpathian Trough – the external, developed over platform basin, and the internal, set up over geosyncline flysch substratum. These authors disclaimed concept of Carpathian nappe tectonics including Fore-Carpathian area, which was supported by O.S.Vyalov and leading scientists of Lviv. That time so called “fixists” thoughts were accepted and these ideas have been reflected in the geological maps in the scale 1:200 000. And it was only in 1960-1970, upon results of deep drilling and geophysical data receiving, when almost all authors have acknowledged the nappe structure of Carpathian region.

Since 1949, the teams of “Lvivnaftogazrozdivka” and UkrSGRI had performed in the map sheet territory the special geological mapping in the scale 1:25 000 and 1:50 000 aiming discovery of oil-gas-bearing structures. These works were headed by O.L.Artsabka, V.S.Burov, V.V.Glushko, G.F.Kozytskiy, A.L.Kryvin, Ya.O.Kulchytskiy, V.M.Utrobin, and others. Based on generalization of special mapping results and data from targeted drilling geophysical works, V.V.Glushko and V.G.Korneeva have published in 1953 the geological map of the north-eastern slope of Carpathians and Fore-Carpathian Trough in the scale 1:50 000.

In the beginning of 60th, the works have commenced in the region related to preparation of the “State Geological Map of USSR” in the scale 1:200 000. In this relation, in 1961-1962 Lvivska GEE of exploration trust “Kyivgeologia” under leadership of N.E.Stril’kova had carried out extended geological study and hydrogeological mapping in the scale 1:200 000 and 1:50 000 aiming discovery of oil-gas-bearing structures. These works were headed by O.L.Artsabka, V.S.Burov, V.V.Glushko, G.F.Kozytskiy, A.L.Kryvin, Ya.O.Kulchytskiy, V.M.Utrobin, and others. Based on the results of special mapping works, V.V.Glushko and V.G.Korneeva have published in 1953 the geological map of the north-eastern slope of Carpathians and Fore-Carpathian Trough in the scale 1:50 000. In the beginning of 60th, the works have commenced in the region related to preparation of the “State Geological Map of USSR” in the scale 1:200 000. In this relation, in 1961-1962 Lvivska GEE of exploration trust “Kyivgeologia” under leadership of N.E.Stril’kova has carried out extended geological study and hydrogeological mapping in the scale 1:200 000 for the map sheet M-35-XXV and new data were received on geology of this territory [128]. The “State Geological Map of USSR” in the scale 1:200 000, designed by N.E.Stril’kova and published in 1972 under edition of V.V.Glushko, is based both on previous studies results and the data of complex geological mapping conducted by the map authors. Backbone of the published map included geological map in the scale 1:100 000 for the north-eastern slope of Carpathians and Fore-Carpathians designed under leadership of V.V.Glushko. This is why the thoughts of leading Carpathian geologists from Lviv on the nappe structure of Carpathians were reflected in the map and explanatory notes. However, tectonic zonation of
the area was mainly established on the ground of ideas of geologists from Moscow geological school, while stratification of sedimentary sequence was based on the scheme of Miocene sediments in Fore-Carpathians not consented between geologists.

In 1963-1974 the teams of Lvivska GEE of exploration trust “Kyivgeologia” and complex research group of trust “Lvivnaftagrozdivka” have conducted in the area the complex geological mapping in the scale 1:50 000 under leadership of I.P.Mochalin [114], A.M.Denysevich [83], V.O.Vashchenko [63], P.G.Lazarenko [110], L.S.Gerasimov [77]. These studies were accompanied by significant amount of prospecting drilling and various sampling.

Simultaneously to the geological mapping, a huge amount of studies were performed in the area by various organizations with regard to mineral resources. Drilling for oil and gas was conducted by the trust “Lvivnaftagrozdivka” under leadership of A.A.Ilyina, V.N.Muravetskiy, A.V.Zenkina, V.N.Utrobin, V.I.Yushkevych, and others. Prospecting works for hard minerals were carried out by Lvivska GEE. Rock salt prospecting was headed by M.M.Belskikh, A.I.Fedchenko; potassium salt – K.B.Donchenko, M.A.Klimov, V.M.Stupnitskiy, O.P.Mishchenko, V.P.Telegin, and others. Prospecting works for native sulfur were conducted under leadership of Z.O.Burlayev, I.I.Aleksenko, G.T.Saksev, S.M.Shchedenko, V.I.Dovgan. Studies of manganese mineralization were performed by M.P.Kovalyova. Prospecting-exploration works for construction materials were headed by O.E.Biryulyov, L.V.Biryulyova, V.A.Murogin, V.N.Khanov and others. Claydite raw materials were prospected by V.V.Khokha, M.Z.Kunik, V.I.Koydan; sands and sand-gravel mixtures – G.I.Osadchiy, M.M.Kovshovikov, N.T.Shehyryba; gypsum for cement manufacturing – R.M.Dragushchak; marls for cement manufacturing – V.V.Khokha. Carbonate raw materials for lime manufacturing and application in sugar industry were studied by M.P.Rybak.

All prospecting and mapping works were preceded and forwarded by geophysical studies. Gravimetric works performed by L.E.Filshhtynskyi (1968) and V.Ya.Bilichenko (1976, 1977, 1987) are most systematic and cover entire territory of the map sheet with regular network 500 by 500 m in size and include 0.5 mG maps of Ag in Bouger reduction with density of intermediate layer 2.3 and 2.67 g/cm², the maps of local residual anomalies in the scale 1:50 000, tectonic schemes for Mesozoic and Paleozoic units in the scale 1:200 000. However, some maps of Bouger anomalies with variable actual density of intermediate layer, as well as maps of local anomalies designed in various years with diverse averaging radius do not match one another. Structure of basement and sedimentary cover was studied by gravi-magnetic data, major fault zones were defined and traced, as well as elevated and subsided blocks distinguished. Schematic map of tectonic elements in pre-Alpine tectonic floor is designed in the scale 1:200 000 for Fore-Carpathian Trough and adjacent part of Carpathians on the ground of gravity survey and seismic data taking into account deep drilling results (V.Ya.Bilichenko, 1987, 1993). It was defined that pre-Alpine surface with altitudes -2000 … -9500 m is plunged in the south-western direction by the system of normal faults.

With the seismic survey conducted by M.M.Charnosh (1992, 1993), P.M.Sheremeta (1992), V.V.Gnevush (1996, 2002, 2003) using methods of reflected waves or joint deep point in the scale 1:50 000, almost entire territory of Sambirska and Boryslavsko-Pokutska zones of Fore-Carpathian Trough is studied. In Bilche-Volytska zone of the Trough theses works were carried out mainly over some fields and along some profiles. In the south-western margin of Eastern-European Platform seismic survey is almost not conducted. V.I.Antypov, S.I.Subotin and others have examined geophysical data obtained during oil and gas exploration works. In 1998-2001 research group of Western-Ukrainian GEE has examined and re-interpreted seismic data in Carpathian region and Volyno-Podolian margin of Eastern-European Platform.

Airborne magnetic survey in the scale 1:50 000 in the margin of Eastern-European Platform, Fore-Carpathian Trough and External Carpathians is conducted in 1975-1979 by the airborne magnetic group of the complex geophysical expedition of the SE “Pivnichukrgeologia”.


Before 1939, hydrogeological studies were carried out in the oil deposits only. Brief notes on geological conditions and features of underground waters are contained in the works of K.Tolvynskyi, O.Vyshysnyi, K.Katz and others. Over that times (1906-1911, 1930-1939) the searching for sources of water supplying for Stanislav (now Ivano-Frankivsk) were conducted. Later on, the regular studies were performed aiming provision of new water supplying sources. Over first years after the war hydrogeology of the territory and design of hydrogeological maps were carried out by the division of Carpathian Expedition of Moscow Geological Exploration Institute under leadership of A.M.Ovchynnikov, and then division of Lvivska GEE under leadership of N.E.Strikova [47]. Description of underground waters in natural gas, oil, potassium salt and sulfur deposits is
contained in the works of L.G.Tkachuk, I.A.Kvalvaser, V.Z.Zakharov, L.P.Myshkin, G.A.Goleva, A.F.Romanyuk, T.M.Seletskiy, A.E.Babynets, and others. Almost permanent works on prospecting for inhabited locations water supplying sources and mineral waters are being conducted by Lvivska GEE. In 1992 is has completed studies on perspective appraisal the mineral water resources in Ivano-Frankivska and Chernivetska Oblasts.

The problems of stratigraphy and structure of sedimentary sequences in the region were studied by specialists from various research institutions who provided key contributions to the creation of stratigraphic schemes approved in 1993 by UIISC. Concerning territory under consideration, these include first of all the works of S.I.Pasternak, V.A.Khyzhnyakov, Ya.M.Sandler, O.S.Vyalov, Yu.M.Senkovskyi, V.O.Shakin, Ya.O.Kulchytskiy, M.R.Ladyzhenskiy, V.M.Utrobin, and others.

The former approaches to the study of Late Cenozoic continental sediments were essentially different from the modern ones. The sediments have been being subdivided in other fashions and with fewer details. In most cases Quaternary sediments were divided into four counterparts – Lower, Middle, Upper Pleistocene and Holocene. Yu.Polyanskiy had subdivided Upper Cenozoic sedimentary cover along Dnister River valley for the first time. Over there, he had distinguished five Pleistocene and one Pliocene terraces, as well as three loess horizons (Late Reesean, Early and Late Vurmian) and two former soils in between. The modern subdivision of Quaternary sediments is currently being performed under the scheme developed by M.F.Veklych and approved by UIISC.

S.S.Kruglov had contributed much to the solutions of regional and local problems. In his monograph devoted to the geodynamics of Carpathians [28], this region study results over many years are summarized. In explanation of nappe formation mechanism he had used the concept of pulsing Earth development as the alternative to plate tectonics. And for the system of Carpathian nappes S.S.Kruglov had suggested the new term – Carpathian Mega-Nappnorium comprising English expression of the term “Mega-Thrust” introduced in 1980 by V.S.Burov, V.V.Glushko and G.D.Dosyn.

Significant geomorphological studies in Carpathian region commenced in the first half of last century. Based on analysis of neo-tectonic motions, B.Sviderskiy (1932, 1934) had concluded that extensive Carpathian relief transformation occurred at the boundary of Pliocene and Pleistocene. The works of G.Teisseire (1928-1938) were devoted to the comprehensive and detailed study of geomorphology in Fore-Carpathians. Over there, he had distinguished some denudation levels: low – 30-50 m, high (“Loeva level”) – 50-150 m, and highest (200-250 m). According to this author, formation of “Fore-Carpathian pene-plain” (“Loeva level”) took place in Pliocene. Despite of the wrong conclusion of G.Teisseire on pene-plain development in Fore-Carpathians, his works are still highly valuable. This first of all concerns his studies on development and reworking of hydrographic network in Pliocene and Pleistocene under influence of neo-tectonic motions.

In the first after-war years the well-known works of G.Alferyev (1948), V.Butsura (1946), K.Gerenchuk (1947), N.Ermakov (1948), and P.Tsys (1951, 1952) had appeared on geomorphology of Carpathians and Fore-Carpathians.

The works of I.D.Gofshtein (1962, 1964, 1995) were important for the studies of geomorphology and neo-tectonics of Carpathians and Fore-Carpathians; these works concerned issues of relief history, problem of flattening surfaces, detailed analysis of river valleys and their terraces, river network re-arrangement etc.

Over the 60-70th of the last century all authors dealt with the studies of geomorphology in the region, in the mapping of terrace levels have accepted the scheme of I.D.Gofshtein who distinguished seven over-flood terraces in Fore-Carpathians. And later on, upon development of more substantiated scheme of M.F.Veklych for terrace relief in Middle Prydnistrovya [7, 8], where sixteen terrace levels are distinguished, all mapping geologists have accepted this scheme. However, geomorphologists from scientific institutions dealing with geomorphology of Fore-Carpathians, do still prefer recognition of seven terrace levels only (Ya.Kravchuk, 1999).

The fundamental work of V.P.Palienko [36] is devoted to the problems of recent geodynamics and its reflection in the relief of Ukraine including the studied area.

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2 “Loeva level” – surface of ancient pra-Dnister terrace which stratotype is known nearby Loeva village, Nadvimyanskiy area. The term was suggested by G.Teisseire.
2. STRATIFIED UNITS

The territory of map sheet M-35-XXV (Ivano-Frankivsk) in tectonic respect encompasses the fragments of some first-order geotectonic domains, specifically: ancient Eastern-European and young Western-European platforms, External Carpathians, and Fore-Carpathian Trough. Each of these domains by sedimentation conditions essentially differs one from another and this is reflected in the patterns of their constituting sedimentary sequences. Inside these major structures, by column lithology of even-aged units and tectonic structure, additional litho-tectonic zones (LTZ) are distinguished (see “Tectonic scheme in the scale 1:500 000”).

Upper Proterozoic – Paleozoic sedimentary sequence in the ancient platform margin was forming under conditions of transitional regime from epi-continental basin through continental slope towards continental foothill. This had caused sharp changes in lithology and thickness of even-aged sediments. In the south-western margin of ancient Eastern-European Platform, within geographic coordinates of the former Eurasian plate, almost permanent formation of peri-cratonic trough (Dniesterkiy) had occurred over Paleo-Archean crystalline basement; in the trough, the terrigenous-carbonate sequence which at present constitutes Kovel’sko-Khotynska LTZ (see “Litho-tectonic zonation in the scale 1:500 000” and “Legend to the map of pre-Quaternary sediments”) was depositing in Vendian – Early Devonian times. Peri-craton closure is marked with fore-mountain trough formation (Boyanyetskiy) filled with Lower Devonian continental red-coloured rocks. Paleozoic column in the ancient platform margin is capped with Middle and Upper Devonian sediments developed in Roztotska LTZ, as well as Lower Carboniferous sediments developed in Lvivsko-Volynska LTZ, in Lvivskiy Paleozoic Trough (see “Legend to the map of pre-Quaternary sediments”).

In the north-eastern margin of Western-European Platform, in the map sheet boundaries, three litho-tectonic zones of age-different, Late Baikalian and Caledonian, consolidation are distinguished. The first one is comprised of Roztotska LTZ which is traced from the north quite conventionally, just by geophysical data. Zones of Caledonian tectonic complex – Kokhanivska LTZ and Rava-Ruska LTZ – are traced by some parametric boreholes. The first zone is composed of medium-dislocated Lower Cambrian rocks, and the second one – of weakly-dislocated Lower Devonian rocks. During Caledonian tectogenesis Paleozoic sediments of Western-European Platform had undergone folding and lateral displacement towards ancient platform providing folded envelope (epi-orogenic zones) of the latter. Present zone boundaries in the young platform are thought to be tectonic. Upper Jurassic carbonate-targiocenous rocks fill up the south-eastern part of major Jurassic depression – Striyskiy Trough which is superimposed with stratigraphic and angular discontinuities over Paleozoic sediments of both platforms. Some LTZs are distinguished in the limits of Striyskiy Trough, of which two ones – Rudkivska and Sokalska are traced by drill-holes in the map sheet. Cretaceous system, which overlies Upper Jurassic rocks with stratigraphic discontinuity, does also fill up major structure – Lvivska Cretaceous Mold. By patterns of lithotypes in the upper part of Late Cretaceous column in the studied area, three LTZs are distinguished in the limits of this mold – Verbizka, Zhuravnenska and Lukvynska.

The thick sedimentary complex of External Carpathians and internal part of Fore-Carpathian Trough is composed of typical flysch and molassa sediments of Late Cretaceous – Early Miocene age. By lithological varieties, the fragments of the following first-order LTZs are traced in the map sheet limits – Skybova, Boryslavsko-Pokutskaja and Sambirskaja. Sediment deposition in these zones occurred far away from their present geographic position which these units had occupied during Alpine tectogenesis when they had been being transformed into the nappe tectonic structures.

The external (allochthonous) part of Fore-Carpathian Trough – Bilche-Volytska zone – does actually comprise the platform margin, buried by the system of normal faults and flexures and under-thrusted beneath Carpathian Mega-Thrust, and composed of thick Middle-Late Miocene carbonate-targiocenous sequence. Considerable lithotype differences in sediments of this age had provided the ground to distinguish the separate Zakhidnopodilska LTZ (see “Litho-tectonic zonation in the scale 1:500 000” and “Legend to the map of pre-Quaternary sediments”).

Structure of the platform margin and external part of the trough includes important tectonic-erosion elements such as buried Kolomiyska and Molodyntska paleo-valleys; their formation most probably occurred in Paleogene. In the Middle-Late Miocene times they were filled with thick carbonate-targiocenous sequence (see contours of these paleo-valleys in “Tectonic scheme in the scale 1:500 000”).

Almost entire territory of the map sheet is blanketed by thin Upper Miocene – Pliocene and mainly Quaternary continental sediments.

The boundaries of almost all stratigraphic subdivisions in the margin of Eastern-European Platform and External zone of Fore-Carpathian Trough are stratigraphically discontinuous with time-considerable continental
interruption in sedimentation. Each sequence lies over eroded surface of underlaying age-different rocks. Sediment thickness depends on the underlaying relief patterns. In addition, entire thick sedimentary cover, gently monoclinally plunging under the angles 4-5° towards Carpathians, is cut by series of normal faults and flexures. By these breaks, some large blocks are set down to various depths. Each of numerous drill-holes in the area does intersect the top and bottom of each stratigraphic subdivision (suite) at the depths from +50 m to -3500 m. And concerning the stratified units in the nappe-fold structures of Carpathians and Internal zone of Fore-Carpathians Trough, their top and bottom altitudes are out of the question at all. This is why the authors do not set forth such information in description of stratigraphic subdivisions. All fact sheet data on the map sheet M-35-XXV (drill-holes, observation points, analytic results) are contained in the electronic database supplementary to respective report on EGSF-200 [67].

Study degree of stratigraphic subdivisions is irregular. The lower part of sedimentary cover in the platform margin is weakly studied by sole deep boreholes drilled both inside the map sheet and adjacent areas. Description of Mesozoic and Cenozoic sediments is based on the data from own and previous field studies of natural outcrops and results of numerous boreholes drilled in various purposes.

Stratigraphic subdivision of rocks developed in the area is done in compliance with the “Stratigraphic Code of Ukraine” approved by the National Stratigraphic Committee of Ukraine on April 2, 1997, the “Correlation Stratigraphic Schemes” approved by UISC on May 25, 1993, the “Legend to the geological map in the scale 1:200 000, Carpathian series map sheets” approved by Scientific-Editorial Council of SGSU on June 22, 1995, and the “Legend to the State geological map of Ukraine in the scale 1:200 000, Volyno-Podilska series map sheets” approved by Scientific-Editorial Council of SGSU on November 15, 1995.

Description of stratified units and rocks indicated in the geological maps is given below from old to young ones.

### Stratigraphic scheme of Precambrian and Phanerozoic rocks in the map sheet territory

#### PHANEROZOIC

**Cenozoic era** (CZ)

- **Quaternary System (Q)**
  - **Holocene division (H)**
    - $\pi H$ – mud-volcano sediments
    - $t H$ – technogenic sediments
    - $b H$ – biogenic sediments
    - $e H$ – eluvial sediments
    - $a H$ – alluvial sediments

**Upper Pleistocene branch and Holocene division undivided (P_{III}-H)**

- $d z P_{III} H$ – deluvial-slide sediments
- $d P_{III} H$ – deluvial sediments
- $d c P_{III} H$ – deluvial-coluvial sediments
- $e d P_{III} H$ – eluvial-deluvial sediments

#### Pleistocene Division

- **Neo-Pleistocene (P)**
  - **Upper Neo-Pleistocene branch (P_{III})**
    - $v d, e d P_{III}$ – aeolian-deluvial and eluvial-deluvial sediments
    - $e d, v d P_{III}$ – eluvial-deluvial and aeolian-deluvial sediments
    - $a ^{1} P_{II} d s$ – Desnyanskiy ledge. Alluvial sediments of the first terrace
    - $v d P_{II} p c$ – Prychornomorskiy climatolith. Aeolian-deluvial sediments
    - $e d P_{II} d f$ – Dofinivskiy climatolith. Eluvial-deluvial sediments
    - $a ^{1} P_{II} v l$ – Vilshanskiy ledge. Alluvial sediments of the second terrace
    - $v d P_{II} b g$ – Buzkiy climatolith. Aeolian-deluvial sediments
    - $e d P_{II} v t$ – Vytachivskiy climatolith. Eluvial-deluvial sediments
    - $a ^{1} P_{II} t b$ – Trubizkiy ledge. Alluvial sediments of the third terrace
    - $v d P_{II} u d$ – Udaskyi climatolith. Aeolian-deluvial sediments
    - $e d P_{II} p l$ – Prylutskyi climatolith. Eluvial-deluvial sediments
Middle Neo-Pleistocene and Upper Neo-Pleistocene branches undivided (P₂₃-₃₃)
edP₂₃₃₃ – eluvial-deluvial sediments
evdP₂₃₃₃ – eluvial and aeolian-deluvial sediments

Middle Neo-Pleistocene branch (P₂₃)
a₄P₂₃ck – Cherkaskiy ledge. Alluvial sediments of the fourth terrace
vdP₂₃ts – Tyasminskiy climatolith. Aeolian-deluvial sediments
edP₂₃kd – Kaydatskiy climatolith. Eluvial-deluvial sediments
a₅P₂₃hd – Khadzhybeyskiy ledge. Alluvial sediments of the fifth terrace
vdP₂₃dn – Dniprovskiy climatolith. Aeolian-deluvial sediments
edP₂₃zv – Zavadivskiy climatolith. Eluvial-deluvial sediments
evdP₂₃ – eluvial and aeolian-deluvial sediments

Lower Neo-Pleistocene and Middle Neo-Pleistocene branches undivided (P₁₋₂₃)
evdP₁₋₃ – eluvial and aeolian-deluvial sediments

Lower Neo-Pleistocene branch (P₁)
edP₁ – eluvial-deluvial sediments
evdP₁ – eluvial-deluvial and aeolian-deluvial sediments
a₆P₁kn – Krukenytskiy ledge. Alluvial sediments of the sixth terrace
vdP₁tl – Tyligulskiy climatolith. Aeolian-deluvial sediments
vdP₁lb – Lubenskiy climatolith. Eluvial-deluvial sediments
a₇P₁de – Donetskiy ledge. Alluvial sediments of the seventh terrace
vdP₁sl – Sulskiy climatolith. Aeolian-deluvial sediments
edP₁mr – Martonoskiy climatolith. Eluvial-deluvial sediments
a₇P₁bk – Budatskiy ledge. Alluvial sediments of the eighth terrace
vdP₁pr – Pryazovskiy climatolith. Aeolian-deluvial sediments
edP₁sh – Shyrokynskiy climatolith. Eluvial-deluvial sediments

Eo-Pleistocene division and Lower Neo-Pleistocene branches undivided (E₋P₁)
edE-P₁ – eluvial-deluvial sediments
evdE-P₁ – eluvial-deluvial and aeolian-deluvial sediments

Eo-Pleistocene (E)
ed,EvdE – eluvial-deluvial and aeolian-deluvial sediments
a₈E₀ing – Nogayskiy ledge. Alluvial sediments of the ninth terrace
vdE₀il – Illichivskiy climatolith. Aeolian-deluvial sediments
edE₀kr – Kryzhanivskiy climatolith. Eluvial-deluvial sediments
vdE₀br – Berezanskiy climatolith. Aeolian-deluvial sediments

Pliocene and lower branch of Eo-Pleistocene division undivided (N₂₋E₀)
a₁₀N₂₃-E₀kz – Kyzylzharskiy ledge. Alluvial sediments of the tenth terrace
Neogene System (N)

Pliocene (N2)

Boryslavsko-Pokutska, Sambirska and Bilche-Volytska LTZs

\[ \text{edN2bv} \] – Beregivskiy climatolith. Eluvial-deluvial sediments
\[ \text{vdN2sv} \] – Siverskiy climatolith. Aeolian-deluvial sediments
\[ \text{edN2bd} \] – Bogdanivskiy climatolith. Eluvial-deluvial sediments

Upper Miocene – Pliocene undivided (N1-2)

\[ \text{N1:gg} \] – clayey-pebble sequence. Alluvial, aeolian-deluvial and eluvial-deluvial sediments

Miocene (N1)

Sarmatian regio-stage

Bilche-Volytska LTZ

\[ \text{N1ds} \] – Dashavskya Suite
\[ \text{N1ds}_2 \] – Upper Sub-Suite
\[ \text{N1ds}_1 \] – Lower Sub-Suite

Badenian regio-stage

Bilche-Volytska LTZ

\[ \text{N1ks} \] – Kosivska Suite
\[ \text{N1tr} \] – Tirasksa Suite
\[ \text{N1bg} \] – Bogorodehanska Suite

\[ \text{N1op} \] – Opilska Suite

Carpathian regio-stage

Sambirskya LTZ

\[ \text{N1bl} \] – Baliyska Suite

Bilche-Volytska LTZ

\[ \text{N1pv} \] – sandy-limestone sequence

Zakhidnopodilska LTZ

\[ \text{N1on+br} \] – Oncophore and Berezhanski layers combined

Otnangskiy regio-stage

Boryslavsko-Pokutska and Sambirska LTZs

\[ \text{N1st} \] – Stebnytska Suite

Egenburgskiy regio-stage

Boryslavsko-Pokutska LTZ

\[ \text{N1vr} \] – Vorotyshchenska Suite
\[ \text{N1pl} \] – Polyanytska Suite

Egerskiy-Egenburgskiy regio-stages

Skybova LTZ

\[ \text{N1ml3} \] – Menilitova Suite. Upper Sub-Suite
Oligocene – Miocene ($P_{3-N1}$)

Ombronskiy-Egerskiy regio-stages

Skybova LTZ

$P_{3-N1ml2}$ – Menilitova Suite. Middle Sub-Suite

Boryslavsko-Pokutsko LTZ

$P_{3-N1ml}$ – Menilitova Suite undivided

Paleogene System ($P$)

Oligocene ($P_3$)

Skybova LTZ

$P_{3ml1}$ – Menilitova Suite. Lower Sub-Suite

Eocene ($P_2$)

Eocene undivided ($P_2$)

Boryslavsko-Pokutsko LTZ

$P_{2pg}$ – sandstone-clayey sequence

Skybova and Boryslavsko-Pokutsko LTZs

Bystrytskiy regio-stage

$P_{2bs}$ – Bystrytska Suite

Vygodskiy regio-stage

$P_{2vg}$ – Vygodskia Suite

Manyavskiy regio-stage

$P_{2mn}$ – Manyavska Suite

Paleocene ($P_1$)

Striyskiy-Yamnenskiy regio-stages

$P_{1jm}$ – Yamnenska Suite

Paleocene – Eocene undivided ($P_{1-2}$)

Skybova LTZ

$P_{1-2p}$ – sandstone sequence

Boryslavsko-Pokutsko LTZ

$P_{1-2av}$ – aleurite-limestone sequence
Cretaceous System – Lower Paleocene (K2-P1)

Coniacian – Maastrichtian stages + Lower Paleocene

Skybova and Boryslavsko-Pokutska LTZs

K2-P1st – Striyska Suite

Mesozoic eratheme (MZ)

Cretaceous System (K)

Upper Division (K2)

Santonian – Campanian stages

Bilche-Volytska LTZ

K2ap – argillite-sandy sequence

Verbizka LTZ

K2yr – Verbizka Suite

Zhuravnenska LTZ

K2žr – Zhuravnenska Suite

Lukvynska LTZ

K2lk – Lukvynska Suite

Turonian – Coniacian stages

K2db – Dubovetska Suite

K2db1 – Lower Sub-Suite

K2db2 – Upper Sub-Suite

K2vi – layers of inocerame limestones

Lower-Upper divisions (K1-2)

Cenomanian-Turonian stages

K2vi – layers of inocerame limestones

K2vi – layers of inocerame limestones

K2vi – layers of inocerame limestones

K2vi – layers of inocerame limestones

Albian-Cenomanian stages

Zakhidnopodilska LTZ

K1-2nz – Nezvyska Suite

K1-2nz – Nezvyska Suite

K1-2nz – Nezvyska Suite

Lower Division (K1)

Albian-Turonian stages

Skybova LTZ

K1-2gl – Golovynska Suite

Barremian-Albian stages

Skybova LTZ

K1sp – Spaska Suite
Jurassic System (J)

Upper Division (J₃)

Tithonian stage

Rudkivska LTZ

J₃nž – Nyzhnivska Suite

Sokalska LTZ

J₃nž – Nyzhnivska Suite

Kimmeridgian stage

J₃rr – Rava-Ruska Suite

Oxfordian stage

J₃rd – Rudkivska Suite

J₃sk – Sokalska Suite

Paleozoic eratheme (PZ)

Carboniferous System (C)

Lower Division (C₁)

Visean stage

Lvivsko-Volynska LTZ

C₁ol+us – Oleskvivska, Vyvnivska, Nesterivska, Volodymirsvka, Ustlyuzka suites combined

Devonian System (D)

Upper Division (D₃)

Frasnian-Famennian stages

Roztotska LTZ

D₃ug – Chervonogradska Series

Middle – Upper divisions (D₂₃)

Eifelian-Frasnian stages

D₂₃zu – Zakhidnoukrainska Series

Lower Division (D₁)

Lochkovian-Emsonian stages

Kovelsko-Khotynska LTZ

D₁dn – Dnisterska Series
Lochkovian stage

*Kovelsko-Khotynska and Rava-Ruska LTZs*

$D_{tv}$ – Tyverska Series

*Silurian System (S)*

Upper Division ($S_2$)

Pridolian stage

*Kovelsko-Khotynska LTZ*

$S_{sk}$ – Skalska Series

Ludlowian stage

$S_{ml}$ – Malynovetska Series

Lower - Upper divisions ($S_{1,-2}$)

Wenlockian-Ludlowian stages

*Kovelsko-Khotynska LTZ*

$S_{jr}$ – Yaruzka Series

Rava-Ruska LTZ

$S_{gk}$ – clayey-carbonate sequence

*Ordovician System (O)*

Middle – Upper divisions ($O_{2,3}$)

Karadocian-Ashgylian stages

*Rava-Ruska LTZ*

$O_{ml}$ – Molodovska Series

*Cambrian System (Є)*

Middle – Upper divisions ($Є_{2,3}$)

*Kovelsko-Khotynska LTZ*

$Є_{ap}$ – aleurite-sandstone sequence

Middle Division ($Є_2$)

$Є_p$ – sandstone sequence

Lower – Middle divisions ($Є_{1,2}$)

$Є_{br}$ – Berezhkivska Series

$Є_{bl}$ – Baltiyska Series
Lower Division ($C_1$)

$C_{1br}$ – Berezhkivska Series

$C_{1bl}$ – Baltiyska Series

**Rava-Ruska and Kokhanivska LTZs**

$C_1f$ – undivided flyschoid sequence

**PRECAMBRIAN**

*Proterozoic (PR)*

**Vendian System (V)**

Lower – Upper divisions (V1,2)

**Kovelsko-Khotynska LTZ**

$V_{2kn}$ – Kanylivska Series

$V_{2mp}$ – Mogyliv-Podilska Series

$V_{2vl}$ – Volynska Series

**Riphean (R)**

**Lezhayska LTZ**

$Rsn$ – Sanska Series

**Archean-Proterozoic (AR-PR)**

**AR-PR** – undivided granite-metamorphic rocks of Eastern-European Platform basement

Description of stratified sediments indicated in the geological maps is given below in ascending order, from older to younger.

**PRECAMBRIAN**

**Archean-Proterozoic (AR-PR)**

Undivided granite-metamorphic rocks of Eastern-European Platform basement (AR-PR). The rocks of granite-metamorphic complex in Kovelsko-Khotynska LTZ, in the territory adjacent to the studied map sheet, are intersected by some parametric drill-holes (Zavadivka-1 [15, 80], Khmelivka-1 [15, 80], Buchach-1 [64], Chernivtsi-1 [65] – all in adjacent territory) at altitudes from -900 m to -2163 m. This complex is constituted of mainly grey and pink granites and granodiorites, medium- to coarse-crystalline. Drill-hole Chernivtsi-1 [65] intersected biotite gneisses and schists of hetero-blastic and granoblastic texture, gneiss-like structure. Conclusion on the Svecofennian-Karelian age of granite-metamorphic complex consolidation in the basement of ancient platform is based on the rocks dating by K-Ar method which yield 3.4-3.5 Ga age of the complex rocks.
Proterozoic (PR)

Riphean (R)

Lezhayska LTZ

 Sanska Series (Rsn) which constitutes Lezhayska zone in the basement of Western-European Platform is nowhere intersected by drill-holes and is only being traced by seismic data at the depths 7.5-8.5 km beneath Carpathian Mega-Thrust (Fig. 2.1). The zone of Krakovetsko-Striyskiy fault of apparently thrust nature is conventionally accepted to be the north-eastern boundary of Series development. As it is revealed from composition of conglomerates in Lower Miocene molassa deposited through erosion of Sanska Series rocks, this Series is composed of highly-dislocated green-coloured chlorite-sericite, sericite-chlorite, quartz and clayey schists, quartzites, quartzite-like sandstones and aleurolites combined in quartzite-phillite formation (metamorphosed terrigenous flysch). This sequence is cut by numerous milky quartz veins from 5 cm to 1 m thick. The time of consolidation and metamorphism of this green-schist complex, which is also determined by K-Ar method, is conventionally ascribed to Baikalian tectogenesis. It is also supported by fact that this complex is overlain by non-dislocated Cambrian rocks as it is established by drilling in the territory of Poland [28].

Vendian System (V)

Lower – Upper divisions (V1-2)

Vendian sediments are intersected by parametric drill-holes in Kovelsko-Khotynska LTZ in adjacent territory [9]. The rocks lie with angular unconformity over eroded surface of platform basement and include epi-continental sediments of lower and upper divisions. Volynska (V1vl), Mogyliv-Podilska (V2mp) and Kanylivska (V2kn) series are distinguished in the Vendian column.

Volynska Series in the lower column part is composed of coarse-grained arkosic sandstones, gravelites and conglomerates, mainly red-coloured, up to 15 m thick, and in the upper part – of pyroclastic rocks, basalts and lava-breccia with characteristic high magnetic figures. The intersected thickness of the Series at the map sheet boundary is 46 and 155 m.

Upper Vendian sediments lie over Lower Vendian rocks with slight angular unconformity. These include Mogyliv-Podilska and Kanylivska series.

The column of Mogyliv-Podilska Series is composed of dark argillites with sandstone interbeds and batches of thin-rhythmic intercalation of grey, in places brown sandstones, aleurolites and argillites. Thickness of the Series is 40-50 m.

Kanylivska Series, which lies over underlaying rocks with slight angular unconformity, is composed of thin-rhythmic intercalation of grey and green-grey argillites, aleurolites and sandstones up to 130-160 m thick. Imprints of Vendotaenia antiqua G n i l. and others determined in the Series rocks suggests for Late Vendian age.

In geological map of pre-Mesozoic rocks in the map sheet M-35-XIX (Lviv) adjoining studied area from the north, the undivided Vendian-Cambrian sediments (V-Cf) are shown in Kokhanivska zone [15]. In the territory under discussion and further to the south-east none of drill-holes in the mentioned zone did not intersect thick flysch Cambrian rocks, thus, there is no evidences to conclude for Vendian sediment development over there.

PHANEROZOIC

Paleozoic Eratheme (PZ)

Paleozoic sediments are intersected by numerous drill-holes in the adjacent territory. In the map sheet area some drill-holes intersected only certain parts of Paleozoic column. Just the parametric drill-hole 1-IFR [80] has intersected almost complete Paleozoic column being stopped in the Lower Cambrian sediments (see cross-section to “Geological map of pre-Quaternary sediments”).
Fig. 2.1. Schematic geological map of pre-Mesozoic sediments.

1 – Riphean, Sanska Series (Rsn); 2 – Cambrian System, flysch sequence (Gf); Devonian System: 3 – Tyverska Series (D1tv), 4 – Dnisterska Series (D1dn), 5 – Zakhidnoukrainska Series (D2-3zu), 6 – Chervonogradiska Series (D3ur); 7 – Carboniferous System: Oleskivska, Vynnykivska, Nesterivska, Volodymyrska, Ustyluzka suites combined (C1ol+us); 8 – frontal thrusts of epi-orogenic tectonic zones (nappes) of Western-European Platform, proven and probable; 9 – frontal thrusts of minor nappes, probable; 10 – tectonic sutures separating litho-tectonic mega-blocks, probable; 11 – major pre-Mesozoic faults, probable; 12 – minor pre-Mesozoic faults, probable; 13 – boundaries of age-different stratigraphic subdivisions, probable; 14 – drill-holes: to the left – hole number, to the right – age index of sediments at drill-hole bottom and depth of their top in meters.
Cambrian System (C)

Lower – Middle divisions (C1,2)

In the map sheet area, in Rava-Ruska LTZ, drill-hole 1-IFR [80] at the altitude -3283 m has intersected eroded Lower Cambrian surface and run inside these sediments over 890 m. The Cambrian rocks are overlain by Lower Silurian rocks which lie with angular unconformity.

In Kokhanivska LTZ Lower Cambrian sediments are intersected beneath Upper Jurassic rocks by some holes [71, 111, 119] at the altitudes from -805 m to -4302 m. This fact clearly emphasises the block structure of this zone. Close to its external margin the column is composed of coarse-elastic rocks – pink conglomerates, coarse-grained sandstones with argillite interbeds. These rocks deposition most probably occurred under conditions of continental slope (DH 15-KR [147], 11-GRN [71], 105-DSH [88]). Away from LTZ margin the Lower Cambrian rocks comprise thin-rhythmic flysch composed of dark phillitized argillites and quartzite-like sandstones (DH 25-GRN [71], 1,2-PRG [82], 36-BPR [90]). The rocks intersected by drill-holes 34,40-BPR [90], 1,2-LS [81] essentially differ from this litho-type. These include red-brown coarse-grained sandstones and argillites which probably comprise the rocks formed in turbidite flows.

Sole spores of Zeiopsosphaera N a u m. group encountered in these sediments allow their ascription to Lower Cambrian. Their maximum intersected thickness in this zone is 267 m (DH 40-BPR [90]).

In the adjacent territory, in Kovelsko-Khotynska LTZ, the Cambrian sediments include Lower, Middle and Upper divisions.

The part of Lower Division is comprised of Baltiyska Series rocks (C1,bl) which lie over underlaying rocks with slight angular unconformity. The Series comprises intercalation of green-grey argillites and aleurolites with some glauconite sandstone interbeds. In the upper column part, the pile of light-grey quartzite-like sandstones with interbeds of brown aleurolites and argillites with scarce acrytarchs occurs. Thickness of the Series is 100-130 m.

The major portions of Lower and Middle divisions are composed of Berezhkivska Series sediments (C1,2,br) which lie over eroded rocks of Baltiyska Series. These sediments include thin-rhythmic intercalation of sandstones and aleurolites, sandstones and argillites, aleurolites and argillites with poor acrytarch complex. Thickness of the Series is 256-300 m.

Berezhkivska Series sediments are conformably overlain by 40-100 m thick sequence of light-grey sandstones (C2,p).

Middle – Upper divisions (C2,3)

The column of Cambrian sediments in adjacent territory is capped with sequence of black mica aleurolites with quartzite-like sandstone interbeds (C2,3,ar). This sequence age is transitional from Middle to Late Cambrian. Thickness of the sequence is 65-200 m.

Ordovician System (O)

Middle – Upper divisions (O2,3)

Karadocian-Ashgylian stages

In the map sheet territory these sediments are intersected in Rava-Ruska LTZ by single drill-hole 1-IFR [80] at the altitude -3238 m thus it is difficult to judge on their distribution. Ordovician rocks lie over eroded Cambrian surface while their eroded surface is, in turn, overlain by Silurian rocks. Ordovician sediments include dark re-crystallized organogenic-detritus limestones with dark argillite, aleurolites and sandstone interbeds. In the territory, adjacent from the north, these rocks are intersected over the distance of 11 km from the northern map sheet border, in Kovelsko-Khotynska LTZ, by drill-hole Berezhany-1 [15]. Over there, their thickness is 34 m only. By lithology, quite similar to Ordovician sediments in adjacent territory, Ordovician in drill-hole 1-IFR [80] is conventionally ascribed to Molodovska Series (O2,3,ml). On the ground of coral and brachyopoda Porambonites gigus S c h m., Corynotrypa inflata (H a l l.) and other remnant findings, its age is defined as Karadocian-Ashgylian. Thickness of the Series is 23 m (see fragment of cross-section in exaggerated scale to “Geological map and map of mineral resources of pre-Quaternary sediments”).
Silurian System (S)

Lower – Upper divisions (S₁-2)

Silurian sediments in the map sheet area are only intersected by drill-hole 1-IFR [80] in Rava-Ruska zone. In the margin of Eastern-European Platform, in Kovel’sko-Khotynska LTZ, complete column of Silurian sediments, which overlie eroded Ordovician and Cambrian surface, is intersected by some drill-holes in the areas adjacent from north and east (DH Berezhan-1 [15], Zavadivka-1 [15, 80]). Over there, the column comprises terrigenous-carbonate rocks including Yaruzka (S₁-2 jr), Malynovetska (S₂ ml) and Skalska (S₃ sk) series (see fragment of cross-section in exaggerated scale to “Geological map and map of mineral resources of pre-Quaternary sediments”).

Wenlockian-Ludlowian stages

Yaruzka Series (S₁-2 jr) is composed of grey platy or lumpy limestones with dark aleurolites and argillite interbeds. The rocks contain brachyopoda Plagioryhyncha analoga (W e n. n.), Pentamerus gothlandicus L e b., Baltoeutypterus tetragonophtalmus (F i s c h.) and others which indicate their Wenlockian-Ludlowian age. Thickness of the Series is 105-130 m.

Ludlowian stage

Malynovetska Series (S₂ ml) lies over eroded surface of Yaruzka Series. It comprises intercalation of dark clayey, cryptic-crystalline, mainly lumpy limestones with interbeds of dark carbonate aleurolites, in places marls and argillites. Ludlowian barchyopoda Kirkidium knighti S o w. n., Hawellella bragenesis (W e n.) remnants are determined in the rocks. Thickness of the Series is 121 m.

Pridolian stage

Skalska Series (S₂ sk) lies over Malynovetska Series sediments with slight stratigraphic interruption. It is composed of dark clayey crystalline massive limestones with interbeds of greenish-grey, dark-grey to black carbonate argillites and single tuffite interbeds. Brachyopoda Nollarothyris canaliculata (W e n. n.), Delthyris magna K o z l. n., Dayia bohemica B o u c. n. and others define Pridolian age of these sediments. Thickness of the Series is 125-135 m.

In Rava-Ruska LTZ undivided Silurian sediments lie over eroded Cambrian surface and are gradually overlain by Devonian rocks. Over there, the column is composed of clayey-carbonate sequence (S₁-2 gk). These are dark, almost black siliceous argillites with single sandstone and marl interbeds, deposited under conditions of continental slope and foothill. Thickness of the sequence is 890 m (see fragment of cross-section in exaggerated scale to “Geological map and map of mineral resources of pre-Quaternary sediments”).

Devonian System (D)

Devonian sediments with gradual transition lie over Silurian rocks and in the map sheet M-35-XXV include three divisions. In the central and south-eastern parts just the lower division rocks are intersected including Tyverska (D₁ tv) and Dnisterska (D₁ dn) series. Middle and upper divisions are intersected in adjacent territory, in Roztotska zone, in proximity to the northern and eastern (DH 1-ZV [76]) map sheet margins, where the rocks with clear angular unconformity lie over eroded surface of Dnisterska Series. In turn, over eroded surface of Upper Devonian sediments, in adjacent territory to the north, with angular unconformity lies Carboniferous System. In the column of Middle-Upper Devonian rocks Zakhidnoukrainska (D₂ z u) and Chervonogradskka (D₃ ur) series are distinguished. These are subdivided into several suites. In the map sheet area the rocks are being traced just by extensions of geological boundaries drawn up from adjacent territories, and their description is only provided for series-rank subdivisions. The north-western boundary of Upper Devonian sediments distribution in adjacent territories is traced by series of tectonic breaks (see fragment of cross-section in exaggerated scale to “Geological map and map of mineral resources of pre-Quaternary sediments”).
Lower Division (D₁)

Lochkovian stage

Tyverska Series (D₁tv) caps Paleozoic column in Rava-Ruska zone. It is intersected by drill-hole 1-IFR [80] beneath Upper Jurassic sediments at altitude -549 m, as well as at the site where buried Kolomiyska paleo-valley crosses this zone (DH 1,2,4-STP [119], 8-KI [112], 3.6-STP [119]). Over there, on the eroded surface of Tyverska Series at various altitudes do lie either Upper Jurassic, or Lower or Upper Badenian sediments and this relations unequivocally suggest for the erosion nature of this negative element in pre-Miocene surface. The Series column is composed of dark flinted argillites with sandstone, aleurolites and limestone interbeds. In places chalcopyrite films occur by cracks in argillites (DH 3-STP [119]). Limestones are dark, cryptic-crystalline, lumpy, often dolomitized. By layering patterns and composition these sediments can be ascribed to flysch deposited under conditions of continental slope foothill. The holes drilled in Kolomiyska paleo-valley did not exit the Series rocks, and in drill-hole 1-IFR [80] its thickness remained from erosion attains 1844 m (see fragment of cross-section in exaggerated scale to “Geological map and map of mineral resources of pre-Quaternary sediments”).

At the margin of ancient Eastern-European Platform, in adjacent areas, in Kovelsko-Khotynska LTZ, Tyverska Series is intersected by some drill-holes. Over there, the Series lower part is comprised of dark limestones with scarce interbeds of marls and argillites with brachyopoda Plectodonta maria K o z l. and others. Middle part is composed of dark argilites with single interbeds of organogenic limestones with brachyopoda remnants Howellella laeviplicata (K o z l.1), as well as intercalation of dark limestones, argilites and aleurolites with brachyopoda, fish remnants, and conodonts. Higher in the column appear some interbeds of brown-red argilites with brachyopoda Mutationella podolica (S i e m.) and others. Upper Series part is composed of alternating parti-coloured argilites, aleurolites and grey sandstones. Upper boundary of the Series is set by disappearing of limestone interbeds with fauna remnants typical for Lochkovian time. Patterns of the sediments suggest for deposition under conditions of continental shelf at extensive basin bottom subsidence. Total thickness of the Series in adjacent territory is estimated to 596-611 m.

Lochkovian-Emsian stages

Dnisterska Series (D₁dn) at the margin of ancient platform, in Kovelsko-Khotynska zone, fills up depression of Caledonian tectogenesis – Boyanetskiy Trough (see fragment of cross-section in exaggerated scale to “Geological map and map of mineral resources of pre-Quaternary sediments”).

The eastern boundary of the Series distribution, which is traced in adjacent territory, is of erosion type while the western one – of tectonic type and is comprised of Rava-Ruskiy fault. Lower boundary of the Series, which lies over Tyverska Series with gradual transition, is rather conventional and is set by appearance of mainly red-coloured sediments. Outside the studied area, in sections along Dnister River at Zalishchyk town, the clear diachronic features of this boundary are observed. Surface of Dnisterska Series, as it is revealed from altitudes, is highly eroded (from +235 m to +125 m), and over this surface, at various sites, do lie either Middle Devonian, or Upper Jurassic or Lower Cretaceous sediments, and in buried Kolomiyska paleo-valley – Miocene rocks. In the lower Series part, in adjacent territory, the light, massive-layered sandstones with batches of thin-alternating red-brown argilites and aleurolites are developed. The middle part is mainly comprised of alternating thick rhythms composed of grey sandstones, aleurolites and parti-coloured argilites. Upper part consists of red-brown argilites and aleurolites with lenses of grey sandstones. Entire sequence exhibits frequent and sharp lithotype changes in both lateral and vertical directions. Its genesis is thought to be related to the continental lake-alluvial or deltaic regimes.

Minute ichthyo-fauna remnants of Althaspis longirostra – Brachypteraspis latissima, Seretolepis elegans and others allow ascription of the sequence to upper part of Lochkovian-Emsian stages. Thickness of the column retained from erosion in adjacent territory to the north and east is 300-500 m.

Middle – Upper divisions (D₂₃)

Eifelian-Frasnian stages

Zakhidnoukrainska Series (D₂₃zu) mainly consists of dolomites and clayey lumpy limestones with dark argillite and marl interbeds. In places in the column middle part the batches of alternating argilites and
aleurolites with subordinate interbeds of dolomites, limestones and anhydrites are developed. Numerous findings of brachyopoda *Lingula bicornata* K u l., *Atripa desquama*ta S o w., *Polignathus decorosus* S t. and others allow ascription of these sediments to Eifelian – lower part of Frasnian stages. Thickness of the Series in adjacent territory is 170-250 m [15].

Chervonogradska Series (D₂ur) is almost completely composed of dark organogenic-detritus lumpy limestones, often dolomitized, cavernous, with single thin marl and anhydrite interbeds. The rocks are rich in remnants of brachyopoda *Atripa tenuisulcata* W e n., *Aparichtes calculus* P l i e b. et Z a s p., *Theodossia tanaica* N a l., and others, leading for Frasnian and Famennian stages. Thickness of the Series in adjacent territory is 500-600 m [15].

Carboniferous System (C)

In the territory adjacent to the north, the rocks of this age fill up major depression – Lvivskiy Paleozoic Trough. Over there, by rocks types of Carboniferous sediments, the separate Lvivsko-Valynska LTZ is distinguished. By drilling and geophysical data, pericline closure of the trough is traced in 10-12 km away from the northern boundary of studied area. In the geological map of pre-Mesozoic rocks in map sheet M-35-XIX, to the south-west from the boundary of main distribution area of Carboniferous System, another band of these rocks up to 6 km wide is traced and extended to the northern border of M-35-XXV map sheet [15]. Apparently, in the latter the band of Carboniferous sediments, bounded by thrusts from both sides, is extended to the zone of Rogatytskiy fault. In adjacent territory, by drilling and geophysical data, pericline closure of the trough is traced in 10-12 km away from the northern boundary of studied area. In the geological map of pre-Mesozoic rocks in map sheet M-35-XIX, to the southern border of M-35-XXV map sheet [15]. In the latter the band of Carboniferous sediments, bounded by thrusts from both sides, is extended to the zone of Rogatytskiy fault. In adjacent territory, by drilling and geophysical data, pericline closure of the trough is traced in 10-12 km away from the northern boundary of studied area. In the geological map of pre-Mesozoic rocks in map sheet M-35-XIX, to the southern border of M-35-XXV map sheet [15].

The band of Carboniferous rocks development is not crossed by cross-section to the geological map. It is only shown in the “Schematic geological map of pre-Mesozoic sediments” in the scale 1:500 000.

Mesozoic Eratheme (MZ)

Mesozoic sediments are widely distributed in the studied map sheet and include Jurassic and Cretaceous systems.

Jurassic System (J)

Jurassic sediments fill up major depression – Striyskiy Trough. Its formation commenced at the margin of already merged by that time ancient and young platforms. By these reasons, Jurassic sediments with obvious angular unconformity overlie age-different Paleozoic rocks of various litho-tectonic zones. In the most descended trough part, in the north-west of studied area, Jurassic System includes all divisions. Over Jurassic time the gradual basin transgression occurred in the south-eastern direction, and in Late Jurassic time only the basin had encompassed entire map sheet area and adjacent terrains to the south-east. This is why Jurassic sediments over there are comprised of upper division only (see fragment of cross-section in exaggerated scale to “Geological map and map of mineral resources of pre-Quaternary sediments”).

Upper Division (J₃)

The modern eastern distribution boundary of Upper Jurassic sediments is of erosion nature, it exhibits wavy shape caused by post-Jurassic relief and in some sites is relatively clear controlled by regional-rank destructive zones. In the map sheet territory this boundary is being traced in the north-eastern part after drill-holes located in adjacent areas. The western boundary is buried beneath Carpathian thrust and is traced by seismic data at the depth 7.0-7.5 km with sudden limestones disappearing along Krakovetskiy fault of apparently nappe nature. Upper Jurassic eroded surface from north-east to south-west gradually descends from altitudes +240 m to -100 m in the zone of Kaluskiy fault, and further next to the latter Jurassic surface sharply goes down up to the altitude -300 m. Further to the south-west, the surface stair-like subsidence occurs by the system of normal faults, and beneath Carpathian thrust the depth of Jurassic surface attains -4000 m (DH 2-LS) [81].
However, in some tectonic blocks, over short distances, essential changes of Jurassic surface altitudes are also encountered suggesting for cut enough buried post-Jurassic paleo-relief [77].

The columns of Jurassic sediments in the studied area do represent two facial zones in Striyskiy Trough – Rudkivska and Sokalska. Over there, the rocks include all stages of upper division and are subdivided into Rudkivska (J3rd), Sokalska (J3sk), Rava-Ruska (J3rr), and Nyzhnivska (J3rr) suites.

**Oxfordian stage**

Rudkivska Suite (J3rd) is developed in the south-western part of map sheet, in Bilche-Volytska zone, where it is intersected just by the single drill-holes (DH 60, 82-KI) [112]. Here, the Suite lies over eroded surface of Dnisterska Series and is overlain by Rava-Ruska Suite. The Suite column is composed of typical marine shallow-water and lagoon sediments. These are grey spotty dolomites and sandy dolomitized limestones which contain inclusions of pyrite grains, phyto-detritus and anhydrite pods. Higher, with gradual transition, the batch lies of grey and cream limestones, bioherm, organogenic-detritus, commonly dolomitized, breccia-like. Organic remnants include brachyopoda, palyno-complex and foraminifera Choffatella tingitana Hottinger, Alveosepta jaccardi (Schodt) and others allowing ascription of these sediments to the upper Oxfordian stage. Thickness of the Suite is up to 50 m.

Sokalska Suite (J3sk) is only intersected in the north-eastern part of the territory. Over there, at the altitudes from -200 m to -400 m the Suite with clear angular unconformity lies over Devonian rocks of the ancient platform margin and is overlain by Rava-Ruska Suite. On the slopes of buried Kolomiyska paleo-valley, at the site where the latter cuts through the margin of ancient platform and Rava-Ruska zone of young platform, the Suite at the altitudes from -338 m to -650 m lies over eroded surface of Lower Devonian Tyverska or Dnisterska series, and is overlain by Rava-Ruska Suite or Upper Badenian clays. In the territory adjacent from the east, close to the external distribution boundary of Jurassic sediments, essentially eroded surface of Sokalska Suite is overlain by Cretaceous rocks and Quaternary sediments. The south-western border of Sokalska and Rudkivska suites is clearly and conventionally traced by the zone of Kaluskiy fault (see “Distribution scheme of Jurassic sediments” in “Legend” and fragment of cross-section to the map in exaggerated scale).

At the north-eastern distribution boundary of Sokalska Suite, at the Suite bottom the basal conglomerates occur with fragments of red-brown and grey sandstones of Dnisterska Series. The size and rounding of clastic material suggest for the Late Jurassic basin coast proximity. Lower part of the Suite comprises typical coastal-marine sediments locally developed in the band along paleo-coast. The Suite middle part is composed of lake-alluvial non-carbonate sandstones, aleurolites, clays, in places gravels. The Suite upper part includes lagoon-continental rocks: parti-coloured clays, aleurolites and sandstones with sulphate rock interbeds. In transitional zone between Sokalska and Rudkivska suites the column comprises intercalation of limestones, dolomites and sandstones with lens-like interbeds of brown argillites, aleurolites, and sulphate lenses with considerable admixture of terrigenous material. Towards the core of paleo-basin the basal conglomerates gradually disappear while parti-coloured rocks get thinned and are replaced in vertical and lateral directions by typical marine sediments of Rudkivska Suite comprised of organogenic-detritus, slightly-flinted limestones, dolomitized limestones and dolomites with single interbeds of dark sandstones and argillites.

Scarc gastropoda Ammodiscus sp., Marssonella jurassica (M i f.) and others are determined in the rocks. In term of stratigraphy for this part of Upper Jurassic column, foraminifera complex is important with Lower Oxfordian zonal varieties - Ceratholamarckina spesiosa (D a i n.), Marssonella jurassica M i t. and others. Their occurrence allows Sokalska Suite ascription to Oxfordian. Thickness of the Suite is up to 103 m.

**Kimmeridgian stage**

Rava-Ruska Suite (J3rr) upward gradually substitutes Rudkivska and Sokalska suites and is overlain by Nyzhnivska Suite. The Suite includes coastal-marine lagoon sediments and is mainly composed of dolomites and dolomitized limestones with anhydrite interbeds which in the lower column part alternate with sandstones, aleurolites and argillites. In the south-western direction the Suite composition notably changes with decreasing of anhydrite and dolomite content and increasing amount of pure limestones. Carbonate colour is spotty due to anhydrite concretions. The interbeds occur with irregular layering and sun cracks typical for dolomites of upper tidal zone. The rocks are dense, in places porous. In the upper column part thin wavy layering occurs in the rocks as well as inclusions of clay enriched in needled calcite crystals and fine pyrite concretions. Low-magnitude stilolite sutures are observed over entire sequence.

Organic remnants include brachyopoda, gastropoda and Characeae algae characteristic for back-reef basins, foraminifera – zonal varieties of Lower Kimmeridgian Alveosepta personata (T o b i e r), Torinosuella peneropliformis (Y a b e et H a n z a w a). Characeae algae remnants suggest for shallow enough sedimentation.
Gypsum and anhydrite interbeds indicate periodic water salinity increasing due to basin shoaling and isolation, while occurrence of typical continental parti-coloured clayey rocks with sun cracks (DH 2-LS [81], 2-PdGR [111]) suggest for local sedimentation in sub-aerial conditions. Limestones in places contain typical Kimmeridgian gastropoda *Camptonectens lens* S o w., *Pleuromya varians* Ag. and others. Suite thickness varies in the range 61-136 m apparently reflecting bottom irregularities of Late Jurassic paleo-basin. Sharp thickness increasing up to 205-258 m noted in DH 1-LS [81] and 2-PdGR [111] can be only explained by con-sedimentation subsidence of paleo-basin bottom in the south-western limb of fault zone which is also expressed in the older sediments in Kokhanivska zone (see fragment of cross-section in exaggerated scale to “Geological map and map of mineral resources of pre-Quaternary sediments”).

**Tithonian stage**

*Nyzhnivska Suite* (J₃nž) gradually substitutes Rava-Ruska Suite upward in the column. It is overlain by Lower Cretaceous sediments and in the slopes of buried Kolomiyska paleo-valley – by Badenian molassa. The Suite consists of the back-reef lagoon rocks. The lower column part is composed of marls with aleurolites and sandstone lenses. Higher lie grey pelitemorphic, in places pseudo-oolite limestones with thin lens-like dark clay interbeds. Close to the coast of paleo-basin the signs of erosion and sediment sliding structures are observed in limestones. The rock is cavernous, cut by stilolite sutures. Away from the paleo-coast the rock becomes less clayey and gets massive structure. Upper Suite part is composed of banded organogenic-detritus limestones and organogenic limestones of bioherm bodies with scarce green-grey argillite interbeds. Limestones are grey with characteristic yellowish and cream shade, often dolomitized, in places slightly-flinted. The rocks are pelitemorphic, in places oolitic, with high-magnitude (up to 10 cm) stilolite sutures filled with dark and greenish clay. Abundant caverns are observed in the rock filled with crystalline calcite. Limestone groundmass is composed of fine calcite grains with admixture of clays, quartz grains and quartzite fragments. Organic remnants occupy 30% of the rock and mainly include foraminfera shells. Remnants of gastropoda *Favreina salevensis* (P a r e j a s.) and others as well as Tithonian foraminifera complex *Quinqueloculina verbizhiensis* D u l u b, *Trocholina alpina* (L e u p o l d) allow Suite dating by Tithonian age. Change of Suite thickness from 100 m in the north-east, close to its distribution boundary, to 250 m in the south-west, beneath Carpathian thrust, suggests for con-sedimentation subsidence of paleo-basin bottom, or for extensive post-Jurassic erosion (see fragment of cross-section in exaggerated scale to “Geological map and map of mineral resources of pre-Quaternary sediments”).

**Cretaceous System (K)**

These rocks in the map sheet area include two formations: terrigenous-carbonate and flysch. Lower-Cretaceous terrigenous-carbonate formation of epi-continental shelf fills up major depression which was forming along south-western margin of Eastern-European Platform – Lvivska Cretaceous Depression. It had encompassed involving terrains at the end of Early Cretaceous time only. The north-eastern margin of this structure is being mapped outside the map sheet area, its south-western limb is buried beneath Carpathian mega-thrust; alike Jurassic depression it is apparently bounded by the zone of Krakovetskiy fault. By sediment lithological types in the upper part of Upper Cretaceous column some facial zones are distinguished in the mold of which in the studied area Verbizka, Zhuravnenska and Lukvynska facial zones are traced. The lower column part (Albian-Coniacian stages) in two first zones includes *Nezvyska Suite* (K₁₋₂nž), *layers of inoceramus limestones* (K₂vi), and *Dubovetska Suite* (K₂db). The upper part (Santonian-Campanian stages) includes same-named *Verbizka* (K₂vr), *Zhuravnenska* (K₂žr) and *Lukvynska* (K₂lk) suites. In the buried platform margin – External (Bilche-Volytska) zone of Fore-Carpathian Trough – Cretaceous System is comprised of *argillite-sandy sequence* (K₁₋₂ap).

The typical flysch formation of Cretaceous – Early Paleocene time is developed in Skybova zone of Carpathians and in Boryslavsko-Pokutska zone of Fore-Carpathian Trough where it comprises principal column counterpart of these LTZs. Over there, formation includes *Spaska* (K₁sp), *Golovynska* (K₁₋₂gl) and *Stiyska* (K₂₋₃st) suites (see “Legend” and “Stratigraphic columns” to the “Geological map of pre-Quaternary sediments”).

**Lower Division (K₁)**

Lower Cretaceous flysch sediments are encountered in Skybova LTZ where these include Spaska and Golovynska suites.
Barremian-Albian stages

*Spaska Suite (K₁sp)* is intersected in the frontal part of Orivska nappe close to Ilemka River mouth by parametric drill-hole 1-LG [148] in the depth interval 5487-5650 m. The Suite lower part is cut by the thrust while the upper one is gradually changed by Golovynyska Suite. The Suite is mainly composed of black siliceous argillites intercalating with thin interbeds of black flints, dark-grey siliceous aleurolites and sandstones. Foraminifera complex *Trochmmina vocontiana* M., *Acanthhoplites cf. bigoureti* (S a u n.), *Gleicheniidites laetus* (B o l.) and others suggest for Barremian-Albian age of the rocks. The Suite thickness remained above the thrust plane is about 140 m (see cross-section to “Geological map of pre-Quaternary sediments”).

**Lower – Upper divisions (K₁₁₂)**

Albian-Turonian stages

*Golovnynska Suite (K₁₁₂gl)* is intersected by drill-hole 1-LG [149] in the depth interval 2775-5487 m at the dipping angles 40-60°. It gradually replaces Skaska Suite and is conformably overlain by Striyska Suite. At the bottom and top of the Suite the 10-17 m thick batches of parti-coloured argillites are observed. The main volume of the Suite is composed of rhythmic intercalation of grey cryptic-crystalline platy limestones, dark-grey argillites and greenish-grey marls. Over entire carbonate aleurolite and sandstone interbeds are observed. Foraminifera complex *Ammodiscus tenuissimus* (G u m. b.), *Neohibolites minimus* L i s., *Thalmanninella deeckei* (F.) and others suggest for Albian-Turonian age of the rocks. The Suite thickness is about 320 m (see cross-section to “Geological map of pre-Quaternary sediments”).

**Albian stage – Lower Cenomanian sub-stage**

*Nezvyska Suite (K₁₁₂nz)* is developed in Lukvynska, Zhuravnenska and Verbizka facial zones. It lies over eroded Upper Jurassic surface. In the first two zones Nezvyska Suite is overlain by the layers of inoceramus limestones. In Verbizka LTZ it is overlain by Dubovetska Suite. Filling all gaps over post-Jurassic surface, the footwall of Nezvyska Suite is plunged alike Upper Jurassic surface, that is, gradually first and then stair-like by the system of normal faults attaining the depth of 4000 m. Lower column part is comprised of the basal layer 0.2-0.5 m thick composed of apparently Lower Cretaceous black flint, Devonian sandstone and Upper Jurassic cream limestone pebbles. Above grey-green glauconite sands occur enriched in black flint and white quartz gravel. Upper Albian cephalopoda *Parahibolites tourtia* (W e i g n.) and others are determined in the rocks. Thickness of this column part is 2-6 m. It is overlain by Lower Cenomanian sands with phosphorite nodules. Cephalopoda *Neohibolites ultimus* (O r b.) and others are determined in the sand. Higher in the column organogenic-detritus limestones with sand admixture occur enriched in phosphorite nodules, fragments of phosphoritized shells, fine limestone and quartz pebble. Thickness of the Suite is 8-10 m (see “Stratigraphic columns”).

To the south-west, the Suite footwall gradually plunges down while sediment type and thickness almost do not change. Just behind Kaluskiy fault, in Verbizka LTZ, sharp thickness increase of Albian-Cenomanian sediments is observed, specifically up to 80-90 m, suggesting for con-sedimentation paleo-basin bottom subsidence in the south-western limb of this fault, likewise it had occurred in the time of more older sediments deposition. Over there, Albian-Cenomanian sediments are comprised of argillite-sandy sequence *(K₁₁₂ap)* with basal conglo-breccia lenses at the bottom which lies over eroded Upper Jurassic surface. The sequence column is composed of deeper sediments including greenish-grey and dark-brown argillites with interbeds of marls, organogenic-detritus limestones and quartz-glaucioite sandstones. Foraminifera complex *Eponides chalilovi* (D j a f f. et A g a l.), *Tritaxia tricarinata* R e u s s., *Cibicides Gembix* (M a r s s.) and others support their Albian-Cenomanian age.

**Upper Division (K₂)**

Cenomanian stage, lower sub-stage

*Layers of inoceramus limestones (K₂vi)* conformably overlie Nezvyska Suite sediments and upward are gradually changed by Dubovetska Suite sediments. On the slopes of Kolomiyska paleo-valley eroded surface of these layers is overlain by Lower Badenian rocks. This is relatively thin batch composed of organogenic-detritus
dense limestones enriched in phosphorite nodules. The latter are most abundant in the column lower part. At the
batch top limestones are ash-grey, platy, with wavy-layered clay lenses. Inoceramus limestones comprise reliable
geophysical marker. Their minimum apparent resistance is 100 Ohm, gamma-activity – 25 mcr/h. Numerous
findings of macro-fauna Praectinocamax plenus acutus N a j d and others suggest for their Middle-Late
Cenomanian age. Thickness of inoceramus limestone batch is 4-5 m.

From the platform margin towards Carpathians the gradual change of this straton carbonate composition
by terrigenous rocks is observed. Quartz-glauconite sandstones appear in the column while organogenic-detritus
limestones still occur in the interbeds. Further the latter disappear and beneath Carpathian thrust the Cenomanian
rocks are comprised of sandstone sequence with dark argillite lenses. Thickness of this sequence is up to 50-60 m (see “Stratigraphic columns”).

**Turonian – Coniacian stages**

*Dubovetska Suite (K2db)* with gradual transition lies over inoceramus limestone layers and upward in the
column is gradually changed by Santonian-Campanian lithotypes – Verbizha, Lukvynska and Zhuravnenska
suites. In places, where the latter suites are removed, eroded surface of Dubovetska Suite is overlain either by
oncophora layers or Quaternary sediments in Zakhidnopodilskaya LTZ, or by Carpathian sandy-limestone
sequence in Bilche-Volytska LTZ. The Suite is divided into two sub-suites.

The lower sub-suite (K2db1) is composed of uniform ash-grey and snow-white porcelain-like, strong
enough, clayed in various extents limestones. In 15-20 m higher sub-suite footwall black flint concretions appear
in limestones which amount increases upward in the column. Various-scale stilolite sutures are characteristic for
total thickness of these layers.

Upper sub-suite (K2db2) is composed of platy clayey limestones and massive marls with green
glaucolite films along layering planes. In Bukivna village outskirt the shard teeth Pterygocystites poligurus A g. e.
are found in these rocks. Black flint concretions are absent in these sediments. Notable lithology change in the Suite
is observed in the same direction as in the underlying rocks. Behind the zone of Kaluskiy fault carbonates in the
Suite lower part are enriched in clayey material while the upper part is mainly composed of greenish-grey clays,
aleurolites and aleuritic limestones where accumulations of large bentos foraminifera, inoceramus prisms and
shell fragments are known. Beneath Carpathian thrust, on the ground of logging data, it can be assumed that sub-
suite column is mainly composed of terrigenous material (sandstones etc.). From the rocks of Suite column
lower part characteristic Turonian pelecypoda Inoceramus woodsi B o e h m. and others, and from the upper one
– leading Coniacian Inoceramus involutus S o w. and others are determined. Suite thickness varies from 80 m at
the platform margin to 150 m in the part of Cretaceous mold buried beneath Carpathians. Over there, however,
considerable thickness variations from 80 to 150 m are also observed over short distances which can be only
explained by basin paleo-relief in Turonian-Coniacian times (see fragment of cross-section in exaggerated scale
to “Geological map and map of mineral resources of pre-Quaternary sediments”).

**Santonian – Campanian stages**

These sediments include three even-aged litho-facial units – Lukvynska (K2lk), Zhuravnenska (K2žr) and
Verbizha (K2vr) suites which upward in the column gradually change Dubovetska Suite. These units are
developed in the same-named litho-facial zones (see distribution schemes of litho-facial zones in the legend to
“Geological map of pre-Quaternary sediments”). Eroded surface of these suites is mainly overlain by Badenian
rocks, and in case of their lacking – Pliocene and Quaternary sediments.

*Lukvynska Suite* is developed in the platform margin where it is observed in outcrops and quarries in the
map sheet eastern part. The Suite stratotype is exposed along Lukva River in the area of Krylos village. To the
north the Suite is extended far away outside the map sheet area, and to the south (by drilling data) Radekhivskiy
fault zone can be considered as the Suite conventional boundary. The boundaries between Lukvynska,
Zhuravnenska and Verbizha suites are litho-facial. Column of Lukvynska Suite is constituted of uniform
sequence of light- and dark-grey platy marls where lenses of clayey, organogenie-detritus limestones are
observed in places. The boundaries between these rocks and marl are not clear. In lateral direction, over short
distances marls are changed by grey argillites with thin lenses of glaucolite sandstones whose elastic material
include angular quartz grains and well-rounded glaucolite grains, in places pyrite occurs.

*Zhuravnenska Suite* in the studied territory is locally developed. At the surface, the part of Suite column
is exposed over the distance of 8 km along left cliffy bank of Dnister River in front of Zhuravno village. Here,
the Suite outcrops are composed of sandstone sequence which is divided into some batches. Of these, the lower
ones comprise rhythmic alteration of strong sandy organogenie-detritus limestone and weakly-cemented
(almost sand) carbonate sandstone interbeds. The upper batches include intercalation of lighter and darker
sandstone interbeds where coarse oblique and cross bedding is observed. The batches and their individual beds are separated by clayey lens-like interbeds with almost horizontal bedding. At the top of some beds the washed channels (“pockets”) up to 1 m deep and 2-3 m wide are observed filled with gravelite and coarse-grained sand. Besides that, quite often lens-like 3-4 m thick interbeds are observed composed of green-grey sandy marls with irregularly-disseminated dark-green glauconite grains. In the replacement zone of Zhuravnenska and Lukvynska suites, intercalation is observed of the rocks characteristic for each of these units. After data of drill-holes intersected the Suite its column vertical and lateral features are established allowing Suite ascription to the sediments of ancient shallow-water constructive fan-type deltaic system. In deltaic deposition centre thickness of sandy sediments exceeds 360 m. The frontal delta part, by the system of normal faults, does gradually plunge down in south-western direction towards Carpathians where it is enriched in the deeper-water sediments, gets thicker and is distinguished as Verbízka Suite. Over there, the lower 80-130 m thick part of this Suite is composed of green-grey marls with lens-like organogenic-detritus limestone interbeds. The upper part is composed of quartz-glaucolinite diverse-grained carbonate sandstones with dark argillite interbeds.

On the ground of macro-fauna complex including pelechypoda Goniateuthis quadrata (B 1 v.), Inoceramus baliticus B o e h m, Gribinova vesicularis (L a m.), brachyopoda and others from Zhuravnenska and Lukvynska suites their age is accepted to be Santonian-Campanian. In Verbízka Suite rocks cephalopoda Baculites vertebralis L a m., Bostrychoceras poliplocum (R o e r.) and others as well as Campanian micro-fauna zone of Orbignyna simplex (R e u s s), Pseudaualvineria clementiana (O r b.), Spiroplotammina baudouniana (O r b.) are determined. From these data, at present Verbízka Suite is considered to be of Campanian age. Maximum thickness of Lukvynska Suite is 250 m, Zhuravnenska – 320 m, and Verbízka – about 400 m.

Cretaceous System – Lower Paleocene

Coniacian – Maastrichtian stages + Lower Paleocene

Striyska Suite (K2-P1,ṣt) in the studied area comprises thick Upper Cretaceous – Paleocene flysch sequence and occupies considerable column part in Skybova and Borislavsko-Pokutska LTZs. The sequence was depositing under deep-water conditions of tectonically active orogenic belt through turbidite flows of partially suspended sedimentary material. By these reasons the sediments are heterogeneous (sharp vertical and lateral changes of litho-types). In places, however, some vertical homogeneity in the column is observed. At the surface Striyska Suite is traced in the bands confined to the frontal portions of minor nappes. At the depth they are intersected by drill-holes in the anticline cores. Striyska Suite conformably overlies Golovnynska Suite sediments but in most cases the lower Suite part is cut by the thrust. And Striyska Suite is conformably overlain by Yamnenski sediments. The Suite lower part is composed of thin-rhythmic intercalation of grey carbonate sandstones, aeurolites, argillites, in places limestones and marls with foraminifera Globotruncana coronata B o 1 l and others, and the middle part – of coarse-banded sandstones with batches of thin-rhythmic flysch. In this column part foraminifera Globotruncana stuarti (L a p . p .) and others are determined. The Suite is capped with diverse-rhythmic intercalation of grey carbonate sandstones, aeurolites and argillites with interbeds of limestones and marls with foraminifera Globorotalia angulata W h i t ., Globigerina trivialis S u b . b . and others. The boundaries between all Suite parts are diachronic. In places thin batchs of part-coloured clays are observed which quickly disappear by strike. At various Suite levels conglomerate and gravelite lenses are observed which amount and thickness increase towards the external margin of Carpathians. These rocks are composed of well-rounded fragments of green Ryphean phyllites, quartz, and Jurassic limestones. Carbonate sandstones of the Suite exhibit incrusted strontium content.

The age of the Suite lower and middle parts by complex of foraminifera is defined to be Coniacian – Maastrichtian. The upper part which formerly has been completely ascribed to Upper Cretaceous (Maastrichtian-Danian), at present is thought to be transitional to Paleogene, according to decision of Paleogene Commission of UISC (1983). Thickness of Striyska Suite attains 1150-1300 m (see “Stratigraphic columns”).

Mesozoic Era (MZ)

Paleogene System (P)

Paleogene sediments are most widespread in Skybova zone of External Carpathians and in the inner part of Fore-Carpathian Trough where they conformably lie over Striyska Suite sediments and comprise essential column part in Skybova and Borislavsko-Pokutska zones. Paleogene units include Upper Paleocene Yamnenska Suite (P3-ym), Eocene Manyavskya (P3-mn), Vygodska (P3-vy) and Bystrytska (P3-bh) suites, and Oligocene – Lower Miocene Menilitova Suite (P3-N1,ml) (see “Stratigraphic columns”).
Paleocene ($P_1$)

**Striisky – Yamnenskiy regio-stages**

*Yamnenska Suite* ($P_{1jm}$) conformably lies over Striyska Suite and is overlain by Manyavska Suite. At the base of Yamnenska Suite in places *Yaremchanskiy horizon* is observed comprising 15-35 m thick batch of parti-coloured thin-rhythmic flysch. It is overlain by the sequence of medium-grained turbidites composed of light massive sandstones, from fine- to coarse-grained, mainly non-carbonate. Well-rounded grains in sandstones are comprised of minerals characteristic for the older platform sediments. Thickness of individual beds is 1-3 m, in places up to 6-8 m. They are separated by thin (0.1-0.2 m) greenish-grey argillites interbeds and 0.8-4.0 m thick batches of thin-rhythmic intercalation of green argillites and greenish-grey fine-grained quartz-glaucite sandstones. In places the batches of black bituminous sheeted argillites are observed. Over entire sequence, at various levels, occur lens-like interbeds and lenses of conglomerates and gravelites similar in composition to those in Striyska Suite. In places, at the Suite top, the 3-5 m thick parti-coloured *Nadyamnenskiy horizon* is observed. Foraminifera complex *Nummulites deserti* Harr., *Globorotalia angulata* White, and others suggests for Late Paleocene age of the Suite. Thickness of the Suite is 150-200 m.

Paleocene – Eocene undivided

In Beregova and Orivska nappes Upper Paleocene and Eocene rocks constitute *sandstone sequence* ($P_{1p}$) comprising typical fan sediments. In sandstones, at various levels, thin lens-like batches of greenish-grey thin-rhythmic are observed, visually resembling the flysch of Manyavska and Bystrytska suites. In lateral direction, these batches are being quickly replaced by grey coarse- and medium-grained turbidites comprised of thick-banded sandstones. Thickness of this sequence is 350-400 m.

Eocene ($P_2$)

**Manyavskiy regio-stage**

*Manyavska Suite* ($P_{2mn}$) conformably lies over Yamnenska Suite and is overlain by Vygodskia Suite. Sometimes in the bottom the batch of parti-coloured argillites, 3-5 m thick, in places up to 20 m, occurs. Inside this batch, up to 2.5-4.5 m thick package of green-grey platy siliceous argillite is observed somewhere. Above lies the sequence of uniform thin-rhythmic intercalation of thin-platy green-grey sandstones, aleurolites, argillites, marls and limestones with sole gravelite lenses concentrated at the bottom of the rhythms. Thickness of the lenses is 0.5-1.5 m. Amount of marl interbeds in the column decreases from Skyboviy to Boryslavsko-Pokutskiy nappe. Over entire column the rocks are flinted and in the upper part these are almost thin-platy flints and flinted limestones. The Suite rocks contain abundant biogliths (worm passes) at the bottom of interbeds. Foraminifera complex *Nummulites globulus* Leym. and others suggests for Early Eocene age of the Suite. Thickness of the Suite is 250-300 m.

Vygodskiy regio-stage

*Vygodskia Suite* ($P_{2vg}$) in the studied area includes mainly massive and coarse-banded grey sandstones, diverse-carbonate and diverse-grained. Massive sandstones are arranged in the batches 30-50 m thick alternating with thinner batches of coarse-banded sandstones. Thickness of individual beds is 0.5-3.0 m. They are separated by interbeds of green-grey non-carbonate argillites 0.1-0.3 m thick. In places the batches of dark thin-rhythmic flysch are observed in sandstones, and more frequently – lens-like conglomerate interbeds of the same composition like ones in underlaying rocks. In Boryslavsko-Pokutska zone, in the upper column part, in lateral direction massive sandstones are being replaced by “Bukovynski Layers” composed of ash-grey thin-platy aleurolites with interbeds of flinted limestones and marls. Thickness of these rocks is 15-40 m. Foraminifera complex *Acarinina bullbrooki* Balbi, *Nummulites laevigatus* (Brug.) and others suggests for Middle Eocene age. Thickness of the Suite is 250-300 m.

Bystrytskiy regio-stage

*Bystytska Suite* ($P_{2bs}$) conformably lies over Vygodskia Suite sediments and is overlain by Oligocene rocks. In the northern structures of Skybova LTZ and southern ones of Boryslavsko-Pokutska LTZ, the Middle
Eocene 10-25 m thick horizon of red and parti-coloured argillites often occurs in the Suite lower part. In lateral direction parti-coloured argillites over short distances are replaced by thin-rhythmic intercalation of grey sandstones and dark argillites. Higher lies sequence of grey-green thin-rhythmic flysch where argillites predominate; in places Suite column is completely composed of green non-carbonate argillites with scarce thin (5-15 cm) sandstone, aleurolites and marl interbeds. In lateral direction frequent litho-facial changes are observed from green argillites to thin-rhythmic intercalation of green-grey sandstones, aleurolites and argillites with frequent lens-like interbeds of green fine-pebble conglomerates. In the Suite upper part, in the northern structures of Boryslavsko-Pokutska LTZ, the batch occurs composed of brown-black argillites, greenish-grey marls and almost black aleurolites which are distinguished as 25-35 m thick “Sheshorskíy Horizon”. In argillites from parti-coloured horizon foraminifera complex *Acarinina bollbrooki* B o l l and others and others are determined allowing this part of Suite column ascription to upper portion of Middle Eocene. In argillites from main part of the Suite foraminifera *Cyclammina amplement Grz.*, *Ammodiscus latus Grz.* and others are found suggesting for Late Eocene age. Thickness of the Suite is 250-350 m.

**Eocene undivided**

In Boryslavsko-Pokutska LTZ Eocene sediments are mainly intersected by prospecting drill-holes and include sandstone-clayey sequence (*P*₂*pg)*. In its column the elements of all aforementioned Eocene suites occur. These are diverse-thickness lens-like batches of thin-rhythmic flysch visibly similar to the rocks of Manyavská or Bystrytská suites. In lateral direction the batches are quickly changed by grey coarse- and medium-grained turbidites comprised of coarse-banded sandstones of Vygodskíy appearance. Upper Eocene portion in the natural columns is mainly comprised of greenish argillites of typical Bystrytskíy appearance where batches of coarse-banded sandstones and thin-platy flinted aleurolites are observed. In general, by lithology the column is very similar to the column of undivided Eocene in the outer structures of Pokutskíy Carpathians. Thickness of this sequence is about 350 m (see legend to the “geological map of pre-Quaternary sediments”).

**Oligocene – Lower Miocene (P₁-N₁)**

**Ombronskíy (Menilitovy) regio-stage**

Flysch sediments of this age are included in Oligocene and Lower Miocene Menilitova Suite (*P*₁*ml*). In Skybova LTZ by patterns of lithology vertical changes the Suite is divided into three sub-suites. The lower and part of middle sub-suite by age belong to Oligocene. The rocks of upper part of middle sub-suite and upper sub-suite are deposited in Early Miocene time. In structures of Boryslavsko-Pokutska LTZ the Suite by composition is more uniform and is mapped as undivided (see legend and stratigraphic columns to “Geological map of pre-Quaternary sediments”).

*Lower Menilitova Sub-Suite (P*₁*ml*) commences with the rocks of under-flint batch which conformably lies over Bystrytska Suite rocks. This batch is composed of dark sheeted argillites (“Menilitovy shale”) with thin interbeds of aleurolites and sandstones and single dark-brown flint layer. Thickness of the batch is 15-25 m. Foraminifera complex with *Globigerina wialovi M j a t l* and others suggests for Early Oligocene age of these sediments. Higher lies lower flint horizon consisting of batches composed of flints and flinted marls of massive and banded structure. In the lower flint horizon sandstones, aleurolites, argillites, in places tuffites and diatomites also occur. All these varieties are observed in 3-5 cm thick layers. Above the flint horizon a sequence of just Lower Menilitova Sub-Suite lies which in the lower column part is mainly composed of alternating batches of black, sheeted on weathering, 2-5 m thick argillites (“Menilitovy shale”), and batches of thin-rhythmic flysch with 2-5 cm thick interbeds of grey quartzite-like sandstones. Mainly in the column lower part, the 30-40 m thick batch of light massive coarse-grained sandstones occur (“Klivski”). Boundaries of this batch are diachronic. In places it occupies considerable part of lower and middle parts of Sub-Suite, and in general, its column is high-sandy over there. Foraminifera *Globigerina wialovi M j a t l* and others are determined in the sequence rocks, characteristic for Lower Oligocene. Thickness of sub-suite is 270-320 m.

Higher in the column dark argillites (“Menilitovy shale”) are gradually changed by ash-grey carbonate argillites which actually belong to the *Middle Menilitova Sub-Suite (P*₁*ml*)*. This grey sequence, where “Menilitovy shale” are almost absent at all, is known for the long time under the own name – “Lopyanetskiy Layers”. At its base the banded limestone horizon (“Golovetskiy”) is observed everywhere having important correlation value. It is normally 0.2-0.3 m thick, in places up to 1.5 m. Limestones of this horizon are grey or brown, thin-platy, with very thin parallel layering. Higher the sequence lies where clear change of litho-types with diachronic boundaries is observed from the inner structures of Skybova LTZ to the outer ones. In Orivska nappe, in the sub-suite lower part, the 30-50 m thick batch of black non-carbonate argillites is developed with
interbeds of grey fine-grained quartzite-like sandstones and single lens-like interbeds of dolomitized marls. In Beregova nappe, thickness of black argillites in the Sub-Suite lower part is reduced to 15 m and most part of the column is composed of more terrigenous rocks – medium-grained turbidites of which sandstones occupy almost 60% of the total Sub-Suite volume. Foraminifera complex Cibicides lopjanicus M j a t l., Bolivina crenulata C u s h m., Turborotalia liverovkae (N. B y k), Uvigerinaella majcopica K r a i e v a in sub-suite rocks allows its ascription to Late Oligocene – Early Miocene. Thickness of Sub-Suite is 250-300 m.

The boundary between Middle Menilitova Sub-Suite and Upper Menilitova Sub-Suite (N1ml) is clear and is traced over upper flint horizon which visibly notably differs from the lower one. This horizon is comprised of thin-rhythmic intercalation of brown thin-platy banded flints with black argillites and grey quartzite-like sandstones. Thickness of individual interbeds is 2-10 cm, and horizon thickness varies from 2 to 6 m. Lower part of Sub-Suite, overlaying flint rocks, is composed of sheeted non-carbonate dark-brown and black argillites with bright-yellow jarosite and brown iron oxide spots on weathered surface. Bun-shaped siderite lenses often occur in these argillites. Gradually upward, the column gets enriched in grey coarse-platy carbonate argillite and marl interbeds. Thickness of this Sub-Suite part attains 500-550 m. And above the batch of light-grey tuffs, tuffites and tuff-sandstones (“Chechvynski”) up to 60 m thick occurs which is exposed in the left cliffy bank of Chechva River in the western outskirt of Verkhniy Strutyn village. By strike, the lens of Chechvynski tuffaceous rocks is traced in some outcrops and is intersected by drill-holes over the distance up to 30 km form the principal rock outcrop. The rock is massive, uniform, with terrigenous material admixture providing tuff-aleurolite and tuff-argillite interbeds. Ash particles in these rocks are very fine (0.01-0.1 mm) and are composed of montmorillonitized volcanic glass and in places of quartz, plagioclase, biotite, zircon, sanidine, hornblende crystal fragments. In tuffs, where tuffaceous fraction attains 50%, the ash material is being recognized by relic volcanic glass forms only. Considerable tuffaceous material content makes upper Sub-Suite different from the lower one while in other features they are very similar. Volcanic rocks are overlain by dark sheeted argillites with grey sandstone and marl interbeds comprising up to 20% of the column. In places, over short distances in lateral direction, replacement of black argillite batches by thin-rhythmic intercalation of sandstones with grey and dark argillites is observed. In black argillites the lenses of dolomitized marls and siderites often occur. Foraminifera complex Globigerina angustiuniformatica B o l i., Globigerina pseudoedita S u b b., Neobulimina elongata (O r b.) and others suggests for Early Miocene age of Sub-Suite. Thickness of Sub-Suite is 300-350 m.

In Boryslavsko-Pokutska LTZ Menilitova Suite is involved in the deep structures. Its composition is almost the same as in Skybova LTZ but all subdivisions are considerable reduced in thickness (from 500-600 m in the southern structures to 200-300 m in the northern ones). Middle Menilite Sub-Suite is comprised just by the batch of grey carbonate platy argillites up to 60-70 m thick. In the outer structures of the zone erosion of upper part of Menilitova Suite is observed while the Suite itself is distinguished as undivided (Pml-Nml). Foraminifera complex Cibicides lopjanicus M j a t l., Globigerina ciperoenisis B o l i., G. pseudoedita S u b b. and others provides the Suite sediment age to be Oligocene – Early Miocene.

Neogene System (N)

In Skybova LTZ Neogene sediments include upper part of Middle Menilitova and Upper Menilitova sub-suites described above. In Boryslavsko-Pokutska LTZ (thrust) the Lower Miocene rocks of the upper part of undivided Menilitova Suite stake up molassa sediments of Egerskij-Carpathian age in Polyanytska (N1pl), Vorotyshchenska (N1vy), and Stebnytska (N1st) suites. The body of Sambirska LTZ (thrust) is mainly composed of molassa sediments of Stebnytska and Balytska (N1bl) suites. In some sites of this zone, above the thrust plane, Vorotyshchenska Suite sediments also occur. In Sambirska LTZ sedimentation substratum of molassa rocks is not identified. At the platform margin Lower Miocene sediments include Oscophora and Berezhansky layers which due to their low thickness are indicated as combined (N1on+br). By age, in Bilche-Volytska zone these rocks are correlated to sandy-limestone sequence (N1pv). Middle Miocene rocks of Badenian regio-stage constitute various litho-facial complexes, including Opilska Suite (N1op) in Zakhidnopodilska LTZ, and Bogorodchanska Suite (N1bg) in Bilche-Volytska LTZ. In both zones these suites are overlain by Tyraska Suite (N1tr). The Middle Miocene column is capped with Kosivska Suite (N1ks). The Upper Miocene rocks include Dashavskaya Suite (N1ds) of Sarmatian regio-stage developed in Bilche-Volytska LTZ only. Friable continental rocks of undivided Upper Miocene (Pontian) – Pliocene age and Quaternary System do cover entire map sheet territory with the solid thin blanket (see legend and stratigraphic columns to “Geological map of pre-Quaternary sediments” and “Geological map of Quaternary sediments”).
**Miocene Division (N$_3$)**

**Egenburgskiy regio-stage**

Polyanytska Suite (N$_{pl}$) is observed in representative natural outcrops in the basins of Limnytsya and Bystrytsya-Solotvynska rivers at the outskirts of Porogy, Krychka, Bogrivka villages, and is traced by single outcrops in the area between these rivers. The Suite is intersected by numerous deep drill-holes in Boryslavsko-Pokutska LTZ. In its far north-east the Suite rocks with local erosion overlie Lower Menilitovi sediments. From the external, north-eastern zone margin to its more inner part, the gradual litho-facial replacement of Polyanytska Suite by Menilitova litho-stratigraphic unit is observed. The Suite rocks are overlain by facially-diverse rocks of Vorotyshchenska Suite, which also most likely replace the Suite in many cases. Transition from Menilitova Suite to Polyanytska Suite does mainly occur through the batch of coarse-clastic sediments which are observed both in natural outcrops and in drill-holes core sections (DH 1,2,11-PRG [82], 6,12-Vl [56]).

In general, Polyanytska Suite is comprised of ash-grey carbonate terrigenous sequence of argillites, argillite-like clays, in placed gypsumized, aleurolites, sandstones, gravelite and conglomerate lenses. In the external structures of Boryslavsko-Pokutska LTZ the Suite column commences with conglomerates which in more inner structures are replaced by sandy-clayey sediments. There is observed gradual transition from black non-carbonate argillites of Menilitova Suite to grey carbonate argillites which belong to Polyanytska Suite. In the transition zone intercalation of grey and black argillite batches is observed (column of Chechva River). Conglomerate lenses, which some authors [108] consider to be the basal horizon and evidence for erosion and sedimentation break, do first appear in the column of black argillites. In places where conglomerates predominate in Polyanytska Suite, the gradual transition to Menilitova Suite sediments is also observed.

The Suite sandstones and aleurolites are light-, dark-, greenish-grey, mainly weakly-cemented. The clastic material comprising 75-95% of rock includes quartz grains, Menilitova Suite and Ryphean rock fragments, in places coalified fossil detritus. The Suite clays and argillites are normally grey and greenish-grey with blue shade. From argillites of Menilitova Suite they differ in chipping fractures and permanent carbonate content (15-20%). Occurrence of gypsumized clay interbeds is characteristic for mainly clayey upper Suite part (areas of Bytkiv, Dolyna). In this column part the boundary between Polyanytska and Vorotyshchenska suites is fairly conventional. In practice, this led to various estimations of Polyanytska Suite thickness in the same drill-holes. The gradual transition of one suite into another is observed almost everywhere.

The logging curves sharply change their patterns at the transition from Menilitova to Polyanytska suite. Specific electric resistance of most layers in Menilitova Suite is higher than in Polyanytska Suite rocks. Transition from Polyanytska Suite to Vorotyshchenska Suite is not expressed in the logging plots.

In the approved stratigraphic scheme [46] Polyanytska Suite, based on findings in its clays the microfauna complex *Globigerina pseudoeodita* S u b b., *G. juvenilis* B o 1 1 i, *Turborotalia brevispira* (S u b b.), is dated to lower part of Egenburgskiy regio-stage. However, its time boundaries are most likely diachronic. Geological observations performed during works research works over entire Carpathians [6, 64] had provided evidences for partial replacement of Menilitova Suite by Polyanytska Suite rocks and, therefore, their deposition had been probably commenced in Oligocene or at Oligocene-Miocene boundary in the north-eastern margin of the flysch basin. The local erosions at the bottom of Polyanytska Suite (as well as Vorotyshchenska Suite) are also observed over there. In the south-western, more inner portions of Boryslavsko-Pokutska LTZ, the Suite rocks stratigraphically normally lie over various parts of Menilitova Suite and the latter gradually replaces Polyanytska Suite in the south-western direction. This suggests for gradual diachronic ascending of Polyanytska Suite lower boundary from Early-Menilite to post-Late-Menilite times. Geological observations over facial relationships of Polyanytska and Vorotyshchenska suites, both in the natural outcrops and in drill-holes, allow consideration the upper Polyanytska Suite boundary also to be diachronic. This boundary, in general, becomes younger towards the inner elements of Boryslavsko-Pokutska LTZ where Polyanytska Suite rocks replace those of Vorotyshchenska Suite. The latter in places (in adjacent territory to the south-east) are almost completely replaced by Polyanytska Suite rocks. In the columns of deep prospecting boreholes intercalation of Polyanytska-type carbonate-terrigenous batches and salted clays characteristic for Vorotyshchenska Suite is observed. The noted strataons are most likely mutually-replacing over short distances. This is why in most borehole descriptions these sediments are normally distinguished to be undivided (N$_{pl}$-vr). Thickness of Polyanytska Suite at the outskirts of Dolyna town attains 1000 m. To the south-east it decreases to 400-500 m (area of Strutyn-Rypne villages).

Vorotyshchenska Suite (N$_{vr}$) is developed in Boryslavsko-Pokutska LTZ and in the inner nappes of Sambirksa LTZ. In the first case the Suite normally lies over various parts of Polyanytska Suite replacing the
latter facially. In the frontal part of Boryslavsko-Pokutska LTZ clayey-sandy and conglomerate rocks of Vorotyshchenska Suite with erosion lie over Lower Menilitovi sediments. Vorotyshchenska clayey and conglomerate units often contain olistolites of Menilitova Suite and in general are replaced by olistostrome. In Sambirska LTZ the Suite lower part is cut by the thrust and nature of its sedimentary substratum remains problematic (see cross-section to “Geological map of pre-Quaternary sediments”).

In the external part of Boryslavsko-Pokutska LTZ (Rungurska litho-facial unit) and sometimes in Boryslavsko litho-facial unit of this zone, as well as in Sambirska LTZ, the Suite is gradually overlain and partly replaced by parti-coloured sediments of Stebnytska Suite. In adjacent territory to the south-east, in some columns (Novomarkivka village) the red-brown rocks, which are typical for Stebnytska Suite, do lie directly over Vorotyshchenska Suite conglomerates, apparently completely replacing its upper (Dobrotivska) part.

In the internal part of Boryslavsko-Pokutska LTZ (Boryslavsko litho-facial unit) the Suite rocks are directly overlain by the External Carpathian thrust. And in the area of Pereygsne village only over the Suite sediments with angular unconformity does sub-horizontally lie the sequence of sandstones, gravelites and clays which most authors correlate with Upper Badenian – Lower Sarmatian Kovalivski layers of Bilche-Volytska LTZ.

The lower part of Vorotyshchenska Suite is comprised of olistostrome, clayey-sandy sediments and conglomerates. Olistostrome is composed of chaotic lily clayey-sandy matrix enriched in Menilite Suite, rarely Eocene olistolites (up to first hundred of meters in size). The rocks of Menilite Suite in olistolites are highly- tectonized, folded, and exhibit tectonic breccia appearance. The matrix clays are very similar to those of Polyanytska Suite and in many cases the boundary between the two cannot be clearly defined. Superimposed gypsum and salt content are characteristic for clays of Vorotyshchenska Suite. Carbonate content of clays varies in the range 20-40% and by this parameter they also do not differ from the clays of Polyanytska Suite. Among the newly-formed minerals calcite, gypsum, anhydrite, polyhalite, potassium salt minerals, celestine, barite, pyrite, galena and sphalerite occur in clays [32]. Numerous light-grey sandstone and aleurolites interbeds occur in clays. The 0.03-0.05 m thick interbeds are platy, strong, with thin wavy layering and imprints of sediment sliding over the bed footwalls. Sandstones, 0.5 m thick, are more cemented. Under tectonic tension, sandstone interbeds get broken into the angular fragments and form breccia-like rocks (“sandy-clayey breccia”) with mainly halite cement. This secondary brecciation of salt-bearing clays is also characteristic for their natural outcrops. Somewhere strong batches are also observed in clays where coarse-layered sandstones are separated by more or less thick layers of massive clays. Sandstones are composed of exotic (off-Carpathian) material fragments – red and green philllites, white and grey limestones, black flints, etc. Conglomerates are observed in thick lenses within clayey-sandy rocks and are composed of the fragments, cobbles and pebbles of Ryphean green, grey and red philllites, Jurassic light limestones and dolomites, quartzites, jasper-like rocks, milky-white quartz, Menilitova Suite rock fragments. These coarse-clastic sequences are developed in the outer nappes of south-eastern part of Boryslavsko-Pokutska LTZ (the area between Bystrytsya-Solotvynska and Lyuchka rivers) where they are known as Slobidski Conglomerates. In general, aforementioned rock varieties (clayey-sandy, conglomerate, olistostrome) in the natural outcrops and drill-holes exhibit quite variable thickness, in places completely pinching out, most likely suggesting for their fast facial mutual replacement.

In many sites of Vorotyshchenska Suite development essential part of its column is composed of grey- coloured sandy-clayey non-salted sequence. In the south-east, not far outside the map sheet area, such sequence comprises upper part of the Suite and is known as Dobrotivski layers. The distinct patterns of the latter in the column at Prut River include abundant geoglyphs described and systematized in details by O.S.Vyalov. Comparison of Vorotyshchenska Suite upper part columns suggests for their fast and sharp enough litho-facial changes. After O.S.Vyalov, by facial features of Vorotyshchenska Suite in Boryslavsko-Pokutska LTZ the internal Borylsvasksa and external Rungurska units can be distinguished. The latter differs in development of Dobrotivski Layers and thick conglomerate sequence (Slobidski) which deposition was accompanied by local erosion of Upper Menilitovi sediments. In Boryslavsko unit these conglomerates are essentially reduced in thickness or completely absent being replaced by sandy-clayey salt-bearing rocks where rock salt layers and thick lenses of potassium salts are developed.

Traditionally Vorotyshchenska Suite is divided into three parts but, taking into account essential Suite rock facial variability, the authors consider the Suite stratification into sub-suites to be not reliable. It is more appropriate the mapping in Vorotyshchenska Suite the litho-facial “layers” of limited distribution, for instance, salt-bearing clay, Dobrotivski layers, Slobidski conglomerates, as well as olistostrome rocks.

In Sambirska zone Vorotyshchenska Suite is locally developed and is comprised of grey clayey sequence with interbeds and lenses of sandy-aleuritic material. In the natural columns along Berezhnytsya stream the gradual transition of Vorotyshchenska Suite sediments to parti-coloured rocks of Stebnytska Suite is observed.
In Boryslavsko-Pokutska LTZ in general Vorotyshchenska Suite is salted. Almost over its entire distribution area, mainly in the lower (olistostrome) part, the salt-bearing rocks are traced in the bands of some kilometers long. They contain 5-60 m thick potassium salt lenses encountered at some sites. Potassium-bearing horizons comprise intercalation of relatively pure potassium salts with thin interbeds of clays and salted sandstones providing layered structures. Above the salt-bearing sequence, in the zone of its leaching, the gypsum-clay “cap” is formed comprising grey clayey mass enriched in transparent gypsum crystals as well as yellow and pink gypsum cobbles. Thickness of gypsum-clayey cap is 50-100 m, in places 200 m.

In the approved stratigraphic scheme Vorotyshchenska Suite encompasses upper part of Egenburgskiy regio-stage [46]. Geological observations over representative natural sections in the basin of Lyuchka River in adjacent territory clearly indicate that Vorotyshchenska Suite lies over the lower part of Menilitova Suite and completely replaces Polyanytska Suite. Thus, the lower boundary of Vorotyshchenska Suite coincides with the lower boundary of Polyanytska Suite and probably follows Oligocene – Miocene border. In clays of Vorotyshchenska Suite numerous remnants of re-deposited Upper Cretaceous and Paleogene macro-fauna are determined. Miocene macro-fauna complex with Globigerinoides trilobus (R e u s s), Globigerina pseudoeedita S u b b., Turborotalia brevispira (S u b b.), Globorotalia fohsi C u s h m. e t E l l i s., Lithomibra turritiformis S u b b., Globigerina bulloides O r b., G. woodyi connecta (J e n k i n s), Globorotalia cf. squalida P i s h v., Globoquadrina cf. globosa H a n t k and others suggest for Egenburgian-Otnangian age of sediments. Nano-plankton complexes determined by N.A.Savytska include numerous types of wide distribution in Miocene: Coccolithus pelagicus (W a l l), Cyclicargolithus floridanus (R o t h & H a y), Reticulofenestra pseudoumblicus (G a r t n e r), Braarudosphaera bigelowii (G r a n & B r a a r u d); single Lower Miocene types: Sphenolithus belemnos B r a m l. & W i l c., Helicosphaera mediterranea M u l l e r, H. euphratis H a g., and those types widely distributed in Middle Miocene: Calidiscus leptoporus (M u r r a y & B l a c k.), Cyclicargolithus premacintyrei T h e o d o r i d i s. From direct geological observations and determined fauna remnants, the lower part of Vorotyshchenska Suite is ascribed to Egerian-Egenburgian while its upper part encompasses Otnangian, Carpathian and lower portions of Badenian. Thickness of Vorotyshchenska Suite is 700-1200 m.

Otnangian regio-stage

Stebnytska Suite (N1st) in Boryslavsko-Pokutska LTZ is developed mainly in the north-eastern part (Rungurska facial unit) and very locally in the south-western part (Boryslavskaja facial unit) (see cross-section to “Geological map of pre-Quaternary sediments”). The Suite gradually changes Vorotyshchenska Suite and facially replaces its upper part. The boundary between these two suites is fairly conventional and partly coloured rocks predomination comprises ascription criteria for Stebnytska Suite. Facial relationships of mentioned suites are clearly observed in adjacent territory along Prut River where in the southern limb of Dobrotivska anticline thick Dobrotivski layers are developed above conglomerate sequence while in the northern limb thickness of these layers decreases and they include considerable amount of red-coloured sediments typical for Stebnytska Suite. In the area of Novomarkivka village the Suite, as it was pointed above, apparently completely replaces Dobrotivski layers occurring directly above Slobidski conglomerates. In Boryslavsko-Pokutska LTZ the Suite completes its Miocene column and is overlain by Pliocene and Quaternary sediments [6, 64]. Over there, in its typical appearance the Suite is comprised of red-coloured and grey batches intercalation. The first are composed of thin-rhythmic alternating clays, marl-like, red-brown, pink, greenish-grey and grey, with thin aleurolites and sandstone interbeds. Grey batches are composed of alternating grey clays and aleurolites which visibly do not differ from Dobrotivski layers. Thickness of the batches is 50-100 m. In pink clays the batches and interbeds of greenish clays are frequently observed. In the column lower part, in the pink clay pile, the coarse-layered sandstone batches up to 5-6 m thick are widespread. Structure features of some lens-like sandstone interbeds allow their ascription to deltaic formations. At the bottom of some sandstone beds the pebble from underlaying clayey rocks is often observed. In some sandstone batches abundant aleurolites interbeds are enriched in fossil detritus as well as copper mineralization (“cupriferous sandstones”) [63, 65].

In Sambirska LTZ the lower boudary of Stebnytska Suite is observed in the inner nappes only (Trostyanetsko-Petrankivskiy and Velykoturyanskiy). Over there, the Suite gradually changes grey clayey non-salted sediments of Vorotyshchenska Suite. In the most part of Sambirska LTZ the Suite lower portions are cut by the thrusts. In this zone upward the column the Suite is gradually changed by grey-coloured Balystska Suite. The boundary between the suites is rather conventional and is set by predomination of red-coloured and grey-coloured rocks, respectively, and apparently is diachronic. In Sambirska LTZ the Suite is mainly clayey. This is thin-rhythmic intercalation of marl-like clays, pink, green-grey, grey, with thin aleurolite interbeds. In clays, the interbeds of dark, almost black varieties are observed.

According to the approved stratigraphic scheme, the age of Stebnytska Suite is defined as Otnangian. However, Miocene fauna association collected by the authors comprises mixture of Early and Middle Miocene
varieties. Among general Miocene ones *Globigerina falconensis*, *G. Subcretacea* and *Orbulina* sp. occur. Foraminifera association which is close in composition to Middle Miocene complexes includes *Globigerina cf. subcretacea* L o m n., *Globigerinoides trilobus* (R e u s s.), *Elphidium ortenburgense* (E g g e r.) and others. In the Miocene limestone nano-plankton associations some complexes are distinguished which include: 1. nano-plankton varieties of wide distribution in Miocene: *Coccocithus pelagicus*, *Cyclicargolithus floridanus*, *Helicosphaera carteri*, *Sphenolithus moriformis*; 2. specific Early Miocene nano-plankton varieties: *Helicosphaera mediterranea*, *H. scissura*, *Discoaster druggii* and others; 3. specific Middle Miocene nano-plankton varieties: *Helicosphaera walbersdorffensis*, *Discoaster variabitis*, *Thoracosphaera heimiti*. Occurrence of micro-fauna complex which contains Middle Miocene varieties among the Miocene association allows assumption on either the Lower Miocene varieties re-deposition or supposing the age of Stebnytska Suite to be Early-Middle Miocene. Based on geological observations coupled with determined paleontological remnants, at the present state of knowledge the authors accept the Suite age as Otnangian – lower part of Badenian with diachronic lower and upper boundaries. Thickness of Stebnytska Suite is 450-1000 m.

**Carpathian regio-stage**

*Balytska Suite* (N,b1) is developed in Sambirska LTZ only where it completes the zone stratigraphic column gradually changing Stebnytska Suite which underlies and partly replaces Balytska Suite. Balytski sediments are overlain by continental friable Pliocene-Quaternary rocks. Likewise Vorotyshchenska Suite, the variable lithology, frequent facial changes and essential time interval of the rocks are characteristic for the Suite. In the central and south-eastern parts of Sambirskiy LTZ, the Suite lower portions include uniform sequence of grey, massive and thin-layered clays with single sandstone and aleurolites interbeds. In grey clays, the pink clay batches and thin interbeds of Stebnytskiy appearance occur. From the Striy River valley to the south-east, at the frontalpart of Boryslavsko-Pokutskiy thrust, the main Suite volume is occupied by olistostrome sequence which facially replaces lower clayey part of the Suite and lies over either parti-coloured Stebnytski sediments or grey layered Balytski clays. Olistolites of red-brown and grey clayey-sandy rocks are often tectonically dismembered and in places are composed of tectonic breccia [64]. During the large-scale mapping [64] all salt-bearing and olistostrome rocks, in view of their laying above the red clays, were ascribed to Upper Stebnytska Sub-Suite. Under this status they were included into approved stratigraphic scheme [46]. In other nappes of Sambirskiy LTZ the middle portion of Balytska Suite is comprised of the sequence of dark massive and thin-layered clays, in places salted where potassium salt bodies are encountered. In the weathering zone they form sandy-clayey breccia with halite cement which visibly does not differ from the similar rock from Vorotyshchenska Suite. Somewhere in clays, beneath rock salt lenses, up to 2-5 m thick gypsum-anhydrite lenses are intersected by drill-holes [83].

In the area of Kalush town, in clays which underlie gypsum and salts, the Early Badenian fauna “horizon with Amussium denudatum” is determined. In clays overlaying rock and potassium salts the complexes of Late Badenian foraminifera are established. On this ground, Bogorodchanska, Tyraska, Kosivska and even Dashavskya (Neo gene) suites are distinguished over there in Sambirskiy nappe [83]. However, even in case of mentioned gypsums in Sambirskiy LTZ comprise facial analogue of Tyraski ones, the clayey pile which underlies and overlies these rocks, does not differ in lithology from Balytska Suite, but instead is somewhat different from molassa rocks of the Trough outer zone. By lithology, this sequence belongs to the upper part of Balytska Suite, while its even-age score to the rocks of Bogorodchanska, Tyraska and Kosivska suites cannot provide the ground for artificial separation of this sequence from Balytska litho-stratigraphic unit and ascription to the mentioned suites. In fact, same age can only suggest for diachronic nature of Balytska Suite boundaries with molassa rocks in the Trough external zone. In the approved stratigraphic scheme [46], in Sambirskiy LTZ just the lower portion of clayey sequence is ascribed to Balytska Suite which contains Early Miocene micro-fauna varieties characteristic for Carpathian: *Globigerina bulloides* O r b., *Globorotalia bukovae* (A l s.) and others. The clayey rocks which lie below salt-bearing sediments, on the ground of findings in the Kalush area the horizon with *Candorbulina universa*, and layers with *Uvegerina asperula*, are ascribed to Bogorodchanska Suite. Salt-bearing sediments in the Kalush area and north-eastern part of Sambirska LTZ are defined as *Kaluski Layers*, which by the fact of gypsum-anhydrite lenses occurrence below the salts, are correlated to gypsum-anhydrite sequence of Tyraska Suite in the Trough external zone and platform margin. Salt-bearing sediments and olistostrome sequence which formerly has been incorrectly mapped in the south-east of Sambirska LTZ as Upper Stebnytska Sub-Suite, are indicated in the approved scheme in the similar way. As a result of this mistake, in the salt-bearing molassa of Fore-Carpathians three potassium-bearing formations appeared – Vorotyshchenska, Stebnytska and Tyraska which had caused misunderstanding for a long time. Recent studies of the authors have shown that salt-bearing rocks in the Prut River basin belong to Balytska Suite and are correlated to *Kaluski Layers* [6, 64].
A.S. Andreeva-Grygorovych

NN 8 – Discoaster hamatus

...and C. sp. allows nano-plankton ascription to the zone NN 8 – Catinaster coalithus. The second complex include varieties: Discoaster hamatus Martini et Braml., Catinaster calyculus Martini et Braml., Minylitha cf. convallis Bukry, Tetralithoides cf. symeonidesii Theodoreis and others which allow definition of the zone NN 9 – Discoaster hamatus. The zones NN 8 and NN 9 are identified in Sarmatian sediments in Romania, in Sub-Carpathian thrust (formation Sipotel, Internal Zone and formation Susita, External Zone). In Poland, association of zones NN8 / NN 9 is distinguished in the layers with (top parts of Upper Badenian) and Sarmatian Krakovetsky clays in the north-eastern part of Fore-Carpathian Trough (area of Tarnobzheg). Thus, nano-plankton study results allow definition the age of upper (sandy-clayey) part of Balytska Suite to be Sarmatian.

Krakovetsky Sub-Carpathian thrust (formation

...is known in geological publications as Cretaceous rock fragments, and higher in the column the rocks include diverse-grained quartz-glauconite stratigraphic scheme [46]. At the bottom of these layers the basal horizon is normally observed with Upper Cretaceous surface and is overlain by either Tyraska or Kosivska suites, or by Upper Cenozoic sediments. In the stratigraphic scheme approved by UISC, Baranivski, Mykolatvski, Naraiivski and Erviliev layers are distinguished in Opilska Suite. However, it was proven in the works of L.N.Kudrin [30] that these layers do actually comprise the even-aged litho-facial units replacing one another over short distances both in lateral and vertical directions. It is therefore reliable to define the Suite in the mapping as the single geological body defining just the diverse litho-facial varieties inside. Generalized Suite column in the platform margin comprises mainly the litho-type of bioherm limestones, light, dense, containing frequent lens-like inclusions of thin-layered chemogenic limestones. Thickness of bioherm limestones is 1.5-3.0 m. At their bottom the fine-pebble conglomerate lenses from underlaying rocks are observed often enough. Higher the bioherm limestones the lens-like 0.5-0.8 m thick layers of Rhodophycea limestones occur. The rocks are light, yellowish, enriched in sea urchin and sponge fragments. The layers of Rhodophycea limestones consist of individual blobs (Rhodophycea algae colonies) 5-10 cm in size cemented by sandy-limestone material. Some limestone layers are separated by greenish-grey clay interbeds which also form spotty inclusions in limestones. Thickness of Rhodophycea limestones is 5-20 m. In lateral direction they often and quickly bifurcate in lens-shaped mode, the

...
lenses and beds of sandstones and clays appear inside enriched in organogenic detritus and single fine lithoammonium blobs. Sandstones form 0.3-1.2 m thick layers which in lateral direction are also replaced sharply enough by clayed Rhodophycea limestones. Total thickness of this litho-type varies depending on the column from 8-10 m to 30 m. Somewhere above bioherm limestones the thin (0.2-0.3 m) layer of organogenic yellowish-grey limestones is observed enriched in pelercyoda shells Ervilia pusilla P h i l., Ostrea digitalina D u b. and others. These limestones in geological literature are known as “Erviliiev Layers”.

In the western direction the facies of bioherm limestones is gradually changed by clayey-sandy litho-
type developed in the area of Zhoravno village. Conventional boundary between these rocks spatially coincides with the facial boundary of Upper Cretaceous Lukvynska and Zhoruvnenska suites. The clayey-sandy facies of Opilska Suite is composed of quartz-glaucocite sands and sandstones and green-grey clays enriched in shell fragments. Mainly sandy litho-type (pseudo-abyssal and lower part of sub-litoral facies) is developed in the slightly subsided platform margin. Transition from Rhodophycea litho-type to sandy one is observed through marl-clay-aleuritic facies. The marls contain abundant imprints of molluscs Pseudoamussium corneum denudatum (R e u s s.) and others suggesting for the Early Badenian age. Thickness of Opilska Suite varies from 15-20 m in the north-eastern part of the territory to 53 m close to the boundary with Bilche-Volytska LTZ [65, 77].

Bogorodchanska Suite (N, bg) is developed in Bilche-Volytska LTZ where it overlies eroded surface of mainly Upper Cretaceous rocks. And only in the buried Kolomiyska paleo-valley the Suite lies over Upper Jurassic and Lower Devonian sediments. Slightly eroded surface of the Suite is overlain by Tyraska Suite. In lateral direction, towards Carpathians up toKalushkiy fault zone, the gradual transition is observed from sandy-clayey litho-type of Opilska Suite to marl-limestone one of Bogorodchanska Suite as well as gradual change in composition of the latter to essentially clayey. The complex of molluscs is determined in the rocks with Pseudoamussium corneum denudatum (R e u s s.) and others indicating the Early Badenian age. By mapping drill-holes data, the Suite is composed of grey and greenish-grey clays, marls and limestones. Diverse-thickness lens-like interbeds of sandstones, aleurolites and tuffites are widespread in this sequence. At the Suite bottom, almost over entire its distribution area, the basal conglomerates occur. By lithology, Bogorodchanski rocks do not actually differ from the underlaying Carpathian Zhurivski layers. Thus, it seems to be reasonable the proposal of S.E.Smirnov [42] to ascribe the whole sequence of Carpathian-Badenian rocks developed in Bilche-Volytska LTZ into the single Zhurivska Suite. Thickness of Bogorodchanska Suite depends on pre-Miocene paleo-relief and varies from 10 m to 45 m [65].

Tyraska Suite (N, tr) in the platform part of the territory, in Zakhidnopodilska LTZ, does form impressive cliffs and gorges at the gully slopes, and in Bilche-Volytska LTZ it is intersected by numerous drill-
holes [65, 77]. It mainly lies over eroded surface of Lower Badenian sediments, and in case of their lacking – over more older rocks. Slightly eroded surface of Tyraska Suite is overlain by Upper Badenian sediments or Upper Cenozoic rocks. Three litho-facies are distinguished in the sediments – sulphate, chemogenic carbonate and terrigenous (sandy) sediments. In the map sheet M-35-XXV Tyraska Suite is mainly comprised of the sulphate rock facies – gypsums, gypsum-anhydrites, anhydrites with admixtures and interbeds of clayey, carbonate or organic material, as well as chemogenic limestones. In the buried part of Bilche-Volytska LTZ Tyraska Suite in places may be comprised of the chloride facies rocks – rock salts with clay and anhydrite interbeds. They are confined to the erosion depressions in pre-Miocene basement. The separate group of post-sedimentation rocks in Tyraska Suite includes secondary metasomatic limestones (with or without sulfur). These are the products of metasomatic transformation after sulphate rocks and all sulfur deposits and significant sulfur occurrences in Fore-Carpathian sulfur-bearing basin are related to these rocks. At the Suite top 0.1-0.5 m thick yellow-brown chemogenic limestones are observed (Ratynski layers) with foraminifera Getrarium minima (M o n t.) and others characteristic for lower part of Upper Badenian. The rocks provide the reliable geophysical marker with low gamma-activity (2-3 mcR/h) and high apparent resistance – up to 1500 Ohmm.

In the approved “Stratigraphic scheme of Miocene in Gore-Carpathians” [46] Badenian regio-stage is divided into three parts and Tyraska Suite is ascribed to Middle Badenian. Development of nano-plankton complexes in Badenian column suggest for only two-fold division of Badenian. Change of complexes is observed at the level of Tyraska Suite which in the suggested stratigraphic scheme [6] is ascribed to Upper Badenian. Thickness of Tyraska Suite is 20-60 m [65, 77].

Kosivska Suite (N, ks) is developed in the platform margin and comprises main part of Miocene column in Bilche-Volytska LTZ. The Suite lies mainly over eroded surface of Tyraska Suite and in places where the latter is eroded completely – over the older sediments up to Paleozoic inclusively. The Suite is overlain by Dashavska Suite rocks or Upper Cenozoic sediments. In the lower Suite part does lie the 10-40 m thick batch of greenish clays with interbeds of aleurolites, tuffis, light-grey vitro-elastic or crystalline-elastic aleuritic or pelitic tuffites, as well as brownish-greenish carbonate clays (Verbovetski Layers). These layers are well identifiable by logging and micro-fauna complex suggesting for Late Badenian age. The main Suite column part is constituted

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of the uniform grey sandy-clayey sequence. It consists of 10-30 m thick batches composed just of massive clay, and same-thick batches of thin intercalation of clays with aleurolites and sandstones. Over entire column, with periodicity of 5-8 m, the thin (1-3 cm) interbeds of light bentonite clay are observed. In the clay sequence the signs of periodic linear bottom flows (channels) occur expressed in shallow (0.2-0.3 m) "pockets" filled with clayey blobs. Sandstones and aleurolites in the column occur in up to 10-20 cm thick interbeds. In the platform-side part of Bilche-Volytska LTZ thickness of sandstone interbeds attains 3-4 m. The rocks are weakly-cemented, micaceous, diverse-grained, massive or thin-layered, with oblique and wavy bedding of bottom flows. The mineral composition is mixed, characteristic for both platform and Carpathian rocks. The upper part of Kosivska Suite over there is more enriched in terrigenous material from the platform complex and is distinguished as Buglivski layers. In the clays and sands of these layers the thin tuff interbeds are frequently observed. In the clay sequence of Kosivska Suite which fills up the buried Kolomiyska paleo-valley, drill-hole 52-KI [112] at the depth 1000 m had intersected the cobbles of Jurassic and Cretaceous limestones most probably of proluvial-alluvial origin. Kosivska Suite foraminifera association with Corbula gibba O 1, Globigerina bulloides O r b. and others, and pelecypoda (Chlamys elini (Z h i z h.) and others) suggest for Late Badenian age. Thickness of the Suite varies from 40-65 m at the platform margin to 150 m in the external part of Bilche-Volytska LTZ and to 500 m in front of Sambirskiy thrust. Towards Carpathians the gradual Suite thickness increasing is observed. Above the ancient faults the con-sedimentation bends are observed offset fast enough by clay sequence deposition and as a result along Carpathian thrust the Suite thickness attains 1500 m.

At the outskirts of Rozhnativ town, in Boryslavsko-Pokutska LTZ, the spot of sandy-clayey sediments is mapped which with clear angular unconformity lies over Vorotyshchenska Suite. At the bottom of this pile the weakly-cemented conglomerates (almost pebble-stones with sandy-clayey filler) are observed composed of Carpathian rock fragments. Thickness of pebble-stone layers is 1-6 m. Rounding patterns of clastic material, occurrence of sandy-clayey lenses with coarse-wavy bedding suggest for alluvial origin of these sediments. Above pebble-stones the sequence of clays and weakly-cemented sandstones is observed. The clays are dark-grey, diverse-carbonate, enriched in coalified fossil remnants by bedding. Grey diverse-grained weakly-cemented sandstones also contain brown coal lenses and remnants of coalified fossils. In clays are determined numerous gastropoda Turtiella pythagorica H i l b. and others, and pelecypoda Cardium praechinatum H i l b., weakly-preserved crab remnants, as well as micro-fauna complex Corbula gibba O 1, Globigerina bulloides O r b. and others. On the ground of lithology, flora and fauna similarity with the sediments developed in adjacent area nearby Pistyn village, these sediments are thought to occupy transitional position from Upper Badenian to Lower Sarmatian. Their thickness is 80-120 m.

Sarmatian regio-stage

Upper Miocene in the studied map sheet is comprised of Dashavska Suite (N1ds) which is developed in Bilche-Volytska LTZ only where it is extended in the band from the north-western map sheet corner to its central part (Berezhnysya village area). The north-eastern boundary of Dashavska Suite with Kosivska Suite is traced conventionally enough but over there it almost completely coincides with the zone of Kaluskiy fault. In the south-west the rocks by the system of normal faults plunge down beneath Carpathian mega-thrust. Dashavska Suite lies over eroded surface of Kosivska Suite and is overlain by Pliocene-Quaternary sediments. Most part of the Suite is composed of grey argillite-like clays with interbeds of weakly-cemented and strong sandstones with transitional micro-fauna complex; by the reasons, the same column intersected by neighbouring drill-holes can be dated both as Upper Badenian or Lower Sarmatian [83, 92, 93]. The Suite is divided in two sub-suites. Lower Dashavska Sub-Suite (N1d1s) is composed of alternating batches of massive and thin-layered grey clays with thin interbeds of tuffs, weakly-cemented sandstones and single thin conglomerate lenses. Thickness of Sub-Suite is 450-500 m. Upper Dashavska Sub-Suite (N1d2s) is mainly composed of clays with aleurolite interbeds, sandstone and conglomerate lenses, and thin tuff layers. Thickness of Sub-Suite part remained from erosion is about 350 m. Numerous findings of pelecypoda Modiolia volhunica E i c h w., Cardium volkyenicum G r i s c h k., Cardium obsolatum E i c h w. and others in the Suite rocks suggest for their Early Sarmatian age. Total thickness of Dashavska Suite is 585-655 m (see "Stratigraphic columns").

Upper Miocene – Pliocene undivided (N1,2)

Undivided Upper Miocene – Pliocene sediments are developed in Boryslavsko-Pokutska, Sambirska and Bilche-Volytska LTZs. They are comprised of continental, mainly alluvial, pebble sequence (N1,gg) of pra-Dniester XVI-XI over-flood terraces, which is overlain by Pliocene or Quaternary aeolian-deluvial and eluvial-deluvial sediments. Remnants of the highest and oldest (apparently XVI) terrace are being mapped along the outer margin of Carpathians nearby Krasne village (denudation “Krasnoi Level”), as well as in the upper course
of Lukva stream in the area between Lukva and Bystrytsya-Solotynska rivers close to Mezhgyira and Kryvets villages. The socle of this Dniester River terrace in aforementioned areas is observed at altitude 583-585 m. In contrast to the old terraces of Dniester left bank developed further down its course outside the map sheet area, alluvium of all Dniester terraces and its major branches in its left-bank side includes cobbles and pebbles of only those rocks which constitute the flysch Carpathians with minor admixture of sandy-clayey material. Often “exotic” pebble occurs from the rocks characteristic to Lower Miocene molassa – green phillites, white quartz. Thickness of alluvium remained is 5.5-8.5 m. At Krasna mountain alluvium is overlain by the modern soils. Close to Kryvets village, alluvium of old terrace is overlain by Upper Pleistocene – Holocene 1.5-1.8 m thick peat. Most authors [19, 51] accept Pliocene age of this terrace just on the ground of highest for entire Fore-Carpathians altitudes. However, in Fore-Carpathians, in the right bank of Dniester River, according to the crossing geomorphologic profiles data, the denudation levels of XV-XI terraces are also relatively clear mapped and these terraces age is also considered to be Pliocene [65, 67]. Thus, the authors conventionally ascribe the age of XVI terrace alluvial sediments to Pontian regio-stage. In the northern outskirt of Bogrovka village, in the upper course of Pereyneys stream, in the steep gully walls, the buried soils are exposed, brown-red, in places parti-coloured, spotty, fractured, with clear parallel layering. These sub-aerial rocks in the volume of Dacian and Romanian regio-stages constitute the columns of pra-Dnister XV-XI over-flood terraces. Alluvium remnants of these terraces are widespread at the flat watersheds of Bystrytsya-Nadvirnyanska – Linnytsya – Svicha rivers. Thickness of remained alluvium in each Pliocene terrace is different and varies from 3.5 to 8.5 m. Pliocene alluvium is overlain by sub-aerial rocks which in the previous descriptions of mapping drill-holes performed in 60-70s of the last century are indicated as Pliocene-Quaternary undivided [83, 110]. The qualified description of Pliocene-Quaternary sediments by drill-hole core sections is conducted by Yu.M.Veklych [68]. Comparison of these results with core description from previously drilled boreholes allows assumption on development of Upper Pliocene sub-aerial rocks which overlie the older alluvial sediments. According to Yu.M.Veklych, the Pliocene sediments in sub-aerial facies are ascribed to Bogdanivskiy, Siverskiy and Beregivskiy climatoliths.

Bogdanivskiy climatolith. Eluvial-deluvial sediments (edN2bd). It is noted in some points along Dniester right bank where it lies over pre-Bogdanivski terrace relief forms. It is mainly overlain by Siverskiy climatolith. It includes sub-tropic and meadow soils often glued. It is composed of orange-ochre-brown clay, dark-grey, lumpy-fragmented, lumpy, dense. Thickness is 0.8-0.1 m.

Siverskiy climatolith. Aeolian-deluvial sediments (vdN2sv). It is described in the points as the previous unit. It is observed in terraces older than XI terrace. It includes clayey loess rocks. It is composed of clay, inhomogeneous, orange-light-brown, coarse-fragmented, with more dark-brown soil interbeds. Thickness is up to 3.5 m.

Beregivskiy climatolith. Eluvial-deluvial sediments (edN2bv). It is developed widely enough in Pliocene terraces. It includes intercalating soil and loess rocks. Clayey loess is dark-olive, lily-grey, amorphous-coarse-fragmented, dense. The soils are of meadow-forest sub-tropic landscapes with signs of salination and gluing – ochre-brown clay with fine red-brown and large light-lily-grey spots, very dense and heavy, fragmented-lumpy. At the layers bottom the clay becomes lighter and its texture more lumpy. The boundaries between soils and loess are sharp and wedge-shaped. The rocks are overlain by mainly sub-aerial Eo-Pleistocene sediments. Thickness of Beregivskiy climatolith is 0.5-4.4 m.

Quaternary System (Q)

Quaternary sediments cover entire territory of map sheet M-35-XXV with almost solid blanket. In the terraces of Dniester River right-bank side their thickness attains 30 m. In Carpathians it varies from 1.2 m in the upper slope course to 8 m at the foothills. These sediments are lacking on the steep cliffy Dniester River banks, its large right branches, as well as in the courses of mountain streams where the hard rocks are exposed. In the Fore-Carpathians watershed areas the Quaternary sediments somewhere lie over red-brown Pliocene clays, often without stratigraphic interruption. On the valley slopes the sediments lie over more older rocks. They include Pleistocene rocks of which by genesis sub-aerial (aeolian-deluvial – vd, eluvial – e), sub-aqueous (alluvial – a) and intermediate (deluvial-coluvial – dc, eluvial-deluvial – ed, deluvial – d, deluvial-sliding – dz, biogenic – b, and technogenic – t) sediments are distinguished.

The studied territory encompasses several areas of various patterns of geology and origin of Quaternary sediments and relief which are the counterparts of the higher-rank regions [51]. The south-western part of the territory is located in Gorganskiy area (A-1) and the area of Marginal ridges (A-II) of the External Carpathian sub-region. The central part encompasses some areas of Fore-Carpathians region, particularly: Maydanskiy (B-I), Mizhbystrytskiy (B-II), Prylukvynskiy (B-III), Voenlivskiy (B-IV), Zalisky (B-V), Bystrytskiy (B-VI), Kaluskiy (B-VII) and south-eastern margin of Strysko-Zhydachivskiy (B-VIII). The north-eastern and eastern parts include Opilskiy (C-I) and Prydnistrovskiy (C-II) areas. The area boundaries of Quaternary sediments
coincide with the boundaries of geomorphologic zonation (see legend to the “Geological map and map of mineral resources of Quaternary sediments” and “Geomorphologic scheme in the scale 1:500 000”).

In Gorganskiy area, with characteristic steep mountain slopes composed of strong thick sandstones the Upper Neo-Pleistocene – Holocene deluvial-coluvial and eluvial-deluvial sediments predominate. Deluvial-sliding sediments are locally developed only in places of Oligocene clayey sequences distribution.

The area of Marginal ridges, where less erosion-resistant Oligocene-Miocene sequences are developed, is characterized by predominated deluvial and deluvial-sliding sediments. Canyon-like extensions of major water-flow valleys in this area are filled with alluvium of the low and medium over-flood terrace complex.

In Maydanskiy area, which represents low-mountain zone with relatively steep slopes, eluvial-deluvial and deluvial-coluvial sediments predominate.

Watershed portions of Mizhbystrytskiy, Prylukvynskiy, Voynylivskiy and Zaliskiy areas in the near-surface part are composed of sub-aerial loamy sediment complex (mainly Middle-Upper Neo-Pleistocene eluvial-deluvial and aeolian-deluvial sediments) which overlie the older sub-aerial and sub-aqueous sediments. By the patterns of Quaternary sediments these area almost do not differ one from another. And their splitting into the individual domains is caused by their separation by the areas with different morphology and composition of Quaternary sediments.

Bystrytskiy and Kaluskiy areas as well as south-eastern margin of Striysko-Zhydachivskiy area exhibit maximum development of sub-aerial loamy sediment complex which constitute Upper-Middle Neo-Pleistocene terraces of the major water-flows in the territory. These sediments are overlain by Upper Neo-Pleistocene sub-aerial complex.

Complete lack of high terraces comprises the distinct feature of Opilskiy area in the Dnister left-bank side. On the slopes of extensively cut hilly height the Upper Neo-Pleistocene – Holocene deluvial sediments are developed, and in the flat watersheds – Middle-Upper Neo-Pleistocene eluvial, eluvial-deluvial and aeolian-deluvial sediments. The wide flat flood-lands of major water-flows in the area are filled with Holocene biogenic formations.

In the southern part of Prydnisterskiy area the lack of old sub-aqueous sediments is also characteristic. The gentle slopes and flat watersheds of the minor water-flows are covered with mainly Upper Pleistocene sub-aerial sediments. Development of deluvial-sliding sediments is permanently activated on the slopes. At the northern margin of the area sub-aqueous sediments of old Dnister terraces are overlain by Lower-Middle Pleistocene loams.

Extended study of Quaternary sediments in the area was conducted mainly on the ground of the field works conducted in 1990-1993 by Yu.M.Veklych, leading scientist of UkrSGRI [68]. These results had allowed authors studying of 40 quarries, 180 outcrops and data re-interpretation of 130 boreholes drilled during large-scale mapping [61, 77, 83, 110]. Subdivision of Quaternary columns is performed up to climatoliths. Unfortunately, most (about 75%) of previous boreholes were drilled in the upper part without or with very limited core sections coupled with fairly schematic core description. This made essentially difficult the mapping of Quaternary cover. Nevertheless, the mapping climatoliths were marked with regard to the map scale. Each subdivision used in the map design, in the column is composed of alternating cold and warm stage climatoliths, mainly soils and loess. Since the cold and warm stage strataons exhibit considerable lithological and facial differences, description of major subdivisions is given for each climatolith. Their description is performed under the uniform scheme on the ground of study over basic and additional columns. Lithological descriptions are supplemented by analytical data from previous studies [68]. In adjacent territory to the north for some climatoliths the absolute age is determined in the laboratory of Lublin University, Poland, by thermoluminescent analysis [15].

For sub-aqueous sediments, which include alluvium of ten over-flood terraces, the ledge is a mapping subdivision. In the column of sub-aerial sediments, in some natural and artificial outcrops and in the core sections, specific climatoliths reflecting cold or warm stages are distinguished relatively reliable only by rock lithology. Their mapping over the area is almost impossible and by these reasons they are indicated only in the typical lithological-stratigraphic columns and in the scheme of Quaternary sediments. In the map of Quaternary sediments sub-aerial units in most cases are indicated within undivided branches. However, some aeolian-deluvial subdivisions exhibit persistent enough thickness and lithology and are being mapped quite reliable. It is reflected in the geological map of Quaternary sediments where the youngest pre-Holocene subdivisions are indicated, as well as mineral resources related to the Quaternary sediments. In this map design was also used the map of soils prepared by “Ukrzemproekt” in 1968.

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Pliocene and lower branch of Eo-Pleistocene undivided (N2-E1)

Kyzylzharskiy ledge. Alluvial sediments of tenth terrace (a10N2-E1kz). The rocks, which age encompasses upper parts of Late Pliocene and lower part of lower branch of Eo-Pleistocene, are being mapped in the area between Bystyrtysa-Solotvynska and Bystyrtysa-Nadvirynska rivers at the outskirts of Gvizd village, and in the area between Bolokhivka and Syvka rivers at the outskirt of Golyn village. Alluvium thickness of this terrace, intersected by some mapping and exploration drill-holes, is 5-6 m.

Pleistocene Division (P)

According to “Stratigraphic Code of Ukraine” (1997), the Eo-Pleistocene and Neo-Pleistocene sections are distinguished in Pleistocene Division.

Eo-Pleistocene Section (E)

Eo-Pleistocene section includes the own spectrum of facial complexes of which the following are being mapped:

Berezanskiy climatolith. Aeolian-deluvial sediments (vdE1br). It is fairly locally developed. Normally it is confined to the incisions emerged in Beregovskiy time. It is composed of heavy loam, brown-pale, and soil rocks, often with signs of re-deposition and hydromorphism. Thickness is about 0.5-1.8 m (often is lacking or re-worked, eroded in further stages). By lithology, this is clay or heavy loam, often sandy, brown, light-brown, fragmented and lumpy-columnar. In some cases Berezanskiy straton almost does not differ by facial features from young loess and then the principal stratigraphic difference from the latter comprises its position in the column.

Kryzhanivskiy climatolith. Eluvial-deluvial sediments (edEIIkr). It is widely enough developed in the watershed back-terrace areas of the Dnister left-bank side. It is comprised of eluvial-deluvial sediments. It is composed of sub-tropic type forest soil (pile of two-three soils), in places with re-deposition signs. In some case it is intercalating with loess. By mechanical composition it is heavy loam or clay, often sandy, red-brown, fragmented or amorphous-lumpy, in places with newly-formed carbonates. Thickness is 1.2-4.0 m.

Illichivskiy climatolith. Aeolian-deluvial sediments (vdEIIil). It is very rarely known in the tenth terrace. It is comprised of clayey loess which at the bottom somewhere contains embryonic clayey soil material, often with signs of re-deposition and hydromorphism. The rocks lie mainly over pre-Quaternary sediments and are overlain by undivided Middle Pleistocene rocks. It is composed of olive-grey clay and heavy loam, in places sandy, brown, light-brown, fragmented and lumpy, somewhere with large (up to 5 cm) newly-formed carbonates and cut by soil wedges. From the older loess sediments these ones differ in essential gluing (extensive-lily colour), and from the younger ones – in mainly clayey composition and more hydromorphic facies. Thickness is up to 1 m.

Nogayskiy ledge. Alluvial sediments of ninth terrace (a9E1Ing). The rocks are developed in the same areas as the tenth over-flood terrace. Pebble taluses are observed on the slopes of Nogayska terrace and full thickness of alluvium is intersected by some drill-holes [68, 83]. In the column of cobble-pebble sediments composed of Carpathian rocks the gradual changing is observed from coarse-pebble with cobbles through fine-pebble to sandy-clayey. Thickness of terrace alluvium is 4.5-5.0 m. Alluvium of tenth and ninth terraces are overlain by mainly undivided Middle Pleistocene sediments.

Eluvial-deluvial and aeolian-deluvial sediments (ed,vdE) are only developed at the level of X terrace where they are 3-5 m thick and are known from several points. The rocks are comprised of Berezanskiy, Kryzhanivskiy and Illichivskiy climatoliths described above. Kryzhanivskiy climatolith comprises the major counterpart of Eo-Pleistocene columns while Berezanskiy and Illichivskiy climatoliths often pinch out from the column mainly due to re-working by the soil-forming processes.

Eo-Pleistocene section and Lower Neo-Pleistocene branch undivided (E-P1)

Eluvial-deluvial and aeolian-deluvial sediments (ed,vdE-P1) are only developed at the level of X terrace where they are 3-5 m thick and are known from several points. The rocks are comprised of Kryzhanivskiy, Illichivskiy and Illichivskiy climatoliths described above. Kryzhanivskiy climatolith comprises the major counterpart of Eo-Pleistocene columns while Berezanskiy and Illichivskiy climatoliths often pinch out from the column mainly due to re-working by the soil-forming processes.
cold stages (loess). The soil units predominate in the columns. Thickness is 10-25 m. Description of individual climatolith is given in the section “Lower Neo-Pleistocene branch”.

*Eluvial-deluvial sediments* (edE-P1) are observed in the same sites as the previous ones. The rocks include exclusively soil piles (description of individual stratigraphic counterparts is given in respective sections). Thickness is 2-7 m.

**Lower Neo-Pleistocene branch (P1)**

The Lower Neo-Pleistocene branch includes Shyroksiyi (edP1sh), Martonoskiy (edP1mr) and Lubenskiy (edP1lb) climatoliths of warm stages which are respectively overlain by Pryazovskiy (vdP1pr), Sulskiy (vdP1sl) and Tyligulskiy (vdP1tl) climatoliths of cold stages. In the map sheet area these stratons are comprised of some facies and complexes of sub-aerial (loess-soil) and sub-aqueous (mainly alluvial) types. Among the Lower Neo-Pleistocene stratigraphic subdivisions the following ones are distinguished:

*Shyroksiyi climatolith. Eluvial-deluvial sediments* (edP1sh). It is widely enough developed in the back-terrace area of the Dnister left-bank side and in terraces older than the eighth one. It is comprised of soil units (group of 2-3 soils, somewhere complex of piles) of sub-tropic type, brown-colour range, in places with signs of re-deposition and gluing, complicated by soil wedges, in places is separated by loess sediments. The soil is sub-tropic, forest (up to forest-steppe in the upper part). By mechanic composition it is clay or heavy loam, often sandy, red-brown to grayish-brown with light-lily-grey sub-vertical spots, prismatic, nuts-fragmented, somewhere with newly-formed carbonates. Thickness is relatively high – 3-5 m.

*Pryazovskiy climatolith. Aeolian-deluvial sediments* (vdP1pr). It is known somewhere in the distribution areas of ninth-eleventh terraces. It is comprised of loess which at the bottom often contains embryonic soil formations. It is composed of loams, yellowish- and brown-pale, dense, lumpy, often porous; embryonic soils are darker and often contain iron-enrichment spots. Thickness is up to 1 m, somewhere is completely eroded.

*Budatskiy ledge. Alluvial sediments of eighth terrace* (a8P1bk) and mainly developed in Fore-Carpathians at watersheds of Bereznytsya, Syvka, Limnytsya, Bystrytsya-Nadvirnianska and Bystrytsya-Solotynska rivers. In the mountains the remnants of this terrace are traced over valley slopes in the minor flats. The rocks include pebble-stones with cobbles, diverse-grained sands and sandy loams, layered sandy loams, dense, at the bottom – gravelous and less clayey. Thickness of alluvium in the fore-mountains is 5.5-6.0 m, in the mountains – up to 2 m.

*Martonoskiy climatolith. Eluvial-deluvial sediments* (edP1mr). These rocks are often enough observed in the same sites as the older units but are normally lacking below the middle portions of valley slopes. Climatolith is relatively frequently observed in terraces older than seventh one, as well as in Lower Pliocene ones. It is mainly comprised of 2-3 interbeds of sub-tropic type, red-brown range soils, often hydromorphic, somewhere with re-deposition signs. In some cases the soils are separated by thin loess layers. Climatolith is composed of heavy loam, red-brown with light-lily-grey sub-vertical spots, dense, prismatic or fragmented-lumpy, with newly-formed carbonates up to 5 cm in size. Thickness is about 3 m.

*Sulskiy climatolith. Aelolian-deluvial sediments* (vdP1sl). These rocks are relatively rarely known in the area but they are well-expressed in the column. It is comprised of loess and moderate soils (mainly at the bottom). By lithology, it is heavy loam, brown-pale, lily-pale (loess), grayish-brown (soil), lumpy, slightly-porous, with newly-formed carbonates 2-3 cm in size. Thickness normally is low – up to 0.5 m (often loess is removed). In the south-western part of map sheet area it somewhere attains abnormal thickness (up to 10.5 m). In the rocks of this straton the malaco-fauna complex is found – the shells of surface molluscs Succinea oblonga Dr a p., Papilla muscorum (L.), Vallonia pulhella (M u 11.), indicating for climate change from relatively warm in the beginning of Sulskiy time through moderate-cold to cold peri-glacial at the end.

*Donetskii ledge. Alluvial sediments of seventh terrace* (a7P1dc). These are developed in the same areas where the sediments of eighth terrace occur. Include sands with pebble-stone lenses. Thickness is 3.5-4.0 m.

*Lubenskiy climatolith. Eluvial-deluvial sediments* (edP1lb). It is most developed on the gentle back-terrace slopes in the same extent as Sulskiy climatolith and does mainly overlie the latter. Somewhere it is known in terraces older than sixth one and at the highest watershed sites of Pliocene terraces. It includes suite of 2-3 soils, moderate sub-tropic, in places with signs of re-deposition, separated by loess-like loams. Loamy soils are dark-grey, brown, dense, nutty, lumpy-nutty, in places with fine concretions of manganese hydroxides. From Martonoskiy climatolith it differs in less intensity of brown shading, as well as in much higher hydromorphism degree. From the similar in colour Shyroksiyi climatolith is differs in the lighter mechanic composition, lesser thickness and density. It is composed of heavy brown to grey-brown loam (in meadow facies – brownish-dark-grey), lumpy, with newly-formed carbonates 2-4 cm in size. Thickness is mainly up to 3 m, somewhere it attains 9 m.
Tyliogulsy climatolith. Aeolian-deluvial sediments (vdP1tl). At the surface these sediments are known from some sites in the Dnister right-bank side, somewhere they occur in paleo-cuts in the column of Lower Quaternary sediments. Include loamy loess and moderate soils (mainly at the bottom). By composition the loam is heavy to medium, brown-pale, lumpy, slightly-porous, with newly-formed carbonates (2 cm). Thickness is 0.8-3.2 m.

Krukenytskiy ledge. Alluvial sediments of sixth terrace (a6P1kn). These are developed on the slopes of all major water-flows in the mountains and fore-mountains. The rocks include alternating pebble-stones and sands with sandy loam lenses. Thickness is 3.5-5.5 m.

Eluvial-deluvial and aeolian-deluvial sediments (ed,vdP1). These rocks are widespread and exposed mainly at the flat watersheds and in the upper slope parts. In the most parts of the areas between Dnister right branches they are overlain by younger rocks. The sediments are lacking in the lower third of the steep-slope sites of water-flow and gully valleys. The rocks include former soils alternating with loess, in places deluvial. Thickness attains 15-25 m. Higher of eighth terrace these sediments lie over Eo-Pleistocene rocks. Description of climatoliths involved is given above.

Eluvial-deluvial sediments (edP1) are developed at the slope-side valley parts and are mainly composed of soil piles (loesses are lacking). Rock thickness is 3-8 m. Description of individual subdivisions is given above.

Lower Neo-Pleistocene and Middle Neo-Pleistocene branches undivided (P1-II)

Eluvial and aeolian-deluvial sediments (e,vdP1-II). These are widely distributed everywhere except flood-land river portions. In places are overlain by the younger friable cover. For the plain part of Fore-Carpathians continuity of Lubensko-Zavadivskiy pedo-complex is characteristic (Tyliogulsy straton is re-worked) providing the ground for definition of such complex. Thickness is 5-25 m. Description of each Middle Neo-Pleistocene straton of this complex is given in the next section.

Middle Neo-Pleistocene branch (P1i)

Middle Neo-Pleistocene branch includes Zavadivskiy (edP1zv) and Kaydatskiy (edP1kd) stratons of warm stages which are overlain by Dniprovskiy (edP1dn) and Tyasminskiy (vdP1ts) stratons of cold stages respectively. In the map sheet area the complexes are developed which include specific facies and facies complexes of sub-aqueous (mainly alluvial) and sub-aeiral (loess-soil) types. Among these sediments in drill-holes and in some sections the following subdivisions are distinguished relatively reliably:

Zavadivskiy climatolith. Eluvial-deluvial sediments (edP1zv). It is developed at the same sites as the previous stratons. It includes compact soil suite of moderate sub-tropic type, red-brown range. Somewhere it exhibits re-deposition signs. The soils are often separated by thin loess interbeds. It is composed of medium or heavy loam, light-reddish-brown to reddish-brown, lumpy, with newly-formed carbonates up to 3 cm in size. In the rock the clay fraction (<0.001 mm) content is 32.6-41.5%, coarse fraction (1.0-0.063 mm) – 2.5-4.3%; quartz predominates, and calcite, feldspar, montmorillonite signs, hydro-mica and kaolinite occur. From Lubenski soils it differs in more intensive red-brown shades, and from similarly-coloured Martonoskiy climatolith – in the lighter mechanic composition and lesser density. Absolute age of these rocks is from 320\(\pm\)30 to 410\(\pm\)40 thousand years. Thickness is about 1.5 m but at the high levels of fifth and sixth terraces in places attains 4 m.

Dniprovskiy climatolith. Aeolian-deluvial sediments (edP1dn). It is widely enough developed, mainly at the watershed portion of slopes, and also occurs in the column of friable sediments overlaying terraces older than fifth one. It is comprised of loess which at the bottom often contains soil of embryonic type. By lithology it is medium loam, grayish- and brownish-pale, dark-grey-pale (soil), lumpy, porous, with carbonate tubes. Clay fraction content is 16.8-20.3%, coarse one – 3.9-8.5%; quartz predominates, and calcite, hydro-mica, dolomite, kaolinite and chlorite signs occur. In the embryonic soil interbeds of Middle Dniprovian age single shells Succinea oblonga D r a p are determined suggesting for the warmer and wetter climatic conditions. Absolute age of the soils is from 277\(\pm\)41 to 342\(\pm\)51 thousand years. Thickness of 2-3 m is fairly persistent by strike; in places it is cut by the modern soil or the surface.

Khadzybeyskiy ledge. Alluvial sediments of fifth terrace (a5P1hd). These are developed on the slopes of all major water-flows. The sediments include pebble-stones with cobbles and lenses of sands and sandy loams. Thickness is up to 6.5 m.

Kaydatskiy climatolith. Eluvial-deluvial sediments (edP1kd). It is relatively widely known at various sites of slopes and watersheds. It is comprised of brown-colour range soils. In places it exhibits evidences for re-deposition and salination. In the paleo-cuts climatolith often comprises the lower column part. It is composed of medium or light loam, grayish-brown to brown (meadow soils are dark-grey), lumpy, slightly-prismatic, in places with newly-formed carbonates up to 1.5 cm in size. Kaydatskiy soil (as the counterpart of Kaydatsko-
Prylutsko-Vytachivskiy pedo-complex) from the similar Lubenskiy straton differs in the lighter mechanic composition, lesser density and more prominent stratigraphic and lithological differentiation. Absolute age of Kaydatskiy former soil complex is from \( 212^{+32}_{-26} \) to \( 259^{+30}_{-26} \) thousand years [15]. Thickness is 0.2-1.5 m.

**Tyasminskiy climatolith. Aeolian-deluvial sediments (vdP\(_{\text{IIts}}\)).** It is relatively rarely known and in most cases is re-worked over subsequent soil-forming stages. It is comprised of thin loess. By lithology it is medium or light loam, grayish- and brownish-pale, dark-grey-pale, lumpy, often porous, with carbonates up to 1 cm in size. From the most similar Upper Neo-Pleistocene Udayskiy loess it almost does not differ. The main age evidence – stratigraphic position. In the adjacent territory in loams of Tyasminskiy climatolith the spore-pollen complex is determined where grassy plant pollen predominates being characteristic for peri-glacial climatic conditions. Absolute age of this straton is determined in the range from \( 172^{+26}_{-28} \) to \( 211^{+32}_{-30} \) thousand years [19]. Thickness is 0.1-0.3 m, in places (in the cuts and in fourth terrace) up to 0.5-0.6 m.

**Cherkaskiye ledge. Alluvial sediments of fourth terrace (a\(_{\text{IV}}\)P\(_{\text{II}}\)).** These are developed over the valleys of all major water flows. The sediments include pebble-stones with cobbles and lenses of sands and sandy loams. Thickness is up to 10 m.

**Eluvial and aeolian-deluvial sediments undivided (e,vdP\(_{\text{II}}\)).** The rocks are observed mainly in the flat areas in between major Dniester right branches where they often conformably lie over Lower Neo-Pleistocene sediments described above. In the columns the soil sediments (Zavadivskiy, Kaudatskiy) predominate over the loess ones (Dniprovskiy, Tyasminskiy). They are composed of medium loams, somewhere light ones. Thickness varies from 10.5 to 12 m (in paleo-cuts). Each climatolith of Middle Neo-Pleistocene branch exhibits specific patterns described above.

**Middle Neo-Pleistocene and Upper Neo-Pleistocene branches undivided (P\(_{\text{III}},\text{IV})\).**

**Eluvial and aeolian-deluvial sediments undivided (e,vdP\(_{\text{III}}\)).** These are developed in Fore-Carpathians, where they overlie alluvium of Lower-Quaternary terraces, and in the back-terrace areas of Podillya margin. They include former soils and loess in lesser extent of total thickness from 5 to 12 m. Description of individual climatolith in this complex is given in the sections for Middle and Upper Neo-Pleistocene branches.

**Eluvial-deluvial sediments undivided (edP\(_{\text{III}}\)).** These are developed in Fore-Carpathians and in the low-mountain part of Carpathians on the gully slopes, in paleo-cuts and in the valleys of water flows with flat bottoms. They include soil piles (loesses are lacking). Thickness of sediments is 1.0-4.5 m.

**Upper Neo-Pleistocene branch (P\(_{\text{IV}}\)).**

This branch includes sub-aqueous sediments of the third-first terraces and sub-aerial sediments of Prylutskiy (edP\(_{\text{IV}}\)pl), Udayskiy (vdP\(_{\text{IV}}\)ud), Vytachivskiy (edP\(_{\text{IV}}\)vt) climatoliths of warm stages, and Buzkiy (vdP\(_{\text{IV}}\)bg), Prychornomorskiy (vdP\(_{\text{IV}}\)pc) climatoliths of cold stages. Among sub-aerial units the following are being mapped:

**Prylutskiy climatolith. Eluvial-deluvial sediments (edP\(_{\text{IV}}\)pl).** It is relatively widespread in Fore-Carpathians at the flat surface of terraces older than fourth one and on the gentle terrace slopes. Often it lies over Kaydatskiy soil and is overlain by Vytachivskiy one. It is comprised of the soils from moderate forest-steppe landscapes, normally meadow (dark-grey-coloured). In places it exhibits evidences for re-deposition and salination. It is composed of brownish and olive-grey loams; forest soil varieties are orange-brown; in places with fossil remnants, dense, lumpy, nutty, often porous. In Kaydatsko-Prylutsko-Vytachivskiy pedo-complex Prylutskiy soil comprises its middle grey-coloured part which is somewhat similar to Lubenskiy soil but differs from the latter in the lighter mechanic composition, lesser density and lesser differentiation by both colour and stratification. The most prominent pattern of Prylutskiy pedo-horizon comprises its widespread breaking by the frost deformations expressed in fine-polygonal fracturing. Solifluction deformations are also characteristic. Thickness is 0.2-0.6 m, and somewhere (in cuts) up to 1.4 m.

**Udayskiy climatolith. Aeolian-deluvial sediments (vdP\(_{\text{IV}}\)ud).** It is very rarely observed since normally it is re-worked by subsequent soil-forming processes or is eroded. It is comprised of thin glued loess. By lithology the loam is light, grayish- and brownish-pale, lumpy, porous, with carbonates 0.5-1.0 cm in size. From Dniprovskiy and more older stratom of cold stages it differs in much less thickness, lack of steppe embryonic soil. From the similar Tyasminski climatolith it differs only in stratigraphic position. Thickness is 0.3-0.5 m, in places up to 1.5 m.

**Trubizkiy ledge. Alluvial sediments of third terrace (a\(_{\text{IV}}\)P\(_{\text{IIt}}\)).** These are developed over the valleys of almost all water flows. They are composed of pebble-stones with cobbles, gravel, sands and sandy loams. Thickness is up to 5 m.
Vytačivský climatolith. Eluvial-deluvial sediments (edPIIIvt). It is widely developed both in watershed areas and over terrace relief (except first over-flood terrace and flood-land itself). It is comprised of the compact series of moderate steppe soils of brown-colour range. In places it exhibits evidences for re-deposition and salination. In paleo-cuts it often comprises upper part of the complex. Thickness is 0.4-1.5 m (in paleo-cuts). It is composed of light loam, brownish-grey to dark-grey, lumpy, in places with newly-formed carbonates up to 1.5 cm in size. Buzkiy climatolith. Aeolian-deluvial sediments (vdPIIIbg). It is widespread in the fore-mountain part of the area, at the watershed and close slope sites, where it mainly overlies middle part of the slopes, as well as most of Quaternary terraces. It is comprised of loess, somewhere hydromorphic or deluvial, in most complete columns with embryonic soil in the straton lower part. Upper column part is composed of loess-like loams, pale, yellow- and brown-pale, homogeneous, light, slightly densely, porous, with distinct vertical columnar jointing, with carbonate concretions 1.0-3.5 cm in size. Somewhere in the upper loess part the steppe landscape soil interbeds occur. In the middle column part characteristic dense sandy loams and loams of irregular colour occur where in places large deformations are observed resembling pseudomorphs after polygonal-veined ice. The lower part of climatolith is composed of medium and heavy loams and sandy loams of essential density and wetting. Over there, iron-manganese inclusions are often observed and colour becomes lily-greenish through guing. In the upper part of this straton Yu.M.Veklych has found the shells of surface molluscs Helicella striata (M u l l.), Succinea oblonga D r a p., of which the first one comprises xerophile form characteristic for sub-periglacial dry steppe landscape. Thickness is 2-4 m (mainly 3.5 m).

Vilšansky ledge. Alluvial sediments of second terrace (a2PIIvl). These are developed over the valleys of all major water flows. In maximum extent they are distributed over the valleys of Dniester River and its branches. The sediments are composed of pebble-stones with cobbles, sands and sandy loam lenses. Thickness is up to 20 m.

Dofinivs'kiy climatolith. Eluvial-deluvial sediments (edPIIIdf). It is mainly developed over low terraces in the lower parts of gentle slopes, gullies and ravines, where it overlies loesses of Buzkiy straton appearing as thin soil at the bottom of Holocene soil suite. In about 300 m from the flat gully bottom upward the slope the sediments of this straton disappear. However, in places they are also known at the watershed sites. Climatolith is comprised of the suite of moderate-cold steppe and forest-steppe soils which are somewhere separated by deluvial loess. It is composed of light loam, brownish-grey to light-grey, saline, with prominent lumpy texture, with newly-formed carbonates up to 0.2-1.5 cm in size. Numerous malaco-fauna Helicella striata (M u l l.), Papilla muscorum (L.), Succinea oblonga D r a p. and others suggest for repeating climatic changes over that time under predomination of warm and irregular in wetting climate. Thickness is 0.3-1.5 m.

Prychornomors'kiy climatolith. Aeolian-deluvial sediments (vdPIII). In the Bystrytskiy, Kaluskiy and Verkhnyodnistrovskiy areas it covers alluvium of Upper Neo-Pleistocene terraces with the solid blanket. In the back-terrace area it is locally developed beneath Holocene soil in the slope lower parts of paleo-cuts where it overlies Dofinivs'kiy soil, and in case of their lacking – the loess of Buzkiy climatolith. In many outcrops along the low terrace ledges the columns of Prychornomors'kiy climatolith are observed which are comprised of loess-like loams, dark-grey-pale, in the upper part with fine iron hydroxide stops, lumpy, porous, with fine gravel at the bottom. Upward they are gradually changed by Holocene soil. Climatolith is encountered in some points on the gully slopes in the valleys of Dniester right branches where its thickness is 0.5-0.8 m. It is comprised of loess normally re-worked by the modern soil. It is composed of light loam, grey-pale, light-grey, lumpy, porous. In the walls of deep cuts, which cross the slopes of back-terrace inter-river areas, structure of climatolith is more complex. Over there it is comprised of the sequence of aeolian-deluvial and alluvial-deluvial loess sediments, of which from bottom to top are distinguished: 1 – loess-like loams, yellow-grey-pale, light, slightly-dense – 0.3-0.5 m; 2 – deluvial embryonic soil – light-brown-grey loam, lumpy, porous, with rare ochre spots – 0.2 m; 3 – deluvial grey-pale loess, lumpy, dense, in the upper part with pseudo-micellar carbonates – 0.2 m; 4 – embryonic eluvial soil, dark-brown-pale, porous, with lenses of diverse-grained sand – 0.2 m; 5 – loamy loess, grey-pale, lumpy, porous, light, coarse-columnar, with carbonate spots – 0.3 m; 6 – light-grey loam, nutty-fine-grained, dense, with micellar carbonates, with lenses of coarse-grained sand – 0.3 m. Loesses of Prychornomors'kiy stage reflect sub-periglacial moderate wet landscape of branched plains which is supported by the findings in the rocks the typical for these condition biotope with Helicella cf. Instabilis (H s s m.), Volvonia tenulabris (A l. b r.) and others. From the older loesses they differ in lighter mechanic composition, more lumpy texture, and occurrence of embryonic soils in the middle part of climatolith.

Desnyans'kiy ledge. Alluvial sediments of first terrace (a1PIIId). These are developed over the valleys of all water flows except gullies and ravines. The sediments are composed of pebble-stones with cobbles, sands and sandy loam lenses. Thickness is up to 25 m.

Eluvial-deluvial and aeolian-deluvial sediments (ed,vdPIII). These are widespread in Fore-Carpathians and in the margin of Podillya. They are mainly comprised of thick loesses. Former soils are thin. Thickness of
entire complex is 2.5-20.0 m. Most often the loesses of Buzkiy and former soils of Pylutschy and Vytachivskiy climatoliths are observed in the column of these rocks.  

* Aeolian-deluvial and eluvial-deluvial sediments* $(v_d, e_d P_{III})$. These are mainly developed in the fore-mountains in the middle and lower slope parts and gully bottoms where in the loess-like loams of Buzkiy and Prychornomorskiy appearance the lenses and interbeds of washed older medium and heavy loams, sandy loams, brown, dense, lumpy are observed. The loesses of Buzkiy climatolith predominate in the column. The sediments are locally developed in the low terraces of Fore-Carpathian water flows. Thickness is 0.5-2.5 m (up to 8 m in paleo-cuts).

* Upper Neo-Pleistocene branch and Holocene Division undivided* $(P_{III-H})$

These include transitional-type rocks of which the following are most developed:  

* Eluvial-deluvial sediments* $(e_d P_{III-H})$. These are developed in the mountains and in fore-mountains where they cover flattened watershed areas. They are composed of sandy loam, sand, gravel with boulders and cliffs. Somewhere cliff erosion remnants are observed. Thickness is mainly 2-4 m.  

* Deluvial-coluvial sediments* $(d_c P_{III-H})$ are most widespread on the mountain slopes and on steep slopes of Dnister River and its branches. These are composed of loams, sandy loams, enriched in gravel and cobbles. Thickness at the slope tops is 0.2-0.5 m, at the foot – 5-6 m.  

* Deluvial sediments* $(d P_{III-H})$. In the fore-mountains they cover gentle slopes of back-terrace extensively cut areas between the rivers. These are mainly re-deposited, washed sub-aerial rocks of various Pleistocene strata enriched in sand, gravel, and cobbles from underlaying pre-Quaternary sediments. Deluvium thickness increases from watersheds towards the slope foots from 0.2 m to 3-4 m.  

* Deluvial-sliding sediments* $(d_z P_{III-H})$ are most developed in the fore-mountains in the inner Trough part where Quaternary column is comprised of thick clayey sequence cut by the modern hydro-network. In maximum extent these rocks are developed on the right slopes of Turyanka, Berezhnytsya and Lukva streams, as well as on the gully slopes in the extensively cut back-terrace area between both Bystrtytsya rivers at the outskirts of Gvizd village. These sediments are also observed in the slightly-cut back-terrace inter-river areas in the outer Trough parts at the outskirts of Otnyna village, as well as in Carpathians where they are confined to the exposures of Oligocene clayey sequences. They include mainly slides-blocks which are displaced almost without breaking the primary bedding in the rocks. Lower slide part is composed of wetted soil mass mixed with clayey-gravel deluvial material. Small sliding bodies are composed of clayey soils enriched in sand and gravel. Their thickness attains 25 m.

**Holocene Division (H)**

* Alluvial sediments* $(a H)$ fill up the flood-land and water flow bottoms (mainly out of the scale). These are composed of pebble-stones with cobbles, diverse-grained sands, sandy loams. Thickness in the mountains is up to 2 m, in the fore-mountains – up to 15 m.  

* Eluvial sediments* $(e H)$ comprise the rock of warm stage. These are only indicated in the typical lithological-stratigraphic columns. The sediments are distributed almost everywhere and are only lacking in places of hard-rock exposures. They are mainly comprised of deep black-earths, low- and medium-humus, light-medium-heavy loamy in composition. Thickness is 0.2-1.8 m (normally 0.5 m). The sediments are composed of light loam, dark-grey, grainy, nutty, in places with friable newly-formed carbonates up to 1.5 cm in size.  

* Biogenic sediments* $(b H)$. In the fore-mountains the areas of these sediments are observed in the left watershed of Chechva River at the outskirts of Rozhnyativ town, as well as in the left watershed of Bystrtytsya-Solotvynska in between Kryvets and Mizhgirya villages. In the back-terrace areas of Dnister left-bank side these sediments fill up water flow bottoms with wide flat flood-lands. The rocks include incompletely decomposed peat with mud interbeds enriched in fossil humus. Thickness is 2-4 m. In some places peat is being mined for mineral fertilizers.  

* Technogenic sediments* $(t H)$. These include waste dumps of stripped rocks in Dombrovskiy and Podorozhnyanskiy quarries. They are composed of clayey-sandy-gruss-boulder mixture and tailing clays of 20-40 m thick.

* Mud volcano sediments* $(π H)$. These are encountered at the only point in Ukrainian Fore-Carpathians at the south-western outskirts of Starunya village. Over there, on the left bank of Lukovets Velykiy stream, around the neck of mud volcano, over some tens of years the cone 9 m across is formed. Its maximum height in the centre is about 1 m. The cone is composed of salted clays formed from decomposition of salt-bearing sequence of Vorotyshchenska Suite.
3. TECTONICS

The territory of map sheet M-35-XXV (Ivano-Frankivsk), according to the “Scheme of tectonic zonation of Ukrainian Carpathians” [17, 48], is located at the junction of four mega-structures. It encompasses insufficient by size fragments of the ancient Eastern-European Platform, young Western-European Platform and their Alpine envelope – External Carpathians and Fore-Carpathian Trough (see “Tectonic scheme of Mesozoic litho-tectonic complex” in the scale 1:500 000).

Platforms

Basement tectonics

Eastern-European Platform

The basement of Eastern-European Platform is intersected in the adjacent territories [5, 15, 64] (DH Zavadivka-1 [15, 80], Khmelivka-1 [80], Chernivtsi-1 [5], Buchach-1,2 [64] at altitudes from -900 m to -2163 m. It is composed of melanocratic biotite gneisses and schists underwent cataclasm and retrograde metamorphism (Lower Archean), as well as hypersthene granitoids. By absolute age appraisal the gneisses are ascribed to Late Karelides while granitoids can be compared to Osnitskiy Complex of Ukrainian Shield. As it is revealed from analysis of geophysical fields (see “Scheme of gravity anomalies” and “Map of anomalous magnetic field” in the scale 1:500 000), the strike of basement structures is mainly north-western [9, 14]. From the gravity data, the leading role in the crystalline basement structure is played by the diagonal system of north-eastern and north-western regional faults. By seismic data, the basement surface is plunged by these faults from -2.4 km in the north-eastern part of the territory to -6.4 km in its centre. Here, along Rava-Ruskiy (Davydenskiy) fault of thrust nature, defined by drilling in adjacent territory, structures of Eastern-European Platform are overlain by the young Western-European Platform. To the south-west from Rava-Ruskiy thrust the surface of crystalline basement apparently plunges in the stair-like fashion by normal faults which accompany the regional thrusts of Western-European Platform structures (Fig. 3.1).

Morpho-structure of magnetic field in the limits of Eastern-European basement is irregular. Two field types are clearly observed with their boundary by Rava-Ruskiy thrust, which is also expressed in seismic data by extensive zone of horizontal gravity field gradients as well as by linear Δg minimum of clear north-western extension. To the north-east from the fault magnetic field exhibits differential patterns of ΔTa (see “Map of anomalous magnetic field”) and includes some anomalies of various size which spatially coincides with the local gravity anomalies by dimension mark and orientation. To the south-west from Rava-Ruskiy fault magnetic field is less differentiated and is somewhat lower in magnitude. Horizontal field gradient is also lower over there and the matching with gravity field is not observed. Change of fields is probably related to the boundary line of geo-structures with age-different rock complexes in the basement of south-western extension of Eastern-European Platform and geo-structures of Western-European Platform [14].

Western-European Platform

The frontal part of the young Western-European Platform in the map sheet area is expressed in Radekhiv-Rogatynsky (tectonic suture) and Rava-Ruskiy faults (see Tectonic scheme of pre-Mesozoic litho-tectonic complex” in the scale 1:500 000). Its fragment is constituted of four north-west-trending LTZs of age-different consolidation: Lezhayska, Kokhanivska, Rava-Ruska and Roztotska (Fig. 3.1). Lezhayska LTZ is defined in the south-western part of the territory beneath Carpathian thrust at the depth 7.5-8.5 km [9, 10]. Krakovetsko-Striyskiy fault comprises the north-eastern boundary of this zone. By seismic data, thick (about 400 m) sequence of Jurassic limestones in Striyskiy Trough suddenly disappears along this fault which is apparently of thrust nature. Evidences for thrusting of Lezhayska zone rock complex over Striyskiy Jurassic Trough are obtained in the north-west of Fore-Carpathians [10]. Lezhayska zone is composed of Ryphean green-schist formation. Structure of the zone is unknown but it is apparently complicated by the north-west-trending faults, supported by seismic data (Verkhovynskyi and Peredkarpatytskiy faults), which also probably are of thrust nature. It is thought that formation of Lezhayska zone is related to Baikal tectogenesis and it is classified as the median massif which in Early Paleozoic was separating the inner and outer bands of
Early Caledonides. S.S.Kruglov [28] had supposed that this zone can be ascribed not to Baikalides but to Early Caledonides.

![Fig. 3.1. Tectonic scheme of pre-Mesozoic sediments.](image)

1 – Eastern-European Platform; 2 - Western-European Platform; 3 – Lezhayska LTZ; 4 – Kokhanivska LTZ; 5 – Rava-Ruska LTZ; 6 – Roztotska LTZ; 7 – isohypses of basement surface of Eastern-European Platform (m); 8 – frontal thrust of deep-seated thrust zones, proven and probable, their names; 9 – tectonic sutures separating litho-tectonic mega-blocks and their names; 10 – major faults probable and their names; 11 – minor faults probable: 1 – Berlogskiy, 2 – Manyavskiy, 3 – Bogorodchanskikiy, 4 – Tysmenychanskiy; 12 – drill-holes: to the left – DH number, to the right – depth and rock index at the bottom.
Kokhanivska zone comprises elongated 10-15 km wide structure, apparently of Salairian folding. From the west Lezhayska zone is thrust over the given zone. With Rava-Ruska zone it is in contact by Kakhskiy fault which is the thrust of north-eastern virgation. Direct evidences for thrusting junction mode of these zones are obtained just outside the map sheet area. Lower Paleozoic rocks in Kokhanivska zone are intersected at the depth from -1132 m to -3365 m by some drill-holes: 105-DH [80], 1-BV [102], 25-GRN [71], 1-KD [93] and others. These sediments underwent major folding in Salairian epoch resulted in extensive rock dislocations with numerous sliding surfaces oriented sub-parallel to the bedding. Structure of the zone is complicated by some latitudinal faults of apparently also thrust nature, of which most proven is Sudovo-Vyshnyansky thrust.

Rava-Ruska zone in the map sheet limits is extended in the band 15 km wide. From the south-west it is overthrust by Kokhanivska zone, and in the north-east its boundary is comprised of Rava-Ruskiy fault which is traced by extensive zone of horizontal gravity gradients and linear $\Delta g$ minimum of clear north-western extension. By this fault of thrust nature (as it is supported in adjacent territory), the Rava-Ruska zone is thrust over the rocks of Roztotska zone and Lower Paleozoic complexes of Eastern-European Platform. Apparently, the plane of Rava-Ruskiy thrust from Ivano-Frankivska town further to the south-east comprises the footwall of the frontal part of Western-European Platform. The rocks of this zone are intersected at the depth -765 m…-861 m by drill-holes 15-KR [147], 1-IFR [80], 1,5-STP [119], 3-SKN [104] and others. Their lower part is composed of medium-dislocated Salairian complex (Lower Cambrian) with the fold limb inclination 25-30°. The upper part includes Ordovician – Lower Devonian rocks (Tyverska Series). These rocks underwent insufficient deformation in the mid of Early Devonian with further re-working by Herizinian movements expressed in elongated folds with fold limb inclination 10-15°.

Roztotska zone comprises the frontal tectonic element of Western-European Platform. This zone is developed to the north from studied area. Its southern closure is traced into the map sheet as the limited in size wedge just on the ground of geophysical data. The boundary of Roztotska zone with Eastern-European Platform coincides with Radekhiv-Rogatynska flexure – normal fault zone (tectonic suture), which apparently defines general tectonic patterns not only in the crystalline basement but also in the sedimentary cover, and by its emerging time belongs to the ancient elements. By seismic data, the zone is mantle-seated and apparently corresponds to the boundary between Baikalian and older basements. In the gravity field this zone is expressed in several wide sub-longitudinal gravity stairs (see “Scheme of gravity anomalies”). To the north from the map sheet M-35-XXV area the vertical displacement magnitude of Western-European Platform basement surface by this zone exceeds 600 m. In the map sheet limits just the minor flexure bend of this surface is observed and, respectively, this fault is ascribed to the minor ones [10, 14]. Folded base surface of Roztotska zone plunges down in the south-western direction in a stair-like mode attaining altitude -10 km close to Rava-Ruskiy fault which comprises the western boundary of this zone. The zone is composed of Upper Proterozoic – Cambrian sedimentary-extrusive complex which thickness over there is estimated to 1500-1700 m [14].

By geophysical data, in the basement of both platforms the blocks of various ranks are distinguished and the boundaries between these blocks are defined by the extended fault zones of the cross-diagonal system. Of the diagonal faults, the north-east-trending Sushchano-Perzhanskiy fault is most prominent; it separates litho-tectonic mega-blocks and belongs to the deep-seated (tectonic sutures) [14].

The major faults of the same direction include Ostrozkiy and Teterivskiy, which are being traced across the basement of both platforms, and north-west-trending Chernivetskiy fault. The latter is being traced from the south-east, from the border with Romania up to the studied area, where close to Burshtyn town outskirt it disappears beneath the zone of Butyn-Khlevchanskiy fault of thrust nature which is supported in adjacent territory to the north-west [15]. Vertical displacement magnitude of the ancient Eastern-European Platform basement along Ostrozkiy, Teterivskiy and Chernivetskiy faults attains first hundreds of meters [6, 14]. Positive movements of Eastern-European Platform basement blocks along Ostrozkiy and Teterivskiy faults were most extensive over Alpine tectogenesis. This facilitated formation of the large arc-shaped crossing uplift – Stanislavskie which in Late Badenian – Early Sarmatian times had been separating the External zone of Fore-Carpathian Trough in two parts [16, 65] (see Fig. 3.1).

Some major north-west-trending faults complicate basement structure in both ancient and young platforms. These are Sudovo-Vyshnyanskiy, Pereckarpatskiy and Verkhovynskiy breaks – the normal faults by which the large basement blocks of Western-European Platform plunge down beneath Carpathians [16, 65]. Vertical displacement magnitude by these faults attains some hundreds of meters which is proven by geophysical data and supported by drilling. The major tectonic breaks of north-western system do form the destructive zones, apparently related to the primary Eastern-European Platform basement folding, and comprise the oldest Proterozoic fault system, which had accompanied formation of the crustal granite-metamorphic layer during the Svecofenno-Karelian tectogenesis. Most likely, these faults comprise the system of strike-slips and normal faults – strike slips without single displacement plane resulted from the basement block shear movements. The width of destruction zones accompanying the faults is about 4-6 km.
The minor north-east-trending breaks are defined by geophysical methods in the Western-European Platform basement only (Berlogskiy, Manyavskiy, Bogorodchanskiy, Tysmenychnskiy). Their reliability is supported by deep drill-holes – 1-KD [93], 11-GRN [71], 1-PdGR [111], 1-GLB [111], 1,5-STP [119] and others (see Fig. 3.1). Formation of these breaks of normal fault- strike-slip nature is most likely related to Caledonian tectogenesis when the folded rim of ancient platform was formed (epi-orogenic Lezhayska, Kokhanivska and Rava-Ruska LTZs).

**Tectonics of platforms sedimentary cover**

In the structure of sedimentary cover in the Eastern-European Platform margin three major elements of various ranks are distinguished – Dnisterskiy peri-cratonic trough, Boyanetskiy fore-mountain trough and Lvivskiy Paleozoic trough [14].

Mesozoic terrigenous-carbonate cover have been depositing in the margin of both, combined platforms, during formation of Striyskiy Jurassic trough and Lvivska Cretaceous depression. Cenozoic part of cover has been formed as the separate tectonic unit.

Dnisterskiy peri-cratonic trough comprises the oldest mega-structure with general depressiv structure inherited from Riphean. It is included in the Baltic-Prydnisterska system of peri-cratonic subsidence [9, 10]. In the east Dnisterskiy peri-craton is rimmed by crystalline complexes of Ukrainian Shield, and in the west – by Carpathian Aplides. This is typical platform structure with crystalline basement and multi-layer tectonic complex of the cover. By tectonic features it is divided into some major tectonic elements. The studied area is located within one of these elements – Volyno-Podilska monocline. In the structure of the latter the sediments of Late Baikalian and Caledonian sedimentary complexes participate. In the Late Baikalian complex the following units are distinguished: 1 – Lower Vendian trapp formation (Volynska Series); 2 – continental-marine formation (Vendian Mogylev-Podilsksa and Kanylivska series and Lower Cambrian Baltiyska Series).

Caledonian tectonic complex includes Ordovician, Silurian and Lower Devonian sediments (Tyverskiy Series). By geological setting, this complex resembles Late Baikalian one which is separated by insufficient interruption resulted in some tectonic re-arrangement. Marine terrigenous-carbonate rocks of this complex, deposited under shelf conditions, are similar in their formational features and complete the column of Dnisterskiy peri-craton. In the structure of this complex the same regional north-west-trending destructive zones as in the crystalline basement are important. Activation by these breaks is noted in Caledonian and Herzinian epochs. Most likely, they have caused predomination of tectonic directions and general structure patterns of Paleozoic. Con-sedimentation vertical movements along these zones were accompanied by notable rock thickness increasing in the south-western direction. At the general monocline position with slight (2-5°) southwestern inclination the wide and elongated brachyform structures are observed which development is related to the Late Caledonian tectogenesis.

The folding of Late Caledonian orogenesis had caused formation of narrow fore-mountain Boyanetskiy trough at the platform margin which subsequently was partly overlain by Caledonide thrusting over the platform. Centricline closure of this trough is traced to the adjacent south-eastern territory (map sheet M-35-XXXI). Most likely it is caused by development of crossing uplift known in geological literature as Bukovynske, which separated sedimentation basins of Volyno-Podilsksa and Moldavska plates since the end of Tyverskiy time. The modern eastern boundary of Boyanetskiy trough is erosion one. The trough is filled with continental terrigenous red-coloured formation of Dnisterska Series. On the background of gently inclined (2-4°) south-western monocline rock bedding the elongated brachy-structures 15-20 km long and 5-6 km wide are observed. Their height in the core portion is 40-80 m, the limb inclination angles are 3-8°, and the south-western limbs are steeper and somewhere look like flexures complicated by fine folding. Inherited formation of large-block structure in Boyanetskiy trough had apparently occurred over Cimmerian tectogenesis.

Lvivska Paleozoic trough comprises sub-platform depression developed at the junction of age-different platforms and superimposed on the northern part of Dnisterskiy peri-craton. Its wide eastern limb is located in the limits of Volyno-Podilska monocline. The central part overlies earlier units of Roztotska zone cover. The short, essentially reduced south-western limb is apparently developed over the frontal elements of Caledonides and is buried beneath the thrust of Rava-Ruska zone. Major portion of Lvivskiy Paleozoic trough is developed to the north from the map sheet area [15] where it is filled with Middle and Upper Devonian terrigenous-carbonate sequence and Carboniferous coal-bearing terrigenous sediments. The south-eastern margin of the trough, according to geophysical data and drilling directly in adjacent territory to the north, encompasses the map sheet north-eastern part. The western, most subsided part of the trough separated from the eastern limb by Radekhiv-Rogatynskiy fault, is most complicated in tectonic respect. Over there, the north-west-trending compression structures predominate. Their formation in con-sedimentation mode had commenced in the Middle-Late Devonian time and completed in the end of Carboniferous time with formation of fold and fault dislocations. The
latter in the sediments of Lvivskiy trough are expressed in the most contrasted mode in Roztotska zone (block). Here, between Rava-Ruskiy and Belz-Baluchynskiy thrusts in adjacent territory [15] the complex linear-elongated dislocations are observed where the chains of anticline folds are connected with north-west-trending reverse fault-thrusts (Butyn-Khlevehanskiy thrust, Krekhivska zone of thrusts) (Fig. 3.1). Horizontal displacement magnitudes of some extensively dislocated folds by these breaks attain 400-500 m.

**Striyskiy Jurassic trough** comprises the single-limb depressive structure involved in the system of suture trough extended over entire Central Europe and known as the Danish-Polish groove [10]. In the map sheet area the south-eastern trough closure is observed filled with Upper Jurassic sediments only. The eastern trough boundary (outside the map sheet area) is curvilinear due to the ancient relief of Paleozoic surface. By lithological features of Jurassic columns and fold morphology several tectonic domains are distinguished in Striyskiy trough, which are bounded from the south-west by the thrust-type dislocations. The map sheet territory includes one of these tectonic domains – **Krukenyiyska zone with Krakovetsko-Striyskiy thrust** comprising the modern western boundary of the trough. Thickness of Jurassic rocks is highest along this thrust indicating that formerly Jurassic sediments were developed further to the south-west and at present they are buried beneath the thrust of Lelzhayskiy massif. The north-eastern trough limb is superimposed on Boyanetskiy trough, and the south-western limb – on Caledonids of Rava-Ruska and Kokhanivska zones. The north-eastern limb of Striyskiy trough up to the zone of Kaluskiy break comprises wide gently-dipping (angles 1-2°) towards Carpathians monocline of north-western extension. It is complicated by some structures enveloping the ancient relief. Beneath the allochthon of Carpathian mega-thrust, on the background of stare-like (by series of normal faults) monocline descending, the seismic data over the surface of Jurassic sediments indicate some arc-shaped brachy-structures apparently resulted from Alpine tectogenesis.

**Lvivska Cretaceous depression (mold)** is a counterpart of Mazovetsko-Prychornomorska system of suture peri-platform trough [10]. Alike Striyskiy Jurassic trough, it exhibits quite asymmetric structure with wide monocline north-eastern limb and relatively narrow south-western one buried beneath Carpathian thrust. The eastern depression boundary is traced by the system of en echelon flexures from Ustylug town (outside the map sheet area) to Ivano-Frankivsk town, approximately along 350 m isopach. To the south-west from this point the centricline mold closure is observed. The map sheet area is located in the limits of south-eastern margin of this depression where it is composed of Lower and mainly Upper Cretaceous terrigenous-carbonate formation. The monocline dipping of the mold south-western limb towards Carpathians is weakly observed. Beneath Carpathian mega-thrust, by the same normal faults as in the Striyskiy trough, the rocks of this mold limb are descended in stair-like fashion to the depths -1500...-2500 m. The brachy-structures, which complicate the south-western mold limb and clearly mapped by seismic survey in adjacent territory [5], take up Jurassic brachy-structures with slight fold axes displacement to the north-east.

**Cenozoic tectonic complex** is composed of Carpathian-Sarmatian (Neogene) carbonate-terrigenous formation which overlies eroded surface of the older tectonic complexes. Quite low (angles 1-2°) monocline dipping of this sequence is observed to the south-west with its thickness increasing from 30 to 100 m. The faults, which caused the block structure of the older tectonic complexes, over Alpine tectogenesis have expressed in the Cenozoic cover just in flexure-fault zones (Zhravnenska, Sokolivska, Tlumatska ones) (see “Tectonic scheme in the scale 1:500 000”). Most prominent Zhravnenska zone provides the boundary between the margin of Eastern-European Platform and Fore-Carpathian Trough. By gravity and seismic data, the regional zones of deep-seated thrusts (Rava-Ruskiy, Kaluskiy and Krakovetskiy), normal faults (Kosivskiy) and shears (Chernivetskiy) are traced.

Presented map of local gravity anomalies (R = 10 km) (see “Scheme of gravity anomalies in the scale 1:500 000”) shows the patterns of deep and shallow (up to 2 km) anomalous masses, that is, indicates structures favourable for oil and gas prospecting. The major boundaries, providing local anomalies, in the platform part are confined to the Mesozoic-Paleozoic contact, in Bilche-Volyskta LTZ – Neogene-Mesozoic contact, and in Boryslavsko-Pokutska LTZ – to the contact of flysch rock complex and Paleozoic sediments. The local maximums and minimums are observed in the gravity fields reflecting elevated and subsided sites respectively. The positive structures over Paleozoic surface, defined in Sambirskaya and Boryslavsko-Pokutska LTZs by gravity data, can be recommended at some sites for detailed works by seismic methods aiming preparation of perspective traps for subsequent prospecting for oil and gas. In Bilche-Volyskta LTZ the local maximums do correspond either to the highest elevation of Tyraska Suite sediments or their greatest thickness at the platform margin. As to the negative residual anomalies, they do mainly correspond over there to the greatest thickness of Kosivski clays (Neogene) which fill up erosion dimples in the relief of pre-Kosivskiy time. Notably, the major positive anomalous structures of residual gravity field coincide with the positive magnetic anomalies ΔTa allowing assumption on possible igneous rocks intrusion into the sedimentary sequence.
External Carpathians

External Carpathians encompass the south-western part of the map sheet territory. In general, based on tectonic features they are divided into individual structure zones – tectonic thrusts. In the studied map sheet are known the fragments of a single major most elongated frontal domain of External Carpathians – Skyboviy nappe.

Skyboviy thrust in general is thrusted over Borylsavsko-Pokutska tectonic zone of Fore-Carpathian Trough. Horizontal displacement magnitude along the trough exceeds 30 km. Inclination of Skyboviy thrust footwall at the surface is 40-60o, and to the depth becomes more flat, wavy, and at the depth 5-6 km – subhorizontal. From the inner to the outer, frontal parts of Skyboviy thrust, the minor thrust-type structures – nappes (skyby) are distinguished which have formed as monocline blocks in the beginning of the thrust tectonic evolution, and then have been complicated by the large linear folds broken almost by their axes, resulted in the nappe formation and in their sheeted structure. All nappes comprise the south-eastern anticline limbs separated by regional thrusts. The frontal parts of nappes are normally composed of Striyska Suite rocks (Cretaceous-Paleocene), rarely – Paleocene-Eocene rocks, and the inner parts – Oligocene-Miocene sediments. Some nappes are complicated by the sheets 1-3 km wide. On the background of general monocline rock laying in the frontal nappe and sheet parts the high-order folding is observed with the rock inclination in the limbs up to 70-80o. In Skyboviy thrust, from its inner to outer parts, the following nappes are distinguished: Zelemyanky, Parashky, Skolivska, Orivska, Beregova (see “Tectonic scheme in the scale 1:500 000”). Of these, in the map sheet area Zelemyanky nappe only is absent. Quite insufficient in size fragment of the Parashky nappe frontal part is mapped along the Limnytsya River valley at Osmoloda village. This is a monocline with the south-western rock dipping under the angles 45-70o composed of diverse-rhythmic flysch of Striyska Suite. The shape of the nappe frontal line at the surface directly outside the map sheet area highlights the fairly flat inclination of the thrust plane (about 30o). The front of Skolivska nappe is traced between Lypovytsya and Grynkiv villages. Judging from the thrust line at the surface, the thrust plane inclination in this nappe part attains 65o. The frontal part of structure here is composed of Upper Paleocene massive sandstones (Yamnenska Suite). In the inner part the nappe is complicated by the large anticline fold (Osmolodivska) filled in the core with Lower Eocene rocks (Manyavska Suite). The south-western limb of the fold is overturned by the thrust of previous nappe while the north-eastern limb is complicated by the narrow syncline (Kozmenetska) filled with Lower Miocene sediments (Upper Menilitova Sub-Suite). Structure of Orivska nappe is more complex. In the course of high-magnitude horizontal displacement the detached south-western limbs of large elongated anticlines in this structure were transformed into the sheets which complicated the nappe. Three 2.5-3 km wide sheets are clearly mapped in the nappe; the front of each sheet is composed of the strong rocks of Striyska Suite, and the inner part – of much more soft rocks of Menilitova Suite. The rock dipping in all sheets is south-western, monocline, with angles 45-75o. Most typical is Beregova nappe which front over almost entire length is composed of the soft Oligocene – Lower Miocene sediments (Menilitova Suite) causing smoothed relief patterns of Carpathians. Highly-curvilinear shape of the nappe front at the surface coupled with occurrence of tectonic semi-remnants in the area of Peregonske and Markova villages clearly suggest for very flat (up to 20o) inclination of the nappe’s plane of thrust over the internal part of Fore-Carpathian Trough. The nappe includes two sheets. The outer one is complicated by two relatively large plicative structures. The remnants of anticline structure (Spaska), composed in the core of the Striyska Suite rocks and broken by the Skyboviy thrust almost along the axis, are traced from Peregonske village up to Chechva River valley where this structure gradually plunges down in the north-western direction. The syncline structure (Lopyanetska) composed of Menilitova Suite rocks is extended into the map sheet area from the north-west and in the area of Lopyanka village is closed periclinally. Clear north-eastern virgation is observed in both these folds. The inner sheet of Beregova nappe is also complicated by the wide (up to 2 km) syncline composed in the core of Upper Eocene argillites (Bystrytska Suite) with the northern limb detached by the thrust.

The deep structure of Orivska and Beregova nappes is being deciphered using seismic data. The Eocene sediments provide the major marker horizon in these works in the allochthonous part of Skyboviy and Borylslavsko-Pokutskiy thrusts. Over the surface of these sediments, in both nappes from the south-west to north-east the following positive structures are mapped: Yavorntyska, Syvakivska, Lypovetska, Ilemkivska, Luzka (Fig. 3.2). The north-eastern limbs of these structures are cut by thrusts and by strike they are apparently complicated by low-magnitude faults.
Fig. 3.2. Tectonic scheme of deep structure of Skyboviy and Boryslavsko-Pokutskiy thrusts.

1 – hypsometry contour isolines of Eocene sediments surface in deep positive local structures of Boryslavsko-Pokutskiy thrust; 2 - hypsometry contour isolines of Eocene sediments surface in deep positive local structures of Skyboviy thrust; 3 – sites of partial erosion of Eocene sediments; 4 – frontal zones of Skyboviy, Boryslavsko-Pokutskiy and Sambirskiy thrusts at the surface; 5 – frontal zones of deep sub-thrusts of Boryslavsko-Pokutskiy thrust: I – Boryslavskiy, II – Maydanskiy, III – Bytkivskiy, IV – Delyatynskiy; 6 – frontal zones of minor deep sheets; 7 – probable local steeply-dipping faults with undefined morpho-kinematic features; 8 – inner parts of deep sub-thrusts of Boryslavsko-Pokutskiy thrust; 9 – main positive local structures of Boryslavsko-Pokutskiy thrust: first level: 1 – Verkhnostrutynska, 2 – Spas-Rypynska, 3 – Nyzhnostrutynska, 6 – Slyvkinska, 10 – Pivdennoslyvkinska; second level: 4 – Lukvynska, 5 – Maydanska; third level: 7 – Rosilnyanska; fourth level: 8 – Kosmatska, 9 – Dzvynyatska; 11 – Monastyrchanska, 12 – Gvizdetska; main positive local structures of Skyboviy thrust: 13 – Ilemkivska, 14 – Lypovetska, 15 – Syvakivska.
Fore-Carpathian Trough

Structures of Fore-Carpathian Trough are developed in the wide band extended from the north-west to south-east through the central part of the map sheet area. Most of the plicative and disjunctive structures, which fragments are mapped in the studied area, are also extended far away the map sheet.

Fore-Carpathian Trough is divided into three litho-tectonic zones. Of these, the External – *Boryslavsko-Pokutská*, and Central – *Sambirska*, comprise tectonic thrusts, and the Internal – *Bilche-Volytska* – is autochthonous (see “Tectonic scheme in the scale 1:500 000”).

*Boryslavsko-Pokutská* and *Sambirska* LTZs are traditionally ascribed to the outer allochthonous part of Fore-Carpathian Trough. These zones, respectively, comprise two major tectonic thrusts composed mainly of molassa sediments and thrust over molassa rocks of the outer autochthonous portion of the trough – *Bilche-Volytska* zone. Boryslavsko-Pokutskiy thrust principally differs from Sambirskiy one in Cretaceous-Oligocene flysch rocks occurrence in the sedimentary substratum of Miocene molassa. Sambirskiy thrust is only composed of molassa sediments. The Miocene olistostrome sequence is encountered over most part of the Trough at the boundary between Boryslavsko-Pokutskiy and Sambirskiy thrusts.

In the studied area *Boryslavsko-Pokutská* zone at the surface is comprised of 6-16 km wide band of dislocated Cretaceous-Miocene rocks, which is squeezed in between the External Carpathian unit thrust over this zone from the south, and Sambirskiy unit thrust under this zone from the north. The most (inner) part of Boryslavsko-Pokutskiy thrust is overlain by Skyboviy thrust and is composed of Cretaceous-Paleogene flysch and Miocene molassa of Polyanytska and Vorotyshchenska suites. It constitutes so called “deep folds”. Apparently, entire part of Boryslavsko-Pokutskiy thrust where Stebnytski sediments are absent (including *Maydanske tectonic semi-window* in the studied area and *Pokutski folds* outside) had been later overlain by presently eroded Skyboviy thrust. It is evidenced by tectonic remnants and semi-remnants of this thrust, as well as distinct patterns of tectonic sheets in the inner part of the zone, formed, probably, at the depth, beneath Skyboviy thrust. We ascribe this part of Boryslavsko-Pokutskiy thrust to *Boryslavská litho-tectonic sub-zone* which, in our opinion, underwent folding and had been overlain by Skyboviy thrust in pre-Stebnytskiy time resulted in complete lacking of Stebnytska Suite. More external part of Boryslavsko-Pokutskya LTZ, composed of flysch substratum and Miocene molassa including Polyanytska, Vorotyshchenska and Stebnytska suites, is ascribed to *Rungurska sub-zone*. The names of these units are taken from O.S.Vyalov [12] although their meaning is somewhat extended. These units also approximately correspond to Boryslavska and Truskavetska sub-zones of Internal Fore-Carpathians formerly had been being defined by M.R.Ladyzhenskiy.

Main part of *Boryslavská litho-tectonic sub-zone* is located beneath Skyboviy thrust and comprises the system of so called “deep folds”. In the area between Bystrytsya-Solotvynska and Chechva rivers structures of Boryslavska sub-zone are composed of Cretaceous-Paleogene flysch and Polyanytsko-Vorotyshchenska molassa; these rocks are exposed from under Skyboviy thrust in Maydanske tectonic semi-window and are intersected by drill-holes beneath this thrust. Interpretation of drilling data from numerous boreholes in the area indicates that deep folds of Boryslavskya sub-zone are arranged in some groups (or levels) thrust over one another and are terminated in en echelon fashion at the single thrusting plane of Boryslavskya zone over Rungurska one. These deep positive structures, in fact, consist of the system of tectonic sheets. The latter normally comprise asymmetric anticline folds, thrusted and overturned to the north-east. As a result, the folds do actually include the south-western hanging limbs only. Somewhere small fragments of north-eastern limbs are also preserved being usually overturned. Petroleum people call these limbs “turned below”. The thrusts separating individual sheets are commonly ended blindly (cut) at the plane of Skyboviy thrust, or another thrust constituted of other sheets. It is thought that this system of sheets, which is rhomb-shaped and called “duplex”, is being formed at the depth beneath the moving thrust, inside the para-autochthone, due to its tectonic multiplication – doubling, tripling etc. As a result of tectonic sheet multiplication beneath the thrust the latter may rise up forming “press-in” anticlines, that is, above duplexes the allochthone causes formation of antiform and synform structures. In authors’ opinion, such antiform and synform structures are developed by the thrust of Beregova nappe in the area of Maydanske tectonic semi-window.

From the results of deep drilling almost all authors in the structure of this tectonic unit distinguish so called tectonic levels of folds numbered downward (I-IV). These are separated by the thrusts with higher magnitude in comparison to those which separate individual folds but at the same time are subordinated to the general structure of the zone. These levels or fold groups can be considered as separate minor thrusts. The lower levels are moved out much more to the north-east in comparison to the upper ones. En echelon arrangement of
these minor thrusts comprises one of the distinct features of Boryslavska sub-zone. In the studied area the following levels and local positive structures are mapped by seismic data supported by drilling results (Fig. 3.2):

**First level:** 1 – *Ferkhyostrutynska*, 2 – *Spas-Rypynska*, 3 - *Nyzhnoostrutynska*, 6 – *Slyvkinska*, 10 – *Pivdennoslyvkinska*;

**Second level:** 4 – *Lukvynska*, 5 – *Maydanska*;

**Third level:** 7 – *Rosiynska*;

**Fourth level:** 8 – *Kosmatksa*, 9 – *Dzvyntyska*, 11 – *Monastyrchanskas*, 12 – *Gvizdetska*.

In contrast to the deep folds where flysch sediments are overlain by thick molassa sequence, Maydanska, Slyvkinska and Lukvynska anticline folds are exposed by erosion up to Lower Eocene sediments which are exposed in the cores of these structures. Slyvkinska anticline is slightly asymmetric with the steeper (up to 50°) north-eastern limb. Essential part of south-western limb is buried beneath the thrust of Beregova nappe. By strike this structure is split into three portions by two crossing faults with vertical displacement magnitude up to 150 m. The north-eastern limb of the narrow (up to 3 km), almost asymmetric Lukvynska structure, with steep inclination of both limbs, is cut by the thrust of Boryslavska sub-zone over Rungurska zone.

In opinion of some authors, the deep folds are complicated by numerous crossing faults. These include normal faults – strike slips with essential (first meters) horizontal and vertical magnitudes resulted from folding and thrust movement. These breaks are developed inside some structures only.

Deep drilling data indicate that in the area between Bystrytsya-Solotvynska and Svichema rivers the plane of Boryslavska sub-zone thrusting over Rungurska sub-zone is steep enough, up to sub-vertical, and in places (area of Dolyna town) it is overturned to the south-west.

**Rungurska litho-tectonic sub-zone** constitutes the external part of Boryslavska-Pokutskiy thrust. It is overthrust everywhere by Boryslavska sub-zone while by regional thrust it partly overlies itself Sambirskiy thrust. Sub-zone is composed of flysch Cretaceous-Paleogene and molassa rocks. The latter include Polyanytska, Vorotyschenska and Stebnytska suites; over there Polyanytsko-Vorotyschenski sediments lie over thin Menilitova Suite. Polyanytsko-Vorotyschenski sediments contain thick lenses of conglomerates, fanglomerates (Slobidski) and olistostromes. In general, the steep, narrow, elongated anticline folds with overturned northern limbs are characteristic for Rungurska sub-zone. In the studied area, *Rozhnyatitska* and *Dzvyntysach-Starunska* anticlines are mapped at the surface. In the basin of Bystrytsya-Solotvynska and Bystrytsya-Nadvirnyanska rivers, at the depth, beneath Lower Miocene molassa, by seismic and drilling data the positive structures of the fourth fold level are mapped (*Gvizdetska, Starunska, Dzvyntysa*), which actually comprise the deep extension of major Slobidska anticline. It is being fairly well mapped at the surface in adjacent territory to the south-west up to the Prut River basin where its pericline plunges beneath molassa and further again is exposed at the surface in the left bank of Bystrytsya-Nadvirnyanska River just at the southern map sheet border. Judging from sub-vertical bedding of Slobidski conglomerates and limbs of this fold, in the area of Nadvirna town it becomes isoclinal with vertical axis. The deep boreholes intersected narrow and steep Paleogene flysch cores of these folds. The core portions of three mentioned folds at the surface are comprised of Vorotyschenska Suite, and the limbs – of Stebnytska Suite. To the north-west from Starunya and Dzvyntych villages structures of Dzvyntysa anticline are extended to Dolyna town where at the surface, in the core, are composed of Vorotyschenska Suite, and in the limbs – of Stebnytska Suite. Some other anticline and syncline folds are known in this area which apparently are linear and at the surface are expressed in alternating weakly-exposed bands of Vorotyschenski and Stebnytski rocks intersected by shallow drill-holes.

**Sambirska zone** comprises tectonic thrust composed of dislocated, completely detached from their roots molassa sediments which are overthrust by Boryslavsko-Pokutski zone and, in turn, are thrusted over the external autochthonous part of Fore-Carpathian Trough. This zone at the surface (in the studied area) is expressed in the wide enough (6-20 km) band of Miocene sediments. Over there, flysch sediments are not identified while Miocene molassa is composed of Vorotyschenska, Stebnytska and Balytska suites. Sambirskiy thrust is complicated by the system of second-order thrusts arranged in tectonic sheets extended in sub-Carpathian direction [18].

The most inner structure in Sambirskiy thrust is *Trostanetsko-Petrankivska sheet* which is traced from Strihi River through the studied area to the State border with Romania. This sheet comprises monoclinal composed of Vorotyschenska, Stebnytska and Balytska suites. Under the angles 30-60° this monoclinal plunges beneath Boryslavsko-Pokutskiy thrust and, in turn, is being thrust first over the outer elements of Sambirskiy thrust. In the upper column part, in Balytska Suite, the distinct “fore-thrust” olistostome sequence is observed in this sheet. And this is the sequence which Boryslavsko-Pokutska zone is thrust over while olistostrome itself contains the fragments and large olistoliths of this zone. More outer tectonic elements, relatively to Trostanetsko-Petrankivska sheet, is Velykoturyanska sheet which is traced in the basin of Svichema, Nadvirynska and Solotvynska Bystrytsya rivers and further to the south-east, outside the studied area, into the valleys of Prut and Lyuchka rivers. This tectonic element in the area between Svichema and Lukva rivers is wide
enough and is composed of Stebnytska and Balytska suites arranged in relatively small elongated folds, up to 10 km long to the south of Golyn village. Over there, the core of Krekhovytska anticline is composed of Stebnytska Suite, and the cores of Belevska and Serednyougrynska synclines – of Balytska Suite. In the outcrops of Berezhnytsya stream the dipping angles of anticline limbs are 20-35°. Velykoturyanska sheet is thrust over the external tectonic element of Sambirskiy thrust – Kalusko-Golynska sheet. The latter in the area of Svich and Bystrytsya-Solotvynska rivers comprises the 2-8 km wide band of clay exposures of Balytska and Stebnytska suites. The clays are deformed into fine folds and often are modified into the breccia-like rock. In the basin of Bystrytsya-Nadvirnianska River, nearby Grabovets village, this sheet is completely pinching out. Despite of numerous drill-holes in the area of Kalush town, it is very hard to decipher the internal structure of this sheet since Stebnytsko-Balytska sediments quickly replace another and their tectonics is complicated by processes of salt tectonics – formation of salt breccia, fine disharmonic folds etc. By drilling data, the sheet in general comprises sub-horizontal plate about 1 km thick which overlies Kosivska and Dashavska suites of the Trough External zone, and which more inner tectonic elements of Sambirksa zone are thrusted over. The internal structure of this sheet is complicated by some synclines and anticlines, which cores are respectively filled with Balytsky and Stebnytsky rocks, as well as by the minor thrust. With the latter, traced fairly conventionally, the Kalusko-Golynska sheet is split in two higher-order thrust units (Golynska and Kaluska). The inner one – Golynska, at the outskirts of the same-named village is complicated by two crossing faults with horizontal displacement magnitude of the central sheet part about 2-3 km. The body of rock and potassium salts is confined to this units; the salts are exposed in the quarry in Dombrovo village. In the northern quarry wall symmetric syncline fold is clearly observed with limb range up to 100 m and limb inclination 30-35°. The fold axes exhibits south-western extension uncommon for the general tectonic trend. Its south-eastern limb is complicated by minor flexures and numerous fractures. The core portion is composed of potassium salt pile with interbeds of terrigenous material underlain by thick layer of high-clayey rock salt. In the north-eastern quarry wall, in the fold core portion, the fine isocline folding is well expressed complicated by low-magnitude faults. Kaluska tectonic unit actually comprises monoclinc with south-western inclination of involved clayey sequence thrust over Upper Miocene molassa of the external Trough part.

**Bilche-Volytska zone** is the marginal external structure of Fore-Carpathian Trough. Its boundary with the platform in the studied area is traced over Zhuravynska flexure-fault zone extended outside the south-eastern map sheet boundary into Tlumatska flexure. The south-western boundary of the zone at the surface coincides with the front of Sambirskiy thrust, and beneath Carpathian thrust, apparently, Krakovetskiy thrust. This is well-expressed young (Badenian-Sarmatian) fore-mountain depression filled with thick (up to 2000 m) sequence of carbonate-terrigenous molassa superimposed mainly over domains of Western-European Platform, and partly over the margin of Eastern-European Platform. The general monoclinc plunging beneath Carpathians is characteristic for Bilche-Volytska zone. Taking into account the differences in molassa thickness, composition and, in lesser extent, the basement structure, the zone is divided into several sub-zones. In the studied area the fragments of Lopushynska, Kosivska-Ugerska and Stanislawivska sub-zones are encountered.

**Lopushynska sub-zone** is separated from Kosivska-Ugerska one by the north-west trending normal fault zone which is traced by geophysical methods in parallel to Krakovetsko-Striyskiy break. By this fault zone the Lopushynska sub-zone is buried down to about 1.5 km. Further subsidence of latitudinal blocks in sub-zone with vertical magnitude 400-500 m is revealed from seismic data by Peredkarpatskiy and Verkhovynskiy normal faults. The south-western boundary of sub-zone beneath the External Carpathian thrust is unknown. Some authors [33, 34] suppose that beneath Carpathians the Bilche-Volytska zone is extended almost up to Porkuletskiy thrust. The internal structure of sub-zone in the map sheet area is not studied. In the south-east of the Trough (outside the map sheet area) some brachy-structures insufficient in size and vertical range are mapped by seismic methods in Lopushynska sub-zone.

The external boundary of Kosivska-Ugerska sub-zone with Stanislawska one is traced by Kaluska flexure, and the south-western boundary with Lopushynska sub-zone is defined along the zone of Krakovetsko-Striyskiy break. In the given sub-zone, in Badenian sediments, both in its external part and one overlain by Sambirskiy thrust, the weakly-expressed brachy-structures in average 4×8 km in size and up to 100 m of roof height are mapped (Dashavska, Balytska, Verbyzka, Bolokhivska, Kadobnenska, Pivdennokadobnenska, Krakhvyska, Berlagska, Grynivska, Bogorodchanska, Starobogorodchanska, Pereroslyanska, Paryshchenska). All these ones are cut by numerous low-magnitude (first meters) breaks expressed in tectonic maps designed in the course of detailed exploration of natural gas deposits. This had allowed some authors supposing these faults unequivocally proof the extensive disjunctive re-working of Bilche-Volytska zone of the Trough. It is however most likely that formation of elongated and somewhere sub-parallel brachy-structures is resulted from the ductile side-flow in the course of Carpathian underthrusting – platform underthrusting. These flexures gave rise to brachy-folds and their formation in the viscous-elastic molassa sequences is always accompanied by extension fractures and shears in flexure limbs.
At the pre-Neogene surface of Kosivsko-Ugerska sub-zone the contours of buried Paleogene erosion valleys are clearly expressed.

The external edge of Stanislavska sub-zone is bounded by Zhuravnenska, and the internal one – by Kaluska flexures. Structure of sub-zone is quite simple. From its external edge to the southern boundary molassa thickness gradually increases from 60 to 250 m at the monocline gentle dipping under 1-2°. Behind Kaluska flexure the clear bend is observed accompanied by molassa thickness increasing up to 500 m. On the background of monocline descending the brachy-structures are mapped in sub-zone – Zhuravnenska, Krekhivska, Zagvizdivska, Bratkivska, Tlumatska, Chornolizka. Contours of these structures are weakly expressed. Structure size is normally 4×6 km, roof height – up to 100 m.

Deep narrow canyon-like cuts comprise the distinct paleo-relief feature of pre-Badenian basement of entire Bilche-Volytska zone; these cuts appear in the platform, are further traced over 50-60 km towards Carpathians, and then plunge down beneath Carpathians to inaccessible depth. In the map sheet area, by numerous drill-hole and seismic data [20, 21], the buried Kolomiyska and Molodyntska paleo-valleys are clearly traced; their extension is controlled by destructive zones accompanying tectonic breaks in Paleozoic and Mesozoic cover. The fragment of Kolomiyska paleo-valley, which origin is encountered to the north-east of studied areas [64], is clearly traced in the south-eastern part of the studied area. The fragment of Molodyntska paleo-valley, which begins in adjacent territory to the north [15], is defined in its north-western part. The width of both paleo-valley fragments is 5-6 km, cut depth varies from 400 to 1500 m, and slope inclination in the upper valley courses is 40-45°, in the middle part – up to 20°.

Recently in a series of publications the group of geologists has proposed to exclude the internal – Boryslavsko-Pokutska, and external – Bilche-Volytska zones from the Fore-Carpathian Trough, and remain in the latter just the middle tectonic unit – Sambirskiy thrust [34]. Independently from these authors, Ya.V.Sovchyk [43] has suggested to exclude from Fore-Carpathian Trough its Boryslavsko-Pokutska zone which is classified by him as depression. According to this author, complete tectonic analogues of this zone are absent outside Ukrainian Carpathians. S.S.Kruglov has argued in support of traditional thoughts on the structure of Fore-Carpathian Trough with definition of three major tectonic units – internal, central and external. In his publication [29] he had presented some unequivocal proofs for the primary thoughts on the Trough structure which are most suitable for appraisal of oil-gas perspectives in the region and for development of directions for prospecting of hydrocarbon and other mineral deposits not only in the molassa complex but also in its heterogeneous pre-Miocene basement.
4. HISTORY OF GEOLOGICAL DEVELOPMENT

PRECAMBRIAN

Beginning of geological history in the studied area is thought to be Archean when in the course of Svecofenno-Karelian tectogenesis Paleo-Archean metamorphic complex was formed. Evolution of Eastern-European Platform crystalline basement had accompanied by the oldest north-west-trending fault system development [9, 10, 14].

In the beginning of Proterozoic the stabilized basement had been already arranged into some mega-blocks and basement consolidation had defined further plate development mode at the ancient platform margin. Formation of its sedimentary cover occurred under conditions of spatial coexistence of the sub-platform and mio-geosyncline domains as the single basin resulted in transitional rock lithology and essential thickness variability.

In Riphean apparently flyschoid sequence was deposited in the deep-sea environment and in the course of Baikalian tectogenesis it was transformed into quartzite-phillite formation which fills up modern Lezhayska and Roztotska LTZs (see cross-section A1-A7 to “Geological map of Quaternary sediments”). Tectogenesis was accompanied by faults of modern north-eastern direction and volcanic activity resulted in terrigenous-volcanic sequence of Volynska Series (Lower Vendian). This Series marks beginning of sedimentary cover formation in the earliest platform structure – Dnistrovskiy peri-cratonic trough with one of its element – Volyno-Podilskaya monocline [9, 10, 14]. In the latter over Late Proterozoic time (Late Vendian) thin Mogyliv-Podilskia Series was formed first, and then the rocks of Kanylivska Series.

PHANEROZOIC

It includes Paleozoic, Mesozoic and Cenozoic eras when in the quite different paleo-geographic environments deposition of thick sedimentary sequence of Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Jurassic, Cretaceous, Paleogene and Neogene systems and thin Quaternary sediments had occurred.

Paleozoic Era

In Paleozoic further peri-craton subsidence had facilitated deposition of Lower and Middle Cambrian terrigenous-carbonate Baltiyska and Berezhkivska series under apparently shelf conditions. In the mio-geosyncline, adjacent to peri-craton, more than 800 m thick turbidite sequence was depositing over that time. In the Late Cambrian time the thick terrigenous sequence was depositing in the peri-craton shelf portion.

In Ordovician time the territory most likely was mainly involved in continental regime. Somewhere only the local shallow-water environments remained reflected in thin carbonate Molodovska Series.

Over Silurian time, in the basin shelf part under sub-tropic climate, the sequence of bioherm limestones was depositing with interbeds of fine terrigenous material supplied from the gently-dipping continental slope of Eastern-European Platform. At the border of shelf and slope the stretched bioherm reef was forming. Periodic and apparently short-time uplifts of the basin shelf part bottom in Silurian time are marked with interruptions in sedimentation. At the foot of continental slope the thick uniform clayey-carbonate sequence was depositing over that time under the mode “particle by particle”.

Almost the same sedimentation regime had been remaining in the area in the beginning of Early Devonian. That time, however, the progressive mio-geosyncline “closure” commenced as well as continental slope bottom uplift and complete homogenization of sedimentation environment over entire basin. The mode had emerged at the transition “sea-land” that caused asynchronous boundary of tidal-marine terrigenous-carbonate sediments and parti-coloured, continental rocks in upper part of Devonian Tyverska Series. Most extensive Caledonian movements had occurred in Silurian and beginning of Early Devonian (Tyverskiy time) evidenced by the thickness of respective sediments developed at the platform margin. In adjacent geosyncline these movements were accompanied from time to time by volcanism expressed in tuffite interbeds observed in the column of Upper Silurian sediments in the platform.

Folding over Late Caledonian orogenesis had caused completion of Dnistrovskiy peri-craton formation at the end of Lokhivsky (Devonian) time, subsequent inversion in the former mio-geosyncline, its further tectonic complication and displacement towards the ancient craton of Eastern-European Platform. Baikalian
Lezhayska LTZ had apparently developed under median massif mode. And over Late Caledonian tectogenesis the north-eastern part of this LTZ was probably also involved into tectonic thrusting.

Between Caledonide front and ancient craton the narrow fore-mountain trough (Boyanetskiy) had emerged. In this trough, over Pragian and Emsian stages (Early Devonian) alluvial plain developed under arid conditions where, besides sub-aqueous terrigenous material transportation, aeolian processes have also essentially contributed. Over deposition of Lower Devonian Dnisterska Series, under reducing conditions of stagnant shallow-water lagoon-alluvial plain, the aleuritic material was depositing enriched in fossil detritus. Caledonide uplift was accompanied by more extensive subsidence in the internal margin of Byzhayskoy trough and thick red-colour sequence deposition over there.

Over Herzinian tectogenesis Caledonides have been displaced again towards the craton and overlapped the south-western limb of Byzhayskiy trough giving rise to Lezhayska, Kokhanivska and Rava-Ruska epi-orogenic zones rimmed the ancient platform margin. The continental regime established over there after Dnistrovskaya Series deposition, was interrupted by new transgression in Middle Devonian and further on, up to the end of Devonian, the terrigenous-carbonate sequence of Devonian Zakhdinoukrainska and Chervonogradskaya series was depositing under shallow-water and arid climate conditions in the areas which partly include the map sheet north-eastern part.

In the beginning of Eifelian time (Middle Devonian) the continental regime of marginal trough has been changed by the regime of pulled-apart superimposed suture troughs resulted in formation of Lvivska Paleozoic trough. In the latter, under shallow-water conditions, the thick terrigenous-carbonate and terrigenous coal-bearing sequences were deposited over Middle-Late Devonian and Carboniferous times. Later on, up to the Early Jurassic time, the continental regime was established over these areas.

**Mesozoic Era**

With the beginning of first phase of Alpine tectogenesis, in Early Jurassic time, formation of large peri-cratic unit (Jurassic Striyskiy trough) commenced under conditions of passive continental margin and regional extension. This trough is superimposed over heterogeneous base in the junction zone of Eastern-European Platform and its epi-orogenic rim (young platform). Subsidence involves significant portion of the map sheet territory in the mid of Late Jurassic time only. Over Oxfordian time, the lagoon-marine arid conditions established with minor water inflow, and the sequence of parti-coloured gypsum-enriched clays was formed. In Cimmeridgean-Titonian times the progressive transgression proceeded and the sequence of dolomites and limestones deposited reflecting the change of continental and coastal-marine conditions by the open sea environments. At the western basin coast, apparently comprised of Lezhayskiy massif, the greatest subsidence occurred and the total thickness of Upper Jurassic sediments here attains 500-600 m. Lithology of sediments in the north-eastern margin of Jurassic sea basin suggests for high and cliffy coast, cut by numerous ravines provided the channels of water-stone mud-flows supplied to the basin.

At the Jurassic-Cretaceous boundary the extension regime was changed by compression one resulted in “closure” of the trough; by these reasons the south-western platform margin remained under continental regime almost up to Late Cretaceous time.

In the beginning of Early Cretaceous time formation of riftogenic trough (Carpathian paleo-basin) had commenced far away from the present location of Carpathians. Neocomian sediments of this basin were deposited over structures of passive continental margin under lithosphere extension regime. Starting from Barremian time, the clear differentiation into two separate basins had emerged over there: Sheptisko-Spaskiy and Bilotysensko-Rakhivskiy. The first one most likely had adjoined Lezhayskiy massif and was separated from the second basin by the underwater uplifts known in geological publications as “cordilleras”. In paleo-geographic respect, these comprised en echelon mountain-island or underwater ridges. The cordilleras provided inner-basin source regions and flysch substratum in considerable extent. Clear evidences for cordillera erosion are expressed by conglomerate lenses in Lower Cretaceous piles containing weakly-rounded fragments of diverse older rocks. Early Cretaceous flysch rocks, which reflect paleo-geography of this part of Carpathian flysch trough, are developed mainly outside the map sheet territory.

On the eastern coast of Carpathian basin the paleo-relief was forming. Paleo-rivers supplied the great amount of terrigenous material into the outer basin part.

At the end of Albian time transgression had commenced from the side of Carpathian basin towards Volyno-Podillya. Over most part of the latter the thin terrigenous-carbonate sediments were deposited under conditions of shallow-water shelf.

In the Late Cenomanian time the deep waters, enriched in biogenic compounds, specifically, phosphorus, had flowed into the basin shelf part facilitating formation of organogenic limestones with phosphorite nodules (Nezvyska Suite). Turonian-Campanian time is marked with epi-continental sea deepening
and widespread plankton development supplying material for chalk-like limestones and marls (Dubovetska and Lukvyńska suites).

Into the outer part of Carpathian basin the terrigenous material over Late Turonian – Early Paleocene times was introduced in turbidite flows from the platform slope resulted in deposition of thick flysch sequence of Striyska Suite. In the inner basin part the hemi-pelagites and proximal turbidites of Yalovychorska and Skupivska suites were deposited (developed outside the map sheet in the External Carpathian inner thrusts). Material for their formation had been apparently supplied from the south-west.

Cenozoic Era

The similar conditions of sedimentation in Carpathian basin have been also remained over Paleocene – Eocene times.

The platform part remains the land over Paleogene. At its margin, over entire mentioned period, the extensive erosion continues providing formation of deep cuts (paleo-valleys – Kolomiyska, Molodyntska, Khodorivska) up to thousand kilometers long. Through these valleys, the terrigenous material was introduced into Carpathian basin by turbidite flows and fans resulted in Yamnenska, Manyavska, Vygodska and Bystrytska suites (Late Paleocene – Eocene).

In Oligocene the change of the neutral to reducing conditions commenced in the outer part of Carpathian paleo-basin with respective change of green colour of sediments to black one. Tectonic activization, which apparently occurred in the south-western part of Carpathian paleo-basin, was accompanied by volcanic activity expressed by numerous ash tuff interbeds in Menilitova Suite (Oligocene – Early Miocene). With these processes, dissolved silica and carbon dioxide supplied into the basin in increased amounts facilitating extensive development of micro-organisms resulted further in formation of silicite and banded limestone horizons. In opinion of some authors (G. Dosyn), deposition of organogenic silicites and organic matter of Menilitova Suite, coalified at post-sedimentation stage, had occurred through upwelling – uplift of deep waters, enriched in biogenic compounds including silica, carbon dioxide etc., in the north-eastern coastal zone of Carpathian sedimentation basin.

At the end of Paleogene the next phase of Alpine tectogenesis emerged which under compression regime completed geosyncline stage of Carpathian development. Due to horizontal rock movement some litho-tectonic zones had been being thrusted one over another with predominated north-eastern virgation resulted in considerable geosyncline shortening. The orogenic stage commenced and mega-thrust emerging with fore-mountain trough formation in the front over flysch substratum. As far as structures of the platform margin were underthrusted, the flysch sediments of Carpathian basin most likely were completely detached from their sedimentation substratum and began thrusting over this margin under con-sedimentation mode. Obviously, the thrusting processes did also have the vertical counterpart, thus the frontal part of flysch nappe underwent general uplift and the shallow-water Polyanytsko-Vorotyshchenska molassa (Egenburgian) was depositing over there. In general, the gradual transitions between molassa and flysch (menilite) sediments, their intercalation and facial relationships suggest for continuous con-sedimentation growth mode of the frontal structures in Boryslavsko-Pokutskiy thrust. Molassa sedimentation had accompanied by folding-thrusting processes and uplift of antiline-thrust “arcs” which had been being locally eroded and olistolites and olistoplakes climbed down from there. Hence, molassa Polyanytsko-Vorotyshchenskiy basin had emerged “on the body” of the frontal part of flysch mega-nappe thrusting over structures of the platform passive margin, in the peripheral uplifted part of Boryslavsko-Pokutska zone.

Over entire Early Miocene (Eger-Carpathian) the processes of Western-European Platform underthrusting had caused general shortening of residual flysch basin, including Boryslavsko-Pokutskiy one, at the expense of con-sedimentation folding-thrusting deformations of sediments filled this basin. These deformation processes were accompanied by structure and, respectively, sea bottom uplift. These processes commenced in the outer periphery of Boryslavsko-Pokutskiy thrust and had continuously spread towards its inner part; at present this is expressed in continuous diachronic lower boundary of Polyanytsko-Vorotyshchenska molassa, which becomes younger itself and facially replaces more and more younger subdivisions of Menilitova Suite with transition to the inner elements of Boryslavsko-Pokutskiy zone. This diachronic boundary reflects continuous shallowing towards the inner segments of flysch basin and its transformation into molassa basin where the favourable conditions for deposition of Vorotyshchenski salt-bearing sediments occurred. Irregular tectonic uplift of sea bottom had caused in places formation of coarse-clastic sediments and olistostromes.

Tectonic processes had caused trough formation in front of Boryslavsko-Pokutskiy thrust which apparently emerged outside the mentioned foreland uplift (“exotic sources”). The sea basin appeared in the trough where shallow-water Vorotyshchenski and sub-continental Stebnytski molassa sediments of Sambirska zone were deposited.
Polyanytsko-Vorotyshchenska molassa reflects rather different but in general shallow-water facial conditions. Slobidski and other conglomerates were deposited through the strong mud-stone flows. Antiplane-thrust structures inside the Borystevsko-Pokutskyi thrust had caused formation of sea-bottom elevations from where flysch olistolites and olistoplates climbed down being mixed with coarse-terrigenous exotic material of mud-stone flows.

Stebnytschi sub-continental rocks were depositing at the end of Early Miocene over most part of Rungurska litho-tectonic sub-zone, probably due to above sea-level elevation of the frontal part of Borystevsko-Pokutskyi thrust. The source regions for these sediments include both elevated structures of newly-formed Carpathians and the platform area with not completely eroded foreland uplifts. Stebnytski sediments were also deposited in Sambirska zone where sub-continental sedimentation of red-colour layers had also continuously changed the deposition of grey-colour Vorotyshchenska Suite sediments. Thus, in the outer margin of Borystevsko-Pokutskyi zone the flysch filling of this zone (newly-formed thrust) had been formed in Early Miocene. Sambirska zone (thrust) had emerged from the north-eastern side of this uplift which supplied “exotic” terrigenous matter for molassa.

In Carpathian-Badenian times the inner part of Borystevsko-Pokutskyi zone was underthrust beneath Skyboviy thrust and sedimentation processes had terminated over there and Stebnytski sediments were not deposited over Vorotyshchenski rocks.

Further platform underthrusting had caused Borystevsko-Pokutskyi thrust tectonic overlapping of the foreland uplift which supplied exotic material also prior to thrusting of mentioned nappe over Sambirska zone sediments. Due to thrusting processes the frontal part of Borystevsko-Pokutskyi zone was excluded from sedimentation region and its Vorotyshchensko-Stebnytski molassa was eroding. In front of Borystevsko-Pokutskyi thrust (in Sambirska zone) olistostrome sequence of Balytski Suite (Carpathian-Badenian) was depositing with olistolites and olistoplates of allochthon Vorotyshchensko-Stebnytski rocks.

The sea transgression had gradually caused complete termination of red-coloured sub-continental Stebnytski rocks deposition in Sambirska zone and sedimentation of green-grey sandy-clayey marine Baltyski layers. At the Early-Late Badenian boundary the Baltyskiy basin had been apparently separated from the open sea and was partially dried through sea water evaporation resulted in formation of rock and potassium salts.

At the end of Badenian-Sarmatian times the sediments of Sambirska zone were detached from their sedimentation base and were thrusting over the rocks of Bilche-Volytska zone. Detachment was accompanied by con-sedimentation folding, formation of tectonic sheets and sea regression from the territory of Sambirska zone due to its general uplift. Tectogenesis had gradually caused complete sea regression from Sambirska zone in post-Baltyski time and its transformation into the frontal thrust of Carpathian allochthon domain.

Almost simultaneously with fore-mountain molassa deposition the slight subsidence of platform margin commenced where in the paleo-relief depressions thin terrigenous-carbonate Carpathian regio-stage sediments (Oncophore and Berezhanski layers) were deposited which were almost completely removed over subsequent continental regime.

In the Early Badenian time the platform margin was involved in the depression continuously filling erosion forms of pre-Badenian relief – deeply cut paleo-valleys where evaporite sequence was depositing; later on this depression had encompassed shelf areas where typical shallow-water lithotypes of Opilska Suite were depositing. At the shelf margin, under continental slope environments, the clayey sequence of Bogorodchanska Suite (Lower Neogene) was depositing. At the Early-Late Badenian boundary, upon short-time continental regime, sulphates of Tyarska Suite were depositing. In general, two sedimentation cycles are observed in Tyarska Suite. In the most prominent erosion depressions of Bilche-Volytska zone (Kolomiyska, Gryniwska, Kosivska paleo-valleys etc., most of which are located outside the studied territory) the clayey rock salts with interbeds of clastic gyspums, clays and sandstones were depositing.

Middle Badenian cycle of chemogenic sedimentation is completed with formation of pelitemorphic chemogenic (Ratynski) limestones related to the general water desalination in the basin. This completes development of Fore-Carpathian evaporite basin. After short break in sedimentation, the active subsidence of Western-European Platform margin beneath Carpathians commenced as well as Carpathian displacement towards the platform and formation of the outer part of Fore-Carpathian Trough. This accompanied by active sea transgression, and under conditions of the single fore-mountain basin, but at various depths, sedimentation proceeded of essentially terrigenous sequence – Kosivska Suite (Upper Badenian) which throughout overlies Tyarska Suite. Tectonic activation in Western Carpathians entails volcanic activity renewing far away the Fore-Carpathians: the eruptive material occurs in Verbovetski layers (Kosivska Suite). Conditions for metasomatic modification of sulphate rocks are being continuously emerged.

The platform margin underthrusting beneath Carpathians in Early Sarmatian time had caused rejuvenation of some north-east-trending faults (Teterivskyi and Ostrozkiy in the map sheet area) and positive large block vertical movements in the central part of Fore-Carpathians. Large crossing uplift (Stanislawskie)
appeared over there which split the External zone of the Trough into three parts. The central one, which also includes part of studied area, over Early Sarmatian time apparently developed under continental regime and this explains the lacking of respective sediments over there. The margin of Early Sarmatian sea basin, which mainly encompassed north-western Fore-Carpathians, is traced in the studied area by occurrence of Dashavska Suite sediments (Lower Sarmatian) in the left-bank side of Bystrytsya-Solotvynska River.

Miocene molassa deposition in fore-mountains is occurred on the background of permanent thrusting; as a result, enormous flysch and molassa masses were displaced further to the north-east and had occupied their modern position. The major Alpine rim of the platform was formed – Carpathian mega-thrust. According to the seismic data, the total magnitude of allochthon displacement over Miocene time is about 100 km. As it is revealed from position of gravity minimum beneath Carpathian thrust, which corresponds to the axial part of Fore-Carpathian Trough, its autochthon is apparently located beneath modern Marmaroskiy thrust. It is not excluded, however, that this is already Miocene para-autochthon or halogenic molassa of residual Late-Krosnenskiy basin, which is more likely, and then the total magnitude of Carpathian mega-thrust horizontal displacement is much higher.

Due to the platform margin subsidence beneath Carpathians, the series of flexures was forming in Meso-Cenozoic cover of Bilche-Volytska zone under the side compression; these flexures are arranged in the chains of sub-parallel elongated brachy-structures. The latter provide the traps for hydrocarbons coming from the depth by destructive zones related to the faults encountered by seismic data in the under-thrust platform part.

Increasing of tuffogenic material amount in the column from Late Cretaceous through Oligocene to Miocene does mark continuous increasing of volcanic processes intensity over that time. Two phases of volcanism in Paleogene and Neogene are clearly distinguished in Cenozoic eratheme. Occurrence of insufficient amounts of just the ash material in the flysch and molassa columns suggests for considerable distance from the explosive centers.

Late Cenozoic continental stage in the territory development is governed by periodic rejuvenation of neo-tectonic motions and climatic changes of warm and cold thermo-chrones. Dynamics of vertical neo-tectonic motions in Late Cenozoic is reflected in relative heights of 16 terraces and clear lineaments of modern relief. In the back-terrace areas the numerous paleo-gullies were forming filled with soils and loess. In the valleys of water flows alluvial sediments were depositing. The watersheds and slopes are being covered by the blanket of eluvial, deluvial, sliding and mixed sediments.
5. GEOMORPHOLOGY AND RELIEF-FORMING PROCESSES

The territory of map sheet M-35-XXV (Ivano-Frankivsk) in geomorphologic and morpho-structure respects, according to the scheme of morpho-structure zonation of Ukraine [36], encompasses the fragments of two first-order morpho-structures, particularly, Eastern-Carpathian and Podilsko-Kodrynska. The second-order morpho-structures are distinguished over these ones, specifically, External-Carpathian and Fore-Carpathian in the former, and Podilska in the latter. Further distinguishing into third-order morpho-structures with regard to their origin, relief forms and age is being performed by various schemes. Zonation for the Carpathian part of the map sheet is performed according to the scheme of P.N.Tsys (1951), Fore-Carpathian part – Ya.Kravchuk (1999), and Podilska – V.N.Palienko (1992).

External-Carpathian morpho-structure

The front of Beregova nappe composed of soft Oligocene sediments comprises the north-eastern boundary of External-Carpathian morpho-structure with Fore-Carpathian one. Over entire length of Ukrainian Carpathians this front is expressed in the relief as the clear ledge – the “coast” of Carpathians. The general litho-tectonic continuity of External Carpathians has also caused the uniform mountain landscape where tectonic-denudation-erosion formation factor had played primary role. However, each litho-tectonic element in the Eastern Carpathians exhibits own distinct features reflected in the differences of the minor relief patterns – altitudes, relative heights, morphology of inter-river areas, slopes and valleys. By these reasons, in the External Carpathian morpho-structure some higher-order units are distinguished – geomorphologic areas which encompass certain portions of the studied area, specifically:

Gorganskiy area of medium-height mountains of apparently Late Badenian – Holocene time. It encompasses the far south-western corner of the map sheet in the frontal part of Parashka, Skolivska and Orivska nappes of Skyboviy tectonic thrust; in the area these units are mainly composed of thick strong Upper Cretaceous – Eocene sandstones facilitated formation of steep medium-mountain landscape. The major ridges in the area (Sekhlis, Yavornyk, Grynkiv, Stinka) do form the frontal portions of the nappe structures clearly following their extension. The inter-river area heights in the map sheet are 850-1350 m, and the relief range attains 700 m. All inter-river areas are of the ridge-type, 7-10 km long. The crestal lines, composed of massive sandstones with thin-rhythmic flysch batches, are flat-wavy with alternating gentle elevations and depressions. The height range in between these lines is 50-80 m, in places up to 100-150 m. Some cone-like mountains display relative heights over the watershed surface up to 250-300 m. At the narrow watersheds the hard rocks are often exposed suggesting for low strength of the top surface and permanent replenishment of eluvial clastic material layer. In places of massive sandstone outcrops somewhere denudation remnants are observed up to 10 m high, surrounded by the cobble fans. The cross profile of inter-river areas is asymmetric with steeper (35-40°) north-eastern slopes. Some ridge-type inter-river areas at Gorgany are modified by erosion into the mountain massifs (Yale – 1235.3 m, Za Todorom – 1027.0 m).

In the slope micro-relief the hilly sliding forms are observed. Over the steep slope portions the permanent collapsing and rock-fall processes are developed. At the watershed parts of inter-river areas, over the flat slope portions, the planar deluvial erosion predominates with denudation rate about 0.03 mm/year. In the middle and lower slope parts the linear cut of permanent water flows is more developed with denudation rate up to 0.2 mm/year, which together with planar erosion has formed the system of pediments traced along the slopes with the surfaces gently-plunged (3-5°) outward the slopes. The pediment table width is 30-50 m. In the valleys of major water flows the lower pediment tables do merge with coeval terrace complexes. The slides, expressed in the viscous-ductile deformations, are being developed in the lower slope parts, in places of clayey piles development.

The area of Marginal ridges of apparently Pliocene-Holocene low mountains. The area boundaries coincides with tectonic boundaries of Beregova nappe which back portion is composed of relatively consistent sequence of Striyska Suite thin-rhythmic flysch and its frontal part – of Menilitova Suite clayey rocks. By these reasons the heights in the inter-river areas decrease in the same direction from 1018.2 m (Vulkan mountain) to 557 m (Kont mountain), and the relief range – from 500 to 150 m. The inter-river areas over there are unclear,
short (4-5 km), in places are split into individual small-size massifs with smoothed contours. Some inter-river area parts only are clearly oriented coinciding with the rock strike.

In the structure of low-mountain Marginal ridges the area at Krichka village in between Bystrytsya-Solotvynska – Manyavka rivers is in the special position. Here, erosion-cut tectonic semi-remnant of Beregova nappe, composed of strong Eocene and Oligocene rocks, does form the individual massif, well expressed on the background of surrounding relief. The massif slopes are clearly asymmetric. The steep (up to 35°) south-western slope composed of flat-laying sequence of strong aleuro lites, is cut by strike-slips with breaking wall heights up to 50 m. The maximum height of the massif – Vavenka mountain (791.5 m) comprises the narrow, elongated by rock strike watershed. On the flat north-eastern massif slopes the relics of high terraces are observed expressed in small-scale flattened surfaces.

From watersheds to the slope foots much less extensive, in comparison to the previous area, planar and linear erosion and gravity removal of broken products is observed over there. In the river-course slope parts the sliding and collapse-strew processes are developed.

Three-floor structure comprises the general relief feature of both areas including the floor of upper denudation level inter-river areas, the floor of middle terraces and the floor of low terraces. All flat inter-river areas in the External Carpathians comprise the relics of apparently Pliocene peneplain surface which in Gorgany area is traced at altitudes 1150-1200 m, and in the area of Marginal ridges – 650-700 m.

The river system in the first area exhibits branch-lattice, and in the second area – branch patterns which are also related to the geological structure. The major water flows (Bystrytsya-Solotvynska, Limnytsya, Chechva) are mainly oriented across the strike of major Carpathian structures. They display trapezium-like cross-sections, and alternation of their river course latitudinal, longitudinal and diagonal portions clearly depends of litho-tectonic features of the underlaying country rocks. This had also facilitated formation of meandered and terraced sites over entire valley length in the mountains. In the latitudinal river profile the alternation of sandbank dimples and rapids is observed clearly enough confined to the back and frontal zones of tectonic structures (nappes). The water flows had formed several denudation-accumulative floors. Relicts of ancient Pliocene and Early Quaternary terraces are observed in minor flats. Their accumulative ascription is defined by findings of Carpathian rock pebbles disseminated over the terrace flat surfaces inclined towards the river courses. The complex of Middle Neo-Pleistocene (IV-VI) terraces does form the plain floor of total width 200-300 m which is traced in the 0.5-1.0 km long bands in the valley bunches and especially at their entrance to the fore-mountains at the height 60-100 m above the river course. Accumulative portion of these terraces is essentially destroyed. Terrace elements are prominent but their back edges are overlain by deluvial-coluvial fans. The complex of Late Neo-Pleistocene terraces does form the plain floor at the river-course valley parts. The total width of this terrace floor in the mountains is 0.3-0.6 km, in places it increases (up to 1.5 km) on exit from the mountains.

The system of minor water flows (Menchylka, Lypovytsya, Kamenets, Godor, Sviniy streams etc.) is mainly of branch-lattice, in places lattice type. Direction of their courses varies from latitudinal to diagonal. The valley bottoms are beads-shaped in the plane with slight meandering in the flood-land alluvium sediments. Their most narrowed portions look like gorges with rapid courses. In the bunched sites the valley slopes are terraced. The narrow up to 2-3 m high high socle terraces are developed over these sites.

The lowest-order hydro-network is essentially branched. The stream valleys are triangular, symmetric with steep (up to 35-40°) slopes. Their upper courses are combined in the erosion circus while the mouths are open into the valleys of bigger water flows. The bottoms are filled with coarse-clastic material which over the rainfalls provides the stone-mud flows and small-scale fans.

Fore-Carpathian morpho-structure

The map sheet territory almost entirely encompasses the north-western part of Prygorganske Fore-Carpathian (see “Scheme of geomorphologic zonation in the scale 1:500 000”). From Carpathians it is separated by the well-expressed in the relief orographic ledge which coincides with the zone of External Carpathian Beregova nappe thrusting over the internal zone of the Trough. The boundary of Fore-Carpathian morpho-structure with Podilska one is comprised of the Dnister River valley in the north-east, and the Bystrytsya River valley and its major right branch Vorona – in the east.

In the tectonic respect Fore-Carpathian morpho-structure coincides with the Internal zone of the Trough (Boryslavsko-Pokutskiy and Sambirskiy tectonic thrusts) and External (Bilche-Volytska zone) zone composed of partly flysch and, mainly, thick molassa sequence causing principal morphologic features of this morpho-structure. The orographic boundary between these zones is well-traced in the area between Bystrytsya-Nadvirnyanska and Bystrytsya-Solotvynska rivers.
Fore-Carpathian location at the foot of Carpathian Mountains, which have been being uplifted over Pliocene – Quaternary times, facilitated development of extensive accumulative processes. Periods of neotectonic uplifts changes by periods of relative tectonic inactivity. Formation of denudation-accumulative and denudation surfaces in Fore-Carpathians is related to these periods. Most authors studied the ancient denudation surfaces in Fore-Carpathians (G.Tesseyre, 1933; I.D.Gofshtein, 1962 and others) have distinguished here two age-different surfaces. In the studied area the relics of most ancient in Fore-Carpathians (Pontian-Pliocene) surface which is known as “Krasnoi surface” (I.D.Gofshtein, 1964) are mapped in the areas between Bystrytsya-Solotwynska and Limnytsya rivers (Krasna mountain, Zeleniy Yar ravine), Bystrytsya-Solotvyynska and Bystrytsya-Nadvirynska rivers (uplifts with Potoky, Bzhovach, Tsetsyura tops), Svicha and Chechva rivers (Zalissya mountain). Genesis of some portions of this surface preserved in the studied area is variable. The flat-convex ridge-side surfaces with Potoky, Bzhovach, Tsetsyura tops in the area between both Bystrytsya rivers comprise the remnants of Pliocene denudation surface. The fragments of Pliocene surface in the area between Bystrytsya-Solotvyynska and Limnytsya rivers as well as Svicha and Chechva rivers are overlain by the layer of cobble-pebble material and comprise the remnants of XVI over-flood terrace of Early Pliocene water flows. The surface remnants of various origins suggest for existence of polygenic continental denudation-accumulative surface.

More younger (Early-Late Pliocene) denudation surface in Fore-Carpathian is also polygenic – “Loevoi surface” which is well preserved in the studied area and mainly occupies the inter-river sites. Climatic conditions of Pliocene time facilitated formation not only accumulative and denudation-accumulative but also denudation surfaces. It is evidenced that these surfaces in Pryorganske Fore-Carpathians were formed in Pliocene time, first of all by their relative heights and altitudes which throughout match the heights of denudation-accumulative Loevoi surface.

The valley-terrace relief type caused mainly by accumulative activity of Dnister River comprises the principal relief type in Pryorganske Fore-Carpathians. Over Pliocene-Quaternary time this major Fore-Carpathian water flow escaping from Carpathian boundary has formed in its right-bank side the spectrum of denudation levels from sixteen to first over-flood terraces. The solces of these terraces are mainly composed of Miocene molassa. Relatively thick alluvium in each of these terraces is overlain by the blanket of sub-aerial rocks where aeolian-deluvial loams predominate. However, Dnister River terraces are not alone in Fore-Carpathian morpho-structure. Each of numerous Dnister right-bank branches also has its own terrace complex which rejuvenates Dnister terrace relief. Terrace complex of minor rivers inherits the major feature of Dnister terraces – occurrence of gravel-pebble sediments at the terrace bottom. Terrace relief of Dnister branches, in turn, rejuvenated by terrace relief provided by the minor branches and so forth up to the gully terrace relief. This feature has caused formation of the solid terrace relief.

In the map sheet area, in the right-bank terrace portion, the relatively large geomorphologic elements are also observed comprising trough-like dimples commonly known in the literature as “depressions”. But actually these relief forms by morphology and parameters do more likely correspond to the term “lowland”. These are Bystrytska (Ivano-Frankivska, and primary name – Stanislavska), Kaluska and somewhat different from them Striysko-Zhdydachivska lowlands. These lowlands are located in front of Carpathian mountains and alternate with more elevated sites. Structure of the latter unequivocally indicates that these sites comprise residual Dnister River terrace relief, mainly of Pliocene time, rejuvenated by the younger terrace relief of the lower-order water flows.

Formation of lowlands is explained by some authors [27] from tectonic point of view exclusively and in this case the possible role of exogenic processes is not taken into account at all. However, it is not excluded that this phenomenon is exclusively caused by fluvial processes developed within the tectonically uniform tectono-structure of Fore-Carpathians. It is evidenced from the general patterns of terrace relief – the elevated sites comprise the remnants of high Pliocene terraces while in the lowland bottom and slope sites the Neo-Pliocene alluvial sediments are developed. Apparently, these elevated sites and lowlands are tectonically predetermined (evidenced by the sharp lowland boundaries) but formed under activities of fluvial processes. The fluvial nature of Striysko-Zhdydachivska lowland is doubtless since its entire relief comprises continuous range of Quaternary terraces common for Dnister, Striy and Svicha rivers.

By relief features and its common nature over Pryorganske Fore-Carpathians, the following areas are distinguished in the map sheet territory:

The area of Maydanske low-mountains. It is located in the area between Limnytsya and Bystrytsya-Solotynska rivers and between Mzhgirya (former name Maydan) and Kosmach. Its genesis is related to the denudation of major same-named anticline in Boryslavsko-Pokutskiy thrust where the anticline core with strong Miocene mainly sandy flysch is eroded. In the relief, Maydanske low-mountains is expressed in two island mountains with soft flat-convex contours of surfaces and slopes separated by the Lukva stream valley. The altitudes attain 869.8 m (Klyova mountain), 784.4 m (Kosmachka mountain), 756.8 m (Kosmychara mountain),
702.3 m (Kytvan mountain), and relative heights are 250-300 m. Mentioned mountains and some other nameless ones are confined to the band of Oligocene Menilitova Suite massive-layered strong sandstones which clearly mark the anticline limbs providing relatively steep (up to 30°) slopes overlain by gravel and coarse-cobble strews. The core of structure at the surface is mainly composed of Eocene Manyavska Suite clayey flysch causing clear relief inversion. Along the Lukva stream valley, the lowland bunch is related to the core portion, and on the stream slopes which cut these sediments, abundant slides are developed and the remnants of smoothing surfaces are observed. The linear erosion does mainly comprise the modern exogenic processes in Maydanske low-mountains.

The area of Mîzhbystrytska height occupies the territory between Bystrytsya-Solotvynska and Bystrytsya-Nadvirnianska rivers at Gvizd village outskirts. It is confined to the frontal part of Boryslavsko-Pokutskiy thrust which in this place consists of accumulated deep folds with Lower Miocene molassa in the cores. The maximum height in the area – Bzhovach mountain (575.2 m) is confined to the core portion of Gvizd anticline composed of strong conglomerates of Miocene Vorotyshchenska Suite. In the mountain northern slope several levels are clearly mapped with up to 2-3 m thick cobble-pebble sediments at the surface. In view of the relative heights above both Bystrytsya rivers, these are the relics of ancient (VII-X) terraces of mentioned water flows. To the south-west from Bzhovach mountain, between the latter and Carpathian margin (directly outside the map sheet), the smooth denudation surfaces are observed. The altitudes and relative heights of these levels allow assumption on their same age with the “Loeva level”. The flat-convex surface of Verpil mountain (483.9 m) is composed of up to 7 m thick coarse-clastic alluvium and most likely it is also the remnant of “Loeva surface”. In general, the area relief is hilly-ravine and is extensively cut by numerous branches of major water flows, gullies and ravines. The flat-convex surfaces in the central part of the area comprise the erosion remnants. In the relatively steep slopes of both Bystrytsya rivers the surface levels of certain mountains comprise the relics of Eo-Pleistocene terraces (Gorokholynska mountain – 438.7 m, Berezovtsytsya mountain – 430.2 m). The dense network of deep ravines cuts the relatively flat slopes composed of Lower Miocene clays. The course-side slope portions are mainly cliffy and complicated by numerous slides and mud-streams. The area of Mizhbystrytska height in the territory between Bystrytsya-Solotvynska and Manyavka rivers by its morphology differs in some respects from other sites. Here, the low-mountain massif formed by the tectonic semi-remnant of Beregova nappe, separates small-size micro-area located between Krychka and Porogy villages. Tectonic semi-window, resembling the “bay” in shape, is composed of Lower Miocene clayey sequence. The smoothed surfaces with alluvium remnants, which are clearly mapped in the right slope of Bystrytsya-Solotvynska river, comprise the relics of Eo-Pleistocene and Lower Neo-Pleistocene terraces of this river. The extensive slide development is observed on the flow slopes nearby Krychka village. And the outskirt of Starunya village is the most prominent site in the area of Mîzhbystrytska height.

Over there, on the left slope of Velykiy Lukivets stream, the only in Fore-Carpathians mud volcano is located which date of origin is as far back as 1977. In the relief, at the level of first over-flood terrace, the volcano does form the cone 0.7 m high and 10 m in diameter. But the village outskirts are more renowned in other respects. Here, in the shallow ozocerite (mineral wax) shafts in 1907 and 1929 the well-preserved remnants of mammoth and two woolly rhinos were found which currently are being stored in the natural history museums of Krakow [52] and Lviv.

The area of Prylukvynska height. It occupies most elevated in Fore-Carpathian territory between Limnytsya and Bystrytsya-Solotvynska rivers. In this area the denudation-accumulative surfaces occupy the most squares. Altitudes of the fore-mountain part attain 550-600 m decreasing to 300-350 m in the fore-Dniester areas. In the same direction, the height gradually becomes narrower at the expense of the size increasing in the terraced slopes over Limnytsya, Lukva, Lukvytsya, Bystrytsya-Solotvynska rivers. These morphologic differences are spatially linked with tectonic boundary between the Internal and External zones of Fore-Carpathian Trough. This allows two sub-areas distinguishing in Prylukvynska height: Krasnyanskiy and Galytsko-Ugrynivskiy (see “Geomorphologic scheme in the scale 1:500 000”).

Krasnyanskiy sub-area in tectonic respect is confined to the fold-thrust internal zone of the Trough. On the background of wide smoothed watershed surfaces formed by the remnants of pra-Dniester fifteen over-flood terrace (“Loeva level”), the remnants of older Pliocene surface (sixteenth terrace) rise up in the area of Krasne village (Krasna mountain, 590 m). Maximum relative heights of “Krasna surface” attain 180-190 m, and “Loeva surface” – 90-100 m. The latter occupies most part of the sub-area. In the north-eastern direction the relative heights of smoothed watershed surfaces, which comprise the remnants of Pliocene (XIV-XI) Dniester terraces, do gradually decrease under “stairs-like” mode. In the valley of Limnytsya river (right-bank side) and especially in the valley of Bystrytsya-Solotvynska river (left-bank side), the complex of five-six over-flood terraces is distinguished which form the distinct “stairs” towards the wide inter-river surface. In the fore-mountain part of this sub-area the individual unit is clearly defined which is separated from remaining area by Maydanske tectonic low-mountains. This is Yablunka-Slyvkinska latitudinal valley which is being compared with “Loeva
where the sliding processes are being developed. Essential cutting by numerous streams, gullies and ravines is characteristic for Krasnyanska part of Prylukvynska height. The planar erosion is extensively developed over the slopes while the sliding processes are abundant over the right slope of Berezhnytsya stream.

Galitsko-Ugrynivs’kyi sub-area occupies the north-eastern part of Prylukvynska height. It is located in the External zone of Fore-Carpathian Trough and the margin of Eastern-European Platform. The Upper Badenian and Lower Sarmatian clayey sediments constitute the socles of Quaternary terraces which surfaces do from the smoothed watershed sites and stair-like benches in their slopes. Prevailing altitudes of smoothed inter-river sites vary in the range 300-450 m. The relative heights are also notably decreased – up to 50-100 m. In the valleys of Limnytsya, Lukva and Bystrytsya rivers the relatively narrow bands are occupied by the surfaces of low (I–III) terraces. Along the left-bank side of Bystrytsya river the ledges and flats of fourth, fifth and sixth terrace fragments are observed. The clayey sediments, which blanket the inter-river area, had facilitated its development of slide processes over their slopes.

The area of Vovnylivs’ka height occupies the territory between Syvka and Limnytsya rivers. In the north the height is bounded by the Dniester River valley, in the south and south-west – by Kaluska lowland, in the east by the Limnytsya river valley separates it from Prylukvynska height, and in the south-west the Syvka river valley – from Zaliska height. Morphological and morpho-structure relief features of Vovnylivs’ka height are similar to those of Prylukvynska and Zaliska heights. The most elevated portion of the inter-river area is occupied by the denudation-accumulative surfaces formed by Pliocene terraces. Their relative heights attain 90-110 m. On approach to Dniester River, the territory cutting increases and the weak preservation of smoothed sites in tenth and ninth terraces is notable. The planar erosion processes and gully formation are extensively developed over the slopes, and in the right-bank side of Syvka river and left-bank side of Limnytsya river – the sliding processes.

The area of Zaliska height occupies the territory between Svicha-Chechva and Svicha-Bolokhivka-Syvka rivers. In the north-west the height is bounded by the Svicha river valley, in the south-east – by Chechva and Syvka river valleys as well as Bolokhivka branch of the latter. Prevailing inter-river sites are occupied by denudation-accumulative surfaces of Pliocene terraces which are cut by the dense branching network of minor streams, gullies and ravines. The Bolokhivka valley is sharply expanded at the boundary of Internal and External zones of Fore-Carpathian Trough. Expanded Bolokhivka portion splits Zaliska height in almost latitudinal direction into two sub-areas: Sviche-Chechvynskyi and Sviche-Syvkynskyi.

Sviche-Chechvynskyi sub-area occupies adjacent to Carpathians portion of the height and in tectonic respect it coincides with nappe-fold internal zone of Fore-Carpathian Trough. The maximum altitudes and relative heights are concentrated close to the mountains. The remnant occurrence of the highest for this sub-area denudation-accumulative surface which corresponds to “Loeva surface” (Zalissya mountain, 485 m) is characteristic for the height. This surface relative height is about 130 m. The most part of watershed surface is occupied over there by the remnants of Pliocene and Eo-Pleistocene Dniester terraces whose relative heights vary in the range 80-115 m gradually descending towards the Svicha, Chechva and Syvka river valleys. The ancient terrace slopes are cut by numerous gullies, ravines and minor-stream valleys. The north-western slopes of denudation-accumulative surface do gradually transform into the terraced right-bank part of Svicha river valley, where in the area between Svicha and Turyanka rivers, by relative heights of smoothed surfaces with alluvium remnants, eight over-flood terraces are counted. From its upper course, the Turyanka river valley is trough-like, fairly asymmetric with the complex of low terraces over the left slope. Along the lower portion of relatively steep right slope, over its entire length, the sliding processes are observed.

Sviche-Syvkynskyi sub-area is located between Svicha, Dniester, Syvka and Bolokhivka river valleys. In tectonic respect it corresponds to the part of External zone of the Trough and the margin of Eastern-European Platform. The maximum altitudes do not exceed 360-400 m. Decreasing of relative heights from the mountains to Dniester is observed gradually. Relative heights attain 100 m over there. The smoothed sites of inter-river area are occupied by denudation-accumulative surface of mainly Upper Pliocene – Eo-Pleistocene (tenth) terrace. In the valleys of Svicha, Dniester, Syvka rivers the low terraces – first and second predominate in the terrace complex. The fore-Dniester portion of Sviche-Syvkynskyi inter-river site is extensively cut by the valleys of minor streams. Considerable slope space facilitates development of planar removal and linear erosion processes. Activation of modern processes is observed over the valley slopes (Dniester right-bank side, Syvka left-bank side) where the sliding processes are being developed.

The area of Bystrytska (Stanislavska) lowland. It encompasses the portions of Bystrytsya-Solotvynska and Bystrytsya-Nadvirynska river valleys from their upper courses in the mountains up to the Dniester River valley. The area western boundary follows Bystrytsya-Solotvynska river, and eastern one – Vorona and Obroshyna rivers. The lowland is located at the lowest hypsometry level of Prygoranske Fore-Carpathians. Prevailing altitudes vary in the range of 250-300 m. Significant part of the lowland relief is formed by the flood-land and the complex of over-flood terraces of both Bystrytsya rivers. Geomorphologic profile of the inter-river...
area of these water flows in Ivano-Frankivsk city is conducted by Yu.Veklych [68]. After his observations, the inter-river area, where the city is located, comprises the series of wide terraces with prominent ledges extended along the rivers. The watershed portions of these terraces are common for both rivers. In the city this author has distinguished nine over-flood terraces. Terrace heights one over another (ledge heights) vary from 2.5 to 9.0 m. In opinion of other authors [27], the first three over-flood terraces only are distinguished in Ivano-Frankivsk area.

The area of Kaluska lowland. The relief of Kaluska lowland was formed under activities of Limnytsya, Chechva, Bolokhivka and Syvka rivers. Morphologic features of some sites in the area allow two sub-areas distinguishing: Rozhnyatysiyskiy and Bolokhivskiyy.

Rozhnyatysiyskiy sub-area is located in the expanded portion of Limnytsya and Chechva river, lower down of their exit from Carpathians. In tectonic respect it is confined to the back part of Sambirskiy thrust composed of clayey sequence. Prevailing territory of the sub-area is occupied by the flood-land and first over-flood terrace (2.5-3.5 m). The remnants of II, III and IV over-flood terraces are also observed. The Limnytsya river course is cut into the thick (more than 10 m) alluvium pile. The ideally-flat surface of the flood-land and I over-flood terrace is complicated by numerous arms of Limnytsya and Chechva rivers as well as former river bed dimples. In many places the surface is swamped and peated.

Bolokhivskiyy sub-area is located in the territory between Syvka and Bolokhivka rivers. It is confined to the External (Bilche-Volysksa) zone of the Trough. The most part of sub-area is occupied by the surfaces of I-III over-flood terraces in which formation these rivers had contributed to. Terrace surface is ideally flat and cut by deep streams Kropyvnyk, Sapigiv, Fronyliv and their branches. The south-western boundary of sub-area is set by the conventional border of IV over-flood terrace. Alluvium of these terraces is overlain by aeolian-deluvial loamy blanket of Buzkiy and Prychornomorskiy climatoliths.

Verkhnodnisterskiy area. The main part of this area is located outside the map sheet M-35-XXV. The area is subdivided in two sub-areas. One of these – Striysko-Zhydachivska lowland – encompasses the north-western part of the map sheet, between Striy-Dniester-Svicha rivers, which provide the sub-area boundaries. By drilling data [77, 83], in the sub-area, at the bottom of Quaternary sediments, alluvial gravel-pebble sediments are observed, allowing this territory ascription to the terrace relief. Continuous range of Dniester wide terraces is distinguished. The ideally-flat surface of the flood-land and first over-flood terrace (2.5-3.5 m). The remnants of II, III and IV over-flood terraces are also observed. The Limnytsya river course is cut into the thick (more than 10 m) alluvium pile. The ideally-flat surface of the flood-land and I over-flood terrace is complicated by numerous arms of Limnytsya and Chechva rivers as well as former river bed dimples. In many places the surface is swamped and peated.

Podilska morpho-structure

The area of Opilska height. In the explanatory notes to the State geological map of the map sheet M-35-XIX (Liviv) [15], the notes’ authors had named the northern part of this area as Peremyshlyansko-Berezhanske Opillya. However, in the order of priority, the authors retain the area name after the scheme of V.P.Palienko (1992).

In tectonic respect the area is located at the margin of Eastern-European Platform. The south-western area boundary follows Dniester River whose valley in the map sheet territory includes alternating straight-line and meander sections. Dniester River bed inclination over there is 0.5-2.5%, meanders are of medium radius. The valley cross-profile is notably trough-like, asymmetric, 0.5-4.0 km wide, erosion depth is from 100 to 130 m. The slopes are terraced. The wide band of the first over-flood terrace is extended along the bottom of flat left slope. Close to the mouth of Gnyla Lypa river, in the Dniester left bank, the complex of low (I-IV) terraces is observed which apparently are common with Gnyla Lypa terraces. More older Dniester terraces in the Podilskie left-bank side are lacking in the map sheet territory. The high Dniester right bank from the mouth of Svicha river up to the eastern map sheet boundary is constituted of the relics of its Eo-Pleistocene terraces.

The almost total absence of the bed relief comprises the general feature of Opilska sculpture height. Gnyla Lypa river clearly splits the area into the western and eastern parts with notable difference in the relief (fourth-order morpho-structures). In the western part some sites are also defined which differ in morphology (higher fifth-order morpho-structures). In the western part, in the area between Dniester and Svirzh rivers, from Molodynche village to Bukachivtsi village, the trough-like valley is well-expressed in the relief. Its width is 3.5-4 km, both slopes are very gentle-dipping, flat bottom with altitudes 245-250 m is swamped and peated, and is cut by the network of artificial irrigation channels. The watershed with Svirzh river valley is very flat and is
covered by the blanket of Dniprovs'kyi climatolith loams; transition from the bottom to watershed is invisible. L.S.Gerasimov [77] defines this morpho-structure under the name “Molodyntys'ka dimple” and assumes its formation is related to the tectonic factors only (graben). In the authors’ opinion, formation of this morpho-structure is most likely related to the pre-Miocene cut (Molodyntys'ka paleo-valley) filled with the quite favourable for erosion sequence of Neogene Kosivska Suite clays. In spatial respect, this morpho-structure in the plane coincides with the paleo-valley contours traced by the drilling data. The slow planar erosion is developed in the flat slopes of this morpho-structure.

In the area between Zhuravno-Navoshyn-Kozari villages the relief type is changed abruptly and by its features it is more similar to the Dniester River right-bank side. In the plane this section does from the individual massif. The deep ravines with steep, in places cliffy slopes, cut this massif providing the watershed ridge extended along the Dniester River bed from Navoshyn village to Zhuravenki village, as well as some small-scale flat-top massifs comprising typical erosion remnants (Greda mountain, 336.6 m, Kozara mountain, 336.4 m). In the cliffy slope of the watershed ridge adjoining the Dniester first over-flood terrace Cretaceous Zhuravnenska Suite sandstones are exposed. The steep Dniester slopes over 300-500 m are cut by deep (up to 10 m) narrow grooves filled with mud-flow gruss material and loams typical for Buzkiy climatolith.

The massif watershed portion is composed of Neogene Tyraska Suite gypsum-anhydrites overlain by thin cover of Kosivska Suite clays and Eo-Pleistocene and Lower Neo-Pleistocene loams. This facilitated karst forming processes at the surface mainly in the small karst funnels up to 2-4 m deep. In the gully upper courses some gypsum outcrops do form up to 10 m high cliffs on the slopes. The linear erosion processes are mainly developed in this massif.

The Gnyla Lypa valley is trough-like, clearly asymmetric. The width of its flat swamped bottom (flood-land) attains 2.5 km. The first over-flood accumulative terrace is extended with the wide band along the right slope. Transition of its back part into very gentle slope is overlain by Upper Pleistocene loams and is almost invisible. Close to Burshtyn village the water reservoir is built up over the river. In the river mouth portion its first over-flood terrace joins the same terrace of Dniester River which at this site has also developed common with Gnyla Lypa II-III-IV over-flood terraces with the surface smoothed by the blanket of Buzki loams. The Upper Cretaceous marls are exposed along the steep left non-terraced slope.

The area between Gnyla Lypa and Svirzh rivers comprises the hilly plain slightly cut by gullies with gentle slopes and flat swamped bottoms. Maximum heights of inter-river area are up to 326 m (Lysa mountain) and relief range attains 70-80 m. Some heights comprise erosion remnants.

The eastern part of Opilska height in the studied area by its relief features can be ascribed to the fourth-order morpho-structures. The rivers Uizdski Potik, Naraivka, Bebelka, Gorozhanka have cut this height part into individual ridges extended in the direction of these water flows. In turn, direction of the latter is controlled by the zones of enhanced fracturing in Upper Cretaceous sediments which are intersected by the rivers. Their numerous branches, whose direction is caused by the north-west-trending zones of enhanced fracturing, together with major water flows have created over there the well-expressed branch-lattice type of hydro-network. The major water flow valleys are trough-like with wide (up to 300 m) flat peated bottoms. Over both banks the first over-flood terrace is developed, in places small-scale II and III over-flood accumulative terraces are observed. The slope lower parts adjoining the terraces are overlain by the blanket of Buzki loams and cut by gullies with steep banks. The cross-profiles of deep gullies are triangular with steep strew slopes. Fore-watershed part of the slopes is more flat. The planar erosion predominates over there while linear erosion is less developed cutting deluvial sediments and continuously expanding the gully length; some hills over-inter-river ridges comprise the typical erosion remnants. These are dome-shaped, in places plateau-like with smoothed contours. Their heights decrease from 405 m nearby the northern map sheet border (Lodzhivdinka mountain) to 320-340 m close to Dniester River valley. Significant squares are occupied by the inter-river areas whose watershed parts are composed of gypsum overlain by thin cover of clays and loams. The extensive karst is being developed over there.

The area of Prydnisterska height is located in the right-bank side of Dniester River where it encompasses the watershed areas of Dniester, Bystrytsya and Vorona rivers. The northern part of the area coincides with the platform margin and the southern part – with External zone of the Trough. The northern part by its morphology does not actually differ from the previous area. However, in contrast to the left-bank side, the smoothed watersheds superimpose there comprise the relicts of Eo-Pleistocene and Early Pleistocene Dniester terraces. The steep, cliffy slopes of these terraces plunge down towards either the first over-flood terrace or the river bed. The deep gullies cut this part of the area into some hills and massifs with maximum heights 368-349 m. In the sites of Neogene Tyraska Suite gypsums the karst processes are being developed (Mylovannya, Uzyn villages). The valleys of all minor water flows in their lower courses cut Upper Cretaceous limestones. Over there, these are canyon-like with cliffy banks and stair-like latitudinal profile. In the upper courses, cutting the clayey sediments of Neogene Kosivska Suite, the valleys of these water flows are being sharply expanded and become trough-like.
While their flat bottoms are mainly peated. Tlumach river, cutting Upper Cretaceous limestones, had prepared well-formed asymmetric valley with wide flat bottom, terraced left slope and cliffy right bank. The smoothed surfaces over its right watershed (Skala mountain, 338.4 m) comprise erosion remnants. Away from Dnister River valley to the south the relief is gradually changed and gets hilly-gully appearance. Some hills with smoothed surfaces and heights about 360-320 m comprise erosion remnants. Their gentle slopes are complicated by slides and mud-flows. The most extensive slide development is observed along the steep right bank of Vorona river to the north from Otyniya village. In the right-bank side of Vorona river close to Otyniya village the relief is very similar to the relief in the eastern part of the previous area. The valleys of minor water flows are trough-like over there with wide peated bottoms. Spatially the valleys of these water flows are located in the limits of the buried paleo-valley (Kolomiyska) filled with Neogene Kosivska Suite clays. The smoothed surfaces with heights 320-340 m in this area also comprise erosion remnants. Among the modern erosions processes the planar erosion predominates.

History of modern relief formation, latest geodynamics and exogenic processes

The Late Miocene tectonic collision completed with formation of tectonic thrusts in their almost modern position, do quickly elevate the bottom of Early Sarmatian sea and the latter goes back to the south-east. The continental regime is established in association with active denudation-accumulative processes on the background of permanent cyclic territory uplift. In general, in Late Cenozoic time the territory underwent positive tectonic motions of low intensity. Development of Late Cenozoic landscapes in the territory is reflected in sixteen over-flood terrace levels with gravel-pebble alluvium type and in 32 stratons of sub-aerial sediments (see legend to the map of Quaternary sediments in the scale 1:200 000). Beginning of the relief formation over the territory apparently took place in Late Sarmatian time. By this period Carpathians have been almost completely the peneplain with predomination of north-west-trending hydro-system. The major water flow in the fore-mountains has been Dnister flowed close to the Carpathian margin. Over the Pontian and Early Pliocene times Dnister together with its right branches, coming from Carpathians, has formed the oldest denudation-accumulative level (“Krasnoi level”). Over the Late Pliocene, due to pulsating uplift of Carpathians and adjacent territory, essential Carpathian relief cutting is developed which was accompanied by Carpathian hydro-network re-direction to the north-eastern one. It is evidenced by the relics of major Carpathian water flow valleys outside the studied map sheet (pra-San, pra-Tysa) which were apparently captured in Beregovskiy stage. Over that time Dnister continuously escaped from Carpathian margin remaining behind the complex of wide, oriented in parallel to the mountains, Pliocene terraces, starting from fifteenth (“Loevoi level”) up to eleventh. On the background of the plain alluvial Dnister terraces erosion had cut the core of Maydanska anticline structure providing the low-mountain massif. Perhaps, starting from Early Neo-Pleistocene time sub-aerial blanket deposition has commenced. Terrace surfaces have been gradually, at the periodic climate change from subtropical to pre-glacial, covered either by the soils or loess. Back-terrace left-bank placor areas of Dnister have been continuously cut by its left branches (Gnya Lypa, Naraivka). As a result, the individual plateaus were formed separated by mentioned water flows and oriented in the same direction.

At the beginning of Pleistocene tectonic “moment” had occurred over entire Fore-Carpathian region which separated Late Cenozoic tectonic stage in two sub-stages. It is expressed in the terrace relief. For instance, the Dnister right-bank terrace relief is clearly enough divided by morphologic features into the terrace complex of wide Pliocene terraces with notable relative heights, extended along Carpathians, and the complex of narrow Quaternary terraces steeply plunging down towards the modern river bed. By the beginning of Eo-Pleistocene the Dnister River bed did actually occupy the present position. Further on, over Eo-Pleistocene and Neo-Pleistocene, tectonic regime of the territory stands by in permanent cyclic changes of opposite tectonic phases with various magnitudes reflected in the level and composition of Quaternary terraces. The large Dnister right branches (both Bystrytsya rivers, Limnytsya, Chechva, Svicha) have expanded their basins, cutting the Pliocene terraces and forming the own terrace complex. The younger hydro-system (Lukva, Lukvytsya, Berezhnytsya, Bolokhivka and other rivers) of apparently Late Pleistocene time does cut the Pliocene Dnister terraces. By these reasons the ancient terrace relief of Dnister and its large right branches is rejuvenated by the relief of small rivers and streams up to the gully terrace relief.

In the area of back-terrace Dnister left-bank side the permanent expansion of major water flow basins occurred over Quaternary time. The numerous minor flows, gullies and ravines cut the plateau-like inter-river areas modifying them into the hilly ridges and individual hills, whose slopes and watersheds are overlain by eluvial and aeolian-deluvial sediments.

The magnitude of the latest neo-tectonic discontinuous motions can be thought from the relative heights of denudation-accumulative surfaces of Krasna and Loeva rivers and the river terraces. Analysis of these values indicates that over Quaternary time up to Holocene the continuous ceasing of the fluctuating motions had
occurred. Intensity of neo-tectonic motions was variable over studied area. The area between Limnytsya and Bystrytsya-Solotvynska rivers was elevating most extensively over that time. In Bystrytsya, Kaluska, Striysko-Zhytdachivska lowlands the low-magnitude uplifts occurred on the background of permanent subsidence. The hydro-graphic network of the area similar to the modern one was completely formed over Neo-Pleistocene.

In the beginning of Holocene in the map sheet area, likewise entire region, the general irregular uplifts were restored. It is evidenced by river cuts into the hard rocks and alluvial sediments of previous stages, by extensive erosion of the slope lower parts, and by the local deformations of the first and second over-flood terraces latitudinal profile. The value of these uplifts is 3 m in average.

The deformation of second over-flood terrace in the Bystrytsya-Solotvynska valley nearby Rakovets village, in the extension of Maydanska fold, has been encountered by D.Stadnytskiy in 1964. In the left river bank the terrace has high hard-rock socle and is elevated by 2-3 m above the medium level of this terrace in the area. The river bed is deviated here to the right and undermines the right bank. In the latitudinal profiles of Bystrytsya-Solotvynska and Limnytsya the deformations as the bends are observed in Sambirskiy thrust in the frontal portions of large nappes close to Zhuraky and Berlogy villages. The numerous evidences supporting increasing of tectonic activity in Holocene are found by the authors during field works both in the map sheet area and in adjacent territories [65, 67].

Concerning the magnitude of the modern area uplift the authors do not have common opinion. Various published sources provide different values ranging from 0.2 mm/year to 10.8 mm/year (I.D.Gofshtein, 1970, 1979; G.I.Rudko, 1996). V.I.Somov [19, 45], based on the repeated triangulation observations argues that Carpathian orogenic morpho-structures uplift speed exceeds by 1-2 mm/year the uplift speed in Fore-Carpathian Trough and in Podillya where it attains 0.5 mm/year. Horizontal displacement speed of Skybovi Carpathians (thrusting over Fore-Carpathian Trough), after V.Somov, is 2-3 cm/year while the latitudinal displacement of Boryslavsko-Pokutska zone relative to adjacent Sambirsk and Bilche-Volyska zones in the north-western direction is going on at the speed 0.9±0.2 cm/year.

The active positive geodynamics of entire region over Late Cenozoic time has ensured enormous potential of the relief gravity energy reserve resulted in active continuation of all relief-forming processes nowadays. Taking into account the mechanism and dynamics of exogenic processes the following types are distinguished: erosion, slides, mud-flows and karst. Their brief description is given in the section “Geological-ecological situation”.

Technogenic landscape complex, mainly in the fore-mountains, includes urban agglomerations with diverse industry enterprises. These are water reservoirs (Burshtynske, Rozhnivatske), quarries, large quarry dumps (Kaluskiy, Podorozhnenskiy), dams, ponds, irrigation channels, mounds.

In the map sheet area nine geological objects are accounted which deserve the status of geological landmarks and it is suggested to include these objects into the handbook to be published soon. These are mainly rock outcrops (sections) which are valuable for the area stratigraphy. Location of geological landmarks is shown in the geomorphologic scheme and their brief description is given in the Annex 3.

Besides the geological landmarks, the Late Paleo-Lithic archeological findings are also known in the map sheet territory (Marynopol, Gyanusivka, Vodnyky, Vovchkiv) [1, 23], as well as two settlements studied by the method of stationery excavations (Mezhigiritsi, Galych-I). Archeological studies of these landmarks continue over almost entire century. New Late Paleo-Lithic settlement Galych-I is discovered in 80th of XX century. It is of high importance since this is one of few stratified settlements with abundant fauna material and large collection of rock household equipment items [38]. The landmarks of Early Neo-Lithic culture of linear-banding ceramics are encountered at Bovshiv, Bukivna, Goloskiv villages. In the later times out predecessors have migrated further down by the Dnister River valley and the remnants of Neo-Lithic and younger cultures are not known in the map sheet area. Location of archeological landmarks is shown in the geomorphologic scheme. Their brief description is given in the Annex 4.
6. HYDROGEOLOGY

According to the zonation of Ukraine by the forming conditions of underground waters [127], the map sheet M-35-XXV (Ivano-Frankivsk) encompasses three hydrogeological regions (Fig. 6.1): Carpathian hydrogeological folded region (B), Fore-Carpathian (C) and Volyno-Podilskiy (D) artesian basins.

Carpathian hydrogeological folded region (B) includes the south-western part of the territory which is occupied by structures of Skyboviy thrust with mountain relief.

In Fore-Carpathian artesian basin (C) two hydrogeological areas are distinguished: Internal (C.1) which encompasses allochthonous Boryslavsko-Pokutskiy and Sambirskiy thrusts, and External (C.2) which spatially coincides with autochthonous Biclhe-Volytska litho-tectonic zone of the Trough. In Volyno-Podilskiy artesian basin (D) some hydrogeological areas are distinguished. Two of these – Podilskiy (D.1) and Prut-Dnisterskiy (D.2) encompass the north-eastern and eastern map sheet portions which is tectonic respect correspond to the margin of Eastern-European Platform (Fig. 6.1). The complex geology over the territory has caused wide diversity of hydrogeological conditions. Of these, not all are equal and by the ability to be used the same water-bearing horizons in various places exhibit diverse water content, mineralization and depth of underground waters. Hydrogeological features of the studied area are tightly related to the geology in Carpathian hydrogeological folded region and Fore-Carpathian and Volyno-Podilskiy artesian basins. The depth and thickness of certain water-bearing horizons and complexes over shorter distances do vary from first tens to hundreds of meters. This is why in the description of water-bearing horizons and complexes related to pre-Quaternary units, the authors do not provide respective information. The data contained in the explanatory notes and in the report on EGSF-200 of “Schematic hydrogeological map in the scale 1:500 000” are not sufficient for the targeted prospecting for underground waters. These works require geological data in the scale 1:50 000 – 1:25 000. In the map sheet M-35-XXV only those water-bearing horizons and complexes briefly described below are of practical value for water supplying.

1. Water-bearing horizon in Holocene swamp and lake-swamp sediments (bH). The water-containing rocks include Holocene peat, mud, muddy sands, and sandy loams. Ground water depth varies from 0.5 to 1.5 m. By chemical composition the waters are sulphate-hydrocarbonate sodium-calcium with mineralization 0.2-1 g/dm³. Hardness is 1-5 mg-equiv./dm³, pH – 7.1-8.0. Filtration coefficient is 0.5-4.7 m/day.

2. Water-bearing horizon in Holocene alluvial sediments of river flood-lands and gully bottoms (aH) is confined to pebble-stones, diverse-grained sands, sandy loams and loams of Dnister River flood-land and its branches in Podilska height and in Fore-Carpathians, in lesser extent – in Carpathians over all hydrogeological areas. It lies over age-different watered water-bearing rocks. Between this water-bearing horizon and underlaying horizons the direct hydraulic link often exists. The depth of underground waters varies from 0.5 to 3.6 m. Depending on lithology of water-bearing rocks which varies from clayey to coarse-clastic rocks the water content of these sediments is variable throughout. The yield of certain water points in the flood-lands of major water flows varies from 2.8 to 19.5 dm³/s at the depression to 1.5-4.46 m; specific yields are from 1.79 to 9.94 dm³/s. In the flood-lands of minor water flows these figures are lower. Particularly, the well yields vary in the range 1.5-5.0 dm³/s, specific yields – 0.15-1.0 dm³/s. Filtration coefficients in the Dnister left-bank side vary from 37 to 200 m/day, in the right-bank side these parameters are somewhat less – from 10 to 100 m/day. The waters are fresh (dry residue from 0.3 to 0.7 g/dm³), hydrocarbonate, often hydrocarbonate-sulphate, hydrocarbonate-chloride, in places three-component. Among the cations calcium predominates but almost throughout sodium and somewhere magnesium also occurs. The underground waters of flood-land alluvial sediments are being widely used by local inhabitants for individual water supplying. Four water scoops for centralized water supplying are explored (of these two are in exploitation) but in view of natural unprotected mode of this water-bearing horizon it is reasonable to control periodically the chemical and bacteriological water state.

3. Water-bearing complex in alluvial sediments of the first and second Upper Pleistocene over-flood terraces (a1-2PⅢ) is developed in the valleys of major water flows. This is the water-richest complex. The water-containing rocks – pebble-stones with sandy and sandy-clayey filler, diverse-grained sands with loam lenses and interbeds, are underlain by the age-different and variously-composed pre-Quaternary sediments. The rocks are overlain by Upper Neo-Pleistocene sub-aerial sediments. The hanging-wall is intersected at the depth from 0.5 to 12.5 m. Thickness of pebble-stones varies from 2.8-3.3 to 10-16 m. The waters are slightly-pressurized due to occurrence of heavy and dense loams at the top. Pressure value varies from 0.2 to 3.1 m. Well yields and filtration coefficients vary from 1.2 to 28.0 dm³/s and from 3.4 to 300 m/day respectively (Cherniivske deposit of
Specific yields are 0.5-3.5 dm\(^3\)/s at the depression by 1.2-7.0 m. The major feeding source of water-bearing complex is filtration of atmospheric precipitates.

Fig. 6.1. Schematic hydrogeological map.

Fig. 6.1. Continued.

2. Hydrogeological subdivisions:


2.2. Water-bearing horizons and complexes distribution boundaries occurring below the first ones from the surface: 15 – water-bearing complex in Dashavska Suite sediments; 16 – water-bearing complex in Kosivska Suite sediments; 17 – water-bearing complex in Lower Miocene sediments; 18 – boundaries of artesian basins and hydrogeological region (a), and hydrogeological areas (b).

2.3. Faults:

19 – tectonic sutures which are buried beneath overlying sediments and which do separate litho-tectonic zones; 20 – possible faults buried beneath overlying sediments: a – major, b – minor.

Chemical composition is fairly variable. In the Dniester left-bank side hydrocarbonate calcium and hydrocarbonate-sulphate calcium-magnesium waters predominate. In the basin of Svicha and Bystrytsya rivers where the waters of alluvial sediments are linked with evaporitic sequence sulphate calcium and sulphate sodium waters with high hardness are developed. In Fore-Carpathians, in places where the salt-bearing sediments occur directly below the pebble-stones, the water type is changed to hydrocarbonate-chloride calcium and chloride calcium and sodium, mineralization is higher (0.9-1.8 g/dm³).

Occurrence of dense loams with low filtration properties above the water-bearing pebble-stones protects the ground waters, and in places where these loams are lacking, the danger for their contamination exists. The waters are most suitable for centralized water supplying and can be recommended for expansion of the operating water scoops (Chernivskiy, Bogorodchanskiy) and development of new ones.

4. Water-bearing complex in alluvial sediments of third-ninth undivided Lower-Middle Pleistocene and Eo-Pleistocene over-flood terraces (a3-P3ul+E) is developed in the areas between Berezhnytsya and Sukelya rivers and Svicha-Syvka-Limnytsya and Lukva-Bystrytsya-Solotvynska rivers. It is confined to the sandy-pebble sediments of ancient terrace complex of these water flows. The thick (2.6-11.0 m, mainly 4-9 m) water-bearing alluvium is overlain by also thick (up to 5-7 m) cover of sub-aerial loams. Laying above the age-different rocks, from Cretaceous to Miocene, this complex is hydraulically connected with the waters of these horizons. The surface depth is 4-15 m. The waters are non-pressurized and slightly-pressurized; belong to the bed type. The water regime is not consistent. The water-point yields vary from 0.2 to 4.8 dm³/s, the values of 0.5-1.25 dm³/s predominate at the depression 0.8-10 m. The waters are fresh but mineralized ones are also known. The dry residue content varies from 0.2 to 1.0 g/dm³. By anionic composition the waters are hydrocarbonate-chloride, hydrocarbonate-sulphate, and chloride-hydrocarbonate. Cationic composition is also variable: calcium waters predominate and calcium-magnesium and calcium-sodium waters are widespread. Occurrence of nitrate ion NO₃ in the waters of some water points suggests for their contamination. By water quality and low rate the horizon is suitable for the minor individual water supplying only.

5. Water-bearing complex in Pliocene alluvial and eluvial-aelolian-deluvial sediments (a.evN2) is developed in the flat watersheds of Dnister right-bank side. It is confined to the cobble-pebble sediments with sandy-loamy filler of the ancient (XI-XVI) terrace complex of pra-Dniester overlain by diverse-thick (2-6 m)
cover of sub-aerial loams. The watered alluvium 6-11 m thick lies mainly over sandy-clayey rocks of Lower Miocene molassa. The horizon is slightly-pressurized, and in the slope-side portion – non-pressurized. Static levels are from 4 to 14 m. Well yields vary from 0.1 to 0.6 dm$^3$/s at the depression by 0.5-2.6 m. The waters are hydrocarbonate sodium-chloride, chloro-hydrocarbonate sodium-chloride, in places sulphate-hydrocarbonate sodium-calcium, mineralization is 0.15-0.5 g/dm$^3$. The waters are being used for the household supplying.

6. Water-bearing complex in Lower Sarmatian Dashavska Suite sediments (N1,ds). It is mainly developed in the External area of Fore-Carpathan artesian basin where it is confined to the thick lens-like layers of sands and weakly-cemented sandstones in the sandy-clayey sequence of this Suite. The waters belong to the bed and fracture types. Thickness of water-bearing interbeds varies from some centimeters to 8-14 m. The waters are pressurized, static levels are at the depth 60-155 m, pressure height is 657-713 m. Feeding is provided through infiltration of atmospheric precipitates. Borehole yields are 0.2-0.3 dm$^3$/s. Dry residuum content varies from 1.1 to 61 g/dm$^3$. The waters are chloride sodium-calcium, water mineralization increases with depth. The low borehole yields, low water quality in Lower Sarmatian sediments and their significant mineralization make impossible their use for water supplying.

7. Water-bearing complex in Upper Badenian Kosivska Suite sediments (N1,ks) is widely developed in the External area of Fore-Carpathan artesian basin. It is confined to the lens-like diverse-thick layers of weakly-cemented sandstones in the clayey sequence of Kosivska Suite. They have tight hydraulic connection with underlaying age-different water-bearing complexes. The waters are pressurized, pressure height is from 10 to 240 m. Piezometric levels are at the depth from +2.3 m above borehole head to 145-152 m below the surface. Borehole yields are 0.4-0.9 dm$^3$/s. Filtration coefficient is 1.65-10 m/day. The waters are hydrocarbonate sodium, chloride magnesium-sodium and chloride sodium, iodine and bromine micro-element content significantly exceeds the norm (iodine 10-100 mg/dm$^3$, bromine 50-130 mg/dm$^3$). Dry residuum content is 46-193 g/dm$^3$ and mineralization increases with depth. The waters are of limited practical value for water supplying.

8. Water-bearing complex in sediments of Upper-Lower Badenian Tyraska and Opilska suites (N1,br+op) is developed in Podilski hydrogeological area, where it lies beneath Quaternary sediments, and in Fore-Carpathan artesian basin, where it is intersected at various depths beneath Upper Badenian sediments. The complex is confined to gypsums and gypsum-anhydrites of Tyraska Suite and sands, sandstones and limestones of Opilska Suite. Thickness of water-bearing rocks is 0.5-5.5 m. The tight hydraulic connection exists between the complexes and horizons which underlie and overlie this water-bearing complex. Its hanging-wall in Podilsky area is intersected at the depth 13.45-83.6 m (mainly 10-30 m), and in Fore-Carpathan artesian basin it is subsided to 150-300 m. The waters are pressurized, the pressure value varies from 13.45 to 80.0 m, and in Fore-Carpatians it exceeds hundreds of meters. The waters belong to the bed and fracture or fracture-karst types. Gypsum water-bearing is related to the karst processes. These are expressed in places where these rocks lie directly below water-permeable Quaternary sediments. Borehole yields vary from 0.19 to 5.0 dm$^3$/s at the depression by 3.0-15.8 m. By chemical composition the waters confined to Opilska Suite limestones and sandstones are mainly fresh, hydrocarbonate calcium, somewhere hydrocarbonate calcium-magnesium. The waters in Tyraska Suite gypsum-anhydrites are sulphate calcium, sulphate-hydrocarbonate calcium-magnesium, in places sulfur-hydrogen; total mineralization is from 2.5 to 4 g/dm$^3$, total hardness – 10.7-14.3 mg-equiv./dm$^3$. In the Dnister left-bank side the waters of this complex are being used for the household needs. In Fore-Carpathians these waters are sulphate calcium, enriched in sulfur hydrogen, slightly-salty, with increased mineralization, not suitable for drinking and are only interesting as possible mineral (medical) waters.

9. Water-bearing complex in sediments of Lower Miocene Balytska, Stebnytska and Vorotyshchenska suites (N1,bl+vr) is developed in the internal area of Fore-Carpathan artesian basin. Water-bearing sandy-clayey molasss includes Balytska, Stebnytska and Vorotyshchenska suites. Thick lens-like salt interbeds often occur in the sequence of these rocks. The salt and salt-bearing rocks of Vorotyshchenska and Balytska suites are water-permeable and comprise the water-proof for brines which are being accumulated at the surface of salt-bearing sediments. The brines are being formed through salt leaching from salt-bearing sediments by fresh waters of Quaternary sediments. The brine horizon is discontinuous. The brines are observed also in non-salt-bearing rocks of Vorotyshchenska Suite. The water depth is 21-450 m and thickness of water-containing rocks varies from 0.5 to 5.2 m. The waters are pressurized, the pressure height attains 11.2-26.0 m and more. Water-point yields are of hundredth and thousandth percents of cubic decimeters per second. The waters are highly mineralized, the dry residuum content is 57-330 g/dm$^3$. Chloride sodium and sulphate waters predominate. Increased content of K$^+$ and Mg$^{++}$ indicates occurrence of potassium rocks and comprises prospecting criteria for potassium salts. The brines of pure chloride sodium composition are of practical value as the raw material for rock salt manufacturing.

10. Water-bearing complex in sediments of Lower Miocene – Oligocene Polyanytska and Menilitova suites (P1-N1,pl+ml). In the Internal area of Fore-Carpathan artesian basin this complex is intersected in the deep anticline structures. In the Folded Carpathians it lies beneath thin cover of Quaternary sediments. At the depth it
is confined to the thick batches of coarse-grained sandstones and at the surface – to the zone of sub-surface fracturing which is traced to the depth of 50-60 m. The spring yields are 0.01-0.1 dm³/s. Thickness of water-bearing layers is 7-94 m. In Fore-Carpathians the depth of this complex varies from 182.6 m (Obolonya village) to 2664 m (Obolonya village). The waters are pressurized, often self-outflow pressure height attains some hundreds of meters. Water mineralization varies from 0.1 to 150.0 g/dm³. In the fractured zone the hydrocarbonate-chloride-sulphate calcium and hydrocarbonate sodium waters are developed (dry residuum is 0.18-0.53 g/dm³). In the zone of deep folds in Boryslavsko-Polutskii thrust chloride sodium brines are characteristic (mineralization is 97 g/dm³). Waters of this complex are not suitable for water-supplying. The site at Dzvynych village is of some interest where the deep waters exhibit very high for Fore-Carpathians yields (up to 2.2 dm³/s) and increased iodine (36.4 mg/dm³) and bromine (802 mg/dm³) contents. These waters can be used as industrial ones.

11. Water-bearing complex in Eocene and Paleocene sediments (P₂₁). Developed in the same hydrogeological areas as the previous one. It is confined to the thick (250-300 m) sandstone piles which constitute Vygodka and Yammenska suites and comprise the major water-bearing rocks. Thickness of water-bearing near-surface highly-fractured zone is 30-50 m, in places up to 100 m. Near-surface waters are non-pressurized and spring yields are mainly 0.05-0.7 dm³/s. On plugging of water-bearing rocks the waters become of fracture-bed type with pressurized properties. In the zone of deep folds the pressure value attains 550 m (Nebyliv village). The water-bearing complex is being fed through infiltration of atmospheric precipitates. Chemical composition of the waters is fairly variable. In the upper fractured zone the waters of hydrocarbonate calcium type predominate with dry residuum 0.3-0.6 g/dm³ and total hardness 1.95-4.0 mg-equiv./dm³. These waters can be used for water supplying. In the depth interval 100-400 m the waters are fresh, in places salty, normally hydrocarbonate sodium. With depth their mineralization increases at the expense of chlorides. In the zone of deep folds chloride sodium brines occur with mineralization 38.0-74.5 g/dm³ and iodine content 2.0-2.5 mg/dm³ and bromine – up to 150 g/dm³. The waters in Eocene and Paleocene sediments are of contour and footwall water types of oil deposits.

12. Water-bearing complex in sediments of Upper Cretaceous – Paleocene Striyska Suite (K₂-P₁št). The distribution boundaries fully coincide with the boundaries of two previous water-bearing complexes. It is confined to 50-65 m thick fracturing zone within thick sequence of Striyska Suite diverse-rhythmic flysch. Near-surface fracture waters are non-pressurized while at the depth they become of fracture-bed type and pressurized. The spring yields are 0.01-0.5 dm³/s, in places 1.0 dm³/s. Borehole yields vary from 0.9 dm³/s at the depression 4.0 m to 1.4 dm³/s at the depression 33.8 m. By chemical composition the waters are hydrocarbonate calcium, hydrocarbonate calcium-sodium, hydrocarbonate-sulphate calcium-magnesium. Mineralization is from 0.05 to 0.2 g/dm³. The total hardness is 3.5-7.2 mg-equiv./dm³. At the depth these waters, like previous ones, become high-mineralized. The waters are suitable for the household needs. The tight hydraulic connection exists between these waters and water-bearing complexes of Paleocene-Oligocene flysch sediments. The bulk water content of these complexes is high enough for the centralized water supplying of the small-scale objects.

13. Water-bearing complex in Upper Cretaceous sediments (K₂) is mainly developed in Podilsksyi hydrogeological area. In the External area of Fore-Carpathian basin this horizon is intersected at various depths by numerous boreholes. The water-bearing rocks include limestones, marls and weakly-cemented sandstones of Lukvynska, Zhuravnenska, Dubovetska and Nezvyska suites. Thickness of the horizon in Podillya is 4.5-75 m, in Fore-Carpathians – 70-90 m. In both regions the tight hydraulic connection exists between this horizon, the overlying Badenian complex and underlaying Upper Jurassic complex. The hanging-wall depth of the horizon varies from 5.5 to 280 m (in Podillya – 5-75 m (mainly 15-25 m)). The waters of this horizon are mainly pressurized, the boreholes often gush forth, the pressure height in Podillya is 16-30 m, in Fore-Carpathians – 902-1155 m. The borehole yields in Podillya are from 0.3 dm³/s at the depression by 83.5 m to 3.4 dm³/s at the depression by 38.1 m. Specific yields are 0.016-2.75 dm³/s. In Fore-Carpathians the borehole yields are 6.0-7.9 dm³/s at the depression by 56-72 m, specific yields – 0.1 dm³/s. Filtration coefficients of water-bearing rocks are 0.096-10.36 m/day. Temperature of horizon water in Podillya is 12-13°C, in Fore-Carpathians – 38-48°C and they are considered to be thermal. The water composition and mineralization is also variable. In the Dnister left-bank side the waters are hydrocarbonate calcium, fresh, with dry residuum content 0.2-0.5 g/dm³ and total hardness of 4.3 mg-equiv./dm³. The waters are of household value but are also suitable for centralized water supplying. In places, where tight connection exists between the waters of this horizon and waters in Tyraska Suite sulphates, their mineralization increases up to 1.9-3.0 g/dm³, and water type is changed to sulphate calcium. In the area of External zone of Fore-Carpathian artesian basin the water mineralization is 47-135.5 g/dm³. These are actually the brines with high content of iodine (35-37 mg/dm³) and bromine (260-320 mg/dm³). In the adjacent from south-east territory the waters are enriched in sulfur hydrogen (up to 144.5 mg/dm³) and are being used in medical purposes. These high-mineralized waters, which are widely developed in Fore-
Carpathians, can be used (similarly to Brusnytske deposit in Chernivetska Oblast) as medical (analogue “Nemyrivska”) and provide the base for expansion of recreation sites in this nice region.

14. Water-bearing horizon in Upper Jurassic sediments (J₃) is developed in the same hydrogeological areas as the previous one and both horizons are tightly connected hydraulically. It is confined to limestones, dolomites, marls, parti-coloured argillites with gypsum lenses of Nyzhnivska, Rava-Ruska and Sokalska suites. The horizon is being fed through both atmospheric precipitates and adjacent water-bearing horizons. In Podils’kiy artesian basin it is intersected by drill-holes and in outcrops close to the eastern map sheet boundary. In Fore-Carpathian basin it is intersected by deep boreholes at the outskirts of Kadobna and Grynivka villages. Thickness of water-bearing rocks in Podillya is 50-70 m. Horizon hanging-wall occurs at the depth 20-100 m. The waters are pressurized. Borehole yields are 1.1-8.75 dm³/s at the depression by 2.8-14.3 m. The waters are fresh and deeper of 150-200 m – salty. Dry residuum content is 1.3-9.6 g/dm³. By chemical composition these are chloride sodium-calcium, sulphate-hydrocarbonate calcium-magnesium, sulphate-chloride sodium-potassium waters. Variability of chemical composition at increased mineralization restricts water use of this horizon for centralized water supplying and individual water consumption. In Fore-Carpathian basin waters of this horizon are high-mineralized (up to 160 g/dm³), enriched in bromine (up to 226 mg/dm³) and iodine (up to 20 mg/dm³) and can be used in medical purposes.

Solution of water supplying problem for inhabited localities and industrial enterprises in the studied area is based nowadays mainly on the use of waters in alluvial sediments.
7. MINERAL RESOURCES AND REGULARITIES IN THEIR DISTRIBUTION

Subsurface of the map sheet M-35-XXV (Ivano-Frankivsk) are rich in deposits and occurrences of various minerals confined to the sedimentary complex of Paleozoic, Mesozoic and Cenozoic rocks. They are classified to be distinguished in five groups: combustible, metallic, non-metallic, salts, and underground waters. The leading minerals in production include natural gas, condensate, oil, native sulfur, construction materials, potassium, potassium-magnesium and sodium salts, underground mineral and fresh waters. By their reserves the minerals occur in small, medium and large deposits.

Distribution of minerals is genetically and spatially related to the territory geology and tectonics. Geodynamics of Carpathian region resulted in its litho-tectonic zonation had also caused clear zonation in the distribution of known mineral resources (see geological cross-section A1-A7 to “Geological map of pre-Quaternary units”). The natural gas and native sulfur deposits are confined to Bilche-Volytska LTZ; petroleum and in lesser extent natural gas and condensate traps, rock and potassium (of mainly sulphate type) salt deposits – to Boryslavsko-Pokutskiy LTZ; rock and potassium sulphate and chloride salt deposits and occurrences – to Sambirska LTZ. Hydrocarbon accumulations are not found in the latter. The types of stratified ore deposits in the platform margin are mainly depend on the paleo-landscape conditions of sedimentation. Of mineral resources, occurrences and deposits of manganese and phosphorite are known over there as well as various construction materials.

Along with the modern oil-gas-geological zonation, the studied area belongs to Baltic-Fore-Dobrudja and Carpathian oil-gas-bearing provinces [2].

In view of tectonic zonation, type and time of ore mineralization, the territory is ascribed to Dnistersko-Prychornomorska and Carpathian-Crimean mineragenic provinces, which, in turn, include Volyno-Podilska and Carpathian mineragenic sub-provinces [24] (Fig. 7.1). The first one encompasses the platform part, and the second one – entire Carpathian region, where by ore formation evidences and their regular relationships with leading geological formations and structures, the Fore-Carpathian and Carpathian tectonic-mineragenic zones (TMZ) are distinguished.

Mineragenic features of Fore-Carpathian TMZ are defined by mineral resources located in particular mineragenic zones (MZ): a) Sambirska, where potassium and rock salt deposits are characteristic; the salt-bearing sequence also contains ozocerite deposits which are spatially accompanied by stratiform polymetallic mineralization; in the red-coloured terrigenous complex the copper mineralization is observed; b) Ivano-Frankivska, specialized for sulfur.

In Carpathian TMZ the anomalies of molybdenum and vanadium are only related to Oligocene – Early Miocene bituminous terrigenous flysch (Menilitova Suite), and copper occurrences – to the parti-coloured sediments of Yamnenksa Suite (Paleocene).

In the map sheet territory deposits and occurrences of those mineral are mapped and described which are (or may be) of practical value or are interesting in mineralogical and metallogenic respects.

Combustible minerals

Gaseous and liquid

The studied territory belongs to the Western oil-gas-bearing region. Its platform part encompasses Volyno-Podilska oil-gas-bearing province with Nesterivskiy and Podilskiy prospective areas, and remaining part – Fore-Carpathian and Carpathian provinces consisting of Bilche-Volitskiy, Boryslavsko-Pokutskiy and Skyboviy oil-gas-bearing areas (OGA) respectively which encompass the same-named litho-tectonic zones (Fig. 7.2). The provinces and areas are not equal by the study degree, hydrocarbon resources potential, number of deposits and their phase state.

In the map sheet territory the hydrocarbons are encountered in Fore-Carpathians so far. Here 21 economic deposits and a number of occurrences are discovered (see Annex 1). Hydrocarbons include natural gas, condensate and oil traps which somewhere do form deposits of mixed composition (Fig. 7.3). The age range of the economic oil-gas-bearing traps is Paleogene-Neogene. It is notable that Bilche-Volytskiy OGA is gas-
bearing only while Boryslavsko-Pokutskiy OGA is mainly oil-bearing. Deposits are mainly of multi-trap type and in Boryslavsko-Pokutskiy OGA these somewhere include the traps of both liquid and gaseous hydrocarbons.

Mineragenic zonation (characters and numbers in the scheme): A – Dnistersko-Prychornomorska mineragenic province of platform covers; Volyno-Dnisterska sub-province: A1 – Lvivsko-Ternopilska TMZ, ore camps: 0.1 Mn – Verkhynodnistierskiy, 0.2 Ph – Zakhidnopodilskiy. B – Carpathian-Crimean mineragenic province of folded structures;
Gaseous Natural gas

Major gas volumes are confined to the external zone of Fore-Carpathian Trough (Bilche-Volytskiy OGA) and related to the sandy-clayey productive horizons in terrigenous sediments of Kosivska and Dashavska suites (Neogene). Hydrocarbon containers include sandstones whose porosity varies from first units to 30-35% and permeability – from parts to some tens of milli-Darcy. Gas is accumulated in traps located in the brachy-syncline cores. The latter are arranged in the chain in the north-western and central parts of Kosivsko-Ugerska sub-zone; partly or completely they are overlain by Sambirskiy thrust. Small-scale free gas deposits are related to Kosivska Suite – Kadobnyanske (II-2-54), Grynyvskie (II-2-57) and Bogorodchanske (IV-2-172); to productive horizons of Dashavska Suite – Dashavske (I-1-2) and Lyubeshivske (I-1-9), as well as upper traps of Kadobnyanske deposit. Gas traps are encountered in all sandy-clayey horizons of mentioned suites and are traced at the depth 210-1235 m, their efficient thickness varies from 10 to 200 m. Structure of deposits is mainly multi-layered, they contain from 1 to 7 productive horizons with traps of mainly lithologically-bounded type due to lens-like shape of containers. In places traps of different age (Kadobnyanske deposit) and combined type are lithologically-bounded arched and tectonically limited. The latter type is characteristic for the zones of Krakovetsko-Striyskiy fault and the front of Sambirskiy thrust. The major component of gas is methane contained in amount of 93.6-99.18%. Ethane concentration is 0.17-0.18% in average, in places it attains 0.37% (Dashavske deposit) and 0.67% (Bogorodchanske deposit). Propane and butane content is from 0.01 to 0.3%. The gases belong to “dry”, methane homologues concentration in the gases is lower than 1%.

One of the biggest gas deposits is Dashavske (I-1-2) located in Striyskiy area at the outskirts of Dashava village. It is discovered in 1912; in 1924 it was the first Ukrainian deposit brought into production. It is confined to the same-named brachy-anticline of north-west strike 9 by 6 km in size and up to 140 m roof height. Structure is composed of Dashavska Suite sediments which are partly cut by Sambirska zone thrust. Deposit includes 10 traps related to six gas-bearing horizons at the depth from 240 to 980 m. In most horizons gas accumulations are sheeted, arched, lithologically-bounded, rarely tectonically-limited. Gas yield primary working is from 10 to 100 thous. m³/day, composition (vol.%): methane – 97.0-98.92; ethane – 0-0.39; propane – 0-0.11; CO₂ – 0-0.8; N₂ – 0.22-2.0. In the deposit column three combined exploitation objects are conventionally distinguished. Over two of these production has been completed in 1987 and they are served as underground gas storages. In the
latter purposes are also being used the exhausted productive horizons of Kadobnyanske and Bogorodchanske deposits.

**Fig. 7.2. Scheme of oil-gas-geological zonation**

*Oil-gas-geological zonation (characters and numbers in the scheme):*  
**I** – Baltic-Fore-Dobrugja oil-gas-bearing province;  
**A** – Volyno-Podilska oil-gas-bearing region, prospective areas:  
**A.1** – Podilskiy,  
**A.2** – Nesterivskiy.
Fig. 7.2. Continued.


Oil-gas-bearing and prospective areas: 4 – Podilskiy prospective area; 5 – Nesterivskiy prospective area; 6 – Bilche-Volytskiy oil-gas-bearing area; 7 - oil-gas-bearing area of Carpathian platform autochthon; 8 – Sambirskiy prospective area; 9 – Boryslavsko-Pokutskiy oil-gas-bearing area; 10 – Skyboviy oil-gas-bearing area.

Tectonic breaks: 11 – faults (a – regional, b – local); 12 – frontal thrust portions; 13 – flexures.

Deposits (number corresponds to the deposit number in geological map and map of mineral resources of pre-Quaternary units): 14 – gas, 15 – condensate, 16 – oil, 17 – oil and gas, 18 – deposit contours.


Gas reserves in all deposits are essentially exhausted except Lyubeshivske deposit (I-1-9) discovered in 1998 to the south-east from Dashavske deposit. It is located in the roof part of the south-eastern pericline of Dashavska brachy-anticline. Deposit includes three traps in sandy-clayey sequence of Dashavska Suite. The trap depth is from 250 to 780 m. The traps are of lithologically-bounded type, rarely sheeted arched, tectonically-limited. Thickness of containers varies from 0.5 to 9 m. Gas composition (vol.%): methane – 97.5; ethane – 0.05-0.23; propane – 0.03-0.05; butane – 0.01-0.04; pentane – 0.001-0.08; CO₂ – 0.11-0.43. Since 2001 deposit is under trial-economic exploitation.

In Bilche-Volytskiy OGA, in numerous boreholes drilled at Gnizdychiv, Krekhiv, Podorozhne, Zhuravne, Stariy Lysets, Tysmenychany and other villages the gas outflows and emissions have been observed from the sandy-clayey rocks of Kosivska and Dashavska suites (see Annex 1). Somewhere gas occurrences were noted in carbonate-terrigenous sediments of Zhuravnenska and Tyraska suites (I-1-4, 5; III-3-141, 143, 144).

As the by-product, gas is also encountered in Boryslavsko-Pokutskiy OGA in condensate deposits – Rosilnyanske (IV-2-177), Kosmatske (IV-2-194), Monastyrchanske (IV-2-202) and oil-gas deposits – Strutynske (III-1-111), Lukvymske (IV-1-165), Dzvyynatske (IV-2-185).

In the territory of Skyboviy OGA at Lugy and Nebykiv villages the flysch Cretaceous and Paleogene sediments contain only sporadic gas occurrences (III-1-115, IV-1-163). The latter occurrence includes oil and gas inflows.

Liquid

Condensate

Together with seam gas condensate is located in Boryslavsko-Pokutskya LTZ where these hydrocarbons occur in economic traps in Rosilnysanske (IV-2-177), Kosmatske (IV-2-194) and Monastyrchanske (IV-2-202) deposits. Hydrocarbon accumulations are confined to anticle-type structures of the third and fourth fold floor and are related to Eocene-Oligocene-Lower Miocene flysch complexes. Anomalous seam pressures (8-10 MPa) are characteristic for structures of Rosilnysanske and Kosmatske deposits. The traps are sheet-arched, tectonically-limited and lithologically-bounded. Containers include beds, batches and local lenses of sandstones and aleurolites in the rocks of Menilitova, Vygodka and Manyavska suites. Highest condensate and gas yields are confined to the medium- and high-porous sandstones which constitute insufficient column part. Their efficient thickness varies over the area from 6 to 118 m. Porosity coefficient of these sandstones is 14-15% in average, permeability – 65-70 mD.
Rosilnyanske and Kosmatske deposits are composed of, respectively, three and two Eocene-Oligocene-Lower Miocene gas-condensate traps, and Monastyrchanske deposit – of one Oligocene-Lower Miocene trap. The seam gas in all traps exhibits high hydrocarbon content (vol.%): 99.3-99.6, but their component content considerably differs in Oligocene and Eocene traps, respectively (in %): methane – 83 and 95.4, ethane – 7.05 and 2.45; propane – 1.6 and 0.58, butane – 1.01 and 0.5. Gas yields are from 38.9 to 1289 thous. m³/day. Potential condensate content in seam gas is 61-436 g/st.m³. Condensate belongs to methane type, it is of high specific and molecular weight (0.776 and 150.0 g/cm³, respectively), contains (mass %): paraffin – 0.88-1.94; tar
– 0.22-0.57; asphaltenes – 0.04-0.51. Condensate boiling point is 53°C. Benzene fraction content is high: boiling point 200°C – up to 62% and 120-240°C – up to 35%. Initial working condensate yield is from 3.7 to 220 t/day.

Separation gas is methane (94-97%); of the other components the following occur: ethane (2.15% in average), propane (0.32-0.88%), butane (0.01-0.11%), and pentane (0.05-0.11%).

Rosilnyanske and Kosmatske deposits gas-condensate deposits are discovered in the mid of 60th of last century and have been entered into production in 1972 and 1968 respectively.

Rosilnyanske deposit (IV-2-177) is located in 20 km to the south-west from Bogorodchany town. Productive horizon hanging-wall depth is from 2094 to 2420 m. Deposit is confined to the third floor of folds. It includes three gas-condensate traps confined to Rosilnyanske north-west-trending asymmetric anticline overturned to the north-east and thrust over Kosmatska structure. Rosilnyanske and Kosmatska folds, in turn, are overlain by the thrust of second-floor Maydanska structure. Condensate yields vary from 46 to 220 t/day, gas – 150-781 thous.m³/day. Major gas reserves are contained in Eocene trap where potential condensate content in seam gas is low – 61.0 g/st.m³. Hydrocarbon extraction is being conducted from two traps – from the northern Menilitovyi and Eocene. Small oil trap was discovered in 1974 in Menilitova Suite which was exploiting over 1975-1986. Oil yield comprised 81 t/day, dissolved gas – 97.9 thous.m³/day.

Close to Rosilnyanske deposit, in 2-3 km to the north-east, Kosmatske deposit is located (IV-2-194). It belongs to the fourth floor of folds. Two gas-condensate traps are confined to Kosmatska asymmetric anticline. Hydrocarbon containers comprise the same sediments as in Rosilnyanske deposit. Thickness of productive horizons varies from first meters to 10-15 m, and total efficient thickness – from 6 to 63 m. Initial working gas yield is from 80 to 1289 thous.m³/day, condensate – from 3.7 to 99.9 t/day. Since 1987 condensate is not received and the traps are being further exploited under the gas regime.

Monastyrchanska deposit (IV-2-202) is located in 3 km to the south-east from Kosmatske deposit. It constitutes the single gas-condensate trap in the sediments of Menilitova Suite (Oligocene – Lower Miocene) which fill up Monastyrchanska anticline of the fourth floor of folds. Productive horizon hanging-wall depth is 2800 m; yield is 76.7 t/day. Seam gas yield is from 38 to 219.3 thous.m³/day. Deposit is entered into production in 1988; its exploration continues.

Oil

Ten oil deposits are known in the studied area: Spaske (III-1-98), Chechvynskie (III-1-101), Rozhnaytivskie (III-1-104), Pidlisivskie (III-1-116), Nebylivskie (III-1-117), Rypnyanske (IV-1-161), Rudavetske (IV-1-168), Maydanske (IV-2-180), Starunske (IV-2-207), Dvizdetske (IV-3-219) located in flysch Paleogene-Neogene and Lower Miocene molassa sediments developed in Boryslavsko-Pokutskaja LTZ. By reserves all deposits are single-layer. Some deposits include several productive horizons at various age levels. The trap distribution over Paleogene-Neogene horizons is irregular and most are related to the sandy sequence of Menilitova Suite (Oligocene – Lower Miocene). The latter contains economic oil accumulations in all deposits except Maydanske and, therefore, comprises the regional oil-bearing horizon. So called “Klivski” sandstones of Neogene and Lower Miocene molassa sediments which fill up Monastyrchanska anticline of the fourth floor of folds. Productive horizon hanging-wall depth is 2800 m; yield is 76.7 t/day. Seam gas yield is from 38 to 219.3 thous.m³/day. Deposit is entered into production in 1988; its exploration continues.

In the deposit formation considerable role is played by the thrust and crossing breaks. The traps containing hydrocarbons are formed in the deep anticline structures overthrust beneath one another. They are complicated by en echelon higher-order anticlines provided multi-layer domains with the general thrust structure. Economic oil accumulations are encountered in almost all floors of folds. The first floor controls Spaske, Chechvynskie, Rozhnaytivskie, Rypnyanske and Nebylivskie deposits; the second one – Pidlisivskie, Rudavetske and Maydanske deposits; the fourth one – Starunske and Gvizdetske deposits. In the structures of the first and second floors the bed pressures are close to hydrostatic ones; in the lower fold floors abnormal pressure increases attaining 8-12 MPa in Starunska and Gvizdetska structures. The maximum differences of 44.2-50.3 MPa (with gradient 1.93-2.04) are found in Rozhnaytivskie deposit in the overturned limb of Nyzhnostrutynska anticline fold.

The oil traps of arched and combined types are normally limited by crossing faults and strike-slips (Spaske, Rozhnaytivskie, Pidlisivskie, Rudavetske and Gvizdetske deposits). Containers discontinuity by strike
had caused in some deposits formation of bed arched tectonically-limited and lithologically-bounded traps (Rypkinske, Nebylivske, Starunske, Maydanske deposits). Number of oil traps is mainly 2-3, in places up to 5 (Spaske deposits); Rozhnativskes and Rudavetske deposits consist of single traps only. Productive horizon hanging-wall depth is from first hundreds of meters (Rypnyanske, Nebylivske, Maydanske and other deposits) to 4.5 km (Rozhnativskes deposit).

All deposits contain non-viscous oils, their average density is 840-850 kg/m³. Oil average molecular mass is 230. They are mainly low-sulfur, high-paraffin, rarely medium-sulfur and low-paraffin. By the group composition the oils are normally methane-naphthenic, in places aromatic-methane-naphthenic; by content of tar-asphaltene components they are normal-tar and low-tar. Gases dissolved in oils are enriched in methane homologues and belong to “greasy”.

The oil fields Rypnyanskiy, Nebylivskiy and Maydanskiy are ones of the oldest in Europe. Artisan oil production was commenced as far back as XVIII century over there. Nebylivske, Maydanske and Starunske deposits are closed. All other oil deposits are in production although resources of Rypnyanske and Rudavetske deposits are almost exhausted. Exploration in Pidlisivske deposit is not completed yet. Greatest oil reserves are contained in Spaske deposit (II-1-98) located in 10 km to the south-west from Rozhnativ town over the square of 21 km². Deposit is discovered in 1959, oil production commenced in 1980. Deposit belongs to the first floor of folds. It contains five traps connected with series of up to 5-7 m thick sandy-aleuritic beds in the column of Menilitova Suite. Three traps are confined to the narrow north-west-trending Spaska anticline with uplift magnitude 1600 m. Other traps are located in Lopyanetska fold with arc height 3000 m. The oil is low-sulfur, high-paraffin, density is 830-850 kg/m³; light fraction emission by 350°C heating exceeds 45%. Oil yield varies from 6 to 28 t/day. Dissolved gas content from 46.7 to 98 m³/t; composition (vol.%): methane – 81.0-94.61; ethane – 1.89-7.5; propane – 1.63-6.1; butane – 0.34-2.6; hecane – 0.11-1.6; CO₂ – 0.18-0.6; N₂ – 0.0.5.

Liquid and gaseous (by-products)

Oil and gas

Occurrences of oil and free gas are known in Boryslavsko-Pokutska LTZ in the area of Peregnynske, Slyvky, Yasen, Lukavytysya and Solotvyn villages (III-1-112, IV-1-167, 170, IV-2-182, 205) in Eocene – Oligocene – Lower Miocene flysch sediments, somewhere in molassa complexes of Miocene Polyanytska and Vorotyshchenska suites. Besides that, in Skybova LTZ oil and gas inflows from Paleogene flysch complexes are encountered in the course of drilling in Ilemkivska anticline structure (occurrence IV-1-162).

Economic oil and gas traps do form Strutynske (III-1-111), Lukvynske (IV-1-165) and Dzvynyatske (IV-2-185) gas-oil deposits confined, respectively, to the first, second and fourth levels of folds in Boryslavsko-Pokutska zone. Hydrocarbons are contained in traps located in the arcs of anticline structures. The traps are bed-arched, tectonically and lithologically limited. Bed pressures are close to hydrostatic and in Dzvynyatske deposit only they attain 8-12 MPa. Gas-oil-bearing complexes are the same as in the oil deposits. Productive horizons include sandstone and aleurolite beds and lenses of discontinuous thickness and significant facial variability. Containing properties of these rocks are medium and low. The number of hydrocarbon traps in Lukvynske and Dzvynyatske deposits is three, in Strutynske – four, their depth varies from 253-1046 m (Dzvynyatske deposit) to 1590-2420 m (Strutynske deposit).

The oils are mainly sulfureous, high-paraffin, methane-naphthenic, somewhere aromatic-methane-naphthenic (Lukvynske deposit), tareous. By density they are non-viscous (820-840 kg/m³); medium and viscous ones are characteristic for Oligocene and Eocene traps only in Strutynske deposit. By chemical composition the gases dissolved in oil belong to “greasy” (homologues content up to 15%); free gas is middle between “dry” gases of Bileche-Volytskiy OGA and “greasy” ones of Boryslavsko-Pokutskiy OGA, it contains up to 92% of methane and up to 8% of homologues.

Except Dzvynyatske deposit, economic oil, dissolved and free gas extraction is being conducted in all other gas-oil deposits. Dzvynyatske deposit had been being exploited since 1873 to 1931 and more than 4 mln. m³ of free gas were received.

Strutynske deposit (III-1-111) is located in 7 km to the south-west from Rozhnativ town. It is discovered in 1959 and oil extraction commenced in 1962. Four hydrocarbon traps are contained in the first floor of folds and are confined to Verkhnyostrutynska asymmetric north-west-trending anticline which is almost completely overlapped by the thrust of Beregova nappe. Fold length is 15 km, height from 0.4 to 4 km; it is split into Obolonskiy, Spaskiy, Pivinchnostrutynske, Strutynske and Vilkhivske blocks. Main oil traps are contained in the rocks of Eocene Vygodska Suite and Oligocene Lower-Menilitova Suite of Pivinchnostrutynske and Strutynske blocks where container thickness attains 100 and more meters. Minor oil traps in all blocks are related to some psammite 4-5 m thick beds in Middle and Lower Menilitova sub-suites.
(Oligocene – Lower Miocene). In Vilkhivskiy block they also contain gas traps. Hydrocarbon trap height is from 178 to 570 m. Initial working yield: oil – from 0.2 to 5.9 t/day; dissolved gas – from 3.9 to 115 thous.m³/day; free gas – 10 thous.m³/day.

In Lukynske deposit (IV-1-165) Eocene and Lower-Menilitoviy productive horizons contain two oil traps. The oil trap with gas cap is confined to Upper Menilitoviy horizon. Trap height is from 57 to 426 m. Hydrocarbons are contained in the traps of bed-arched tectonically limited type. Oil yield is from 13.8 to 155 t/day; free gas – 96-223.6 thous.m³/day.

Solid

Peat

Diversity of natural conditions and variability of relief forms had caused peat deposits formation in the studied area which differ in size, thickness and structure of the bodies, location in the relief, plant cover and peat properties. In total 26 mainly small-scale deposits are known from 20 to 250 hectares in size, rarely to 450 ha (see Annex 2). Of these 6 are in production, 17 out of production, 2 closed and 1 reserved (Turova Dacha reserve). Peat is mainly suitable for use as fertilizer in agriculture. In household fuel purposes the peat from Torgovytsya (IV-4-334) and Berezivka (I-3-244) deposits only. Upon insufficient drying expenditures the peat areas can be used as grazing, mowing or arable lands.

By genesis, all deposits belong to organic group of continental sediments with low-moor, high-moor and mixed peat types. The major factors in deposits formation include development of peat-forming fossil groups and permanent substratum re-wetting under oxygen-free conditions [76]. These environments are being only appeared at the shallow ground water level and slowed infiltration regime and are being defined by climatic and geomorphologic features of the territory. Depending on these conditions, Podilskiy and Fore-Carpathian peat areas are distinguished which respectively belong to Lisostepova and Carpathian peat regions.

Podilskiy peat area, encompassing Dnister left-bank side, includes 14 peat deposits of exclusively low-moor type. Deposits are confined to the valleys of Svirzh, Gnyla Lypa rivers and their branches. Peat areas distribution is clearly controlled by the boundaries of Holocene flood-lands. Multi-layer bodies of sedge and cane-sedge peat types predominate, rarely forest-sedge ones. Average thickness of productive piles attains 1.5-4.3 m. Peat destruction degree is mainly medium; ash content is high – from 12-20% to 35-40%; burning heat from 2580 to 4280 kcal/kg. Peat is normally muded, with sand and carbonate admixtures; increased content of mineral salts is characteristic due to ground water feeding. These peat areas upon some hydro-irrigation are most suitable for arable use in agriculture. Occurrence of carbonate and peat-vivianite facilitate fertility increasing. The biggest peat deposits in the area include Grygorivske (I-2-231), Zhurivske (I-2-232) and Kolokolynske (I-2-234).

Fore-Carpathian peat area occupies right-bank side of Prydnisterska plain where alternating high inter-river areas and wide terraced valleys of Dnister right branches occur. Peat deposits of high-moor as well as mixed and low-moor types are developed over there. The latter ones predominate (7 of 12). Top-type deposits Pid Borom (III-1-295), Turova Dacha (III-1-301) and Kryvetske (IV-2-318) are confined to watershed dimples and are mainly composed of slightly-decomposed sphagnite-type peat, in places with reduced pine-tree or fir-tree. Ash content is normally lower 12%; burning heat 4363-4540 kcal/kg. Mixed and low-moor deposits are mainly located in the valleys of Limnytsya and Chechva rivers; these exhibit irregular quality and notable variability of peat thickness. Diverse sedge-sphagnum and cane-sedge peat types participate in the peat bodies. Decomposition degree is medium, ash content is variable (10-40%). Average thickness of peat bodies in the area is 2.0 m attaining 12 m in some deposits (Pid Borom deposit). Peat of most deposits can be used as fertilizer; part of peat areas is being used in agricultural purposes.

Metallic mineral resources

Ferrous metals

Manganese

In Zakhidnopodilska LTZ in Dnister left-bank side, along the valleys of Svirzh, Gnyla Lypa, Naraivka rivers, increased manganese mineralization is observed in occurrences (I-2-16-19; I-3-31, 37) and economic accumulations (Burshtynske deposit) which form Verkhnyodnisterskiy area of manganese-bearing sediments [24]. Genetic type of mineralization is sedimentary.
Manganese occurrences and ore bodies are located in marl-clayey and marl rhythmoliths and limestone clays developed in the lower part of Kosivska Suite (Verbovetski layers). The ores comprise thin-layered rocks (rhythmoliths) formed over transition period from arid to humid climate in the early stages of Upper Badenian sea transgression. Manganese content in ores varies from 5 to 22%; mineralization includes carbonate minerals – rhodochrosite and mangano-calcite. Most enriched ores were deposited in the sea bottom depressions and hollows (Molodyntyska). In the aeration zones carbonate manganese ores are extensively oxidized providing oxide-carbonate ore type (vernadite) where manganese content in places attains 24% (occurrence I-2-19).

In the area between Svirzh and Naraivka rivers the sites, where economic manganese ore beds are encountered, are combined into Burshtynske deposit (I-3-36). It is located at the junction of Western and Eastern European platforms and is confined to Molodyntyska erosion depression. Deposit includes three sites: Rogatyn-Bukachiivtsivska, Ozeryanska and Svystylnytska. Ore horizon depth varies from 1.7 to 74.0 m, mainly 20-50 m; thickness is up to 25.5 m, mainly up to 10 m. Ore bodies comprise the lenses 100-500 m by length and width; thickness of ore interbeds from 1 to 6 m; manganese content 7-22%.

The setting, manganese content in ore and parameters of Burshtynske deposit and adjacent occurrences suggest for low present economic value of manganese-bearing sediments in Verkhodnisterskiy area.

Non-ferrous metals

Occurrences of copper, lead and zinc are known in the studied map sheet in various by age and deposition conditions sediments.

Copper

In Fore-Carpathians and Eastern Carpathians the clear link of copper mineralization and parti-coloured rocks of some Paleogene and Neogene stratigraphic levels is noted. Specifically, copper occurrences are located at the bottom of sandstones in grey-coloured layers; normally, these rocks are enriched in coalified fossil detritus. Nature of copper mineralization is sedimentary-diagenetic.

In the territory, the copper mineralization related to Paleogene sediments, is encountered in Skybova LTZ in the upper course of Lozochniy stream (occurrence III-1-107). It is confined to the bottom of 0.8 m thick grey sandstone layer which is observed between parti-coloured Yaremchanskiy horizon argillites of Yamnenska Suite. In the lower part of sandstone lies thin (up to 0.2 m) aleurolite interbed with marcasite aggregates at the surface. Highest copper grade in this interbed is 0.63%, average grade by entire sandstone layer – 0.12%. In around occurrence the secondary litho-chemical aureoles and dissemination streams are distinguished with copper content 0.01-0.02%; in heavy concentrates chalcopyrite occurs (up to 200-250 signs per sample). In outcrop at Yasen village scarce chalcosine dissemination is noted in sandstones. Copper mineralization, which is noted somewhere in sandstones of Yaremchanskiy horizon, is mainly of mineralogical interest because of its local appearance as well as low thickness and grade.

Stratiform copper mineralization is more developed in the internal zone of Fore-Carpathian Trough in the parti-coloured molassa of Lower Miocene Stebnytska Suite. The distribution area of these sediments was distinguished by D.P. Khrushchov and V.T. Kardash as Delyatynska copper-bearing zone where in adjacent territory from the north-east occurrences with economic copper grade are encountered [50]. In the map sheet area close Petranika village Petrankivskiy occurrence is found (III-2-127) which includes three minor lenses up to 0.2 km long [79]. Copper mineralization is located in up to 0.3 m thick aleurolite bed which lies at the bottom of sandstone. Copper grade is 0.18-0.35% (in individual chip sample 0.98%). Copper minerals include chalcosine, covellite, chalcopyrite, malachite formed in parti-coloured muds under conditions of shallow-water marine and deltaic facies [50]. Second-generation chalcosine in cementing mass comprises major copper concentrator. Its distribution and appearance patterns suggest for the mineral formation mainly at the stage of diagenetic transformation of sediments enriched in copper. Due to limited size of ore bodies and low copper grade this occurrence is of no practical value.

Lead, zinc

In Fore-Carpathians polymetallic mineralization is located in Boryslavsko-Pokutska LTZ and is traced (in lead and zinc dissemination aureoles and occurrences) over almost entire length of the zone being clearly controlled in space by hydrocarbon occurrences (oil, gas, ozocerite). Mineralization is related to Lower Miocene molassa complexes of Vorotshchenska Suite. In the map sheet territory the hard-rock lead-zinc occurrences are known since XIX century, from the times of first ozocerite production in Dzvyynatske and Starunske deposits. In the first occurrence in breccia-like carbonate clays two interbeds were discovered 65 m long and 25-30 cm thick.
with galena and sphalerite dissemination (occurrence IV-2-192). In Starunske deposit dissemination of polymetals is also noted in salt-bearing sequence (occurrence IV-2-203). Specialized prospecting for polymetals in around Dzvynyatske and Starunske ozocerite deposits provided galena findings in some samples from core sections and old shaft dumps in amounts from single to 487 signs, and sphalerite up to 50 signs [128]. Mineralization is traced to the depth 200 m.

Besides noted ore occurrences, large-scale mapping have resulted in discovery of small secondary polymetal dissemination aureoles which are mainly confined to the distribution band of salt-bearing sequences of Vorotyshchenska Suite [79, 128]. In heavy concentrates the grains of galena, cerusite and shpalerite occur in amounts from single to 30-50 signs and in some samples only – up to 100 signs (upper courses of Syvka and Sadzhavka streams). Increased lead (0.08-0.3%) and zinc (0.015-0.04%) contents are encountered in the bottom sediments of Lukva upper course. In the mud outcomes from Starunskiy mud volcano the crystals and aggregates of vurtcite, galena, pyrite, strotio-baryte, marcasite, calcite, dolomite and gypsum were noted.

Encountered polymetal occurrences and dissemination aureoles do not have any practical value due to low grade but can provides some prospecting interest as well as contribute to the ideas concerning origin of lead-zinc mineralization. Genesis of polymetal mineralization in Fore-Carpathians is being considered from different point of view but all authors emphasize the major feature in its spatial distribution, specifically, its link with salt-bearing breccia-like sequence of Vorotyshchenska Suite in the crestal regions of oil-gas-bearing structures. The ore-bearing sequence is enriched in carbonates and organic carbon. Some authors had ascribed stratiform polymetal mineralization to sedimentary type, others – to infiltration-metasomatic type. Recently S.A.Galiy, S.M.Kurylo [13] and V.V.Naumenko [35] had pointed out its epigenic origin. In their opinion, formation of lead-zinc mineralization takes place under income of thermal brines into gypsum-carbonate pile where cold sulphate infiltration waters are being circulated. Movement of metal-bearing hydrothermal solutions into discharging area (in the core of anticline) had accompanied by solution enrichment in sulphate-reduced sulfur hydrogen of oil water resulted in discharge of metal sulphates (Pb, Zn, Fe). In the circulation zone of infiltration sulphate waters calcite, Celestine, gypsum, barite and other associated minerals were released from the brines. Mineral-forming processes run under both reduced and oxidized conditions.

**Rare metals**

**Vanadium, molybdenum**

In the studied area vanadium and molybdenum mineralization is not visible. However, increased concentrations of these metals in high-contrasted geochemical anomalies are encountered in dark argillites extensively enriched in organic matter (occurrences Lopyanetskiy III-1-103, Lozochniy III-1-108, Pidsukhivskiy III-1-113). Vanadium content in these cases is 0.25-0.32%, molybdenum – 0.008-0.03%. Argillites do form thin interbeds in sediments of Middle and Upper Menilitova sub-suites developed in Skybova LTZ (Carpathian mineragenic zone).

In the distribution area of bituminous argillites some secondary dissemination aureoles with anomalous vanadium and molybdenum contents are also encountered [65, 79, 128]. The biggest one (13.5 km²) is located in around of Lopyanka village where molybdenum content is up to 0.01-0.03%. Lopyanetskiy and Lozochniy occurrences are located within this aureole. In the area of the latter occurrence in one sample of bottom mud content of these elements attains economic values – 0.4% of vanadium and 0.04% of molybdenum [79].

The noted vanadium and molybdenum anomalies comprise just the metallogenic interest. Normally the high content of these metals is accompanied by increased amount of nickel, copper and uranium. This association is characteristic for black-shale formation which elsewhere in the world controls uranium, vanadium, molybdenum and gold deposits.

**Strontium**

In the map sheet area the strontium mineralization is confined to Miocene (Tyraska Suite), Upper Cretaceous (Lukvynska Suite) and Upper Jurassic (Nyzhnivska Suite) rocks and is mainly comprised of celestine, rarely strontianite.

Sulphate-carbonate sediments of Tyraska Suite comprise the major strontium-bearing horizon. Here mineralization is mainly developed in metasomatic limestones; it is also known in sulphate and carbonate facies rocks. Strontium occurrences are divided into sedimentary (syngenetic) and epigenetic. Content of syngenetic strontium is commonly low while the element concentration in the rock increases in the course of its epigenetic re-distribution. Epigenetic type of mineralization is observed together with sulfur in almost all sulfur deposits of Fore-Carpathian sulfur-bearing basin. In sulfur ores strontium is contained in two forms – in celestine and as
isomorphic admixture in calcite. Genetically mineralization is related to the system of faults and flexures (in the studied area these are Kaluskiy fault and ZHuravnenska flexure). These destruction zones comprise the channels where ascended chloride sodium brines with high strontium content and strong reduced properties [84]. Going over fractures in sulphate-carbonate sediments, the brines, being essentially under-saturated in sulphates, do extensively dissolve not only gypsums but also fine-grained celestine disseminated in these rocks. In places, where brines are highly diluted with sulphate waters, discharge of celestine occurs. In sulfur bodies the strontium mineralization of irregularly distributed. The highest element concentrations are normally confined to the lower part of bodies. Celestine does form interbeds, lenses and veinlets, it often occurs in the individual crystals and druses on the hollow walls, as well as it forms fine-crystalline dissemination in sulphate-carbonate rock.

By strontium content the ores of sulfur deposits are low-grade. Strontium content normally does not exceed 1%, in some samples it may attain from 3 to 11.29%. However, these ores could be of interest as strontium raw material if celestine would be mined together with sulfur.

Most studied in the area is Podorozhnenskiy occurrence (I-1-6) confined to the sulfur ores of the same-named sulfur deposit. For the first time increased strontium content was found in 1961 by G.T.Sakseev in the course of sulfur deposit exploration [123]. Strontium mineralization is comprised of celestine. Veinlets, pods and druses of its crystals are mainly confined to the lower part of sulfur-ore layer. In places is developed fine-crystalline celestine disseminated in the rock. Strontium content attains 11.29%. The depth of strontium-bearing sulfur ores varies from 26 to 194 m and their thickness is up to 25.5 m. In the 70th of last century A.M.Denysevych [84] have estimated celestine reserves and provided recommendations for celestine mining as by-product from sulfur ore flotation and production of saleable celestine concentrate. However, technology of by-product celestine mining was not developed and it had not been mined. To date the sulfur reserves in this deposit are almost exhausted; the works on quarry closure and land reclamation are underway. In fact, Podorozhnenskiy occurrence is lost for strontium oxide production from sulfur ores.

Besides metasomatic sulfur-bearing limestones, strontium is also contained in gypsums, gypsum-anhydrites and sedimentary “Ratynski” limestones of Tyraaska Suite. Strontium content in these rocks is low, 0.2-0.3% in average, rarely it attains 3% (occurrences II-3-71, 73; III-3-133, 142; III-4-55, 159). Strontium is contained in celestine, in places strontianite, disseminated in the rock.

In the course of large-scale mapping [77], in some boreholes drilled in the area of Syvka Voynilivska, Nimshyn, Burshtyyn, Kuropatnyky villages, and Podillya, strontium mineralization was encountered in the rocks of Lukvyynska and Nyzhnivska suites. In Upper Cretaceous marls, limestones and sandstones at the depths 26-217 m celestine does form veinlets and veins from part of centimeter to 2 cm thick and pods up to 4 mm in size; thickness of enriched rocks is 0.2-2 m, strontium content from 5 to 30% (occurrences I-3-38, 40, 44-46). Increased celestine concentration in Upper Jurassic sulphate-carbonate rocks is only encountered in the area of Kuropatnyky village (occurrence I-1-30). Thickness of ore zone is 0.2 m, strontium content – 15.3%. Celestine includes disseminated and vein aggregates (types). All Mesozoic strontium mineralization is confined to the zone of Radekhiv-Rogatynskiy fault and intersection of this zone with the zone of Sushchano-Perzhanskiy fault. The major strontium source for vein celestine formation is the zone of high-mineralized waters of Paleozoic and Jurassic. Additional source includes syngenetic celestine disseminated in the rock. Formation of celestine veins and veinlets had occurred in post-Cretaceous time in the zone of increased fracturing related to the destructive influence of Radekhiv-Rogatynskiy and Sushchano-Perzhanskiy faults.

Non-metallic mineral resources

Ore-chemical raw materials

Chemical raw materials

Borates

Boron in nature is widely developed in various compounds but its increased concentrations are rare. It is caused by high degree of this element dissemination. One of perspective sources for boron includes deposits of sedimentary (halogenic) type related to the salt precipitation. Even low (0.10-0.15%) boron content is salt-bearing sediments could have practical value under conditions of by-product mining. Aiming definition the boron specialization of halogenic formations in Fore-Carpathians, sulphate-carbonate rocks of Tyraaska Suite and salt-bearing sediments of Balytska and Vorotyshchenska suite were studied as well as mineral water and brines springs and waters of oil and gas deposit were sampled [99, 100]. The sampling results have shown that in sulphate-carbonate rocks boron is either lacking or its content is much less
of Clarke value; some samples only contain boron in amount up to 0.003-0.005%. In salt-bearing sediments developed in Fore-Carpathian salt-bearing basin, boron is mainly contained in amount of 0.001-0.01%, and in the water and brines – 17-125 mg/dm³. Its highest concentrations are related to clayey varieties of Balтыaska and Vorotyshechna suites, specifically, to the rocks of gypsum-clayey “cap” and salt-bearing sandy-clayey breccia. Maximum content of B₂O₃ (0.25%) is determined in two samples of salt breccia from shaft “Silvin” of Kalush-Golynska potassium salt deposit (occurrence II-2-62). Increased boron content (0.16-0.18%) is also determined in the rocks of gypsum-clayey “cap” developed in the area of Dolynskie rock salt deposit (occurrence III-1-92) and Rosilhynska potassium salt deposit (occurrences IV-2-176, 178) [128]. In salt-bearing piles of Fore-Carpathian basin the regular boron content increasing is observed with clay material amount in the rock increasing apparently related to the adsorption of boron by clayey particles. Boron content in salts is low; in the rock salts it is commonly higher than in potassium salts. In the pure salts boron is actually lacking. Since the highest boron concentrations (0.05-0.18%) are found in the zones of salt-bearing rocks hypergenesis – in gypsum-clayey “caps”, further studies are required for their forming conditions and boron deposition to perform substantiated assessment of salt-bearing rocks for this element. In this respect, additional prospecting is recommended with drilling depth up to 100 m in the areas of gypsum-clayey “cap” and unbroken salt rocks development.

Boron oxide in amount from 30-50 to 456 mg/dm³ is encountered in water-bearing horizons of Cambrian, Jurassic, Cretaceous and Badenian sediments in some prospecting-exploration drill-holes for oil and gas. Their description is given in the section “Industrial waters”.

**Native sulfur**

Sulfur is spatially and genetically linked with sulphate-carbonate sediments of Middle Badenian Tyraska Suite developed in Bilche-Volyska LTZ. Here large Fore-Carpathian sulfur-bearing basin is discovered and explored; it corresponds to Ivano-Frankivska mineragenic zone (Fig. 7.1). The secondary limestones comprise the sulfur-bearing rocks in all sulfur deposits and occurrences of the basin.

Limestones with sulfur (sulfur ores) do form the bodies bounded by clayey rocks; the bodies include the metasomatic replacement beds and lenses of gypsums and post-sedimentary anhydrites involved in Neogene Tyraska Suite. Sulfur ores are normally developed at the top of sulphate rocks, rarely at the bottom or inside the beds; in places they completely replace sulphate rocks.

In the studied area three sulfur deposits are discovered – Podorozhenske (I-1-7), Zhuravenske (I-2-24) and Lysetske (III-3-140). Of these, Podorozhenske only is explored in details while in two other deposits sulfur reserves are estimated by category C2 at the stage of detailed prospecting. Besides these deposits, in the narrow band along Kaluskiy fault a range of sulfur occurrences are encountered – Melnychivskiy-I (I-2-25), Melnychivskiy-II (I-2-26), Taravskyi (I-2-27), Pidgirskiy (II-2-64), Berevskyi (IV-3-214), Bratkivskiy (IV-3-216), Lyipivskiy (IV-3-217). Sulfur mineralization is regularly collated in: a) Rozdol-Podorozhenskiy ore camp bounded by Kaluska fault zone, Krupska and Zhuravenska flexures and large depression structures – Khodorivska and Molodyntyska; b) Lysetskiy ore camp located to the south-east from longitudinal Manyavskiy normal fault-shear between Kolomiyska depression and Kaluskiy fault.

In Rozdol-Podorozhenskiy ore camp in the map sheet territory Zhuravensko-Podorozhenskiy ore junction is distinguished which combines similar in age and genesis spatially closed sulfur bodies of Podorozhenske and Zhuravenske deposits.

**Podorozhenske deposit** (I-1-7) occupies the space of the same-named anticline with magnitude up to 200 m. It consists of 14 sulfur bodies from 0.2-0.5 to 2.4 km wide extended along Kaluskiy fault from first hundreds of meters to 4.5 km. Major sulfur reserves are confined to the Main sulfur body located in the northeast part of deposit. Remaining 13 bodies are small in size and reserves. Depth of sulfur-bearing limestones varies from 26 m in the north-east to 195 m in the west and south-west of deposit. Thickness of ore bodies varies from 1 to 28.3 m, sulfur content – 14.9-27.3%. Major ore type lithology is limestone, rarely limestone-marl and clayey. Ore texture is criptic- and clear-crystalline; structure is disseminated, breccia-like and pod-veinlet; major minerals – calcite and sulfur, minor – gypsum, clay, celestine. Increased strontrium concentrations are related to sulfur ores (see section “Strontium”).

Development of Main body commenced in 1971 by quarry-melting method. In the remaining minor ore bodies sulfur has not been mined. In view of changed world market conditions and sulfur price, as well as due to sufficient negative technogenic changes of hydrogeological and ecological conditions, 1997 it was concluded on closure of Podorozhenskiy quarry and removal the technological complex of ore processing. In the excavated quarry space the lakes of perspective use will be created.

To the south-east from Podorozhenske deposit, along Kaluskiy fault, some sulfur occurrences and mineralization points are encountered. Of these the biggest one is Pidgirskiy sulfur occurrence (II-2-64) located...
nearby Pidgirky village and comprised of 4.8 m thick “intra-gypsum” metasomatic limestone horizon; sulfur content is up to 13.76%.

In Lysetskiy ore junction Lysetske deposit (III-3-140) is discovered. It contains five small sulfur bodies. Of these, 3.5 km long Central body is the biggest. The band of sulfur mineralization is extended along Kaluska normal fault zone over 10 km. Sulfur content varies from 5.0 to 34.6%. By lithology the ores are mainly limestone, rarely clayey and sulphate-carbonate; ore type is mainly veinlet-pod, in places disseminated and banded. Deposit has been never mined.

Besides Lysetske deposit, in this ore junction in the area of Berezivka, Bratkivtsi and Lypivka villages occurrences in metasomatic limestones and gypsum-anhydrites re encountered (IV-3-214, 216, 217). Occurrences are prospected in details and do not have practical value.

Sulfur mineralization is extensively developed along the margins of complex Kolomiyska paleo-valley providing Tlumach-Shevchenkivskiy ore camp. All sulfur deposits of this camp are located outside the map sheet boundaries. In the studied area just the far north-western part of camp is located. Here, in the outskirts of Pshenychnyky and Krasylivka villages the sulfur occurrences III-4-156, IV-4-224 and a number of sulfur mineralization points are known.

One of the most important problems of sulfur mineralization studies in Fore-Carpathian basin is genesis of sulfur ores. In general all concepts of sulfur formation include the following statements: i) sulfur is syngenetic to the host rocks; ii) sulfur comprises result of epigenetic processes. Most authors almost completely refuse idea on possible sedimentary origin of considerable sulfur accumulations syngenetic to the host sulphate-carbonate sediments. The concept of infiltration-metasomatic sulfur formation, proposed by A.S. Sokolov [44], is most acknowledged. The principal statement of this concept is infiltration metasomatism of gypsums in situ with sulfur and calcite formation (sulfur-limestone ore) occurring under favourable combination of sulfur formation factors. Major ore-control agents include deep-seated hydrocarbons and mineral waters, sulfur hydrogen, oxygen-contained near-surface waters, and sulphate-reducing bacteria. The concept allows reliable treatment for not only spatial but also genetic link of sulfur mineralization with sulphate sediments and hydrocarbon accumulations as well as explanation to leading role of tectonic factors in formation and distribution regularities of sulfur deposits providing scientific ground for the sulfur deposit prospecting criteria.

Lithological criteria is one of most important ones in prognosis for sulfur since all sulfur deposits in Fore-Carpathians are related to sulphate-carbonate rocks of Neogene Tyraska Suite. Moreover, among lithofacial varieties of sulphate rocks, the most favourable for metasomatic modification into secondary sulfur-bearing limestones are re-deposited clastic layered sulphate rocks in the upper column part, especially those with admixture of primary carbonate material [138]. It is supported by preferential location of most sulfur bodies in deposits and occurrences in the upper portion of Tyraska Suite column. Rock layering facilitates their extended permeability for the ore-forming agents. Massive mono-sulphate rocks (stromatolitic and coarse-crystalline gypsum) are less favourable or even not favourable to the processes of sulfur metasomatism and in some places these rocks interbeds suppress respective processes. Another barrier to sulfur-formation comprises clay interbeds or the rocks with considerable clay content. In the distribution scheme of Tyraska Suite sulphate-carbonate rocks (Fig. 7.4) are shown fields of sediments with predomination of primary-sedimentary and re-deposited rock varieties.

The spatial location of sulfur deposits is regularly linked with certain tectonic elements. Major ore-control breaks in the basin include latitudinal faults (Kaluskii in the studied area). In the buried part of Bilche-Volytska zone the sulfur bodies can also be confined to Krakovetsko-Striyskiy and Sudovo-Vyshnyanskii faults. Intersection zones of latitudinal and longitudinal faults are most favourable for sulfur deposit formation since these comprise the major paths by which solutions enriched in sulfur hydrogen and hydrocarbons from gas and oil deposits have migrated into sulphate sequence.

Almost all sulfur deposits are confined to the cores or limbs of anticline structures. Other important places of sulfur mineralization include the margins of erosion depressions (specifically, Kolomiyska and Molodynytska).

Occurrence of sulfur hydrogen waters or sulfur hydrogen in Tyraska Suite sediments comprises the classic evidence for sulfur mineralization. Native sulfur formation takes place in the zone of interaction between sulphate waters of surface origin and deep sulfur hydrogen and “oil” waters containing increased mineralization and hydrocarbons. Often sulfur mineralization is accompanied by sulfur hydrogen and hydrocarbon occurrences.

Indirect evidences for sulfur mineralization also include: i) occurrence of minerals paragenic to sulfur – calcite, celestine, barite in Tyraska Suite sulphate-carbonate sediments; ii) occurrence of sulphide mineralization at the bottom of sediments overlaying sulphate-carbonate sequence.
Agro-chemical raw materials

Phosphorites

In the studied area phosphate rocks are traced in Zakhidnopodilska LTZ. By Dnister River and its branches so called “phosphorite-bearing plate” is exposed which belongs to Zakhidnopodilskit phosphorite-bearing area. Major part of the latter is located in adjacent territory from the east where phosphorites have been mined over some time in Nezvyske deposit.

Phosphorite-bearing is related to Upper Albian and Lower Senomanian (Nezvyska Suite) and Upper Senomanian (layers of inoceramus limestones) sediments composed of glauconite-siliceous and siliceous-carbonate sands and sandstones and organogenic-sandy limestones. Characteristic for the rocks is increased content of $P_2O_5$ – from parts of percent to 13.6%.

Origin of phosphorites Yu.M.Senkovskiy attributes to Carpathian-Podolian upwelling [40]. Under conditions of side-continental shelf of Late-Albian sea the deep cold waters enriched in dissolved phosphorus were supplied from Carpathian basin. Dissolved phosphorus together with other biogenic compounds was consumed by siliceous-sponge fauna developed in the shallow-water environments. Due to diagenetic reworking of sediments, organic phosphorus was re-distributed with subsequent formation of phosphate compounds and phosphorite nodules at the bottom of inoceramus layers.

The highest phosphorus concentrations in the map sheet area are encountered and studied in the outcrops of phosphorite-bearing rocks nearby Bukivnya village (Occurrences III-4-147, 150) [60]. Thickness of these rocks is 0.8-1.2 m; they include organogenic-sandy limestones and glauconite sandstones with flint pebble and fine phosphorite nodules. In the lower part limestones are enriched in the fragments of phosphoritized shells and sponges. Content of $P_2O_5$ is 2.65-4.74% and in one chip sample only – 13.6%. Occurrences are of no practical value.

Non-metal ore commodities

Electric and radio-technical raw materials

Ozocerite

Ozocerite deposits and occurrences in Fore-Carpathians are known since the end of XVIII century. Since 1872 it was produced from the mines in Dzvyntsk (IV-2-195) and Starunske (IV-2-200) deposits located in Borylsavsko-Pokutska LTZ. Ozocerite bodies are confined to the core portions of the same-named anticlines composed of sandy-clayey salted olistostrome of Neogene Vorotyshchenska Suite. Merging at the depth of some such structures (so called fold “duplex”) had caused extensive tectonic stress. This led to the rock crushing and development of dense fracture network subsequently filled with solid bitumen – ozocerite. Bitumen impregnation under pressure conformably to the rock laying had facilitated formation of stratabound mineralization. Ozocerite sources include paraffin oil accumulations in the deep structures. Despite of the thick (up to 500 m) clay proof above oil-gearing rocks, tectonic stress had produced the stress high enough for deep hydrocarbon moving to the surface; once upon a time hydrocarbons had formed the “oil lake” where mammoth and rhino bodies were conserved.

In Dzvyntsk deposit (IV-2-195) mainly sheeted mineralization type is developed. Frequent facial changes in ozocerite-bearing rocks do limit its distribution. Ozocerite content in these layers is 0.1-2.63%. Ozocerite-bearing sequence about 80 m thick at the dipping by 50-60° is traced by strike over 300 m. Ozocerite quality varies by lateral and with depth. In the near-surface horizons the solid and high-melting varieties predominate while with depth its quality becomes worse. The colour varies from light-brown to black. Ozocerite properties are as follows: melting temperature – 59.5°C, density – 0.912 g/cm³, refraction index at the temperature 90°C – 1.443, element composition: C – 85.31%, H – 14.2%. Ozocerite mining was periodically conducted from two shafts 200 and 170 m deep until 1960. Over entire period of deposit exploitation about 10 thousand tons of ozocerite were mined. At present in the territory of former mining field the wood-processing plant is built up with the complex of industrial and recreation premises. By these reasons further geological exploration in the area is not reasonable.
Fig. 7.4. Distribution scheme of Tyraska Suite sulphate-carbonate rocks and regularities in the native sulfur location (Fore-Carpathian sulfur-bearing basin).

**Boundaries:** 1 – distribution of Tyraska Suite sediments; 2 – lithological.

**Isolines:** 3 – altitudes of pre-Kosivska surface; 4 – isopachs of Tyraska Suite sediments.

**Sediments with predomination of primary-sedimentary rock varieties:** 5 – gypsum-anhydrites without admixtures; 6 – gypsum-anhydrites with carbonate material admixture; 7 – gypsum-anhydrites with carbonate material in lenses and interbeds; 8 – rock salt and gypsum-anhydrites with halite rock interbeds.
Fig. 7.4. Continued.

Sediments with predomination of re-deposited rock varieties: 9 – gypsum-anhydrites without admixtures; 10 – gypsum-anhydrites with carbonate material admixture; 11 - gypsum-anhydrites with carbonate material in lenses and interbeds; 12 – metasomatic limestones and gypsum-anhydrites with essential interbeds of metasomatic limestones.

Clayey material in the rock: 13 – in admixtures; 14 – in interbeds.

Deposit contours: 15 – native sulfur; 16 – natural gas.

Occurrences: 17 – sulfur (a – in metasomatic limestones b – in gypsum-anhydrites); 18 – natural gas.

Tectonic breaks (ore-control breaks are indicated in the red): 19 – deep-seated fault zones of Fore-Carpathian Trough; 20 – normal faults and strike-slips; 21 – flexures; 22 – major anticline structures of Fore-Carpathian Trough.

Geophysical prospecting evidences for native sulfur: 23 – sites of epigenetic sulphide mineralization in clays of Kosivska Suite (defined by anomalies of apparent polarization > 1.75%); 24 – zones of anomalous Eh and pH values in soils.

Hydrogeological prospecting evidences for native sulfur: 25 – distribution aureoles of sulfur hydrogen waters; 26 – points with increased sulphate-ion content (from 100 to >1000 gm/dm³) in deep waters.

Prognostic sites for native sulfur and their numbers: 27 – high-prospective (2 – Pidgirska); 28 – with unclear perspectives (1 – Bolokhiv-Kadobnyanska, 3 – Kalush, 4 – Grynivka).

In Starunske deposit (IV-2-200) the vein mineralization type predominates. Vein thickness is from some millimeters to 15-20 cm; the veins are conformable to the host rock layering. Average ozocerite content in the rock is 1.5%; the quality profile is as follows: melting temperature – 54°C, density – 0.957 g/cm³, refraction index at the temperature 90°C – 1.415, element composition: C – 84.9%, H – 14.1%. Ozocerite is noted at different depth starting from 2.5 to 489 m. Ozocerite mining in Starunska mine was conducted until 1941 from five shafts up to 140 m deep. In total 4592.7 tons of ozocerite were mined. Possible ozocerite mining reactivation in deposit only depends on the market demands for this rare and valuable raw material.

Facing-stone raw materials

Gypsum

Decorative-facing materials in the studied area are quite limited and include gypsums of Neogene Tyraska Suite which lie in the conditions suitable for open-pit mining. Industrial requirements are matched by the gypsums in Zhuravvenske (I-2-20), Kolokolnske (I-3-32), Medukha (II-4-74) and Trostyanetske (II-4-82) deposits (all in the Annex 1).

Kolokolnske deposit (I-3-32) is located at the eastern outskirt of Kolokolyn village. Square is 3.6 ha, mineral commodity – milky-white, light- and dark-grey gypsum of 21.5 m average thickness, overburden rocks – 12 m. Mechanical strength limit of the rock is 200-590 kg/cm², yield of conventional blocks is 50%, outcome of plates from blocks – 40%. Gypsum is being easily sawed and polished.

Medukha deposit (II-4-74) is located at the south-eastern outskirt of Medukha village. The square is 18 ha. It is composed of yellowish-grey, honey-grey coarse-, fine- and cryptic-crystalline gypsums. Thickness is 20.5 m, overburden – 15 m. Block yield is 75.5%. By decorative features gypsums fit II and II classes, by chemical composition they can be used for manufacturing of I-II grade binding materials.

Construction raw materials

In the map sheet territory construction raw materials are widespread and form a number of deposits (94 deposits, see Annexes 1, 2). Their distribution is controlled by landscape and geological diversity.

Construction raw materials include age-different groups of carbonate, sulphate and clayey sediments. Most of deposits related to Quaternary sediments are located in the Dnister left-bank side where Tyraska Suite (Neogene, Upper Badenian) gypsums are being used for manufacturing of construction gypsum while Cretaceous limestones and marls – for lime manufacturing, and Opilski limestones (Lower Badenian) – for crushed stones. In the brick-tile industry Lower Sarmatian argillite-like clays and thick sub-aerial loess-like Pliocene-Quaternary loams are used.
Cement raw materials

In purposes of cement manufacturing the carbonate rocks are used (limestones, marls) if their CaO content is not less than 45%. Commodity mixture includes 75-78% of CaCO₃ and 22-25% of SiO₂+Al₂O₃+Fe₂O₃. Physical-mechanical properties of the rocks are not limited but the low-strength rocks (100-200 kg/cm²) are preferable. To handle the time of cement solidification gypsum is being added to the mixture.

In the map sheet territory limestone deposits are discovered: Dubovetske-II (II-4-80), Mezhygirsko-Marynopilske, site Marynopil (II-4-81), as well as gypsum and marl: Mezhygirsko-Dubovetske (II-4-77), Dubovetske-I (II-4-78), Mezhygirsko-Marynopilske, site Mezhygirtsi (II-4-79) – (see Annex 1).

Limestone

Mezhygirsko-Marynopilske deposit, site Marynopil (II-4-81) is 108 ha in square and located to the north from Marynopil village, in III and IV Dnister left-bank terraces. Commodity comprises Upper Dubovetska sub-suite (Upper Cretaceous) limestones, grey, light-grey, white, average thickness 65.5 m. In limestones CaO content is 44-55%, volume weight – 2.3-2.4 g/cm³.

Marl, gypsum

Marls of Mezhygirsko-Dubovetske deposit (II-4-77), located to the south from Mezhygirtsi village, are confined to the Upper Dubovetska sub-suite (Upper Cretaceous) sediments. Average thickness of productive pile is 50 m, overburden rocks – 18 m, square of deposit – 132 ha. By chemical composition marls include two varieties. The first one is dense, thick-platy. Clayey marl of second variety is low-carbonate and can be used for manufacturing of Portland-cement in case of addition to the mixture the carbonate and ironiferous correcting components.

Gypsum of Neogene Tyraska Suite, which is being mined in the same deposit, is 8 m thick and is suitable as the mixture addition regulating the time of cement solidification.

Peturgy raw materials and light concrete fillers

Claydite

Vygivske deposit (I-3-41) is located at the western outskirt of Vygivka village. Commodity comprises Neogene and Quaternary clays 16.3 m thick. Clay raw materials are suitable for manufacturing of claydite gravel, 1st quality grade, types “300 and “400.

Raw materials for construction lime and gypsum

Limestone

In manufacturing of construction lime and lime powder Upper Cretaceous limestones of Dubovetska Suite are being used which are explored in Gorozhankivske (II-4-75), Strygantsivske (II-4-83) and Palagytske (III-4-154) deposits (see Annex 1). Strygantsivske deposit is biggest one (6.2 ha) where limestone average thickness attains 48 m. Content of CaCO₃ in the rock is 85.7-98.5%, mechanic strength limit is from 114 to 213 kg/cm². Limestones match industrial requirements and are suitable for manufacturing of II-class construction lime and I-class limestone powder, as well as for cattle and poultry mineral feeding.

Palagytske complex deposit (III-4-154) is located to the north from Palagychi village. Commodity comprises white limestone of Lower Dubovetska sub-suite; average thickness is 32 m, overburden – 6 m. Deposit square is 14.3 ha. By chemical composition and properties limestones belong to “A” and “B” class carbonate rocks and can be used for light lime manufacturing. Content of CaCO₃ in the rock is 86-97%, mechanic strength limit is from 258 to 410 kg/cm². Limestone is also suitable for manufacturing of crushed stone.

Gypsum

Thanks to its binding properties gypsum is being used in construction materials industry for manufacturing of various cement grades, construction liquids, combined blocks etc. Binding commodity comprises gypsum and gypsum-anhydrite stones explored in Novoshynske (I-2-22), Gannusivske (II-4-84),
Gypsum-anhydrite sequence of Neogene Tyraska Suite in Vovchynetske deposit is of 30 m average thickness and is composed of gypsum and anhydrite, light- and dark-grey, transparent, fine-crystalline. From the pure gypsum I-class construction gypsum can be obtained, and from gypsum-anhydrite mixture – II-class gypsum.

**Raw materials for crushed stone**

**Limestone**

Gnylchenske deposit (I-4-48) is located in the steep gully bank to the east from Gnylche village. The square is 1 ha, average thickness – 8 m, overburden – 0.2 m. Commodity comprises limestone of Cretaceous Dubovetska Suite, light-grey to white, chalk-like, with abundant inclusions of black flints. Hydrogeological conditions are suitable, mineral commodity is not wetted.

**Brick-tile raw materials**

**Clay, loam**

The raw materials for manufacturing of brick, tile, ceramic stone, drainage pipes and other coarse-ceramic wares include clays and loams, both Neogene including Voynylivske (II-2-55), Kaluske (II-2-59), Verkhnyostrutynske (III-1-95), Chornoliztsivske (III-4-158) and Kryvotulynske (IV-4-223) deposits (see Annex 1), and Quaternary (71 deposits, see Annex 2). Most developed and accessible commodity for ordinary brick and tile manufacturing comprises Quaternary aeolian-deluvial loams and eluvial clays. These are easily melted clay rocks with necessary ductility and binding properties.

For coarse ceramic manufacturing (drainage pipes, floor plate etc.) refractory clays are mainly used. Kaluske deposit (II-2-59) is located in 4 km to the north-east from Kalush town. Square of deposit is 23.4 ha; commodities – Neogene Dashavska Suite clay, greenish-grey, 25.4 m thick, and Quaternary loams, brown, yellow-brown, 3.7 m thick. Clays and loams in mixtures are suitable for manufacturing of “100” and “125” brick types, as well as “100” and “125” ceramic stone types. Drainage pipes do match industrial requirements.

**Salts**

Fore-Carpathians in general, and the map sheet M-35-XXV (Ivano-Frankivsk) in particular, are rich in various salt resources comprising mineral commodity base for agro-chemical, chemical and other industries of Ukraine. These resources include deposits of potassium-magnesium and rock salts. The latter resources include just the rock salts and natural brines.

Ukraine is ranked in the leading positions by reserves of sulphate potassium salts. In the country the ores are concentrated in Fore-Carpathian salt-bearing basin which occupies the territory of Boryslavsko-Pokutska and Sambirska LTZs (Sambirska mineragenic zone – Fig. 7.1).

Salt bodies are contained in the Lower Miocene molassa complex in which considerable column part is composed of salt-bearing sediments of two halogenic formations – Vorotyshchenska and Balytska. Normally the salts occur together in the single salt-bearing horizon although rock salt is also known separately.

Considerable part of commercial salt reserves is concentrated at the depth 600-700 m, rarely to 1000 m and more. Deposits of potassium-magnesium salts exhibit higher variability in sediments thickness, their morphology, mineral composition, valuable component content, in comparison to the rock salt deposits. The former are normally observed in relatively small by reserves ore fields. In Sambirska LTZ the biggest deposit – Kalush-Golynske (II-2-61) includes a number of separate lenses arranged one above another within relatively small-scale sites. These sites do form Kaluske and Golynske ore fields within Trostyanetsko-Kaluskiy potassium-bearing area. This area also includes deposits of potassium-magnesium salts – Velyka Turya (II-1-51) and Trostyanetske (II-1-52).

In Boryslavsko-Pokutska LTZ the groups of the same ore-formation type deposits are distinguished in: i) in the south-east – Rosilnyansko-Markivske, ii) in the north-west – Bolekhiv-Roshnyativske.
studied area includes Dolynske (III-1-85), Verkhnostrutynske (III-1-99), Yasenovetske (III-1-105) and Roshnyativske (III-1-110) rock salt deposits and Dolynske (III-1-89) deposit of natural brines.

Rack salt

In Fore-Carpathian basin rock (sodium) salt without terrigenous material admixtures is almost lacking; by these reasons by its quality this salt does not match requirements to the food salt and raw material for chlorine industry; it may be of practical interest only as the raw material for underground leaching with formation of saturated brines from which the food salt can be obtained through evaporation.

Of minerals, in the salts of Fore-Carpathian halogenic formations halite (NaCl) is most widespread. Depending on halite and terrigenous components contents, continuous range of rocks is distinguished from salted clay to rock salt with change in halite content in the rocks from 5 to 90%. The purer rock salt is very rare and normally it forms just the thin interbeds.

At present, minimum NaCl content in the sample should be 56% and average content in the bed intersection by drill-hole and in the block – 68-70%, according to requirements for salts in Fore-Carpathians suitable for underground leaching. Besides NaCl and insoluble residuum content, salt quality is also characterized by harmful admixture content, which maximum admissible contents by intersections and blocks (in %) is: Mg – 0.1; K – 0.42; Fe2O3 – 0.01; Na2SO4 – 0.5.

In the studied area rock salt and clayey halite rock batches up to 200-300 m thick (in places up to 415 m) are developed in both Vorotyshchenska and Balytska salt-bearing formations. These batches normally consist of several salt beds or lenses from first meters to 190 m thick separated by salt breccia, salted clays, aleurolites and sandstones. Length of salt beds is up to 6 km; by strike and dip salts are changed by clayey halite rock and salt breccia. Economic batches (according to requirements) are only those whose aggregate thickness of salt beds and lenses is 90 m at least (in Roshnyativske deposit – 145 m).

Specialized works of geologists [59, 141, 142] led to discovery of rock salt deposits: Dolynske (III-1-85), Verkhnostrutynske (III-1-99), Yasenovetske (III-1-105) and Roshnyativske (III-1-110). All deposits belong to bed-lens type with inconsistent thickness, structure of ore bodies and variable salt quality. Harmful component content in the salts is much less than admissible requirements. None of deposit is in production.

Most studied is Verkhnostrutynske deposit (III-1-99) located in Rozhnyativskiy area, in 8 km to the south-east from Dolynskiy salt plant. Deposit is discovered in 1970 [131] and explored in 1986 [141]. Salt bodies are related to Neogene Vorotyshchenska Suite sediments. By lithology the salt-bearing sequence is divided in two batches – lower and upper. The lower one consists of two rock salt beds from 15 to 162.9 m thick separated by salt-bearing breccia, salted clays and sandstones. Upper batch includes rock salt bed from first meters to 58.6 m thick. Higher lies the pile of salt breccia. The upper bed only in the lower batch is economic; its thickness in places attains 124.4-162.9 m. By strike and dip this bed is bifurcated into 2-7 interbeds separated by salt breccia. Rock salt is dark-grey and grey, medium-crystalline, with single gypsum and anhydrite crystals and bunches, with fragments (0.5-4 cm) of clay, argillite, sandstone. Content of NaCl is 76.5% in average. Harmful admixture content is low. In some amounts occur bromine (0.0016-0.0061%) and boron (0.001-0.048%), as well as lithium, rubidium and cesium – less than 0.0002%. From the salt of Verkhnostrutynske deposit the saturated brines can be obtained suitable for I-class food salt manufacturing, and with preliminary purification – of highest class and “Extra” class.

Structure of other deposits in Bolekhiv-Roshnyativskiy ore camp is similar to Verkhnostrutynske and differs only in term of body dimensions and salt quality figures.

In the Neogene Balytska Suite sediments in the area of Gryniivka and Sadzhava villages thick rock salt batches are encountered (occurrences III-2-132; IV-2-174) [133]. Of these, the first occurrence comprises salt batch with single thin (0.5-5.4 m) interbeds of salt breccia, anhydrite and clay. Content of NaCl is from 70.7-94.25%, average content of insoluble residuum – 11.84%. The second occurrence, located in 4.5 km to the southeast from the first one, consists of salt bed with NaCl content from 79.31 to 95.46%. Insoluble residuum content is 5.62% in average.

Potassium-magnesium salts

Potassium-magnesium salts comprise major commodity type of salt-bearing rocks in Fore-Carpathians. These are unique by their mineral composition (more than 20 sulphate, chloride-sulphate and chloride potassium and potassium-magnesium minerals). Sulphate minerals are more widespread than chloride ones. Value of these ores is defined by the fact that sulphate and chloride-sulphate salts are suitable for manufacturing of high-demand non-chlorine potassium fertilizers – potassium sulphate and potassium-magnesia. Besides the direct purposes – manufacturing of mineral fertilizers, potassium salts can be used for manufacturing of chlorine-
magnesium solution (20% solution of magnesium chloride), metallic magnesium, caustic soda and other products.

In Fore-Carpathians sylvinite and kainite salts were discovered in the first half of XIX century in Kalush. As far back as 1867 salt mining commenced. Formation of potassium industry in Fore-Carpathians occurred in 20th of the last century. Prospecting-exploration works for potassium salts had been conducted almost permanently over entire post-II world war time to the mid of 90th of last century. Over this period, in the studied area deposits were discovered in: i) Vorotyshchenska salt-bearing formation – Rosilnyanske (IV-2-181), Dzvynyatske (IV-2-193), Starunske (IV-2-196), Markivske (IV-2-199) and Molodkivske (IV-2-210); ii) Balytska formation – Velyka Turya (II-1-51), Trostyanetske (II-1-52) and Kalush-Golynske (II-2-61).

Potassium-bearing sediments of Vorotyshchenska formation are traced along Skybova zone of Carpathians in almost continuous band from 2 to 8 km wide confined to Boruslavsko-Pokutska LTZ (see “Geological map of pre-Quaternary units”). From the south-west this band is essentially overlain by the thrust of Carpathian flysch. Thickness of salt-bearing sequence is up to 1000 m. It contains up to 5 potassium-bearing horizons extended with interruptions over the distance from 2-5 to 10 km and up to 1,5-3 km across the strike. Horizons comprise the batches of closed potassium-magnesium salt lenses and beds separated by interbeds of salt-bearing rocks of various thickness, in places high enough – up to 75 and more meters. Maximum thickness of the complex horizons attains 100-200 m, and individual salt interbeds (lenses) – 3.5-50 m, rarely 78 m.

Potassium-bearing sediments of Balytska formation are developed in Sambirska LTZ where they mainly form isolated areas up to 15-20 m across. They are related to chemogenic-terrigenous sequence of Balytska Suite from 300 to 900 m thick. Highest degree of sequence salt enrichment is observed in the areas of Golynt-Kalush, Trostyanets-Velika Turya and Rozhnuyativ-Rivnya villages. In the lower and upper, in places in the middle and upper column parts of salt-bearing sequence from 1 to 4 horizons with lens-like bodies of potassium-magnesium salts are distinguished. These horizons are extended up to 10 km by strike and 3-5 km across (Kalush-Golynske deposit). The horizons are either of simple structure or comprise the group of closed salt lenses and interbeds which total thickness does not exceed 50 m.

The salts contain fairly variable and distinct complex of minerals which belong to the water and water-free potassium, magnesium, sodium and calcium chlorides and sulphates. Major rock-forming minerals normally include halite, kainite, langbeinite, sylvine. Minor minerals include polyhalite, kieserite, carnallite, schoenite, epsomite, leonite. Above salt layers, in the zone of salt plane, the “cap” of secondary sulphate salts is being formed with development of mirabilite, tenardite, glaserite, schoenite, astrakhanite and other minerals.

Major rock-forming components in potassium rocks also include clayey and aleurite-sandy material – insoluble residuum (IR). Therefore, salt quality assessment is being done by two major parameters – potassium oxide content not less than 8-9% and IR content below 18%.

Other components contained in the salts and their host rocks, include bromine, lithium, rubidium, cesium and boron. Bromine content varies from 0.0001 to 0.39%, normally 0.015-0.022%. Concentrations of lithium, cesium, rubidium and boron are in the range of thousandth and rarely hundredth of percent; in the clayey fraction of IR these concentrations are about 10 times higher.

Potassium and potassium-magnesium salts are normally composed of several minerals mixture of which predominate 2-3, somewhere 4-5 ones. They form crystalline-grained mixtures in various numeric proportions. However, of these mixtures the major typical types of potassium rocks can be distinguished: kainite, langbeinite, sylvinite, carnallite and polymineral. Most widespread and economic valuable is polymineral type.

Vorotyshchenska salt-bearing formation contains langbeinite-kainite, kainite-langbeinite and kainite salts. Langbeinite rocks are of subordinated value. In contrast to the salt-bearing rocks of Vorotyshchenska Suite, in Balytski salt-bearing sediments, besides thick langbeinite-kainite rocks, thick layers of kainite rocks and sylvinite are also developed, and in places carnallite rock lenses. However, in these cases sulphate salts are also predominate over chlorine ones and form thicker potassium-magnesium bodies.

Rosilnyanske, Dzvynyatske, Starunske, Markivske and Molodkivske deposits (Rosilnyansko-Markivske potassium-bearing area) include mainly steeply-dipping beds of potassium-magnesium salts. Dipping angles are from 50° to 80°. The beds are often lensed and arranged in the narrow folds with closed limbs. Salt depth varies from 30-100 m where salts meet gypsum-anhydrite “cap” to 1000 m and more in the central parts of synclines.

Major salt reserves in the area are concentrated in Rosilnyanske deposit (IV-2-181) located in 14 km to the south-west from Bogorodchany town. It is discovered in 1963 [130] and in 1985 preliminary exploration was conducted. [137]. Salt depth varies from 50 to 868 m by dip. Deposit includes two ore bodies (sites) – Rosilnyanske and Kosmatske. In tectonic respect deposit is confined to asymmetric Zarichivska syncline filled with salt-bearing sediments in the core. Their maximum thickness is 820 m.

Seven stratigraphically-different economic bodies of potassium-magnesium salts are explored in deposit. Ore bodies include from one to five same-age lenses separated in the space. In the column of salt-
potassium-magnesium salts are encountered. One of them comprise salt beds of economic thickness and K\textsubscript{2}O can be considered as additional resource base for Kaluskiy plant.

By their reserves they belong to small deposits which do not have individual economic value and complex of the deposit.

Underground shaft methods. The powerful infrastructure was created in around of the mining-processing feet. The basin feeding regime defines the column patterns of potassium-bearing horizon of salt lagoons. In the course of sedimentation the waters from the land and adjacent basins have periodically entered forming basins of Lower Miocene molassa formation in Fore-Carpathians comprised the chains of highly salted lagoons. In the periods of salt formation the basin water area, in comparison to phase of brine saturation.

Development of Vorotyshchenskiy (Egenburgian) salt-forming basin has been finished with kainite-langbeinite (sylvinite and carnallite) began to form. It is explained by repeating termination of halogenesis at its late stages.

At some specific moments only in the local sites thin sylvinite and, rarely, carnallite interbeds were formed. (sylvinite and carnallite) in salt-forming basin, the brine metamorphism has been never expanded too far when chlorine salts band from 2 to 8 km wide. Despite of multiplied sedimentation of sulphate potassium-bearing rocks (langbeinite and kainite) in salt-forming basin, the brine metamorphism has been never expanded too far when chlorine salts saturated brines attained maximum values, potassium-magnesium salts were formed. Each cycle of brine long process of halite formation. And only in the late stage of halite basin development, when concentration of potassium-magnesium sediments in salt-forming basin has been preceded by relatively long process of halite formation. And only in the late stage of halite basin development, when concentration of saturated brines attained maximum values, potassium-magnesium salts were formed. Each cycle of brine saturation not always was finished with potassium salt formation. In these cases the cycle of halogene sedimentation remained unfinished. These cycles in the studied area essentially predominate over completed cycles.

The aspects of general halogenesis theory and genesis of potassium salts in Fore-Carpathians have been discussed by many authors. Most argued for exogenic or “classic” theory of salt formation [25, 26, 37, 96, 130, 137]. It assumes that the basins, where salts have formed, emerged and existed in the periods of sea regressions, under conditions of extensive and durable subsidence of some sites at the extensive water evaporation. Salt-forming basins of Lower Miocene molassa formation in Fore-Carpathians comprised the chains of highly salted lagoons. In the course of sedimentation the waters from the land and adjacent basins have periodically entered the salt-forming basins. The basin feeding regime defines the column patterns of potassium-bearing horizon which normally comprises intercalation of potassium-magnesium salt, halite rock and terrigenous rock interbeds.

Deposition of potassium-magnesium sediments in salt-forming basin has been conducted by open-cast and underground shaft methods. The powerful infrastructure was created in around of the mining-processing complex of the deposit.

The regularities and geochemical features of halogenesis in Vorotyshchenskiy and Balytskii basins are somewhat different. The general evolution of salt-forming basins in Miocene molassa complex of Boryslavsko-Pokutska and Sambirskaya zones is reflected in the distribution of salt-bearing sequences (Fig. 7.5).

In Vorotyshchenskiy basin the salt-bearing and potassium-bearing rocks are traced in almost continuous band from 2 to 8 km wide. Despite of multiplied sedimentation of sulphate potassium-bearing rocks (langbeinite and kainite) in salt-forming basin, the brine metamorphism has been never expanded too far when chlorine salts (sylvinite and carnallite) began to form. It is explained by repeating termination of halogenesis at its late stages. At some specific moments only in the local sites thin sylvinite and, rarely, carnallite interbeds were formed. Development of Vorotyshchenskiy (Egenburgian) salt-forming basin has been finished with kainite-langbeinite phase of brine saturation.

Balytskii sedimentation basin was extended over entire Sambirskaya zone but salt sediments were not deposited throughout its territory. In the periods of salt formation the basin water area, in comparison to
Vorotyshchenskiy basin, has been sharply reduced and its axial line shifted towards the platform. In general, characteristics of Balytskiy basin are as follows: i) local development of salt-bearing sediments in small bodies of variable shape; ii) predomination of slightly-salted and non-salted facies; iii) lateral zonation by various types of potassium salts. For instance, in direction from Trostyanets to Velyka Turya, Golyn and further to Kalush (direction of basin migration) composition of potassium bodies exhibit the change of mainly sulphate (langbeinite) salts by sulphate-chloride (kainite) and further chloride (sylvinite) ones. Especially clear the lateral differentiation of potassium salts by mineral composition is observed in Kalush-Golynske deposit, in Golynska nappe, where three thickest bodies are composed of the rocks of langbeinite-kainite composition while two minor lenses – of sylvinite. In Kaluska (external) nappe, which salt-bearing sediments were formed in the coastal part of the salt-forming basin, amount of potassium-bearing horizons is decreased and mineral composition of bodies is changed, specifically, amount of sylvinite lenses is sharply increased and sulfur salts are mainly comprised of kainite rocks. Towards the basin centre, where salt-bearing sediments were formed away from the coast line, the rocks of mainly langbeinite and kainite-langbeinite composition were deposited.

The history of Fore-Carpathian salt-bearing basin is not completed with Balytskiy stage of salt deposition. Major processes of salt transformations occurred at the stage of catagenesis under influence of buried incipient brines, conditions of increased pressure and average temperature 70°C. After activity of these processes from the primary sedimentation salts just their primary chemical composition has remained at the regular differences in content of some components. The folding and thrusting processes occurred at the end of Sarmatian time in Carpathians and Fore-Carpathians had also essentially influenced morphology of salt bodies.

Natural brines

Fore-Carpathians is one of the oldest areas of salt manufacturing. In these processes, as the raw materials, the natural brines were used which are developed in the distribution areas of salt-bearing sediments. The latter are almost water-free. Water-bearing horizons are sporadically developed in the rocks of gypsum-clayey “cap” – the product of salt-bearing rocks leaching in the zone of hypergenesis. Water enrichment of the “cap” rocks is insufficient and quite variable in the section. The most water-bearing is the “cap” contact zone with salt-bearing rocks (zone of salt plane). In this zone, which actually comprises the horizon of natural brines, enrichment of fresh surface waters and atmospheric precipitates with mineral components is observed at the expense of salt leaching. The bulk mineralization of natural brines varies in wide range from 20-30 g/dm³ to 300-367 g/dm³.

Despite of wide distribution of these brines in Fore-Carpathians, their use by salt industry is limited by the yields of brine drill-holes not less than 10 m³/day, mineralization not less than 250 g/dm³, and admissible amount of harmful components (in %): Ca < 0.6; Mg < 0.5; K < 1.5; NaSO₄ > 2.2. However, the yields of numerous drill-holes do not exceed 1-5 m³/day and often less. Maximum yields of drill-holes with economic brine concentrations are relatively low and are mainly 12-30 m³/day. Such low yields are caused by low filtration properties of the gypsum-clayey “cap” rocks and significantly slowed processes of salt leaching from salt-bearing sediments. Low filtration and salt leaching speed, in turn, are caused, firstly, by significant contamination of salt-bearing sequence with terrigenous material; secondly, by its fine-grained composition, and, thirdly, considerable predomination in the column of salt-bearing clays, breccia, argillites, sandstones and aleurolites over sodium salt.

Mineralization of the brine horizon and its purity with regard to the harmful admixtures are highly variable. It is because in Fore-Carpathian salt-bearing basin very quick change of one salt rocks by others are observed with frequent content of lenses and batches of potassium salts. Normally nearby the rock salts diverse potassium salts are observed providing their contamination source. Moreover, often potassium and rock salts in the column replace one another.

The standard requirements are matched only by the natural brines in Dolynske deposit (III-1-89) located at the eastern outskirt of Dolyna town. The square is 2.8 km². In tectonic respect deposit is located in Boryslavskiy sub-thrust of Boryslavsko-Pokutskiy thrust. The brine horizon is developed throughout and is confined to the lower part of “cap” over salt-bearing Neogene Vorotyshchenska Suite. Filtration properties of the rocks in brine horizon are fairly variable. Filtration coefficient varies from 0.0024 to 1.2 m/day being 0.25 m/day in average. The highest values are observed in the depressions of salt plane and economic sites (lenses) of brine horizon are also located over there. The bulk brine mineralization varies from salt waters with mineralization 17-30 g/dm³ to very strong brines with mineralization 270-319 g/dm³. The brines are of high-quality and stable chemical composition. Their major component is NaCl; other ones include CaSO₄, MgSO₄, KCl. Extraction of natural brines in the area of Dolyna town commenced as far back as XII century. On the base of deposit
Dolynskiy salt plant is operating. Over the various years, three shafts were exploiting – “Barbara”, “Odnytysya” and “Novychka”, as well as seven drill-holes.

Fig. 7.5. Distribution scheme of Lower Miocene salt-bearing sediments and regularities in salt location (Fore-Carpathian salt-bearing basin).

**Lower Miocene sediments:** 1 – Balytska Suite ($N_1 bl$), terrigenous and salt-bearing sediments; 2 – Stebnytska Suite ($N_1 st$), terrigenous parti-coloured sediments; 3 – Vorotyshchenska Suite ($N_1 vr$), terrigenous and salt-bearing sediments.

**Boundaries:** 4 – geological; 5 – lithological.

**Frontal zones:** 6 – thrusts; 7 – sub-thrusts; 8 – large nappes; 9 – second-order nappes.
Fig. 7.5. Continued.

**Distribution fields of Balytska and Vorotyshchenska suite terrigenous sediments:**
- 10 - sandy-clayey;
- 11 - coarse-clastic;
- 12 - olistostrome.

**Distribution fields of Balytska and Vorotyshchenska suite salt-bearing sediments:**
- 13 - salted terrigenous and salt breccia;
- 14 - salt-bearing with halite rock beds;
- 15 - salt-bearing with potassium salt beds of economic value;
- 16 - salt-bearing (a - with non-economic beds and potassium salt interbeds; b - with potassium salt dissemination);
- 17 - distribution fields of salt-bearing rocks beneath thrusts or terrigenous sediments of Stebnytska Suite (a - proven, b - probable);
- 18 - possible distribution fields of salt-bearing rocks defined by indirect evidences (salt springs, geophysical anomalies).

**Deposits:**
- 19 - potassium salts and their numbers (1 - Turya Velyka, 2 - Trostyanetske, 3 - Kalush-Golynske, 4 - Rosilyanske, 5 - Dzvynatske, 6 - Starunske, 7 - Markivske, 8 - Molodkivske);
- 20 - rocks salt and their numbers (1 - Dolynske, 2 - Verkhnyostrutynske, 3 - Yasenovetsk, 4 - Roshnyatske).

**Hydrogeological salt evidences:**
- 21 - water points where water chemical composition indicates leaching of potassium salts (a - wells, b - springs);
- 22 - water points where water chemical composition indicates leaching of halite rock beds (wells);
- 23 - water points where chemical data for brines and high-mineralized water are absent (a - wells, b - drill-holes, c - springs).

**Geophysical salt evidences:**
- 24 - anomalous zones defined by electric sounding apparently caused by salt-bearing rocks.

**Prospective and prognostic sites for salts:**
- 25 - high-perspective sites for potassium salts and their numbers (7 - Dzvynatske, 8 - Rosilyanske, 9 - Markivske, 10 - Molodkivske);
- 26 - medium-perspective sites for potassium salts and their numbers (1 - Velyka Turya – Mali Didushychi, 3 - Dolyna – Verkhniy Strutyn, 5 - Tsynyava – Krasne);
- 27 - low-perspective sites for potassium salts and their numbers (2 - Velyka Turya – Sloboda Dolynska, 4 - Rozhnyativ – Rivnya, 6 - Yasenovets – Peregnyske);
- 28 - prospective site for rock salt Grynivka-Sadzhava (high-perspective).

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**Waters**

**Underground waters**

The territory of map sheet M-35-XXV (Ivano-Frankivsk) is located at the junction of Prychornomorsko-Dnisterska area of Eastern-European province and Carpathian area of Alpine (Mediterranean) province of mineral waters [89, 102]. The first area encompasses Volyno-Podilskiy artesian basin, and the second one – Fore-Carpathian basin and Carpathian hydrogeological area. Water-bearing horizons are confined to Paleozoic, Mesozoic and Cenozoic sediments (see Fig. 6.1).

Occurrence of mineral waters different in their forming condition, chemical composition and medical properties is characteristic for the area. These are waters without specific components, iodine-bromine and sulfur hydrogen waters. Their medical parameters are being defined depending on mineralization, chemical composition and content of distinct components. Besides mineral waters, economic bromine, iodine, iodine-bromine and iodine-boron-bromine waters are also developed in the studied area. In the zone of active water exchange the water-bearing horizons contain fresh waters providing the base for water scoops supplying waters for Ivano-Frankivsk town, area centers and other inhabited localities.

Geological, tectonic and hydrogeological features had caused not only diversity of underground waters but also defined regular distribution of their main types. Clear enough hydro-chemical zonation is characteristic for the waters of platform and Bilche-Volytska LTZ. The waters in upper column part, where extensive water exchange occurs, are fresh, hydrocarbonate or sulphate in composition, mineralization is in the range 0.3-1.0 g/dm³. Below in the column the water composition is gradually changed to sulphate-chloride, in places hydrocarbonate-chloride; at the column base – to chloride one. At the same time, the gradual increasing of mineralization is observed.

The vertical hydro-chemical zonation in Sambirska and Boryslavsko-Pokutska LTZs is not consistent. Due to leaching of salt-bearing sediments, the mineral waters and brines with mineralization from 2-3 to 400 g/dm³ and more are being formed. Composition of these waters and brines is variable: chloride sodium, sulphate sodium, chloride-sulphate magnesium-sodium.
Mineral waters

Waters without distinct components and properties

These waters are almost throughout developed in the territory and are intersected at various depths in sediments from Neogene to Jurassic. By genesis they are atmospheric infiltration leaching waters and exhibit wide range of chemical composition: from hydrocarbonate-sulphate magnesium-calcium-sodium to chloride calcium-sodium. Bulk mineralization of waters and brines is 2-335 g/dm³. Predominating mineralization values are from 2 to 15 g/dm³. The waters are of various chemical composition and mineralization; they are used as medical-potable and medical (for external use).

In total, over map sheet area 36 occurrences and one deposit of waters (without distinct components) are encountered (see Annex 1). Of these:

1. Most developed waters (15 occurrences) are sulphate, hydrocarbonate-sulphate calcium, sodium and mixed cationic composition with mineralization from 2 to 4.3 g/dm³ including occurrences: Dobrivlyanske (I-2-23), Konyushkynske (I-3-29), Kolokolynske (I-3-33), Bovshivske (I-3-42), Yablunivske (I-4-47), Dorogivske (II-3-67), Selyshchanske (II-3-68), Temyrivske (II-3-70), Pervozetske (II-4-76), Kolodivske (III-4-145), Gannusivske (III-4-146), Uzynske (III-4-148), Mylovanivske (III-4-149), Pidpecherske (III-4-152).

2. Chloride-sulphate sodium, calcium-sodium with mineralization 3.9-4.0 mg/dm³ in Chagrivsky (I-3-34) and Blyudnytskiy (II-3-69) occurrences related to Tyraska and Lukvynska suites sediments. Water types are “Uglytskiy” and “Feodosiyskiy”.

3. Chloride-sodium, calcium-sodium-magnesium with mineralization 2.3-4.7 mg/dm³ in Lukskiy (I-3-42), Pavlivskiy (III-3-135), Slyvky (IV-1-169), Vorotyshchenskiy (IV-3-218) occurrences and Pidlyutenske deposit (IV-1-171). These waters are mainly developed in Fore-Carpathian artesian basin and related to Neogene-Paleogene sediments. Water types are “Khilovskiy”, “Minskiy” and “Myrgorodskiy”. Pidlyutenske deposit of mineral water “Peregynska” is located in the Limnytsya River valley (gorge “Pidlyutne”). The column includes thick sequence of Paleogene flysch. Water-bearing horizon is confined to fractured sandstones of Vygodska Suite. The waters are chloride sodium with mineralization 2.31-2.71 g/dm³. By main composition, bulk mineralization, concentration of admissible micro-components and compounds the water belongs to mineral natural medical-potable waters and can be used for commercial bottling [146].

4. Chloride, sulphate-chloride sodium waters with mineralization 9.6-15 g/dm³ in Ugrynivskiy (III-3-136), Vovchynetskiy (III-3-137) and Rosilnyanskiy-II (IV-2-179) occurrences related to sediments of Tyraska, Vorotyshchenska and Nyzhniivska suites. Water types are “Kaspiyskiy” and “Myrgorodskiy”.

5. Chloride, magnesium-sodium sulphate waters (brines) with mineralization from 118 to 310 g/dm³ are developed in Fore-Carpathian artesian basin; include Turyanskiy (II-1-50), Rakhyyna (III-1-86), Obolonya (III-1-93), Novytskiy (III-2-120), Petrankivskiy-I (III-2-124), Petrankivskiy-I (III-2-125), Krasne-I (III-2-129), Krasne-II (III-2-131), Rosilnyanskiy-I (IV-2-175) occurrences. The waters are confined to Vorotyshchenska and Balytska halogenic formations. Water types are “Moskovskiy” and “Usolskiy”. They can be used (under dilution) as drinking medical waters and for external use.

6. Sulphate-bearing medical brines include unique high-mineralized chloride-sulphate magnesium-sodium waters of “Morshynskiy” type with high (more than 20%) sulphate and potassium contents. They are only developed in Fore-Carpathian salt-bearing basin and confined to salt-bearing sequences of Vorotyshchenska and Balytska suites and genetically linked with potassium and potassium-magnesium salt bodies. Often these waters are observed together with chloride sodium brines. The leaching of secondary and primary salts of potassium bodies in the zone of salt plane comprises the major composition-forming factor in sulphate-bearing brines. Here major water enrichment in various components occurs. Water chemical composition depends on composition of salt bodies. The setting of potassium salt beds beneath the gypsum-clayey “cap” defines the spatial boundary of these medical brines. In the studied area the brines are represented by three occurrences: Kaluskiy-I (II-2-58), Kaluskiy-II (II-2-60) and Molodkivskiy (IV-3-220); in generalized Karlov formula their composition is as follows:

\[
M^{275-335} \frac{SO_4^{38-73}; C/28 - 61}{Na^{37} - 56; Mg^{25} - 42; K^{15} - 22}
\]
Due to low filtration properties of brine horizons their natural resources are limited.

**Iodine-bromine**

One deposit of iodine-bromine water – Starolysetske (III-3-139) is known in the studied area; it is located in the north-eastern outskirt of Starly Lysets village. In tectonic respect deposit is located in Stanislavskva sub-zone of Bilche-Volytska LTZ. Productive water-bearing horizon is intersected at the depth 197 m in fractured sandstones of Upper Cretaceous Zhuravnenska Suite. Mineral-medical waters of deposit are iodine-bromine chloride sodium brines with bulk mineralization 35.3-42.3 g/dm³. Bromine and iodine concentration in water is 31.9-58.1 and 14.5-23.4 g/dm³ respectively. On dilution the mineral water can be used as medical-potable.

**Sulfur hydrogen**

Sulfur hydrogen (sulphide) waters encountered in the area of Sarnyky and Tomashivtsi villages are the waters for external use, hydrothermal-sulphate magnesium-calcium (occurrences I-3-28, 35; II-2-53, see Annex 1). The waters are formed in the zone of active water exchange through leaching of Tyraska Suite gypsum-bearing sediments. Origin of sulfur hydrogen in underground waters is thought to be related to the processes of sulphate-reduction – biogenic sulphate reduction by sulphate-reducing bacteria. Sulfur hydrogen formation is accompanied by sulfur deposition.

**Fresh**

**Drinking waters**

Resources of fresh waters are limited and their distribution over the map sheet territory is irregular. Solution of water-supplying problems for inhabited localities and industrial enterprises here is mainly based on use of waters in alluvial sediments. In the Dniester left-bank side the reliable household water source are the waters from water-baring horizon in Middle-Lower Badenian and Lower-Upper Cretaceous sediments but their resources are insufficient for centralized water supplying. In Fore-Carpathians in limited amounts are being used the waters confined to sandy piles of Dashavska and Kosivska suites. In Carpathians the needs are being covered by the waters related to Upper Pleistocene alluvial sediments and springs which drain up the water-bearing sequence confined to the fracturing zone in Cretaceous-Paleogene flysch rocks.

The centralized water supplying of all major inhabited localities is being provided only from the water-bearing sequence related to Upper Pleistocene alluvial sediments. In total, in the area of these rocks development, 10 deposits with explored and approved reserves of drinking waters are located: Zhuravnenske (I-2-238), Dobrivlyanske (II-2-270), Kaluske (II-2-271), Vistova (II-2-272), Shevchenkivske (II-3-273), Galyske (II-3-275), Rozhnatyivske (III-1-296), Khotynske (III-2-302), Cherniivske (III-3-309), Bogorodchanske (IV-3-324) – all in Annex 2. Most of these deposits are currently in production.

Burshtynske deposit (I-3-39, see Annex 1) is related to the water-bearing horizon in Cretaceous sediments; these waters are mainly being used for the needs of Burshtynska power station.

Besides deposits with explored and approved reserves, there are some tens of single small-size water scoops in the studied area which exploit the waters of modern and Upper Neo-Pleistocene alluvial for the needs of certain organizations and enterprises.

**Industrial waters**

In the underground waters the high concentrations of bromine and iodine, rarely boron are observed which in places exceed the modern industrial conditions. These waters are intersected in Cambrian, Upper Jurassic, Upper Cretaceous, Paleogene and Neogene sediments by numerous boreholes drilled for oil and gas in Bilche-Volytskiy and Boryslavsko-Pokutskiy oil-gas-bearing areas. The spatial association of high-mineralized waters with mentioned micro-components to the oil and gas deposits suggest for their genetic link with hydrocarbon accumulations.

In total 26 occurrences of these waters are encountered (see Annex 1). By chemical composition these are chloride sodium and chloride calcium-sodium waters with mineralization from 43 to 383 g/dm³.

Besides noted industrial waters, the salt-bearing sequences of Vorotyshchenska and Balytska suites contain the natural sodium brines which are being used for evaporation of food salt (see section “Salts”).
**Bromine**

According to requirements, bromine content in case of separate extraction should be not less than 250 mg/dm³. These requirements are matched by two occurrences in the area of Kalush (II-2-63) and Starunya (IV-2-211). The waters are chloride sodium with mineralization 319-321 g/dm³ and bromine content 374-496 mg/dm³.

**Iodine**

The lower iodine concentration limit in case of separate extraction is 18 mg/dm³. These requirements are matched in three occurrences: Lyskivskiy (I-1-11), Nyzhnoostrutynskiy (III-1-96) and Grabivskiy-I (III-2-126) where chloride sodium brines with mineralization from 53 to 119 g/dm³ and iodine content 26.0-50.7 mg/dm³ are developed.

**Iodine-bromine**

These waters (brines) are most widespread among other industrial waters (16 occurrences, see Annex 1). Their industrial value is defined by bromine content not less than 200 mg/dm³ and iodine – not less 10 mg/dm³. The brines are chloride sodium and chloride calcium-sodium in composition with mineralization from 43 to 383 g/dm³.

In Bilche-Volytska LTZ the brines, most enriched in iodine and bromine, are intersected by drill-holes in Grynivske gas deposit in Cambrian, Jurassic, Cretaceous and Neogene sediments (occurrences II-2-65, 66; III-2-118, 122, 123 and others) at the depth 898-2350 m. Iodine content is from 22.8 to 88.8 mg/dm³, bromine – from 220 to 531.4 mg/dm³.

In Boryslovsko-Pokutska LTZ the major water-bearing units include thin layers and interbeds of Paleogene sandstones with low container properties. Specific feature of bed waters in Paleogene sediments is their pressure including high abnormal bed pressure and spouting over the borehole head. Although abnormal pressure of bed liquids (water and oil) in places is high enough at the head, the yield of self-outflowing boreholes are low and somewhere only attains 200-500 m³/day. Water mineralization varies from 50 to 300 g/dm³ and more regardless the depth of water-bearing horizon; iodine content is from 12.7 to 53 mg/dm³, bromine – from 254 to 804 mg/dm³. These waters occur in Yasenovetskiy (III-1-102), Ivanivskiy (III-1-114), Dzvyynatskiy-I (IV-2-183), Maydanskiy (IV-2-187), Dzvyynatskiy-III (IV-2-191), Starunskiy-I (IV-2-206) and Starunskiy-III (IV-2-212) occurrences.

**Iodine-boron-bromine**

The lower limits of iodine, boron and bromine concentrations in the waters under their complex extraction are (mg/dm³): I – 10; B₂O₃ – 150, and for boron concentrates preparation – 200; Br – 200. These requirements are matched by the brines developed in the area of Dzvyynatskiy and Starunske oil-gas deposits – Dzvyynatskiy-II (IV-2-186), Nadiya-I (IV-2-204), Starunskiy-II (IV-2-208) occurrences, and in the area of Nazavyzov (occurrence IV-3-221). The brines are chloride sodium, chloride calcium-sodium with mineralization 263-292 g/dm³ and contents (mg/dm³): I – 15-38.0; B₂O₃ – 200-456.8; Br – 200-461.9. The brine-bearing horizons are related to sediments of Vorotyshchenska (Neogene) and Nyzhnivska (Upper Jurassic) suites.
8. ASSESSMENT OF THE AREA PERSPECTIVES

The leading mineral resources developed in the studied area include hydrocarbons (gas, condensate, oil), peat, native sulfur, construction raw materials, potassium-magnesium and sodium (rock) salts, underground waters. Assessment of their perspectives is conducted on the ground of factual data and recent scientific developments concerning geology of the territory, history of its geological development and regularities in mineral formation and distribution.

Combustible minerals

Gas, oil

In the studied area the small deposits and numerous oil-gas occurrences are found so far only in Boryslavsko-Pokutski and Bilche-Volytskiy oil-gas-bearing areas which encompass the same-named lithotectonic zones. Here 21 hydrocarbon deposits are known of which five gas, three gas-condensate, 10 oil, and three gas-oil deposits (see Annex 1). The oil, gas-oil and gas-condensate deposits are located in Boryslavsko-Pokutski oil-gas-bearing area and are related to Paleogene flysch and Lower Miocene molassa complexes while free gas deposits – mainly in Bilche-Volytskiy oil-gas-bearing area. In the latter the gas containers include sandy horizons in Upper Badenian – Lower Sarmatian sandy-clayey sequence.

The hydrocarbon resources are essentially exhausted nowadays. Of 16 deposits in Boryslavsko-Pokutski oil-gas-bearing area three ones are closed (Nebylivske, Maydan ske and Starunske), one is out of production (Dzvynyatske), and remaining deposits are in production. Perspectives for discovery of new hydrocarbon traps in deposits are mainly related to their deep portions at the depth more than 4-5 km.

In Bilche-Volytskiy oil-gas-bearing area Dashavske, Kadobnyanske and Bogorodchanske deposits are about to complete gas production and single still producing horizons are being exploited over there. Exhausted traps in these deposits are being used as the large gas storage of international value. Lyubeshivske deposit in 2001 is entered into trial-commercial exploitation. Perspectives for gas production increasing in Grynivske deposit are related to discovery of still not drained gas-bearing horizon portions along the margins of Grynivske uplift.

Despite of high study degree of Boryslavsko-Pokutski and Bilche-Volytskiy oil-gas-bearing areas and a number of known hydrocarbon deposits, the oil-gas potential of these areas is thought to be fairly significant still. Here is possible discovery of new economic objects confined to some prospective structures identified by seismic works [74]. By study degree, these structures are subdivided into just identified, those prepared for prospecting-exploration drilling, and those involved in prospecting-exploration drilling (see Fig. 7.2). Structures, fluid type and prospective complexes are summarized in the table 1 [74].

The perspectives for discovery of new hydrocarbon traps are being related to the traditional directions first of all – study of Paleogene flysch complex in deep folds of Boryslavsko-Pokutski zone and Badenian-Sarmatian sediments of Kosivsko-Ugerska sub-zone in Bilche-Volytska zone. It is also recommended to perform prospecting for hydrocarbon traps in sediments of Skybova zone. Here reserve upgrade is expected from Cretaceous and Paleogene flysch sediments in the frontal nappes and para-autochthonous elements of the zone. In this area, Syvakivska structure is encountered by seismic survey and Lypovetska and Ilemkivska structures are prepared for prospecting-exploration drilling.

At present one of the crucial tasks in hydrocarbon searching comprises identification of prospective structures at low (up to 1500 m) depth. In Kosivsko-Ugerska sub-zone the possibility of new gas trap discovery at low depth is supported by Lyubeshivske deposit encountered late in 90th of last century in Sarmatian sediments. The first-order objects for gas prospecting include Makhlynetska, Zarichnyanska, Nevochynska and Chertyzhka perspective structures where the depth of productive horizons is 1.0-1.5 km.

Considerable interest is provided by Kosivska Suite sediments developed in the south-eastern part of Stanislavsko sub-zone in the area of Kolomiyska depression. Here, in the territory adjacent from the east, minor gas traps are encountered in Cheremkhivska-Strupkivske deposit. Since containers and fluid-proofs of Kosivska Suite sediments as well as lateral bounding in the area of Kolomiyska depression and mentioned deposit are similar, it is expected discovery of lithologically bounded traps in the studied area. Gas-bearing features here are related to the enveloping of pre-Neogene relief erosion remnants by Upper Badenian sandy lenses. The gas
potential here is supported by numerous gas emanations (area of Chornoliztsi, Lisniy Khlibychyn, Khomyakivka villages) noted in the course of drilling for gas and sulfur.

### Table 1

<table>
<thead>
<tr>
<th>No. in map of oil-gas-geological zonation (see Fig. 7.2)</th>
<th>Structure</th>
<th>Fluid type</th>
<th>Square, km²</th>
<th>Prospective complex (stratigraphy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Fore-Carpathian oil-gas-bearing region</td>
<td></td>
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<td></td>
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<tr>
<td>1. Boryslavsko-Pokutskiy oil-gas-bearing area</td>
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<td></td>
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<tr>
<td>a – identified structures</td>
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<tr>
<td>10 Sukhodilska</td>
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<td>29.3</td>
<td>P₂</td>
<td></td>
</tr>
<tr>
<td>15 Kryvetska</td>
<td>Gas</td>
<td>18</td>
<td>P₂</td>
<td></td>
</tr>
<tr>
<td>16 Velykopolivska</td>
<td>Gas</td>
<td>15</td>
<td>P₂</td>
<td></td>
</tr>
<tr>
<td>17 Zakhidno-dzynyatyska</td>
<td>Oil</td>
<td>6.2</td>
<td>P₂</td>
<td></td>
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<tr>
<td>b – structures prepared for prospecting-exploration drilling</td>
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<td></td>
<td></td>
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<tr>
<td>13 Skhidnobogrivska</td>
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</tr>
<tr>
<td>18 Pivnichnogvizdetska</td>
<td>Oil</td>
<td>17</td>
<td>P₂</td>
<td></td>
</tr>
<tr>
<td>19 Pivdennomonastyrchanska</td>
<td>Gas</td>
<td>6.0</td>
<td>P</td>
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<tr>
<td>c – structures involved in prospecting-exploration drilling</td>
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<tr>
<td>7 Vilkhivska</td>
<td>Gas</td>
<td>6.0</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>11 Grynkivska</td>
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<td>11.0</td>
<td>P</td>
<td></td>
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<tr>
<td>12 Bogrivska</td>
<td>Oil &amp; gas</td>
<td>5.2</td>
<td>P₂</td>
<td></td>
</tr>
<tr>
<td>14 Skhidnolukvymska</td>
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<td>P</td>
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<td>2. Bileche-Volytskiy oil-gas-bearing area</td>
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<tr>
<td>a – identified structures</td>
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<td></td>
</tr>
<tr>
<td>1 Makhlynetska</td>
<td>Gas</td>
<td>6.2</td>
<td>N₁s</td>
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<tr>
<td>4 Nevochynska</td>
<td>Gas</td>
<td>9.0</td>
<td>N₁b</td>
<td></td>
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<td>b – structures prepared for prospecting-exploration drilling</td>
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<td></td>
<td></td>
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<tr>
<td>3 Chertyzhiska</td>
<td>Gas</td>
<td>51.6</td>
<td>N₁,b-s</td>
<td></td>
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<tr>
<td>5 Mocharivska</td>
<td>Gas</td>
<td>9.0</td>
<td>N₁b</td>
<td></td>
</tr>
<tr>
<td>c – structures involved in prospecting-exploration drilling</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2 Zarichnyanska</td>
<td>Gas</td>
<td>40.0</td>
<td>N₁s</td>
<td></td>
</tr>
<tr>
<td>B. Carpathian oil-gas-bearing region</td>
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<tr>
<td>1. Skyboviiy oil-gas-bearing area</td>
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<tr>
<td>a – identified structures</td>
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<td></td>
</tr>
<tr>
<td>8 Syvakivska</td>
<td>Oil</td>
<td>8.0</td>
<td>K₁</td>
<td></td>
</tr>
<tr>
<td>b – structures prepared for prospecting-exploration drilling</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>6 Ilemkivska</td>
<td>Oil</td>
<td>9.5</td>
<td>P₂</td>
<td></td>
</tr>
<tr>
<td>9 Lypovetska</td>
<td>Oil</td>
<td>24.0</td>
<td>P₂</td>
<td></td>
</tr>
</tbody>
</table>

Hydrocarbon perspectives of Volyno-Podilska oil-gas-bearing region, which encompasses the platform part of map sheet, are related to Paleozoic rocks [69]. It is evidenced by gas traps in Devonian sandy-clayey complexes discovered in the field Velyki Mosty adjacent from the north, as well as direct gas indications in Cambrian sediments in Peremyshlyanska field where methane fountain with bed water was observed over single day.

**Peat**

The natural environments of the studied area are not favourable for peat deposition as it is evidenced by:

i) discovery of only minor peat deposits with very limited reserves; 
ii) high study degree of the area. And only in the Dniester left-bank side, in the Svirzh and Gnyla Lypa valleys, at the more detailed prospecting, discovery of small (up to 10-20 ha) sites with thin, mainly high-ash carbonate peat.

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Native sulfur

To date none of sulfur deposits discovered in the map sheet territory is in production. Until the end of 90th of last century sulfur had been being mined by quarry-autoclave method only in the Main body of Podorozhnenkes deposit. Here sulfur reserves are almost exhausted. Remained bodies of this deposit by their depth are suitable for underground sulfur melting only. However, low body thickness, insufficient reserves and very low water-permeability of sulfur ores make no sense their exploitation.

Study degree of small-reserves Zhuravnenske and Lysetske deposits remained at the stage of detailed prospecting. Perspectives for reserve upgrade are only possible in Lysetske deposit upon more detailed studies in the area of Central body.

Considerable perspectives for discovery of new sulfur bodies are evidenced by geological and geophysical data as well as results of prognostic studies repeatedly conducted in the previous years. By general favourable geological-geophysical factors (stratigraphic, lithological, tectonic) and integrated prospecting evidences, in the map sheet territory one prospective (Pidgirskaya) and three prognostic (Bolekhiv-Kadobno, Kalush, Grynivka) sites are distinguished where discovery of new economic sulfur bodies is expected (see Fig. 7.4) [78, 138].

Pidgirskaya site is located in Stanislavska sub-zone in the south-eastern extension of Podorozhnes deposit. It is confined to the uplifted limb of Kalukskiy normal fault where at the depth up to 300 m sulphate-carbonate rocks are widely developed being favourable for sulfur-ore metasomatism, as well as secondary limestones which in places contain sulfur pods and bunches. Here the sulfur ore layer of economic grade is discovered (occurrence II-2-64). The site exhibits characteristic indirect evidences for sulfur-bearing: sulfur hydrogen waters, rock pyritization at the bottom of Kosivska Suite, rock enrichment in sulfur hydrogen, proximity of Grynivske and Kadobnenske gas deposits. It is assumed discovery of small sulfur bodies in this site.

Potential reserve for discovery of new sulfur deposits is Neogene Tyraska Suite developed in the deeply buried portion of Bilche-Volytska LTZ (Kosivsko-Ugerska sub-zone). Here productive horizon lies at the depth from 800 to 1800 m. The horizon is not studied by specialized prospecting works. However, in the mentioned sub-zone a number of prospecting and deep boreholes for oil and gas are drilled and these data, especially results of logging plots were used for assessment of the area sulfur-bearing with definition of prognostic sites – Bolekhiv-Kadobnenska, Kaluska and Grynivska [78, 138]. The sites are located in the limits of gas-bearing anticline structures along ore-control deep-seated faults (Krakovetsko-Striyskiy, Sudovo-Vyshnyanskiy and Kaluskiy), at the intersections of longitudinal and latitudinal faults, in the zones of gypsum-anhydrite horizon pinching out. After study results of single core sections and slurry, as well as logging data, it was established that possible productive sequence in these sites is composed of sulphate-carbonate rocks. In some drill-holes “over-gypsum” and “under-gypsum” secondary limestones of essential thickness are distinguished. The hydrochemical anomalies are observed with sulphate-ion content in deep waters from 102 to 840 mg/dm³.

It should be noted that primary data on Tyraska Suite sediments developed in the deeply buried Kosivsko-Ugersko sub-zone are not sufficient for proper assessment of their sulfur-bearing potential. Should the needs appear for discovery of sulfur deposits at these depths, the deep geological mapping has to be conducted over defined areas first of all. This is because potential productive sequence is intersected over there by boreholes for oil and gas only drilled almost without core sections.

Construction raw materials

All deposits of construction raw materials known in the studied area do have significant reserve potential. Over last years production from most of these deposits is suspended due to low profitability and changes in technologies of construction materials manufacturing. Explored reserves completely meet demands of construction industry for many years ahead. By these reasons further prospecting and exploration for new deposits at present seems not reasonable.

Salts

The territory of map sheet M-35-XXV (Ivano-Frankivsk) belongs to one of the most prospective salt-bearing parts of Fore-Carpathian salt-bearing basin. In the Neogene Vorotyshchenska and Balytska salt-bearing formations 8 deposits of potassium-magnesium salts, three deposits of sodium (rock) salts and one deposit of natural chloride sodium brines are discovered. However, potential for new salt deposit discovery is not exhausted yet.
Potassium-magnesium salts

Of all potassium-magnesium salt deposits the most explored in details is Kalush-Golynske deposit which comprise industrial base of Kaluskiy chemical-metallurgical plant. In this deposit, as far back as 70th of the last century, the salt reserves of all blocks in Kaluske ore field were mined by underground method. In Golynske ore field the salt reserves in East and West Golyn as well as Syvka Kaluska blocks were executed in 1996. Dombrovo block comprises the only producing site which is being periodically mined by Dombrovskiy quarry. Outdated and depreciated technology and equipment had caused permanent reduction in potassium salt outcome. In addition, low quality of active salt reserves in operating mines comprises important reason for outcome reduction. At present the Piyo site is in preparation for mining. However, the active reserves in this site are insufficient for newly-developed mine and it cannot provide the profitable salt production. In view of initial needs for increasing potassium fertilizers production rate the preparation of upgraded potassium salt resource base is urgently required. There are no major deposits nearby Kaluskiy potassium plant which can be exploited by single mine and the grounds to expect discovery of such deposits are also lacking. Trostyanets and Velyka Turya deposits located in 20 km to the west from Kalush are weakly studied and do not have significant perspectives.

It is thought that Rosilnyansko-Markivska potassium-bearing area is most prospective for additional resource base preparation with regard to operating enterprise or for resource base creation at the new plant; this area is located in 30-40 km to the south from Kalush town and includes Rosilnyanske, Dzvynyatske, Starunske, Markivske and Molodkivske deposits.

In the studied area potassium salt bodies are found at the sites which can be considered as potentially prospective for new potassium deposits [96, 97, 136, 137]. Occurrence of economic bodies is assumed not only on the ground of direct evidences but also from the integrated indirect geophysical and hydro-chemical anomalies, geomorphologic factor etc. By the rate of perspectives seven prospective (resource categories P1 and P2) and three prognostic (resource category P3) sites are distinguished which, respectively, belong to high-, medium- and low-perspective ones (see Fig. 7.5).

High-perspective sites with resource category P1 encompass the flanks of Rosilnyansko-Markivska group of deposits: Rosilnyanske, Dzvynyatske, Markivske and Molodkivske. In this potassium-bearing area, besides perspectives for reserve upgrade in the deposit flanks, the sediments of Vorotyshchenska Suite should be studied for potassium salts; these sediments are developed in the band between Dzvynyatske, Starunske and Markivske deposits and are overlain by Stebnytski rocks.

In the north-western part of Boryslavsko-Pokutska LTZ (Vorotyshchenska salt-bearing formation) two medium-perspective sites are distinguished: Dolyna – Verkhniy Strutyn and Tsenyava – Krasne. Occurrences of kainite, kainite-langbeinite and polyhalite rocks are found over there in some boreholes. They are arranged in the lens-like beds quickly pinching out by strike.

In the south-eastern extension of Dolyna – Verkhniy Strutyn site prognostic site Yasenovets – Peregyenske is defined which remains almost not studied. Here single boreholes only have intersected salted sediments with halite rock interbeds [131]. Detailed geophysical survey by electric profiling had revealed, with some discontinuity, from one to two-three anomalies of increased resistance which are thought to be the salt beds projection beneath gypsum-clayey “cap”.

Remained weakly-studied site in Sambirska LTZ (Balytska salt-bearing formation) include those located nearby Velyka Turya and Trostyanets deposits (Mali Didushychi – Velyka Turya and Velyka Turya – Sloboda Dolynska sites) and in the area of Rozhnyativ village (Rozhnyativ – Rivnya site). Of these, Mali Didushychi – Velyka Turya site, located in 2 km to the north from Velyka Turya deposit, is most prospective. Here, after electric survey data, 3 km long and 500-600 m wide anomalous zone of increased resistance is traced and partly checked up by prospecting drilling for salts [136]. Polyhalite, kainite and sylvine interbeds, pods and bunches are intersected in one drill-hole. Evidences for potassium-magnesium salts in the site also include the brine well in Velyka Turya village with sulphate-chloride magnesium-sodium waters; their genesis is thought to be related to the salt leaching. Salt-bearing sediments are weakly studied by drilling both in lateral direction and to the depth.

The rocks of Balytska salt-bearing formation remained almost unstudied by specialized prospecting works for salts in the areas Velyka Turya – Sloboda Dolynska and Rozhnyativ – Rivnya. The first site is located to the south-east from Velyka Turya deposit. Here, after electric survey data, the salt-bearing sediments are traced further to the south-east from the lenses of the latter deposit and this is also supported by data from single boreholes drilled for oil and gas. In addition, in one drill-hole halite rock is intersected with up to 2 cm thick polyhalite interbeds and sylvine pods.
In the site Rozhnativ – Rivnya the boreholes drilled in the course of geological mapping [54] the band of salt-bearing Balytska Suite sediments is encountered. In two drill-holes potassium salt dissemination is noted. After electric survey data the anomalous zones are defined apparently caused by salted rocks and salt beds.

Potassium industry of Ukraine is only based in Fore-Carpathian salt deposits where two potassium plants were operated – Kaluskiy and Stebnytskiy. At present they are actually suspended or minor production amounts are released from time to time. Nevertheless, Fore-Carpathian potassium deposits are unique for manufacturing of high-demand sulphate fertilizers. Ukrainian demands in potassium fertilizers are met by less than 20%. At the same time, even in the studied area amount of potassium-magnesium salt reserves with high upgrading potential suggest for availability of significant resource base for halurgy industry.

The opportunities to increase the output of potassium fertilizers include reconstruction of operating enterprises, development of known deposits and discovery of new ones, as well as application of new mining technologies, specifically, underground leaching of potassium salts through boreholes. This method could allow development of small-scale deposits (like Velyka Turya, Trostyansetske and others) as well as reduction of environment impact and mining costs. Development of numerous deposits by shaft-less geotechnological mining will allow not only sharply change the complex and expensive technology of potassium salt mining but also resolve the issue of high-demand in these slats for the agriculture.

To increase efficiency of prospecting for potassium and potassium-magnesium salts it is necessary to conduct in Sambirska and Boryslavsko-Pokutskas LTZs geological mapping in the scale 1:50 000 with study depth 300-500 m and more, first of all, over perspective for potassium fields (map sheets M-35-97-C, -109-A,B,D). Geological mapping in 60th of last century has been normally accompanied by drilling of shallow (5-60 m) mapping holes which in most cases did not intersect even gypsum-clayey “cap” and did not enter hard salt-bearing rocks. This is why available geological maps in the scale 1:50 000 for mentioned zones are not suitable for use as the geological base for salt prospecting.

The first-order works in the studied area aiming perspectives definition and creation of potassium salts reserve base for Kaluskiy chemical-metallurgy plant include:

- extended exploration over the flanks of Rosilnyansko-Markivska group of deposits;
- data preparation for the draft of requirements over Rosilnyansko-Markivska group of deposits;
- data preparation for the draft of requirements over Kalush-Golynske deposit; potassium salt reserve re-estimation for Piylo and Dombrovo sites;
- prospecting in the sites Mali Didushychi – Velyka Turya and Velyka Turya – Sloboda Dolynska aiming reserves upgrade in Velyka Turya deposit;
- prospecting in the sites Dolyna – Verkhniy Strutyn and Tsenyava – Roshnyate where potassium salts are encountered in drill-holes and surface geophysical survey is conducted.

**Sodium salt and natural brines**

In the studied map sheet the perspectives for discovery of economically-valuable natural brines of chloride sodium composition, suitable for the food salt manufacturing, are low. It is caused by too low productivity of these brines and high content of harmful components.

Genetically the brines are linked with gypsum-clayey “cap” of Neogene Vorotyshchenska and Balytska salt-bearing formations. The industry standards, including yield values, mineralization and harmful admixture contents, are only matched by the brines of Dolynske deposit but their reserves cannot meet increasing demands of Dolynskiy salt plant. Prospecting and prospecting-evaluation works, undertook in around deposit, had revealed limited development of the brine horizons and their low water content. This makes impossible upgrading resource base of Dolynskiy plant from additional reserves of chloride sodium brines [59]. The raw material can be obtained from rock salt of Verkhnostrutynske, Yasenovetske, Dolynske and Roshnyativske deposits located close to the salt plant. The salts of these deposits in view of insoluble residuum high content are only suitable for underground leaching, formation of saturated brines and further food salt manufacturing through evaporation.

Of the salt deposits Verkhnostrutynske is only explored in details and prepared to industrial development. Salt reserve upgrade is possible in Yasenovetske deposit located in 1.5 km to the south-east the latter.

Rock salt in Dolynske deposit located in direct proximity to Dolynskiy salt plant (area of “Novychka” and “Odynytsya” brine shafts) is of high quality containing up to 94% of NaCl. However, main salt reserves are restricted to the inhabitant building sites and roof pillars and, therefore, are not suitable for exploitation.

Roshnyativske deposit by study degree matches preliminary exploration requirement and its resources can cover salt plant needs for two amortization periods. However, this deposit is not recommended for
development in the coming years [142]. Thus is because of relatively low NaCl content (68-69%), low thickness of individual beds and complex mining-technical exploitation conditions.

The high potential for rock salt discovery is related to the salt-bearing sediments of Balytska Suite developed in the area of Grynivka and Sadzhava villages. Here the prospective site is defined where thick halite rock is intersected with average NaCl content in excess of 80% [134]. Rock salt reserves in this site can provide mineral resource base for the foreseen salt plant in Ivano-Frankivska Oblast. The site is recommended for prospecting-evaluation works.

Underground waters

Mineral waters

In the map sheet area, besides two deposits (Pidlyutenske and Starolysjetske), a number of mineral water occurrences of various types are encountered; on this ground the perspective sites are defined for further study of their hydrogeological conditions and opportunities for medical purposes [102]. In total, 14 perspective sites are defined comprising mineral water points without specific components and properties; in view of existing ecological and recreation conditions, creation of sanatorium-resort units and bottling plants is possible over there. Information on these sites – water points is given in Table 2.

Discovery of unique medical sulphate-bearing brines of Morshynskiy type is also expected in the sites of potassium-magnesium salt beds beneath gypsum-clayey “cap” in Rosilnyanske, Dzvynyatske, Starunske and Markivske salt deposits [102].

In Stanislavska sub-zone the site of Tyraska Suite sulphate-carbonate sequence in vicinity to Kaluskiy normal fault is thought to be perspective for deposits of sulfur hydrogen waters.

The mineral water potential, favourable nature-recreation conditions, developed paved road and railroad network in the area provide necessary ground for resorts creation and bottling plants construction.

Fresh

To meet continuously increasing demands of major inhabited localities in fresh water their further prospecting should be concentrated first of all at the sites of wide development of alluvial sediments in the flood-land and first three over-flood terraces.

Industrial waters

Iodine-bromine

Despite of wide development of iodine-bromine waters and brines with micro-component concentration essentially exceeding the standards, the issue of their practical use is not solved. This is mainly caused by discontinuity of productive water-bearing horizons, low and inconsistent water yields. The standard yield for commercial production should be not less than 200-500 m³/day. Water-bearing horizons with such yields are only intersected in Grynivka (Bilche-Volytska LTZ) and Dzvynyach-Starunya (Boryslavsko-Pokutksa LTZ) sites.

Grynivka site is located in the limits of Grynivske gas deposit. The water-bearing horizons of iodine-bromine waters are confined to the Cambrian, Jurassic, Cretaceous and Neogene (Badenian) sediments. The water content of all these horizons except Cretaceous one is low (yields do not exceed 118 m³/day). The major water-bearing horizon of iodine-bromine waters is intersected at the depth 1000-1500 m and confined to sandstones of Verbizka Suite (Upper Cretaceous). The bulk water mineralization is from 92 to 184 g/dm³, yield from 400 to 690 m³/day, iodine content 22-62.8 mg/dm³ and bromine – 280-377.8 mg/dm³. The favourable geological-hydrogeological parameters suggest for perspectives of iodine and bromine extraction from this horizon.

Dzvynyach-Starunya site encompasses the same-named oil-gas deposits. This site exhibits distinct geological structure and hydrogeological conditions. Dzvynytska and Starunska folds do have very steep limbs and high hydrodynamic regime expressed in the abnormal bed pressure. This causes extensive water and oil-gas inflows in the course of drilling and high for Fore-Carpathians water yields at outflow. The underground waters in Paleogene and Neogene sediments are high-mineralized (220-383 g/dm³) and metamorphosed, with chloride calcium-sodium composition. The micro-element content is high: bromine – from 400-550 to 804 mg/dm³; iodine – from 12-20 to 37 mg/dm³; B₂O₃ – up to 200-456 mg/dm³. Borehole yield at self-outflow is up to 200-
500 m³/day. The brine outflow is observed for many years from the old boreholes as gryphons suggesting for high bed energy resources. The site Dzvynyach-Starunya, in view of high yield of iodine-bromine and iodine-boron-bromine waters, can be ascribed to most prospective in Boryslavsko-Pokutksa LTZ.

Table 2

<table>
<thead>
<tr>
<th>Site – water point number in geological maps*</th>
<th>Location</th>
<th>Recreation conditions</th>
<th>Ecological conditions</th>
<th>Water type</th>
<th>Recommendations for use</th>
<th>Medical parameters**</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-2-23 Zhravenky village, Rogatynskiy area</td>
<td>good</td>
<td>good</td>
<td></td>
<td>Krainskiy</td>
<td>drinking resort and</td>
<td>1-7</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td>bottling plant</td>
<td></td>
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<tr>
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<td>good</td>
<td></td>
<td>Krainskiy</td>
<td>bottling plant</td>
<td>1-7</td>
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<td>bad</td>
<td></td>
<td>Krainskiy</td>
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<td></td>
<td>Krainskiy</td>
<td>drinking resort and</td>
<td>1-7</td>
</tr>
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<td>bottling plant</td>
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<td>good</td>
<td></td>
<td>Feodosiyskiy</td>
<td>drinking resort and</td>
<td>1, 3-5</td>
</tr>
<tr>
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<td>bottling plant</td>
<td></td>
</tr>
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<td>good</td>
<td></td>
<td>Krainskiy</td>
<td>drinking resort and</td>
<td>1-7</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td>bottling plant</td>
<td></td>
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<tr>
<td>II-3-72 Perevozets village, Galytisky area</td>
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<td>bad</td>
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<td>Feodosiyskiy</td>
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<td>1-7</td>
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<tr>
<td>III-3-135 Pavlivka village, Iv.-Frankivskiy area</td>
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<td>appropriate</td>
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<td>Minskiy</td>
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<td>1, 3-5</td>
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<td>Kasiyskiy</td>
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<td>good</td>
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<td>Krainskiy</td>
<td>bottling plant</td>
<td>1-7</td>
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<tr>
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<td>bad</td>
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<td>Krainskiy</td>
<td>bottling plant</td>
<td>1-7</td>
</tr>
<tr>
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<td>appropriate</td>
<td></td>
<td>Krainskiy</td>
<td>bottling plant</td>
<td>1-7</td>
</tr>
<tr>
<td>IV-1-169 Slyvky village, Rozhnativskiy area</td>
<td>good</td>
<td>good</td>
<td></td>
<td>Myrgorodskiy</td>
<td>drinking resort and</td>
<td>1-7</td>
</tr>
<tr>
<td>IV-3-220 Molodkiv village, Bogorodchanskiy area</td>
<td>good</td>
<td>good</td>
<td></td>
<td>Morshynskiy</td>
<td>drinking resort and</td>
<td>1, 3-7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>bottling plant</td>
<td></td>
</tr>
</tbody>
</table>

* Number in Table 2 corresponds to the number of mineral water occurrence in the “Geological map and map of mineral resources of pre-Quaternary sediments.

** Modes of mineral water use (after SSU 878-93): 1 – chronic gastritis: with normal secretory stomach function, with increased secretory stomach function, with decreased secretory stomach function; 2 – non-complicated stomach and duodenum ulcer. Sickness of treated stomach in relation to stomach and duodenum ulcer; 3 – chronic colitis and enterocolitis; 4 – chronic sickness of liver and cholagogue paths, hepatitis, discinesy of cholagogue paths, cholecystitis, angiocholites of various etiology without frequent exacerbation, post-cholecystitis-ectomyc syndrome; 5 – chronic pancreatitis; 6 – sickness of matter exchange: diabetes, fatness, podagra, urine-acid diathesis, ocaluly, phosphatotuty; 7 – chronic sickness of kidney and urine paths.
9. ECOLOGICAL-GEOLOGICAL SITUATION

In the map sheet M-35-XXV (Ivano-Frankivsk), like nowhere in Fore-Carpathians, the harmful mining and oil-gas processing enterprises are concentrated; by these reasons, over most part of the territory the losses imposed by human activities attained almost catastrophic values and ecological situation here cannot be considered as normal and favourable for inhabitants and establishment of recreation zones. The mountain landscape and large forest massifs only, where industrial objects are absent, and agriculture lands remained almost primary environments. Taken together, such components as fresh drinking and mineral water springs, impressive landscapes, fresh air and favourable climatic conditions provide considerable arguments for establishing here, in addition to existing, new recreation units.

Analysis of ecological state of studied area, given below, is based on the studies and analysis of all available data on the breaking degree of geological environment (GE), its contamination with harmful substances, and interaction with other components of ecological systems. Specialized geological-ecological studies in the territory are only performed for the site of Kaluskiy industrial area (P.P.Chaliy, 1999). By special project, the geological-ecological mapping in the scale 1:200 000 is being carried out in the area over last years. And under EGSF-200 works [65] just the limited amount of field observations is conducted.

The territory environment is being formed under influence of natural and technogenic factors. The natural ones include increased content of certain chemical elements and their compounds in soils and rocks, radioactivity of rocks, underground water protection against vertical input of chemical contaminants (thickness and lithology of aeration zone), increased mineralization of underground waters, the territory defeat by dangerous geological processes. Technogenic factors include contamination of soils and bottom sediments by heavy metals, underground waters contamination by toxic chemical elements, and technogenic loading module. The soils, bottom sediments and surface waters were subject to studies as the potential concentrators of contaminating substances.

**Geochemical characteristic of soils.** In the Podilska margin of Eastern-European Platform the dark-grey and black-earth soils predominate, slightly-acid and neutral (pH 5.5-7.0) with essential contents of humus (3.8-6.0%) and micro-elements, especially manganese, and low content of cobalt and iron. In the External zone of Fore-Carpathian Trough the underground composed of Miocene molassa is often salted. By these reasons, the overlying soils inherit the geochemical specialization of natural components with increased content of Pb, Cu, Sr, V, Mn. In the water flow valleys in Fore-Carpathians and Carpathians the turt-podzol soils are developed. On the mountain slopes the brown forest and brown-earth-podzol soils are developed. They display high acidity (pH 3-3.5) and low humus content (2-3%), very low iodine, fluorine and manganese content as well as increased concentration of cobalt, iron and zinc.

The bulk contamination level of Fore-Carpathians by I-III toxic-class heavy metals does not reach the top admissible concentration (TAC) yet. All anomalies are mainly concentrated in around big inhabited localities. Somewhere in agriculture areas the soils contain increased Sr and Ba apparently caused by lime powder input derived from limestones – the dumps of closed sulfur deposits. Almost throughout increased by 1.5-2 times background content of Zn, Pb, Sr, Ba, Cr is noted close to the paved roads and garbage storages.

Content of mobile chemical elements in the soils of Fore-Carpathians is as follows (Table 3).

<table>
<thead>
<tr>
<th>Chemical elements (mg/kg)</th>
<th>Pb</th>
<th>Zn</th>
<th>Be</th>
<th>P</th>
<th>Ni</th>
<th>Mo</th>
<th>Cu</th>
<th>Cr</th>
<th>Mn</th>
<th>V</th>
<th>Ba</th>
<th>Sr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background values</td>
<td>17</td>
<td>62</td>
<td>1.75</td>
<td>750</td>
<td>20</td>
<td>1.3</td>
<td>20</td>
<td>103</td>
<td>700</td>
<td>43</td>
<td>250</td>
<td>200</td>
</tr>
<tr>
<td>TAC</td>
<td>30</td>
<td>150</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>100</td>
<td>100</td>
<td>1500</td>
<td>150</td>
<td>150</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

By results of litho-geochemical sampling in Kaluskiy industrial area and adjacent territories (P.P.Chaliy, 1999) the aureoles are drawn up for the bulk contamination parameter (BCP) of soils with heavy metals classified to be dangerous and very dangerous (Zc>128). Specifically, this contamination is defined in the

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3 Heavy metals (see “Mineral Resources of Ukraine”, 2006, No. 1, p. 45-46) include Zn, Ni, Cu, Pb, Mn, Cr.
area of Tuzhyliv, Dovge, Kaluske, Berlogy, Novytsya and Zaviy villages; the local sites are also distinguished in the area of Kalush town. This is mainly caused by activities of Kaluskiy concern “Oriana” which had contaminated about 40 km² of territory around.

The background radioactivity of soils is 10-14 mcR/h. Much higher (up to 700 mcR/h) values are determined at the outskirt of Starunya village, nearby the head of old borehole (Pioner-1 [31]), which is being gushed forth, in the mud enriched in fossil detritus. In 200-250 m away from borehole the soils radioactivity becomes of background value. The brine, enriched in oil which is being flew out from borehole over almost entire century, contaminates Vel. Lukavets river.

Cornobylska catastrophe has also impacted studied area. In the south-eastern part of map sheet, at the outskirt of Otynya village, in the course of airborne gamma-survey in 1991 the site of soil contamination with cesium-137 (up to 1.0 and more Curie/km²) was encountered. The control measurements performed over EGSF-200 have shown that gamma radiation magnitude in most of earlier defined anomalous sites does not exceed 35-30 mcR/h.

Changes of hydrogeological conditions under influence of technogenic factors. Technogenic contamination of underground waters in Fore-Carpathians is developed almost throughout in Fore-Carpathians. The water-bearing horizon confined to the flood-land and low over-flood terrace alluvium comprises the major source for centralized water supplying. Due to natural exposure to technogenic impact it is often contaminated with nitrates and ammonia nitrogen. Other contamination components include Fe, P, Li, Br, Ba, Mn, Sr, Ti, organic matters. Contamination degree is moderate, in places – high. Average content of nitrates in the anomalous zones is 2.1-4.0 TAC. Somewhere phosphorus content in water attains 10 TAC.

The sites of underground water contamination, where concentration of mentioned substances exceeds TAC by several times, are encountered nearby the operating and closed mining objects (Kaluskiy chemical complex, Podorozhenskiy sulfur quarry, Starunske ozocerite and oil fields). In the water samples taken from Vel. Lukavets river down from borehole Piobr-1, which is being gushed forth, and ozocerite field, contents of Mn, Zr, Sr, Ti, Na, NH₄ exceed TAC by tens times. In addition, bacterial contamination is noted in many wells.

Significant antropogenic loading is noted for Bystrytsya-Nadvirynska river valley where the powerful industrial enterprises of Ivano-Frankivsk are located: Khryplynskiy energy hub, “Presmasg”, “Avtolyvmash”, “Pozytrom”, “Promprylad”, “Karpatagromash”, “Metaloplast”, armature, furniture plants, meat-packing plant, automobile enterprises. Some plants drop down their sewage to Vorona river.

The minor water flows are most susceptible to antropogenic impact. It is exemplified by extensive contamination of Rudka river where in the upper course the TAC excess for organic substances is 2.6 times, iron – 2.7, oil products – 7.1 times. This contamination is caused by the former garbage storage of Ivano-Frankivsk town. Input of contaminating substances into Rudka and Bystrytsya-Nadvirynska rivers takes place up to now. Increased chloride content in underground waters of Kaluskiy industrial hub is related to salt rocks exposure and water pumping out from Dombrovskiy quarry. In addition, long-term activities of “Oriana” plant had also caused contamination of surface and underground waters. The drops of non-cleaned drainage waters from Dombrovskiy quarry to Syvka river attained 0.7 mln.m³/year (under active mining of potassium salt). The drops of partly cleaned waters from this plant into Bolokhivka river attained more than 4 mln.m³/year. In contaminated underground waters in around these enterprises the TAC excess contents of chlorides, Na, K, Mg salts, heavy metals (Zn, Cu, Fe) are found. Huge inflows of fresh waters from Carpathians essentially reduce magnitude of contamination preventing development of catastrophic situations.

Around oil fields, most of which at present are out of production, the non-liquidated boreholes whose heads are not cemented comprise the major sources for underground waters contamination. The ground and rain waters remove from there the technogenic wastes and oil. In case of pipe-line breaking and accidents in operating fields the extensive contamination of surface and underground waters occur with oil and oil products identified in almost all waters around the oil fields. Extensive water contamination is also observed around oil refineries, fuel shops and auto-transport enterprises.

Water contamination is even determined in Carpathians which are thought to be ecologically clean. In water sample, taken at the mountain pass distal from any inhabited localities, in the upper course of minor Limnytsya river branch, the toxic I-class phosphorus and beryllium are detected. Their contents exceed TAC by several times. The sources of water contamination in this site are probably related to the wood mechanic cut and trailing. The household wastes, which are being dropped into the branches of major water flow, did not completely destroy yet the natural cleanliness of the fore-mountain streams.

The operating water scoops, which exploit waters from flood-land and low over-flood terrace alluvium, do lead to essential descending of ground water level in adjacent territories. And mining of sandy-gravel sediments in flood-lands of fore-mountain river parts imposes almost irreversible damage to environment stipulating increased contamination of underground waters in the major for water supplying water-bearing horizon as well as activation of erosion and sliding processes.
The level of underground waters is descended over last years due to their extensive exploitation and this had also caused breaking the equilibrium between erosion and accumulative processes. **Territory defeat by dangerous geological processes.** The dangerous exogenic processes caused by both natural and technogenic factors imposes essential impact on the landscape environment.

The following natural exogenic processes are distinguished:

**Erosion.** Its mode and magnitude depends on physico-geographic and litho-tectonic features of each specific relief element. In the mountains and inter-river watershed areas the planar deluvial removal predominates. Denudation magnitude here attains 0.038 mm/year. In the middle and lower slope parts the linear removal by permanent flows is more developed with magnitude up to 0.22 mm/year. In Fore-Carpathians and Podillya, on the gully slopes the regressive erosion of temporary streams is developed with magnitude up to 28 mm/year leading to continuous shortening of the arable lands. Magnitude of erosion processes in the mountains is being accelerated by wood cutting and trailng over water-scoop areas, total wood cutting over the slopes, and in the fore-mountains – mining of flood-land and low-terrace alluvium, gully and minor river bottom wasting, plowing across the slopes. The most efficient actions against erosion include shrub planting on the slopes and dam construction in the gully mouths.

**Slides.** Enhanced regressive erosion in the thick sandy-clayey sequence provokes almost permanent extensive development of slides. In the map sheet territory the slides are developed in the Dniester right-bank side and in Carpathians. These include sliding slopes, single moving slides and fans confined to the slopes of various origin, as well as ledges of medium and high terraces.

On the mountain slopes the block slides are mainly developed. Periods of activation of these slides are related to the durable wetting. Catastrophic slide activation occurred in the summer 1998 during the rainfalls. These slides normally require the long-term (60-70 years) preparation period with low displacement speed (10-15 cm/year) and fast active stage (up to 10-15 m/day). The volume of displacing rocks attains some millions of cubic meters. The most slide defeating is observed in the south-west of the map sheet in the area of Lypovets, Gryniv, Rakovets villages in the sites where age-different clayey and fleshy sequences are developed.

In Prygrojanske Fore-Carpathians by intensity of sliding processes two bands are distinguished.

The first band is occupied by fore-mountain part of the area between Bystrytsya-Solotvyanska – Bystrytsya-Nadvirnyanska and Bystrytsya-Nadvirnyanska – Prut rivers. Here slide processes are being developed in terrace ledges, gully slopes, on hard-rock slopes where alluvial and deluvial sediments lie over Lower Miocene molassa. In Manyavka river valley, in the lower slope part, the slide massifs are observed (relict and mobile) composed of clayey sequences of Vorotyshchenska and Stebnytska suites (Neogene). In the upper course of almost all streams which cut sliding slopes, the slide circuses are located most of which are mobile. Width of some circuses attains 150-300 m, length – 300-350 m. In many circuses the walls and bottom are cut by numerous gullies in which walls, in turn, the minor slides are developed.

The second band of extensive sliding comprises the area between Syvka-Limnytsya, Limnytsya-Lukva, Lukva-Bystrytsya rivers. Here the slides are developed in the sequences of aeolian-deluvial loess-like loams.

Example of technogenic slide can be seen in Bogorodchanske natural gas storage with detailed engineering-geological and geomorphologic characteristics, observations for its development over 10 years, calculation-forecast of techno-natural risk presented by G.Rudko, M.Koshil, M.Bondarenko (1977), specifically: the slide is located at the watershed between Bystrytsya-Solotvyanska and Sadzhavka rivers, it has emerged in 1988 and was expressing with new activity phases up to 1997. The slides encompass about 3 ha of space and volume of broken rocks is 1.0-1.2 mln.m³.

The collapse-fan processes are locally developed. They are known in the left cliffy bank of Bystrytsya-Nadvirnyanska, at the southern map sheet boundary nearby Nadvirna town and along Dniester right bank nearby Petryliv village.

**Mud-flows** are expressed in the mobile masses comprising mixture of water and solid material with amount of the latter up to 10-20% (by weight) of water counterpart. They are periodically observed over all rivers of Carpathians and Fore-Carpathians. Most part of solid elastic material the rivers collect in the mountain area and bring to the fore-mountains. In the latter the side branches and gullies mainly supply fine-grained material. Amount of brought material in the mud-flows attains 300-400 kg/m³. Extensive floods in 1997 and 1998 had caused significant breaking of protection dams and other constructions, flooding and mudding of significant agriculture lands.

Karst in the map sheet territory is observed in two types: sulphate and halogen. Sulphate karst is mainly developed in the Dniester left-bank side, at the watershed areas of Gnyla Lypa – Naraivka – Bebelka rivers, where sulphate sequence, laying almost at the surface, is completely or partly cut by the streams and fractures. Here the natural enrichment in suffusion-karst units attains 10-20 funnels per 1 km². Halogenic karst is developed in the area of Kaluske salt deposit. Due to non-controlled natural flooding of mine workings with fresh waters the active erosion and dissolution of salt commenced with formation of collapse.
saucers at the surface. The saucer diameter at Kaluske deposit is 2-18 m, depth from 1 to 8 m (G.Rudko et al., 1997). Since the beginning of Dombrovskiy quarry exploitation (1967) it was dried using water-descending drill-holes. This led to extensive development of salt karst both in the quarry and adjacent territory. With salt mining the collapses of gypsum-clayey “cap” appeared and the fresh waters of Middle Neo-Pleistocene pebble horizon were mixing with above-salt brines. As a result of karst development the underground water mineralization in the right bank of Syvka river over only one year has increased from 0.5-0.9 to 16-19 g/dm³. Further on for quarry drying the ring drainage trench was used and this allowed termination of karst formation. The quarry development disregarding protection had resulted in catastrophic slide activation. For many years potassium salts were mined from the shaft which workings are located beneath building of Kalush town. In 1985 the technogenic karst appeared here and almost entire street with newly-built two-floor premises was buried to 3-4 m.

Considerable technogenic influence on the landscape complex in fore-mountains has been put by long-term mining for various construction materials. Numerous abandoned quarries transformed into garbage dumps had broke the valley slopes. Their reclamation is not performed.

For each geomorphologic area with certain complex of relief forms the distinct appearance of dangerous exogenic processes is characteristic. More extensive gully erosion and planar removal occur in the inter-river heights. The slide processes are mainly confined to the ledges of high terraces, stream, gully and ravine banks. Activation of modern exogenic geomorphologic processes is observed in more mobile in tectonic respect band adjacent to Carpathians. Away from the mountains the processes are ceased regardless these areas are composed of the same stratigraphic units. Intensity of processes increases again only in the fore-Dniester part of territory and this is explained by location of main Fore-Carpathian erosion basis at the contact of Fore-Carpathian Trough and Eastern-European Platform.

Since modern exogenic processes impose significant injury to various branches of economy, coordination of industrial and scientific works of various ministries is required aiming elimination of parallel researches and irrational use of financing.

Changes of geological environment. Because of considerable shortening of industrial operations and agriculture works in post-Soviet times, environment state in the studied area became much better but the level of technogenic loading remains high enough. All enterprises involved in Kaluskiy industrial hub up to now comprise potential contamination sources. Of these, the “Oriana” concern first of all with various chemical and processing facilities including containers of industrial wastes, chemical, olephine, potassium fertilizer and magnesium plants, heating-electric lines, slurry containers, ash storages, tailings, Dombrovskiy quarry dumps. Concentration of great amount of these dangerous for environment enterprises provide significant ground to ascribe Kalush town and its neighbouring areas, located in the fore-mountain part of Limnytsya river, to the territory with very dangerous environment state.

Significant environment contaminants also include oil fields: Dolynske, Strutunske, Spaske, Lukvynske, Rosilnyanske, kosmatse, Rudavetske, Pidliske, Nebilivske, Gvizdetske, as well as Dashavske gas field. Technical wastes from these enterprises permanently pollute the soils and major water-bearing horizons with oil products. In gas fields subsurface degassing is not excluded with subsequent gas accumulation in the near-surface sediments in anomalous concentrations.

Existing pipeline system between exploitation boreholes and oil-collecting points is ecologically dangerous. In places, where pipelines are in exploitation for tens of years, due to extensive metal corrosion they are under accidental state and provide the danger for soil and water contamination. These objects are ascribed to potential contamination sources even in cases of unidentified contamination. The sites where gas-oil fields, pipelines and big quarries are located are ascribed to the territories with hard ecologic state.

Environment state is also broken around Podorozhnenskiy quarry where native sulfur was mined. In the course of mining and now the mixing of fresh waters from alluvial horizon with waters from fractured gypsums, as well as soil salination, planar and linear erosion over stripping slopes. At present the quarry reclamation works commenced through its flooding and recreation zone establishing over there. However, the works are hampered by insufficient financing.

The situation is also hard around Dubovetskiy quarry where limestones for cement manufacturing are being mined. In the northern part of map sheet ecology is being essentially impacted by operating Burshtynska heating electro-power station.

According to these criteria the following contamination levels are distinguished in the map sheet M-35-XXV (Ivano-Frankivsk) (Fig. 9.1):
Fig. 9.1. Schematic map of ecological state of geological environment.

**Ecological state of geological environment:** 1 – very hard, 2 – hard, 3 – moderate hard, 4 – appropriate.

**Technogenic objects impacting geological environment:** 5 – heating energy, 6 – heavy industry, 7 – chemical industry, 8 – mining industry, 9 – agriculture, 10 – hydro-technical objects, 11 – waste storage, bury and utilization.
Fig. 9.1. Continued.

Soil contamination by toxic chemical elements of I and II danger class (right-hand – indices of contaminating elements): 12 – heavy metals (a – planar, b – local), 13 – planar geochemical anomalies, 14 – underground water scoops operating with approves reserves.


- admissible state – essential part of studied area where the sites are developed with relative ecological comfort and admissible levels of soils and water contamination and slight defeating degree by dangerous geological processes. These are forest massifs, hayfields and pastures;
- moderate-loaded state – sites of decreased ecological comfort with moderate-dangerous levels of soil and water contamination, with moderate development of some exogenic geological processes and phenomena. These include the urban agglomerations with various enterprises, rural localities with farming complexes, numerous abandoned quarries for construction materials transformed into garbage storages, dams, irrigation channels, paved road and railroad network, oil-gas pipelines, water scoops with partial exhaustion of water-bearing complex, etc. Aggregate contamination parameter in these sites is 16-32;
- hard state – massifs with dangerous levels of soil, bottom sediments and underground water contamination, with high defeat degree by karst and slides. This is, first of all territory of Kaluskiy industrial hub, gas-oil fields, ozocerite mines. Aggregate contamination parameter in these sites attains 32-128;
- very hard (critical) state – sites with very dangerous contamination levels are located around Kaluskiy chemical complex, Dombrovskiy, Podorozhnenskiy and Dubovetskiy quarries and in the south-western outskirt of Starunya village nearby boreholes from which enriched in oil and gas brine flows out. In these sites the aggregate contamination parameter exceeds 128.

Assessment of geological environment state and recommendations for further ecological-geological studies. Ecological state of environment is being assessed by the following criteria summarized in the Table 4 (V.I.Pochtarenko, I.V.Sanina, N.G.Lyuta, 2002):

<table>
<thead>
<tr>
<th>Assessment of soils and bottom sediments contamination degree</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Table 4</strong> Assessment of soils and bottom sediments contamination degree</td>
</tr>
<tr>
<td><strong>Index in pseudo-formula</strong></td>
</tr>
<tr>
<td>A' Dangerous</td>
</tr>
<tr>
<td>G A Moderate dangerous</td>
</tr>
</tbody>
</table>

Assessment of underground waters contamination by chemical elements

| **B''** Very dangerous |
| **B'** Dangerous |
| **B** Moderate dangerous |
| **Admissible** |

Assessment of territory defeat by dangerous exogenic geological processes

| **Defeat degree** | **E''** High |
| **E** Medium |
| **Moderate** |
CONCLUSIONS

In the map sheet M-35-XXV (Ivano-Frankivsk), which encompasses litho-tectonic zones of External Carpathians, Fore-Carpathian Trough and Eastern-European Platform, extended geological study was performed in the scale 1:200 000 and preparation for publishing the set of maps of new series Derzhgeolkarta-200. This had allowed essentially adjust and in some cases present a new vision to the issues of geology, tectonics, history of development and assess the perspectives of the territory for various mineral resources.

Based on generalization of all results of various geological studies and authors’ observations available to date, the new insights on geology of Internal Zone of Fore-Carpathian Trough are presented. Corrections to the approved by Ukrainian Stratigraphic Committee the “Stratigraphic scheme of Lower Miocene salt-bearing sediments in Boryslavsko-Pokutskia and Sambirskia LTZs are recommended Description of ecological-geological state of environment is provided for the first time.

The following new results are obtained:
1. The set of maps designed along with new series Derzhgeolkarta-200 over studied map sheet which contains “Geological map and map of mineral resources of pre-Quaternary sediments” and “Geological map and map of mineral resources of Quaternary sediments”. In the maps all available data of predecessors are generalized as well as new data are synthesized received in the course of EGSF-200 [67] in compliance with recently approved correlation stratigraphic schemes, instruction, Stratigraphic Code, methods and modern ideas on geology of entire Carpathian region. In this respect new geological maps essentially differ from the maps of previous generation.
2. Detailed litho-facial description of all stratons is given.
3. Reconstruction of sedimentation conditions is conducted.
4. Detailed description is given for tectonic structure and history of geological development on the ground of plate tectonic concept.
5. The relief is described in some details as well as the history of its formation, neo-tectonic motions and modern relief-forming processes.
6. The brief description of hydrogeological features is provided.
7. The mineral resources data are synthesized.
8. Specific perspectives and sites of further prospecting activities for major minerals are defined.
9. Ecological-geological situation is briefly characterized.

At the same time, some problems of geology and history of territory development remain disputable. Of these the principal are as follows:
• interpretation of Cenozoic cover structure in the margin of Eastern-European Platform is disputable (contrasted erosion paleo-relief or active tectonic re-working resulted in depressions of graben nature with complex development mechanism);
• different age treatment for some stratons and their relationships (age of salt-bearing molassa in Fore-Carpathians, relationships of its Lower Neogene stratigraphic subdivisions – Polyanytska, Vorotyshchenska, Stebnytska suites etc).

There are also some other differences in the interpretation of geology in External Carpathians and Fore-Carpathian Trough in general but these ones do not essentially affect the uniform view concerning general structure, geological history and practical value of this region.
REFERENCES

Published


Unpublished


Annex 1. List of deposits and occurrences indicated in the geological map and map of mineral resources in pre-Quaternary units of map sheet M-35-XXV (Ivano-Frankivsk)

<table>
<thead>
<tr>
<th>Cell index, number in map</th>
<th>Mineral type, object name and its location</th>
<th>Deposit exploitation state or brief description of occurrence</th>
<th>Geological-economic type and age of productive pile</th>
<th>Notes (references cited)</th>
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<td>Sheeted, arch, lithologically bounded and tectonically blocked traps; $N_{ds}$</td>
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<td>I-1-9</td>
<td>Lyubeshivske; Sykhiv village</td>
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<td>Kadobnyanske; Mostyshche village</td>
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<td>IV-2-172</td>
<td>Bogorodchanske; Bogorodchany town</td>
<td>In production, gas storage</td>
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<td>I-1-1</td>
<td>Ruda; Ruda village</td>
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<td>I-1-4</td>
<td>Krekhivskiy-I; Krekhiv village</td>
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<td>I-1-5</td>
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<td>Slight gas emanation</td>
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<td>I-1-10</td>
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<td>Slight gas emanation</td>
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<td>Gas inflow</td>
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<td>I-1-14</td>
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<td>I-1-15</td>
<td>Korchivskiy-III; Korchivka village</td>
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<td>I-2-21</td>
<td>Zhuravnenskiy, Zhuravno village</td>
<td>Gas blow under pressure</td>
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<td>III-1-115</td>
<td>Luby; Luby village</td>
<td>Slight gas emanations</td>
<td>Sheeted, K$<em>2$-P$</em>{st}$; P$_2$; N$_ml$</td>
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<td>III-3-134</td>
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<td>Extensive gas emanation</td>
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<td>III-3-138</td>
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<td>Sheeted, N$_ks$</td>
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<td>III-3-141</td>
<td>Starolysetskii-I; Stariy Lysets village</td>
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<td>III-3-143</td>
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<tr>
<td>III-4-160</td>
<td>Grynivtsivskiy; Grynivtsi village</td>
<td>Short-time gas emanation</td>
<td>Sheeted, N$_ks$</td>
<td>110</td>
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<tr>
<td>IV-1-163</td>
<td>Nebylivskiy; Nebyliv village</td>
<td>Water inflows with gas, slight gas emanations</td>
<td>Sheeted, P$_2$; P$_1$-N$_ml$</td>
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<td>IV-2-209</td>
<td>Starunskiy; Starunya village</td>
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<td>IV-3-213</td>
<td>Ivanykivskiy; Ivanykivka village</td>
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<td>IV-3-215</td>
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<td>Slight gas emanation</td>
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<td>Krasylivskiy; Krasylivka village</td>
<td>Slight gas emanation</td>
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<tr>
<td>IV-4-226</td>
<td>Khilibychynskiy; Lisniy Khilibychyn village</td>
<td>Slight gas emanation</td>
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<td>94</td>
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<tr>
<td>IV-4-227</td>
<td>Cheremkhivskiy; Cheremkhiv village</td>
<td>Slight gas emanations</td>
<td>Sheeted, N$_ks$</td>
<td>112</td>
</tr>
</tbody>
</table>

| IV-2-177| Rosilynanske (gas-condensate); Rosilna village | In production | Sheeted, arch, tectonically blocked traps; P$_2$; P$_1$-N$_ml$ | 73 |

**Liquid Condensate Deposit**

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<td>IV-2-177</td>
<td>Rosilynanske (gas-condensate); Rosilna village</td>
<td>In production</td>
<td>Sheeted, arch, tectonically blocked traps; P$_2$; P$_1$-N$_ml$</td>
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<td>In production</td>
<td>Sheeted, arch, lithologically bounded and tectonically blocked traps; $P_2$; $P_3-N_\text{ml}$</td>
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<td>IV-2-202</td>
<td>Monastyrchanske (gas-condensate); Monastyrchany village</td>
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<td>Oil Deposit</td>
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<td>III-1-98</td>
<td>Spaske; Spas village</td>
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<td>Sheeted, arch, lithologically bounded and tectonically blocked traps; $P_3-N_\text{ml}$</td>
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<td>III-1-101</td>
<td>Chechvynske; Nyzhniy Strutyn village</td>
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<tr>
<td>III-1-104</td>
<td>Rozhnymyativske; Lopyanka village</td>
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<td>Sheeted, arch, tectonically blocked trap; $P_3-N_\text{ml}$</td>
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<td>III-1-116</td>
<td>Pidlisivske; Pereginske village</td>
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<td>Sheeted, arch, tectonically blocked traps; $P_3-N_\text{ml}$</td>
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<td>III-1-117</td>
<td>Nebylivoske; Sloboda Nebylivska village</td>
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<td>Sheeted, arch, lithologically bounded traps; $P_3-N_\text{ml}$</td>
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<tr>
<td>IV-1-161</td>
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<td>Sheeted, arch, lithologically bounded and tectonically blocked traps; $P_3-N_\text{ml}$</td>
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<td>Rudavetske; Slyvky village</td>
<td>In production</td>
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<td>IV-2-180</td>
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<tr>
<td>IV-2-207</td>
<td>Starunske; Starunya village</td>
<td>Closed</td>
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<td>IV-3-219</td>
<td>Gvizdetske; Gvizd village</td>
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<td>IV-1-166</td>
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<td>Oil inflow, yield – 0.18 t/day</td>
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<td>Slobodanebylivskiy; Sloboda Nebylivska village</td>
<td>Oil films</td>
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<td>IV-2-184</td>
<td>Lukvytskiy-I; Lukvysa village</td>
<td>Oil inflow</td>
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**Occurrence**

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<td>Strutynske; Verkhniy Strutyn village</td>
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<td>In production</td>
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**Occurrence**

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<td>Oil and gas inflow</td>
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<td>1</td>
<td>Burshtynske; Burshtyn, Bukachivtsi, Ozeryany villages</td>
<td>Deposits</td>
<td>Out of production</td>
<td></td>
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<tr>
<td>2</td>
<td>Chernivskiy-I; Cherniv village</td>
<td>Ferrous metals</td>
<td>Marl-clay rhythm 2 m thick. Mn content – 13.37%</td>
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<td>3</td>
<td>Zhurivskiy; Zhuriv village</td>
<td>Ferrous metals</td>
<td>Marl-clay rhythm 10 m thick. Mn content – 12%</td>
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<td>4</td>
<td>Chernivskiy-II; Cherniv village</td>
<td>Ferrous metals</td>
<td>Marl-clay rhythm 3 m thick. Mn content – 12.6%</td>
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<td>5</td>
<td>Novoshynskiy; Novoshyn village</td>
<td>Non-ferrous metals</td>
<td>Marl-clay rhythm 1 m thick. Mn content – 24%</td>
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<td>6</td>
<td>Yunashkivskiy; Yunashkiv village</td>
<td>Non-ferrous metals</td>
<td>Marl-clay rhythm 3 m thick. Mn content – 12%</td>
<td></td>
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<tr>
<td>7</td>
<td>Burshtynskiy; Burshtyn town</td>
<td>Non-ferrous metals</td>
<td>Marl-clay rhythm 3.1 m thick. Mn content – 11.1%</td>
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<tr>
<td>8</td>
<td>Lozochniy; Lopyanka village</td>
<td>Copper</td>
<td>Grey sandstones of Yaremchanskiy horizon with up to 0.2 m thick</td>
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<td>9</td>
<td>Petrankivskiy; Petranka village</td>
<td>Copper</td>
<td>In grey sandstones three copper-bearing lenses up to 0.2 km long and</td>
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<td>10</td>
<td>Dzvynyatskiy; Dzvynyach village</td>
<td>Lead, Zinc</td>
<td>Two interbeds 25-30 cm thick, carbonate clay with galena and</td>
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<tr>
<td>11</td>
<td>Starunskiy; Starunya village</td>
<td>Lead, Zinc</td>
<td>Galena and sphalerite dissemination in sandy-clayey rocks</td>
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<tr>
<td>12</td>
<td>Lopyanetskiy; Lopyanka village</td>
<td>Vanadium, Molybdenum</td>
<td>Bituminous argillites; V content - 0.25%, Mo – 0.008%</td>
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<tr>
<td>13</td>
<td>Lozochniy; Lopyanka village</td>
<td>Vanadium, Molybdenum</td>
<td>Bituminous argillites; V content - 0.32%, Mo – 0.025%</td>
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<tr>
<td>14</td>
<td>Pidsukhivskiy; Pidsukhy village</td>
<td>Vanadium, Molybdenum</td>
<td>Bituminous argillites; V content - 0.32%, Mo – 0.03%</td>
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<tr>
<td>15</td>
<td>Podorozhenskiy; Podorozhne village</td>
<td>Strontium</td>
<td>Sulfur-ore bodies with veinlets, bunches, druses and pods of celestine</td>
<td></td>
</tr>
</tbody>
</table>

**Metallic mineral resources**

**Ferrous metals**

- **Manganese Deposit**
- **Occurrence**

**Non-ferrous metals**

- **Copper**
- **Occurrence**

**Lead, zinc**

**Occurrence**

**Rare metals**

- **Vanadium, Molybdenum**
- **Occurrence**

**Strontium**

**Occurrence**

**Vein-disseminated**

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<tr>
<td>I-3-30</td>
<td>Kuropatyntski; Kuropatynky village</td>
<td>Anhydrite, dolomitized limestone 0.2 m thick. Sr content – 15.3%</td>
<td>Vein-disseminated; J_{tr}</td>
<td>77</td>
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<tr>
<td>I-3-38</td>
<td>Burshtynski; Burshtyn town</td>
<td>Marl with sandstone 0.2 m thick. Sr content – 15%</td>
<td>Veined; K_{3,7}</td>
<td>77</td>
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<tr>
<td>I-3-40</td>
<td>Podilsky; Podillya village</td>
<td>Limestone 0.5 m thick with celestine crystals. Sr content – 19.6%</td>
<td>Vein-disseminated; K_{3,7}</td>
<td>77</td>
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<tr>
<td>I-3-44</td>
<td>Syvko-Voynylivskiy-I; Syvka-Voynyliv village</td>
<td>Limestone 0.5 m thick, pelitemorphic with celestine veinlets. Sr content in veinlets – 30%</td>
<td>Veined; K_{3,7}</td>
<td>77</td>
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<tr>
<td>I-3-45</td>
<td>Nimshynski; Nimshyn village</td>
<td>Marl 0.2 m thick. Sr content – 5%</td>
<td>Veined; K_{3,7}</td>
<td>77</td>
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<tr>
<td>I-3-46</td>
<td>Syvko-Voynylivskiy-II; Syvka-Voynyliv village</td>
<td>Limestone 2 m thick, pelitemorphic with celestine veinlets. Sr content in veinlets – 20%</td>
<td>Veined; K_{3,7}</td>
<td>77</td>
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<tr>
<td>II-3-71</td>
<td>Kudlativski; Kudlativka village</td>
<td>Gypsum 1 m thick. Sr content – 3%</td>
<td>Disseminated; N_{1,7}</td>
<td>110</td>
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<tr>
<td>II-3-73</td>
<td>Viktorovski; Viktoriv village</td>
<td>Limestone 0.4 m thick. Sr content – 3%</td>
<td>Disseminated; N_{1,7}</td>
<td>110</td>
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<tr>
<td>III-3-133</td>
<td>Pavlivski; Pavlivka village</td>
<td>Gypsum-anhydrite 1 m thick. Sr content – 3%</td>
<td>Disseminated; N_{1,7}</td>
<td>110</td>
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<tr>
<td>III-3-142</td>
<td>Radcha; Radcha village</td>
<td>Gypsum 1 m thick. Sr content – 3%</td>
<td>Disseminated; N_{1,7}</td>
<td>87</td>
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<tr>
<td>III-4-155</td>
<td>Klubivtsi; Klubivtsi village</td>
<td>Gypsum-anhydrite 2 m thick. Sr content – 3%</td>
<td>Disseminated; N_{1,7}</td>
<td>110</td>
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<tr>
<td>III-4-159</td>
<td>Grynivtsi; Grynivtsi village</td>
<td>Gypsum-anhydrite 1 m thick. Sr content – 3%</td>
<td>Disseminated; N_{1,7}</td>
<td>110</td>
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**Non-metallic mineral resources**

**Ore-chemical raw materials**

**Chemical raw materials**

**Borates**

**Deposit**

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<tbody>
<tr>
<td>II-2-62</td>
<td>Kalush-Golynske, potassium salts. “Sylvin” shaft; Kalush town</td>
<td>Sandy-clayey salt-bearing breccia. B_{2}O_{3} content – 0.25%</td>
<td>Sedimentary-chemogenic; N_{1,7,bl}</td>
<td>100</td>
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<tr>
<td>III-1-92</td>
<td>Obolonsky; Dolyna town</td>
<td>Gypsum-clayey “cap” 3 m thick. B_{2}O_{3} content – 0.16%</td>
<td>Sedimentary-chemogenic; N_{1,7,br}</td>
<td>114</td>
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<tr>
<td>IV-2-176</td>
<td>Rosilnyanskiy-I; Rosilna village</td>
<td>Gypsum-clayey “cap” 4 m thick. B_{2}O_{3} content – 0.18%</td>
<td>Sedimentary-chemogenic; N_{1,7,br}</td>
<td>114</td>
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<tr>
<td>IV-2-178</td>
<td>Rosilnyanskiy-II; Rosilna village</td>
<td>Gypsum-clayey “cap” 4 m thick. B_{2}O_{3} content – 0.16%</td>
<td>Sedimentary-chemogenic; N_{1,7,br}</td>
<td>114</td>
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**Native sulfur**

**Deposit**

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<tbody>
<tr>
<td>I-1-7</td>
<td>Podorozhnske; Podorozhne village</td>
<td>Out of production</td>
<td>Sheeted lens-like; N_{1,7,br}</td>
<td>123</td>
<td></td>
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<tr>
<td>I-2-24</td>
<td>Zhuravnenske; Zhuravno village</td>
<td>Out of production</td>
<td>Sheet-like; N_{1,7,br}</td>
<td>124</td>
<td></td>
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<tr>
<td>III-3-140</td>
<td>Lysetske; Lysets village</td>
<td>Out of production</td>
<td>Lens-like; N_{1,7,br}</td>
<td>87</td>
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**Occurrence**

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<tbody>
<tr>
<td>I-2-25</td>
<td>Melnichivskiy-I; Melnichy village</td>
<td>Limestone 4 m thick, metasomatic, with sulfur bunches and veinlets. Sr content – 16.56-28.96%</td>
<td>Lens-like; N_{1,7,br}</td>
<td>86</td>
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<thead>
<tr>
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<tbody>
<tr>
<td>I-2-26</td>
<td>Melnychivskiy-II; Melnyci village</td>
<td>Limestone 4 m thick, metasomatic, with sulfur bunches, pods and veinlets. S content – 20.36-24.72%</td>
<td>Lens-like; N1vr</td>
<td>86</td>
</tr>
<tr>
<td>I-2-27</td>
<td>Tarnavskiy; Tarnavka village</td>
<td>Gypsum-anhydrite 4.9 m thick with carbonate material admixture and sulfur veinlets. S content – up to 14.72%</td>
<td>Lens-like; N1vr</td>
<td>77</td>
</tr>
<tr>
<td>II-2-64</td>
<td>Pidgirskiy; Pidgirky village</td>
<td>Limestone 4.8 m thick, metasomatic, with sulfur veinlets and pods. S content – 13.44-13.76%</td>
<td>Lens-like; N1vr</td>
<td>87</td>
</tr>
<tr>
<td>III-4-156</td>
<td>Pshenychnykivskiy; Pshenychnyky village</td>
<td>Limestone 1.5 m thick, metasomatic, with sulfur pods and bunches. S content – 18.6%</td>
<td>Lens-like; N1vr</td>
<td>87</td>
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<tr>
<td>IV-3-214</td>
<td>Berezivskiy; Berezivka village</td>
<td>Limestone 1.0 m thick, metasomatic, with sulfur pods and bunches. S content – 22.01%</td>
<td>Lens-like; N1vr</td>
<td>150</td>
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<tr>
<td>IV-3-216</td>
<td>Bratkvskiy; Bratkovtsi village</td>
<td>Limestone 1.5 m thick, metasomatic, with sulfur veinlets and bunches. S content – 16.4-19.2%</td>
<td>Lens-like; N1vr</td>
<td>150</td>
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<tr>
<td>IV-3-217</td>
<td>Lypivskiy; Lypivka village</td>
<td>Limestone 2.8 m thick, metasomatic, with sulfur bunches. S content from 1.6 to 33.6%</td>
<td>Lens-like; N1vr</td>
<td>150</td>
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<tr>
<td>IV-4-224</td>
<td>Krasylivskiy; Krasylivka village</td>
<td>Limestone 1.1 m thick, metasomatic, with sulfur inclusions. S content – 8.8%</td>
<td>Lens-like; N1vr</td>
<td>87</td>
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**Agro-chemical raw materials**

**Phosphorites**

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<tr>
<th>Occurrence</th>
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<tbody>
<tr>
<td>III-4-147</td>
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<td>III-4-150</td>
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**Non-metal ore commodities**

**Electric- and radio-technical raw materials**

**Ozocerite**

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<tr>
<th>Deposit</th>
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<tr>
<td>IV-2-195</td>
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<td>IV-2-200</td>
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**Facing raw materials**

**Gypsum**

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<tr>
<td>I-2-20</td>
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<td>I-3-32</td>
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<td>II-4-74</td>
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<td>II-4-82</td>
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<tr>
<td><strong>Construction materials</strong></td>
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<tr>
<td>II-4-80</td>
</tr>
<tr>
<td>II-4-81</td>
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<tr>
<td><strong>Gypsum, marl</strong></td>
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<tr>
<td>II-4-77</td>
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<tr>
<td>II-4-78</td>
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<tr>
<td>II-4-79</td>
</tr>
<tr>
<td><strong>Petrurgy raw materials for light concrete fillers</strong></td>
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<tr>
<td>I-3-41</td>
</tr>
<tr>
<td><strong>Raw materials for construction lime and gypsum</strong></td>
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<tr>
<td>II-4-75</td>
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<tr>
<td>II-4-83</td>
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<td>III-4-154</td>
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<tr>
<td><strong>Gypsum</strong></td>
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<tr>
<td>I-2-22</td>
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<td>II-4-84</td>
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<td>III-4-151</td>
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<td>III-4-153</td>
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<tr>
<td><strong>Quarry-stone raw materials</strong></td>
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<td>I-4-48</td>
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<td><strong>Brick-tile raw materials</strong></td>
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<td>II-2-55</td>
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<td>III-1-95</td>
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<td>III-4-158</td>
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<td>IV-4-223</td>
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</table>

**Salts**

**Sodium salt Deposit**

| III-1-85 | Dolynske; Dolyna town                  | Out of production       | Lens-like; N₁,νr                 | 140        |
| III-1-99 | Verkhnyostrutynske; Verkhniy Strutyn village | Out of production       | Sheeted-lens-like; N₁,νr        | 141        |
| III-1-105 | Yasenovetske; Yasenovets village       | Out of production       | Sheeted-lens-like; N₁,νr        | 70, 141    |
| III-1-110 | Roshnyativske; Roshnyate village       | Out of production       | Sheeted-lens-like; N₁,νr        | 70, 141    |

**Occurrence**

| III-2-130 | Grynivskiy-I; Grynivka village         | Rock salt more than 18.3 m thick | Sheeted-lens-like; N₁,bl          | 83         |
| III-2-132 | Grynivskiy-II; Grynivka village       | Rock salt 261.0 m thick with scarce salt breccia, anhydrite and argillite interbeds from 1.1 to 5.4 m thick. NaCl content from 70.7 to 94.25%; CaSO₄ – 1.86% | Sheeted-lens-like; N₁,bl              | 133        |
| IV-2-174 | Sadzhavskiy; Sadzhava village          | Rock salt 66.0 m thick. NaCl content from 79.31 to 95.44%; CaSO₄ – up to 8.18% | Sheeted-lens-like; N₁,bl              | 133        |

**Potassium-magnesium salts Deposit**

<p>| II-1-51 | Velyka Turya; Velyka Turya village     | Out of production       | Lens-like; ore types: kainite, langbeinite, kainite-langbeinite, N₁,bl | 95, 135    |
| II-1-52 | Trostyanetske; Trostyanets village    | Out of production       | Lens-like; ore types: langbeinite, kainite-langbeinite, N₁,bl             | 95, 135    |
| II-2-61 | Kalush-Golynske, Kalush town          | In production           | Sheeted-lens-like; ore types: kainite-langbeinite, langbeinite, sylvinitie, N₁,bl | 95, 135    |
| IV-2-181 | Rosilnyanske; Rosilna village         | Out of production       | Sheeted-lens-like; ore types: langbeinite-kainite; kieserite-langbeinite-kainite, N₁,νr | 131, 136   |
| IV-2-193 | Dzvynyatske; Dzvynyach village       | Out of production       | Sheeted-lens-like; ore type: kainite-kieserite-langbeinite, N₁,νr            | 131, 136   |</p>
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<tr>
<td>IV-2-196</td>
<td>Starunske; Starunya village</td>
<td>Out of production</td>
<td>Lens-like; ore type: kieserite-langbeinite, N₁vr</td>
<td>131, 136</td>
</tr>
<tr>
<td>IV-2-199</td>
<td>Markivske; Markova village</td>
<td>Out of production</td>
<td>Lens-like; ore type: kainite-langbeinite, N₁vr</td>
<td>132, 136</td>
</tr>
<tr>
<td>IV-2-210</td>
<td>Molodkivske; Molodkiv village</td>
<td>Out of production</td>
<td>Lens-like; ore type: kainite-langbeinite, kieserite-langbeinite, N₁vr</td>
<td>132, 136</td>
</tr>
</tbody>
</table>

**Occurrence**

<p>| II-1-49 | Turyanskiy; Velyka Turya village       | Salt-bearing breccia 5.0 and 1.1 m thick with polyhalite and sylvine bunches and interbeds (10-12 cm) | Lens-like; N₁bl | 135 |
| III-1-87 | Krekhovytskiy; Krekhovychi village    | Halite rock 2.2 m thick with kainite, rarely sylvine, bunches and pods. K₂O content – 7.6%. Kainite rock with halite, 0.5 m thick. K₂O content – 11.55%. | Lens-like; N₁bl | 95  |
| III-1-88 | Rakhynskiy; Rakhynya village          | Kainite-langbeinite rock 6.0 m thick. K₂O content – 11.18%. | Lens-like; N₁vr | 130 |
| III-1-90 | Novytskiy; Dolyna town                 | Kainite, polyhalite and langbeinite bunches (3-4 cm) and interbeds (up to 0.8 m) in salt-bearing breccia from 2 to 25 m thick. K₂O content – 3.75%. | Lens-like; N₁vr | 59  |
| III-1-91 | Dolynskiy-I; Dolyna town              | Kainite rock from 1.0 to 8.8 m thick. K₂O content from 10.77 to 11.6%. Polyhalite rock 11.8 m thick with sylvine bunches. K₂O content – 10.87%. | Lens-like; N₁vr | 140 |
| III-1-97 | Verkhnostrutynskiy-I; Verkhniy Strutyn village | Kainite rock 7.1 m thick with langbeinite and sylvine. K₂O content – 6.47%. | Lens-like; N₁vr | 140 |
| III-1-100 | Verkhnostrutynskiy-II; Verkhniy Strutyn village | Langbeinite rock with polyhalite 4.1 m thick. K₂O content – 8.74%. Langbeinite rock 21.3 m thick. K₂O content – 10.7%. Polyhalite-sylvine rock 3.5 m thick | Lens-like; N₁vr | 59  |
| III-1-109 | Tsenyavskiy; Tsenyava village          | Langbeinite rock 2.2 and 7.9 m thick with kainite, leonite, astrakhanite, polyhalite, kieserite and sylvine bunches. K₂O content – 8.6-9.15%. | Lens-like; N₁vr | 70  |
| IV-2-188 | Dzvynatskiy-I; Dzvyynych village       | Langbeinite rock 3.0 m thick. K₂O content – 13.8%. | Lens-like; N₁vr | 136 |
| IV-2-189 | Dzvynatskiy-II; Dzvyynych village      | Langbeinite-sylvine rock 3.1 m thick with kieserite and epsomite. K₂O content – 8.3%. Langbeinite rock 2.8 m thick. K₂O content – 9.14%. Langbeinite-kainite rock with sylvine, kieserite and epsomite. K₂O content – 8.95%. | Lens-like; N₁vr | 136 |
| IV-2-190 | Dzvynatskiy-III; Dzvyynych village     | Kainite rock 3.0 m thick with langbeinite bunches. K₂O content – 12.72%. | Lens-like; N₁vr | 136 |</p>
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<td>IV-2-197</td>
<td>Starunskiy-I; Starunya village</td>
<td>Kainite rock from 2.1 to 7.0 m thick. K\textsubscript{2}O content from 8.12 to 8.84%.</td>
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<td>Kieserite-langbeinite rock 6.9 m thick. K\textsubscript{2}O content – 7.73%. Langbeinite rock 2.4 m thick. K\textsubscript{2}O content – 9.94%. Kainite-langbeinite rock 9.6 m thick with sylvine, polyhalite, carnallite and kieserite. K\textsubscript{2}O content – 8.72%. Carnallite rock 3.5 m thick. K\textsubscript{2}O content – 9.78%.</td>
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<td>IV-2-201</td>
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<td>Kainite rock 7.7 and 4.0 m thick. K\textsubscript{2}O content 11.4 and 14.0%. Halite rock with kainite. K\textsubscript{2}O content – 4.0-5.57%.</td>
<td>Lens-like; N\textsubscript{1}vr</td>
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**Natural brines**

Deposit

| III-1-89 | Dolynske; Dolyna town | In production | Bed-fractured chloride sodium; N\textsubscript{1}vr | 109, 140 |

**Underground waters**

Mineral

Without distinct features and components

Deposit

| IV-1-171 | Pidlyutenske; Kuzmynets village | In production | Bed-fractured; P\textsubscript{vyg} | 145 |

**Occurrence**

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<td>Dobrivlyanskiy; Zhuravenky village</td>
<td>HySuCa*; Mz** – 2.2 g/dm\textsuperscript{3}; Y*** - 0.2 dm\textsuperscript{3}/s; Krainskiy type</td>
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<td>SuCa; Mz - 4 g/dm\textsuperscript{3}; Krainskiy type</td>
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<td>II-2-58</td>
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<td>Sepyschanskiy; Sepysche village</td>
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<td>Blyudnytskiy; Blyudnyky village</td>
<td>ChSuSo; Mz – 3.9 g/dm³; Y – 1.44 dm³/s; Feodosiyskiy type</td>
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<td>Perevozets; Perevozets village</td>
<td>SuSo; Mz – 2.4 g/dm³; Y – 0.2 dm³/s; Feodosiyskiy type</td>
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<td>ChSo; Mz – 160 g/dm³; Moskovskiy (Boenskiy) type</td>
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<td>ChSo; Mz – 260 g/dm³; Y – 0.1 dm³/s; Moskovskiy (Boenskiy) type</td>
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<td>III-2-124</td>
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<td>ChSo; Mz – 220 g/dm³; Moskovskiy (Boenskiy) type</td>
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<td>ChSo; Mz – 316 g/dm³; Moskovskiy (Boenskiy) type</td>
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<td>ChSo; Mz – 118 g/dm³; Usolskiy type</td>
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<td>ChSo; Mz – 4.5 g/dm³; Y – 0.51 dm³/s; Minskiy type</td>
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<td>Bed-fractured; N&lt;sub&gt;ks-Q&lt;/sub&gt;</td>
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<td>III-4-146</td>
<td>Gannusivskiy; Gannusivka village</td>
<td>SuCa; Mz – 2.2 g/dm³; Krainskiy type</td>
<td>Bed-fractured; N&lt;sub&gt;i,ir&lt;/sub&gt;</td>
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<td>III-4-148</td>
<td>Uzynskiy; Uzyn village</td>
<td>SuCa; Mz – 2.2 g/dm³; Y – 0.3 dm³/s; Krainskiy type</td>
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<td>ChCaSo; Mz – 4.3 g/dm³; Y – 0.013 dm³/s; Uglytskiy type</td>
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<td>Bed-fractured; N1vr-Q</td>
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Iodine-bromine Deposit

| III-3-139 | Starolysetske; Stariy Lysets village | Out of production | Bed-fractured; K₂̅vr | 145 |

Sulfur hydrogen Occurrence

| I-3-28 | Sarnykovskiy-I; Sarnyky village | HySuMaCa; Mz – 0.8 g/dm³; Y – 2.0 dm³/s; Nemyrivskiy type | Bed-fractured; N1tr | 77 |
| I-3-35 | Sarnykovskiy-II; Sarnyky village | HySuMaCa; Y – 0.5 dm³/s; Nemyrivskiy type | Bed-fractured; N1tr | 77 |
| II-2-53 | Tomashivtsivskiy; Tomashivtsi village | HySuMaCa; Y – 0.02 dm³/s; Nemyrivskiy type | Bed-fractured; N1tr | 128 |

Fresh Drinking waters Deposit

| I-3-39 | Burshtynske; Burshtyn town | In production | Bed; K₂ | 57 |

Industrial Bromine Occurrence

| II-2-63 | Potassium Mine; Kalush town | ChSo; Mz – 319 g/dm³; Br – 374 mg/dm³ | Bed-fractured; N1bl | 117 |
| IV-2-211 | Starunksiy; Starunya village | Mz – 321 g/dm³; Br – 496 mg/dm³ | Bed-fractured; N1vr | 117 |

Iodine Occurrence

| I-1-11 | Lyskivskiy; Lysik village | ChSo; Mz – 59-65 g/dm³; I – 38-42 mg/dm³; Br – 136-140 mg/dm³ | Bed-fractured; N1ds2 | 117 |
| III-1-96 | Nyzhnoostrutynskiy; Nyzhniy Strutyn village | ChSo; Mz – 53 g/dm³; I – 26 mg/dm³; Br – 198 mg/dm³ | Bed-fractured; P3, N1ml | 117 |
| III-2-126 | Grabivskiy-I; Grabivka village | ChSo; Mz – 103-119 g/dm³; I – 50.7 mg/dm³; U – 3.25×10⁻³ g/dm³; Y – 0.09-0.39 dm³/s; | Bed-fractured; N1ks | 117 |

Iodine-bromine Occurrence

<p>| I-1-3 | Dashavskiy; Dashava town | ChSo; Mz – 102 g/dm³; I – 28 mg/dm³; Br – 213 mg/dm³ | Bed-fractured; K₂vr | 117 |
| II-2-56 | Kaluskiy-III; Kalush town | ChSo; Mz – 43-92 g/dm³; I – 12.7-42.3 mg/dm³; Br – 58.6-238.4 mg/dm³; Li – 5.5 mg/dm³; Sr – 160 mg/dm³; Y – 0.05-0.2 dm³/s; | Bed-fractured; C₀f, Jn²; K₂vr, N1ks | 117 |</p>
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<td>ChCaSo; Mz = 122 g/dm³; I = 88.8 mg/dm³; Br = 308.5 mg/dm³; Y = 2.04 dm³/s;</td>
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<td>ChSo; Mz = 44-144 g/dm³; I = 32.9 mg/dm³; Br = 591.4 mg/dm³; U = 3.25×10⁻⁷ g/dm³; Y = 0.04 dm³/s;</td>
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<td>ChSo; Mz = 79.3 g/dm³; I = 53 mg/dm³; Br = 482 mg/dm³; U = 3.2×10⁻⁷ g/dm³; Y = 0.01 dm³/s;</td>
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<td>Bed-fractured; N₁,ks</td>
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<td>Berezhnytsiy; Berezhnytsya village</td>
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<td>Bed-fractured; K₂vr</td>
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<td>ChSo; Mz = 52-58 g/dm³; I = 41-51.4 mg/dm³; Br = 328-336.6 mg/dm³; Y = 0.32-1.27 dm³/s</td>
<td>Bed-fractured; N₁,ks</td>
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<td>Zaviy-III; Zaviy village</td>
<td>ChSo; Mz = 119-224 g/dm³; I = 25.3 mg/dm³; Br = 383-543 mg/dm³; B₂O₃ = 30 mg/dm³; Y = 0.01 dm³/s</td>
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<td>Grabivskiy-II; Grabivka village</td>
<td>ChSo; Mz = 84-148 g/dm³; I = 10 mg/dm³; Br = 212.4-347 mg/dm³; Y = 0.57 dm³/s</td>
<td>Bed-fractured; C₃f, J₃nž</td>
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<td>IV-2-183</td>
<td>Dzvynyatskiy-I; Dzvynyach village</td>
<td>ChCaSo; Mz = 207.9-307.6 g/dm³; I = 12.7-22.4 mg/dm³; Br = 414-469.7 mg/dm³; B₂O₃ = 20 mg/dm³; U = 3.5×10⁻⁷ g/dm³; Ra = 16.35×10⁻¹¹ g/dm³; NH₄ = 100 mg/dm³;</td>
<td>Bed-fractured; N₁,vr</td>
<td>117</td>
</tr>
<tr>
<td>IV-2-187</td>
<td>Maydanskiy; Mizhgirya village</td>
<td>ChSo; Mz = 156 g/dm³; I = 26 mg/dm³; Br = 254 mg/dm³; B₂O₃ = 50 mg/dm³; Y of outflow = 19.4 dm³/s</td>
<td>Bed-fractured; P₁-N₁,ml</td>
<td>117</td>
</tr>
<tr>
<td>IV-2-191</td>
<td>Dzvynyatskiy-III; Dzvynyach village</td>
<td>ChCaSo; Mz = 383 g/dm³; I = 37 mg/dm³; Br = 804 mg/dm³; Y of outflow = 19.4 dm³/s</td>
<td>Bed-fractured; P₁-N₁,ml</td>
<td>117</td>
</tr>
<tr>
<td>IV-2-206</td>
<td>Starunskiy-I; Starunya village</td>
<td>Mz = 383 g/dm³; I = 15.6 mg/dm³; Br = 549 mg/dm³</td>
<td>Bed-fractured; P₁-N₁,ml</td>
<td>117</td>
</tr>
<tr>
<td>IV-2-212</td>
<td>Starunskiy-III; Starunya village</td>
<td>Mz = 288 g/dm³; I = 16-21.2 mg/dm³; Br = 274-549 mg/dm³;</td>
<td>Bed-fractured; Ѕ₃vg; P₁-N₁,ml</td>
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<td>Iodine-boron-bromine</td>
<td>Occurrence</td>
<td></td>
</tr>
<tr>
<td>IV-2-186</td>
<td>Dzvynatskiy-II; Dzvynyach village</td>
<td>ChCaSo; Mz – 292 g/dm³; I – 16.9 mg/dm³; Br – 461.9 mg/dm³; B₂O₃ – 200 mg/dm³; U – 3.25×10⁻² g/dm³; Ra – 16.35×10⁻¹¹ g/dm³; NH₄ – 150 mg/dm³; K – 1563.1 mg/dm³</td>
<td>Bed-fractured; N₁νr</td>
<td>117</td>
</tr>
<tr>
<td>IV-2-204</td>
<td>Nadiya-I; Starunya village</td>
<td>I – 22.2 mg/dm³; Br – 278.4 mg/dm³; B₂O₃ – 320.4 mg/dm³; U – 6.5×10⁻⁷ g/dm³</td>
<td>Bed-fractured; N₁νr</td>
<td>117</td>
</tr>
<tr>
<td>IV-2-208</td>
<td>Starunsky-I; Starunya village</td>
<td>ChCaSo; Mz – 263 g/dm³; I – 19 mg/dm³; Br – 0.08 mg/dm³; B₂O₃ – 456.8 mg/dm³; U – 3.25×10⁻⁷ g/dm³; Ra – 80×10⁻¹¹ g/dm³</td>
<td>Bed-fractured; N₁νr</td>
<td>117</td>
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<tr>
<td>IV-3-221</td>
<td>Nazavyzivski; Nazavyziv village</td>
<td>ChSo; Mz – 274 g/dm³; I – 15-38 mg/dm³; Br – 200-450 mg/dm³; B₂O₃ – 350 mg/dm³; Sr – 191 mg/dm³; Li – 12 mg/dm³</td>
<td>Bed-fractured; Jₚnază</td>
<td>117</td>
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Hereafter:
- * Water type by anionic composition: Hy – hydrocarbonate; Su – sulphate; Ch – chloride; by cationic composition: Ca – calcium; Ma – magnesium; So – sodium.
- ** Mz – mineralization, g/dm³.
- *** Y – yield, dm³/s.
Annex 2. List of deposits and occurrences indicated in the geological map and map of mineral resources in Quaternary sediments of map sheet M-35-XXV (Ivano-Frankivsk)

<table>
<thead>
<tr>
<th>Cell index, number in map</th>
<th>Mineral type, object name and its location</th>
<th>Deposit exploitation state or brief description of occurrence</th>
<th>Geological-economic type and age of productive pile</th>
<th>Notes (references cited)</th>
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<tr>
<td>1-1-228</td>
<td>Berezhnytsya; Zabolotivtsi village</td>
<td>Out of production</td>
<td>Low-moor; bH</td>
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<tr>
<td>1-1-229</td>
<td>Mlynyska; Mlynyska village</td>
<td>Out of production</td>
<td>Low-moor; bH</td>
<td>75</td>
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<tr>
<td>1-2-231</td>
<td>Grygorivske; Grygoriv village</td>
<td>Out of production</td>
<td>Low-moor; bH</td>
<td>76</td>
</tr>
<tr>
<td>1-2-232</td>
<td>Zhurivske; Zhuriv village</td>
<td>Closed</td>
<td>Low-moor; bH</td>
<td>76</td>
</tr>
<tr>
<td>1-2-234</td>
<td>Kolokolynske; Kolokolyn village</td>
<td>Out of production</td>
<td>Low-moor; bH</td>
<td>76</td>
</tr>
<tr>
<td>1-2-235</td>
<td>Posvirzh; Posvirzh village</td>
<td>Out of production</td>
<td>Low-moor; bH</td>
<td>76</td>
</tr>
<tr>
<td>1-2-241</td>
<td>Tsvitova; Tsvitova village</td>
<td>In production</td>
<td>Low-moor; bH</td>
<td>76</td>
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<tr>
<td>1-3-243</td>
<td>Vilkhova; Vilkhova village</td>
<td>In production</td>
<td>Low-moor; bH</td>
<td>76, 134</td>
</tr>
<tr>
<td>1-3-244</td>
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<td>In production</td>
<td>Low-moor; bH</td>
<td>76, 134</td>
</tr>
<tr>
<td>1-3-245</td>
<td>Zalyvky-II; Zalyvky village</td>
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<td>Low-moor; bH</td>
<td>76, 134</td>
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<tr>
<td>1-3-246</td>
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</tr>
<tr>
<td>1-3-248</td>
<td>Uizd; Sarnyky village</td>
<td>Out of production</td>
<td>Low-moor; bH</td>
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<tr>
<td>1-3-249</td>
<td>Sarnyky; Sarnyky village</td>
<td>Out of production</td>
<td>Low-moor; bH</td>
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**Combustible minerals**

- Solid
- Peat
- Deposit
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<th>Non-metallic mineral resources</th>
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<td>Construction materials</td>
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<td>Brick-tile raw materials</td>
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<td>Clay, loam</td>
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<td>1-3-250</td>
<td>Nastashyn; Nastashyn village</td>
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<tr>
<td>1-3-252</td>
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<td>Low-moor; bH</td>
<td>76</td>
</tr>
<tr>
<td>1-3-253</td>
<td>Burshyn; Burshyn town</td>
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<td>76</td>
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<tr>
<td>III-1-294</td>
<td>Odynysya; Dolyna town</td>
<td>In production</td>
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<tr>
<td>III-1-295</td>
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<td>In production</td>
<td>High-moor; bH</td>
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<tr>
<td>III-1-297</td>
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<tr>
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<td>III-1-301</td>
<td>Turova Dacha; Sloboda-Nebylivska village</td>
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<tr>
<td>III-4-312</td>
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<td>IV-4-334</td>
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<td>Ivano-Frankivske (Zagvizdya); Ivano-Frankivsk town</td>
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<td>Sheeted; ed,vdP_H; vdPsl</td>
<td>143</td>
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<tr>
<td>III-3-308</td>
<td>Ivano-Frankivske (Krekhivtsi); Ivano-Frankivsk town</td>
<td>In production</td>
<td>Sheeted; vdP_Hbg+pc</td>
<td>143</td>
</tr>
<tr>
<td>III-4-310</td>
<td>Vilshanytske; Vilshanytsya village</td>
<td>Out of production</td>
<td>Sheeted; vdP_bg</td>
<td>143</td>
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<tr>
<td>III-4-313</td>
<td>Markovetske; Markivtsi village</td>
<td>Out of production</td>
<td>Sheeted; ed,vdP_H</td>
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</tr>
<tr>
<td>IV-1-314</td>
<td>Perekinske; Perekinske village</td>
<td>In production</td>
<td>Sheeted; e,vdP_H</td>
<td>143</td>
</tr>
<tr>
<td>IV-2-315</td>
<td>Glybokske; Glyboka village</td>
<td>In production</td>
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<tr>
<td>IV-2-316</td>
<td>Glybokske; Glyboka village</td>
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<tr>
<td>IV-2-317</td>
<td>Sadzhavske; Sadzhava village</td>
<td>In production</td>
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<tr>
<td>IV-2-319</td>
<td>Rakovetske; Rakovets village</td>
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</tr>
<tr>
<td>IV-2-320</td>
<td>Rakovetske-I; Rakovets village</td>
<td>In production</td>
<td>Sheeted; e,vdP_H</td>
<td>143</td>
</tr>
<tr>
<td>IV-3-321</td>
<td>Bogorodchanske; Bogorodchany town</td>
<td>Out of production</td>
<td>Sheeted; e,vdP_H</td>
<td>143</td>
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<tr>
<td>IV-3-322</td>
<td>Zaberezhzivske; Zaberezhzhya village</td>
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<tr>
<td>IV-3-323</td>
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<td>Bystrytske; Bystrytsya village</td>
<td>Out of production</td>
<td>Sheeted; vdP$_{III}bg$</td>
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<tr>
<td>IV-3-325</td>
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<td>Tysmenychanske; Tysmenychany village</td>
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<tr>
<td>IV-3-326</td>
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<td>Gorokholynske-I; Gorokholyna village</td>
<td>In production</td>
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<tr>
<td>IV-3-327</td>
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<td>Gavrylivske; Gavrylivske village</td>
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<td>IV-3-328</td>
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<td>Volovivske; Volosiv village</td>
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<td>IV-3-329</td>
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<td>Nadvirnyanske-I; Pereris village</td>
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<tr>
<td>IV-3-330</td>
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<td>Tarnavytse; Lisova Tarnavytseya village</td>
<td>In production</td>
<td>Sheeted; e,vdP$_{III}bg$</td>
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<tr>
<td>IV-4-331</td>
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<td>Otynya; Otynya village</td>
<td>Closed</td>
<td>Sheeted; ed,vdP$_{III}bg$</td>
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<td>IV-4-332</td>
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<td>Vynogradivsske; Vynograd village</td>
<td>In production</td>
<td>Sheeted; ed,vdP$_{III}bg$</td>
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<tr>
<td>IV-4-333</td>
<td></td>
<td>Strupkivske; Strupkiv village</td>
<td>In production</td>
<td>Sheeted; vdP$_{III}bg+pc$</td>
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</table>

**Underground waters**

- Fresh
- Drinking waters
- Deposit

<table>
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<td>I-2-238</td>
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<td>Zhuravnenske; Zhuravne village</td>
<td>Out of production</td>
<td>Sheeted non-pressurized; a$^1P_{II}ids$</td>
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<td>II-2-270</td>
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<td>Dobrivlyanske; Kalush town</td>
<td>In production</td>
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<td>II-2-271</td>
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<td>Kaluske; Kalush town</td>
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<tr>
<td>II-2-272</td>
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<td>Vistova; Vistova village</td>
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<tr>
<td>II-3-273</td>
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<td>Shevchenkivske; Ostriv village</td>
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<tr>
<td>II-3-275</td>
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<td>Galytske; Galych town</td>
<td>In production</td>
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<tr>
<td>III-1-296</td>
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<td>Rozhnyatyske; Rozhnyativ town</td>
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<tr>
<td>III-2-302</td>
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<td>Khotynske; Khotyn village</td>
<td>In production</td>
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<tr>
<td>III-3-309</td>
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<td>Cherniivske; Cherniiv village</td>
<td>Out of production</td>
<td>Sheeted non-pressurized; a$^1P_{II}ids$</td>
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<tr>
<td>IV-3-324</td>
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<td>Bogorodchanske; Tyemenychany village</td>
<td>In production</td>
<td>Sheeted non-pressurized; a$^1P_{II}ids$</td>
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</table>

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Annex 3. List of geological landmarks shown in “Geomorphologic scheme” in the scale 1:500000

<table>
<thead>
<tr>
<th>Number in the scheme</th>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rock outcrops important for stratigraphy</td>
</tr>
<tr>
<td>1</td>
<td>Verkhniy Strutyn village, Chechva river left bank</td>
<td>Column outcrop of Upper Menilitova sub-suite (Miocene) with thick tuff (“Chechvynski tuffs”) and tuffite batch</td>
</tr>
<tr>
<td>2</td>
<td>Lopyanka village, Chechva river left bank</td>
<td>Column outcrop of Middle Menilitova (Lopyanetska) sub-suite (Oligocene – Early Miocene)</td>
</tr>
<tr>
<td>4</td>
<td>Chechva river, Lugy village</td>
<td>Eocene column outcrop typical for Beregova nappe</td>
</tr>
<tr>
<td>5</td>
<td>Starunya village</td>
<td>Mud volcano</td>
</tr>
<tr>
<td>6</td>
<td>Galych town</td>
<td>Basic section of Quaternary sediments</td>
</tr>
<tr>
<td>7</td>
<td>Krylos village, right bank of Lukva river</td>
<td>Stratotype outcrop of Santonian-Coniacian Lukvynska Suite</td>
</tr>
<tr>
<td>8</td>
<td>Dubivtsi village, quarry</td>
<td>Stratotype outcrop of Turonian-Coniacian Dubivetska Suite</td>
</tr>
<tr>
<td>9</td>
<td>Oleshiv village</td>
<td>Outcrop of Miocene Tyraska Suite sulphates. Classic examples of various gypsum structures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Impressive surface forms of esthetic value decorating the landscape</td>
</tr>
<tr>
<td>3</td>
<td>Chechva river, Lugy village</td>
<td>Chechva break-through valley composed of Upper Paleocene Yamnenska Suite massive sandstones</td>
</tr>
</tbody>
</table>

Annex 4. List of archeological landmarks shown in “Geomorphologic scheme” in the scale 1:500000

<table>
<thead>
<tr>
<th>Number in the scheme</th>
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<th>Description</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Paleolitic settlement. Remnants of fires, flint wares, burned organic remnants. Settlement age by radiocarbon analysis is 23500-25100 years</td>
</tr>
<tr>
<td>10</td>
<td>Galych-1 town</td>
<td>Late Paleolitic settlement. Remnants of fires, flint wares, burned organic remnants.</td>
</tr>
<tr>
<td>11</td>
<td>Mezhygirtsi village</td>
<td>Paleolitic settlement of Mustyrskiy time. Remnants of fires, flint wares (scrapers, knifes etc.)</td>
</tr>
<tr>
<td>12</td>
<td>Lysynchynyky village</td>
<td>Early Neolitic settlement. Linear-band culture landmark</td>
</tr>
<tr>
<td>13</td>
<td>Bukivna village</td>
<td>Paleolitic settlement of Mustyrskiy time. Remnants of fires, flint wares (scrapers, knifes etc.)</td>
</tr>
<tr>
<td>14</td>
<td>Bukivna village</td>
<td>Early Neolitic settlement. Linear-band culture landmark</td>
</tr>
<tr>
<td>15</td>
<td>Goloskiv village</td>
<td>Settlement of second half of IV – beginning of III BD (middle stage of Trypilska culture)</td>
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</tbody>
</table>
Index of geographic names in the text

<table>
<thead>
<tr>
<th>Letter</th>
<th>Geographic Names</th>
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<tbody>
<tr>
<td>B</td>
<td>Bebelka, river</td>
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<tr>
<td></td>
<td>Berezhnytsya, stream</td>
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<td></td>
<td>Berezhnytsya, village</td>
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<tr>
<td></td>
<td>Berezivka, village</td>
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<tr>
<td></td>
<td>Berezovytsya, mountain</td>
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<tr>
<td></td>
<td>Berlogy, village</td>
</tr>
<tr>
<td></td>
<td>Bzhovach, mountain</td>
</tr>
<tr>
<td></td>
<td>Bystrytsya-Nadvirnyanska, river</td>
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<tr>
<td></td>
<td>Bystrytsya-Solotvynska, river</td>
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<td>Bystrytsya, river</td>
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<td>Bytkiv, village</td>
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<td>Blyudnyky, village</td>
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<td>Bovshiv, village</td>
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<td>Bogorodchany, town</td>
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<td></td>
<td>Bogrivka, village</td>
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<td>Bolokhivka, river</td>
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<td>Bratkiytsi, village</td>
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<td>Broshniv, village</td>
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<td>Bukachatinski, village</td>
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<td>Bukivna, village</td>
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<td>Burshtyn, town</td>
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<td>Burshtynske, water reservoir</td>
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<td>V</td>
<td>Vavenka, mountain</td>
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<td></td>
<td>Velyka Turya, village</td>
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<td></td>
<td>Velikiy Lukovets, stream</td>
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<td>Verbivka, village</td>
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<td>Verbil, mountain</td>
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<td>Verkhniy Sekhlys, mountain</td>
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<td></td>
<td>Verkhniy Strutyn, village</td>
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<td>Viktoria, village</td>
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<td>Vovchikiv, village</td>
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<td>Voinyliiv, village</td>
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<td>Vorona, river</td>
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<td>Vulkan, mountain</td>
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<td>Zhuravenky, village</td>
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<td>Zhuraky, village</td>
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<td>Zhuriv, village</td>
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<td>I</td>
<td>Ivano-Frankivsk, city</td>
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<td>Ivanykivka, village</td>
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<td>K</td>
<td>Kadobna, village</td>
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<td>Kaluske, village</td>
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<td>Kalush, town</td>
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<td>Kamenets, stream</td>
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<td></td>
<td>Karpaty (Carpathians), mountains</td>
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</table>
Kytvan, mountain
Klubivtsi, village
Klyova, mountain
Kozara, mountain
Kozari, village
Kolodiyivka, village
Kolokoly, village
Kont, mountain
Konyushky, village
Korchivka, village
Kosmach, village, stream
Kosmachka, mountain
Kosmychara, mountain
Krivik (Krakow), city (Poland)
Krasnyivka, village
Krasna, mountain
Krasne, village
Krehiv, village
Krehovychy, village
Kryvets, village
Krylos, village
Krychka, village
Kropyvnyk, stream
Kuropatnyky, village

L

Lypivka, village
Lypovytysya, village, stream
Lysets, village
Lysa, mountain
Lysiv, village
Limytsya, river
Lisny Khlibychyn, village
Lodzhivivka, mountain
Lopyanka, village
Lugy, village
Lukavets Velykiy, stream
Lukva, river
Lukvytsya, river, village
Lviv, city
Lublin, city (Poland)
Lyuchka, village

M

Maydan, village
Manyavka, river
Marynopol, village
Markova, village
Markivtsi, village
Makhlynets, village
Medukha, village
Mezhigirtsi, Upper Paleolitic settlement
Mezhigirtsi, village
Menchylka, stream
Mylovannya, village
Mizhgiya, village
Molodychna, village
Molodivka, village
Monastyrchany, village
Mostysche, village

N

Novoshyn, village
Nazariv, village
Nadvirna, town
Naraivka, river
Nebyliv, village
Nvachyn, village
Nyzhni Strutyn, village
Nimshyn, village
Novytsya, village
Novomarkivka, village
Novoshyn, village

O

Obolonya, village
Obroshyna, river
Ozeryany, village
Opillya, plateau
Otnyana, village
Ostriv, village

P

Pavlivka, village
Palagychi, village
Perevozets, village
Peregynets, stream
Pereginske, town
Petryliv, village
Petranka, village
Pidgirky, village
Pidpechey, village
Pistyn, village
Podillya, village
Podorozhne, village
Posvirzh, village
Porogy, village
Potok, mountain
Pru, river
Pshenychynky, village

R

Radcha, village
Rakhnya, village
Rakovets, village
Ripne, village
Rypanka, village
Rozhnyativ, town
Roshnyate, village
Rozsila, village
Rozhnyatyske, water reservoir
Rudka, river

S

Sadzhava, stream, village
Sapigiv, stream
Sarnyky, village
Svyny, stream
Svirzh, river
Svicha, river
Selyshche, village
Sekhlys, ridge
Syvka Kaluzka, village
Syvka Voynylivska, village
Syvka, stream
Sykhiv, village
Skala, mountain
Slyvky, village
Sloboda Nebylivska, village
Solottyn, village
Spas, village
Stari Bogorodechany, village
Stariy Lysets, village
Starunya, village
Stari Kryvotuly, village
Stinka, ridge
Striy, river
Strygantsi, village
Strutyn, village
Sulyatychi, village
Temyrivtsi, village
Tysmenychany, village
Tlumach, river
Tomashivtsi, village
Torgovyt sya, village
Trostyanets, village
Tuzhyliv, village
Turyanka, stream
U
Uizdskiy Potik, river
Uzyn, village
Ugryniv, village
F
Fronyliv, stream
KH
Khomyakivka, village
TS
Tsvitova, village
Tsennyava, village
Tseptsyura, mountain
CH
Chagriv, village
Cheremkhiv, village
Chernivetska, Oblast
Cherniv, village
Chechva, river
Chornoliztsi, village
Index of geological terms in the text

A

Anticlines of tectonic floors:
 First floor:
 - Verkhnyostrutynska
 - Nyzhnyostrutynska
 - Pivdennoslyvkinska
 - Slyvkinska
 - Spas-Rypnyanska
 Second floor:
 - Lukvynska
 - Maydanska
 Third floor:
 - Rosilnyanska
 Fourth floor:
 - Gvizdetska
 - Dzvynyatska
 - Kosmatska
 - Monastyrchanska

B

Bilche-Volytska zone
 Boryslavsko-Pokutskiy thrust (zone)
 Boyanetskiy trough
 Bukovynske uplift

V

Volyno-Podilska monocline

D

Dansko-Polska groove
 Denudation-accumulation levels:
 - Krasnoi
 - Loevoi
 Dnistrovskiy peri-cratonic trough

Z

Zarichivska syncline
 (Zakhidno) Western-European Platform
 - Golynska
 - Kaluska
 - Trostyansetsko-Petrankivska

Zakhidnopodilska zone
 (Zovnishni) External Carpathians

I

Ilemkvivska anticline

K

(Karpatskiy) Carpathian mega-thrust

Climatoliths:
 - Beregivskiy
 - Berezanskiy
 - Bogdanivskiy
 - Buzkiy
 - Vitachivskiy
 - Dniprovskiy
 - Dofinivskiy
 - Zavadivskiy
 - Kaydatskiy
 - Kryzhanivskiy
 - Lubenskiy
 - Martonoskiy
 - Pryazovskiy
 - Prylutskiy
 - Prychornomorskiy
 - Siverskiy
 - Sulskiy
 - Tyligulskiy
 - Tyasminskiy
 - Udayskiy
 - Shyrokovskiy

K

(Karpatskiy) Carpathian mega-thrust

Lvivska Cretaceous mold

L

Lypovetska anticline

Lopyanetska syncline

Lvivska Cretaceous mold

Lvivskiy Paleozoic trough

M

Molodyntyska paleo-valley

Maydanske tectonic sub-window

Lvivskiy Paleozoic trough

Shyrokovskiy

S

Sievskiy

Sitskiy

U

Ukraїnska intracontinental range

Wolf's teeth syncline

W

Wolyno-Podilska monocline

X

Zarichivska syncline

Z

Zakhidnopodilska zone
 (Zovnishni) External Carpathians
Osmolodivska anticline

P

(Peredkarpatskiy) Fore-Carpathian Trough
Pokutski Carpathians
Pokutski folds

R

Rava-Ruska zone
Major faults:
- Verkhovynskiy
- Kaluskiy
- Kosivskiy
- Krakovetskiy
- Krakovetsko-Striyskiy
- Ostroziy
- Fore-Carpathian
- RadaKhiev-Rogatynskiy
- Rogatynskiy
- Sushchano-Perzhanskiy
- Teterivskiy
- Chernivetskiy

Minor faults:
- Berlogskiy
- Bogorodchanskiy
- Butyn-Khlevchanskiy
- Krekhivskiy

S

Sambirskiy thrust (zone)
Suites:
- Balhtyska
- Bystrytska
- Bogorodchanska
- Verbizka
- Vygodskaya
- Vorotyshchenska
- Golovynska
- Dashavska
- Dubovetska
- Zhoravnenska
- Kosivska
- Lukvynska
- Manyavskaya
- Menilitova
- Nezvyska
- Nyzhnivska
- Oleskivska
- Opilska
- Polyantyska
- RadaKhiev-Ruska
- Rudkivska
- Sokalska
- Spaska
- Stebnytska
- Striyska

-Tyrska
-Ustyluzka
-Yammenska

Series:
- Baltiyska
- Berezhkivskaya
- Volynska
- Dnistrovska
- Zakhidnoukrainska
- Kanylivska
- Malynovetska
- Mogiliv-Podilskaya
- Molodovska
- RadaKhiev-Ruska
- RadaKhiev-Ruskiy (Davydenivskiy)
- RadeKhiev-Rogatynskiy
- RadaKhiev-Rogatynskiy
- RadaKhiev-Rogatynskiy
- RadaKhiev-Rogatynskiy
- RadaKhiev-Rogatynskiy

Sambirskiy thrust (zone)

(Taistan) Nappes:
- Beregovaya
- Zelemyankiya
- Orivskaya
- Skolivskaya
- Parashkaya

Skybovskiy thrust (zone)
Spaska anticline
Stanislavskaya uplift
Striyskaya trough
Litho-tectonic zones:
- Borysteyska
- Borysteyskaya-Pokutska
- Zakhidnopodilskaya
- Kovelskaya-Khotynskaya
- Kokhanivskaya
- Lezhayskaya
- Lvivskaya-Volynskaya
- RadaKhiev-Ruska
- Roztoyska
- Ruzhynskaya
- Sambirskaya
- Skybovskaya

(Stairs) Ledges:
- Budatskaya
- Vilshanska
- Desnianska
- Donetskaya
- Kyzylzharshky
- Nogayskaya
- Trubizhskaya
- Khadzhibeyskaya
- Cherkasskaya

Sub-Carpathian thrust
(Skhidno) Eastern-European Platform

F

Facial zones:
- Verbizka
- Zhoravnenska
- Lukvynska
- Rudkivskaya
- Sokalska
Flexure-fault zones:
- Zhuravnenska
- Krupska
- Sokolivska
- Tlumatska

YA

Yavornytska anticline