MINISTRY OF ENVIRONMENT PROTECTION OF UKRAINE
STATE GEOLOGICAL SURVEY

PRYCHORNOMORSKE STATE REGIONAL GEOLOGICAL ENTERPRISE
"PRYCHORNOMOR DRGP"

STATE GEOLOGICAL MAP OF UKRAINE

Scale 1:200 000

PRYCHORNOMORSKA SERIES
Map Sheets
L-35-XXIII (Izmail) and L-35-XXIX (Tulcha)

EXPLANATORY NOTES

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In the work, the main data are summarized and given on geological structure of map sheets L-35-XXIII (Izmail), L-35-XXIX (Tulcha) (in the limits of Ukraine) based on results of extended geological studies in 2006.

In the explanatory notes the data are given on the history of geological study in the territory, stratigraphy, tectonics and geological development, geomorphology, detailed description of mineral resources and regularities in their distribution, and their perspective assessment is presented. Description of technogenic loading over geological environment is given and the tasks for further studies are outlined.

The set of graphic materials includes: "Geological map and map of mineral resources of pre-Quaternary units" together with the legend thereof and stratigraphic columns; "Geological map and map of mineral resources of Quaternary sediments" with legends; "Geological map and map of mineral resources of pre-Cenozoic units" with legends thereof; schemes of geological content and small-scale maps, which illustrate the text of explanatory notes and are placed out of the main map sheet frames.

The annexes to the text contain the list of mineral deposits and occurrences and the list of geological landmarks.

The materials are devoted to the broad range of specialists in the field of geological sciences, industry specialists in the field of hydrogeology and ore and non-ore raw materials prospecting, oil and gas prospecting; specialists from construction organizations and agriculture. The set of maps can be used in the course of geological works planning in Prychornomorya.

CONTENTS

Abbreviations used in the text

BCI - bulk contamination indicator
BST - Branch Standard
CMRW - Complex Method of Reflected Waves
CMTS - Complex Magnetic Telluric Sounding
Derzhgeolkarta-200 - the State Geological Map in the scale 1:200 000
DH - drill-hole
DSS - Deep Seismic Sounding
EEP - Eastern-European Platform
EGP - exogenic geological processes
EGSF-200 - Extended Geological Study of the Fields in the scale 1:200 000
EGSF-50 - same one in the scale 1:200 000
EFS - Establishing Field Sounding
GE - Geological Enterprise
GEE - Geological Exploration Expedition
GM-50 - Geological Mapping in the scale 1:50 000
IP - Induced Polarization
LOC - light organic compounds
LTZ - Litho-Tectonic Zone
MCDP - Method of Common Deep Point
MPS - Method of Polarized Sounding
MRW - Method of Reflected Waves
MTS - Magnetic Telluric Sounding
NASU - National Academy of Sciences of Ukraine
NSC - National Stratigraphic Committee of Ukraine
OGA - Oil-Gas-Bearing Area
SBST - State Branch Standard
SEC - Scientific-Editorial Council
SGA - structure-geomorphologic area
SGE - State Geological Enterprise
SE - State Enterprise
SSU - the State Standard of Ukraine
TAC - top admissible concentration
TAL - top admissible level
TC - Technical Conditions
UISC - Ukrainian Inter-Ministry Stratigraphic Committee
UNAS - National Academy of Sciences of Ukraine
VES - Vertical Electric Sounding
VSS - Vertical Side Sounding

INTRODUCTION

The map sheet territory L-35-XXIII (Izmail) and L-35-XXIX (Tulcha) in administrative respect is included into Reniyskiy, Bolgradskiy and Izmailskiy areas of Odeska Oblast and is limited by coordinates $45^o10'$-$46^o00'$ N latitude and $28^o00'$-$29^o00'$ E longitude. In the south, by Danube River, it is limited by the State border with Romania, in the west and north-west – with Moldova. The map sheet square is 2843 km^2; major inhabited localities: Reni, Bolgrad, and Izmail towns (area centers).

In geomorphologic respect the territory comprises loess accumulative-denudation plain and is located within south-western part of Prychornomorska lowland gently inclined in the southern direction. The relief of northern and partly central part of the studied area comprises the plain slightly inclined towards Danube River and its flood-land, which is cut by the Kagul, Yalpug, Velikiy Katlabukh, Maliy Katlabukh river valleys, their branches and gullies. The relief of southern part of the territory comprises the system of diverse-height terraces composed of Quaternary alluvial sediments of Danube River and its left branches. Four over-flood terraces are distinguished with altitudes: 5-20 m, 20-40 m, 20-50 m, and 50-70 m. In the southern part of the area the river valleys are gradually substituted by the same-named, elongated in sub-longitudinal direction large lakes (flooded portions of minor left branches which flew into Danube River).

The altitudes of watershed plain surface vary from 180 to 2 m towards the river valleys and Danube River flood-land. The river valley and gully slopes are steep (30-45^o). In some places, mainly in the southern part, the watershed plain is cut towards the lakes with cliffs from 5 to 20-35 m high (Ozerne village and some sites in the eastern coast of Kagul lake).

The total square of the lakes in studied area is 380 km^2. The major lakes include Kagul, Yalpug, Kugurluy, Kytay, the smallest lake – Sofyan. They are connected with Danube River by the system of passes (eriks). In genetic respect the lakes comprise the mouth portions of Kagul, Yalpug, Velikiy Katlabukh, Maliy Katlabukh rivers under-flooded in the periods of sea transgressions.

The biggest lake, both in the studied area and entire Ukraine, is Yalpug lake. The lake square is about 10 km^2; it is extended in sub-longitudinal direction over 40 km being 6 km wide in the southern part. In the south Yalpug lake, through the spit where motor road Izmail town – Reni town is located nowadays, goes down to Kugurluy lake. The water in Yalpug lake is fresh (mineralization 1.0-1.5 mg/l). The coasts are mainly steep (40-45^o), often cliffy, up to 35 m high (Ozerne village area), in places are complicated by displacements (Kotlovyna village and Bolgrad town areas).

The major water line is Danube River, which flows over single course in the south-eastern direction up to Tulcha town (Romania), and then through the delta with numerous passes (mouths), former river-beds, lakes, islands and swamps. The biggest pass in the Danube delta is Kiliyske mouth which is followed by the State border with Romania. On the left bank of Kiliyske mouth Izmail town is located. Danube River course from Reni town to Tulcha town is 600-1120 m, maximum depth – 27 m. Flow speed is 0.4-0.9 m/s. Width of Kiliyske mouth is 200-800 m being 20-25 m deep. The left bank of Danube River and Kiliyske mouth through the system of coastal ridges goes into the flood-land which had been being filled with water under the floods. The flood-land width somewhere attains 12 km. In places, over couple of kilometers, in the area of Reni and Izmail towns, the flood-land is lacking. The coasts in these cases are steep and cut.

The climate is moderate-continental, warm, favorable to plant diverse agricultural varieties including fruits and grape. The winter is mild and short, with frequent thaw and fog. Predominating day temperature in January is $-2…-3^oC$, in the night - $-4…-5^oC$, the minimums attain $-20…-30^oC$. The snow cover (5-10 cm) is not consistent and available for 30-40 days. The soils are being frost to the depth 8-50 cm. The frostless period when daily temperature does not drop below 0^o is about 200 days.

The spring (March – mid of May) is cold in the first half and warm in the next one; up to the end of April the frost is observed at the soil surface in the night. Precipitates are being fallen in drizzle (rarely in the moist snow).

The summer (mid of May up to October) is warm, in some years hot and droughty. Predominating average day temperature in July is 21-23^oC, in some days it attains 40^oC, the night one – 17-19^oC. The alternating cloudiness is typical. Precipitates are rare, mainly in the summer months, in the short rainfalls.

The autumn (October – mid of December) is warm and dry in the first half and cold with drizzle and fog in the second one. In the second half of October the frost on soil is observed.

The winds over the year are mainly north-western and south-eastern. The wind speed is 3-4 m/s. In the summer dry dust storms (under the wind speed up to 15 m/s) are common. The annual amount of precipitates varies in the range 250-400 mm, of which most part is fallen in the summer and the minimum amount – in October-January.

The most part (>80%) of watershed plain and its slopes is tilled. Danube River flood-land is partitioned with numerous dams and is not being filled under floods while it is used for planting of mainly agricultural fodder crops (lucerne). After the motley grass – fescue, wormwood-straw steppes, the wheat, barley, maize, sunflower, millet, leguminous plants, buckwheat, melons, lucerne, grape and fruits are being planted. The artificial irrigation is being used in some specially arranged fields.

Of the wild-growing land varieties, at the steep slopes and gully bottoms of water-protected band along Kagul, Yalpug, Sofyan, Katlabukh lakes and forest-band, the steppe grass varieties are mainly developed – fescue, wormwood and motley grass. Of the trees, acacia, wild apricot, silverberry, rarely oak, maple are observed, and of the shrubs – silver olive, dog-rose, yellow acacia. In the swamped sites of rivers, lakes and Danube flood-land the swamp grass predominates – sedge, cane, and others. Of the trees, especially along the Danube River coast ridge, the pussy-willow and poplar are developed.

The soils in the map sheet territory are black-earths which are mainly developed over loess-like loams. In Danube River flood-land the turf, sandy, sandy loam and clayey-sandy soils are observed.

The population is mixed: Bulgarians, Moldavians, Ukrainians, Russians, Gagauz, Romanians, and Germans. Most of inhabitants are Bulgarians. The population is mainly employed in agriculture – wine-growing, gardening, tillage, farming, and fishing is also developed in the south. Relatively large industrial centers are the area centers Izmail and Reni towns. In Izmail town, the river port, repair-mechanic and dock are operating, as well as cellulose plant, tinned food factory and brick plant, auto-transport enterprise, municipal and trade entities.

The major communicating lines are paved roads which connect Reni, Bolgrad and Izmail towns one to another and with the Oblast center – Odesa city. All inhabited localities are interconnected by the system of paved roads. Besides the latter, the dirt roads are widespread although being hard accessible in the spring and autumn periods and also rainfall period. Reni and Izmail towns are connected with Oblast center Odesa city by the railway. In addition, Izmail town is connected to Odesa city by the airplane line. In the southern part of map sheet area the sailing is operating by Danube River and Kiliyske mouth.

In the steep slopes of Yalpug, Velikiy and Maliy Katlabukh rivers, coast cliffs of Kagul, Yalpug, Katlabukh lakes, and on large gully slopes just Neogene and Quaternary sediments are exposed. In Orlovka village area in the small surface outcrop Paleozoic sediments (Orlovska Suite) are exposed, and in the area of former Ferapontiy monastery – Triassic rocks. Exposure degree in general is not appropriate.

In tectonic respect the studied area belongs to the south-western slope of Eastern-European Platform (EEP). The territory has two-level structure characteristic for the EEP – pre-Riphean crystalline basement and platform cover. The lower tectonic level (basement) is composed of extensively deformed ultra-metamorphogenic rocks of Archean – Lower Proterozoic complex. The upper tectonic level (sedimentary cover) consists of Vendian, Paleozoic, Mesozoic and Cenozoic sediments. Paleozoic, Mesozoic and partly Cenozoic rocks are cut by intrusive complexes and in some places are essentially deformed.

The basic materials for the set of Derzhgeolkarta (see “Scheme of materials used” to the map sheets of geological map and map of mineral resources of Quaternary sediments) include:

- deep mapping in the scale 1:200 000 for map sheets L-35-XXIII, L-35-XXIX (L.S.Arbuzova, P.S.Surkina, A.A.Pokotun, 1972 [21]);
- geological mapping in the scale 1:50 000 for map sheets L-35-93-D, -94-C, -105-B (northern part), -106-A (northern part) (S.V.Petrov, I.M.Mokryak, 1989 [48]);
- extended geological study in the scale 1:200 000 for map sheets L-35-XXIII (Izmail), L-35-XXIX (Tulcha) in the limits of Ukraine (authors I.M.Mokryak, L.K.Shvets, O.P.Dobosh, S.V.Popov, and others, 2006 [42]).

In the preparation of materials for publication geologists I.M.Mokryak, L.K.Shvets, O.P.Dobosh, S.V.Popov, S.M.Kovtun, A.I.Kucherenko have participated.

The chemical, spectral, chemical-spectral and mineralogical analyses of the rocks have been conducted in the central laboratory of SE “Kirovgeologiya”, Kyiv city. Paleo-magnetic studies of Danube Pleistocene terraces were conducted in the Institute of Geophysics after S.I.Subotin of the NAS of Ukraine.

1. GEOLOGICAL STUDY DEGREE

Geological study of the map sheet territory prior to 1960 was sporadic [40, 46, 63]. Starting from the mid of 60^{th} of last century the study of lowland territory in between Prut and Danube rivers, from the one hand, and Dnister river (Besarabiya) from another hand, became systematic.

In 1969-1972 in the map sheet territory L-35-XXIII (Izmail) the deep geological mapping in the scale 1:200 000 had been conducted [21] resulted in the set of geological maps where which ideas on the geological structure of given territory had provided and the fields were defined seemed prospective for construction materials, gypsum, claydite raw materials, brown coal, zirconium, titanium, as well as general prognosis has been done for oil, gas, bauxites, iodine-bromine waters, and recommendations presented for the large-scale geological mapping.

In 1973-1976 the complex geological mapping in the scale 1:25 000 was conducted in purposes of seismic zonation (Artsyz, Bolgrad, Reni, Izmail towns) [22] when geological and geomorphologic structure was studied, the Quaternary and Pliocene sediments were subdivided, and hydrogeological and engineering-geological conditions have been studied.

In 1977-1980 specialized complex geological mapping in the scale 1:25 000 was conducted in purposes of seismic zonation of the eighth-magnitude zone [23], when the natural conditions were studied and the set of geological map was compiled reflecting geological structure, geomorphologic features, engineering-geological and hydrogeological conditions and mineral resources of the territory. For the first time engineering-geological and hydrogeological zonation of the territory was performed integrating all data on soils, hydrogeological and geomorphologic conditions, modern exogenic processes. New data on stratigraphy, tectonics, geomorphology, and mineral resources were obtained. The results were recommended as the base to further instrumental seismic studies and magnitude adjustment for some sites.

In 1985-1989 in the territory of Northern Fore-Dobruja the geological mapping in the scale 1:50 000 had been conducted together with general prospecting [48]. As a result, science-based geological map was designed, perspectives of the area for mineral resources were assessed, and prognostic evaluation performed for potential and exact ore-bearing of the fields and objects. For the first time the rare-metal specialization of intrusive rocks was defined and perspectives for polymetallic ores and gold of over-intrusive zone and southern exo-contact of Dolynskiy massif were evaluated. The perspective vein type of polymetallic mineralization was encountered confined to the junction zones of tectonic breaks, perhaps similar to Somovo deposit in Romania. The gold-bearing of Lower Triassic coarse-clastic rocks is found as well as increased concentrations of germanium, yttrium, ytterbium, scandium and zirconium in Middle Sarmatian brown coal.

In 2001-2005 extended geological study in the scale 1:200 000 was conducted [42]. The problems of stratigraphy, tectonics, and localization of minerals were elaborated. Stratigraphy of Quaternary sediments was defined and generalized, the correlation with the basic columns of Prychornomorya is grounded, genetic type is adjusted and stratigraphic level of Eo-Pleistocene – Lower Neo-Pleistocene red-brown sequence is defined. Structure features of neo-tectonic and modern planes of the territory were established. The perspectives were assessed for Orlovska sequence (Devonian) and Lower Triassic clastic sequence in term of fine-grain gold mineralization prospecting. Polymetallic occurrence in the area of Nagirne-Orlovka villages is evaluated. Barite occurrence and increased polymetal (galena, sphalerite) mineralization point is encountered in relation with quartz-carbonate veins.

In parallel to geological mapping, prospecting and exploration works for various mineral types were conducted in the map sheet area.

In 1974-1978 the works were conducted to study Carboniferous sediments and their coal-bearing in Fore-Dobruja [20]. In Carboniferous sediments of Fore-Dobruja trough two wells 3u and 4u [20, 42] had intersected 26 coal beds, of these the beds thicker than 0.3-13 m in drill-hole 4u [42] (outside the studied area).

In 1988 prospecting for rock salt was conducted in Izmailskiy and Kiliyskiy areas [59]. Geophysical and hydrogeological works performed and 21 prospecting wells were drilled. The litho-facial map is designed with perspectives for rock salt, geological, paleo-geographic, tectonic maps and cross-sections, the litho-stratigraphy was studied, as well as composition and paleo-geography of Upper Jurassic Kimmeridgian-Tithonian parti-colored terrigenous-chemogenic sediments and their salt-bearing.

In 1985-1990 metallogenic studies were conducted in the territory of Western Prychornomorya [37]. Generalization of geological-geophysical data had been performed, and regularities in localization of ore camps and mineral occurrences were established. The set of geological, facial, formation, metallogenic and prognostic maps as well as maps of factorial material are designed for Western Prychornomorya.

In 1991 prospecting-evaluation works and preliminary exploration of Dolynske deposit of construction sands were performed in Reniyskiy area [47]. It was established that sands of Dolynske deposit in general are suitable for construction works.

In 1995 the handbook "Mineral-resource base of construction materials industry of Ukraine" is published [24] where data are generalized on the commercial development and perspectives of mineral-resource base of construction materials industry.

For the water supplying of Reni town the exploration was carried out of groundwaters from Upper Pliocene water-bearing horizon in alluvial sediments of Danube River [19, 56].

In 1966 G.F.Lysogor [39] had conducted detailed prospecting for groundwaters in Danube River valley for water supplying of Bolgrad town and inhabited localities of Bolgradskiy and Reniyskiy areas. Significant fresh groundwater deposit was encountered in alluvium of Danube River flood-land extended over more than 70 km. Recommendations were presented on water resources protection and it was suggested to perform preliminary exploration of groundwaters and evaluate their exploitation reserves by categories A, B, and C_1.

Geophysical studies in the map sheets L-35-XXIII, -XXIX had been commenced ever since 1948. In the period 1948-1953 the most part of the area between Dnister and Prut rivers was covered by the planar gravity and magnetic surveys in the scale 1:100 000 – 1:200 000. Besides the surface surveys, the mapping in the scale 1:100 000 was conducted in 1953 by aero-magnetic group of Ukrainian Geophysical Trust in the north-eastern part of the studied area [31, 33, 35, 36, 38, 45, 49, 54, 55, 58, 60, 62].

Results of mapping were generalized (G.A.Balabushevych, 1955) and on this ground the maps of gravity and magnetic fields in the scale 1:500 000 were designed for entire territory between Dnister and Prut rivers.

In 1966 thematic group of "Dniprogeofizika" trust had carried out re-interpretation and generalization of aforementioned mapping results and integrated maps of magnetic and gravity fields in the scale 1:200 000 were designed (A.N.Shantyr).

The gravi-magnetic studies of modern type have been commenced since 1968 by the trust "Dniprogeofizika" and Moldavian geophysical expedition aiming preparation of geophysical base for geological mapping in the scale 1:50 000. Specifically, "Dniprogeofizika" trust in 1968-1973 had carried out planar gravity and magnetic surveys in the scale 1:50 000 in the central part and southern margin of Fore-Dobruja trough [31, 45, 49, 55, 60, 62]. In the northern part the gravity survey in the scale 1:50 000 was conducted by Moldavian geophysical expedition [55]. In the same area the aero-magnetic group of Kyiv Geophysical Expedition had carried out in 1981-1985 the survey in the scale 1:50 000 [45].

Results of mapping in the scale 1:50 000 had revealed complex morphology of gravity and magnetic fields in the area between Dnister and Prut rivers where numerous local anomalies are encountered caused by petrographic irregularities and tectonic features of crystalline basement and sedimentary cover.

In general, the gravity and magnetic fields in most extents reflect tectonic elements of the area between Dnister and Prut rivers. In the northern part mosaic field is common with increased values of Δg_a and ΔZ_a. Majority of local anomalies is related to the features of basement petrographic composition and probably with its relief patterns. In the trough central part the gravity and magnetic fields are low-differentiated. The local gravity minimums over there do mainly coincide with the sites of maximum sedimentary cover thickness. In magnetic field the authors distinguish some local maximums of ΔZ_a, mainly of the north-western and sub-latitudinal direction, whose nature is caused by intrusive rocks.

Besides gravi-magnetic works, a number of electric surveys were conducted in Fore-Dobruja. Since 1948 to 1952 the first electric surveys were carried out by VES method over the grid providing efficient design of maps in the scale 1:100 000.

In 1960 VES works results were generalized by thematic group of UkrSGRI aiming design of geo-electric cross-sections in Fore-Dobruja (B.L.Gurevych, O.A.Avramenko). In tectonic maps, designed based on the VES results, the major regional features of geological structure of the area are mainly expressed.

In 1962-1964 electric survey group of All-Union Institute of Geophysics has carried out the works by the EFS method in the western part of Fore-Dobruja (D.P.Fedorova). As a result, tectonic schemes for two basic electric horizons were designed. of which one horizon corresponds to Precambrian basement, and the second one – to the surface of Paleozoic rocks.

Aiming the study of complex geo-electric conditions and perspectives to use electric survey methods in Western Prychornomorya, the thematic group of "Dniprogeofizika" trust in 1967-1968 had carried out re-interpretation of previous works data [61]. The quality analysis of data had allowed assessing the capacity of VES method in Western Prychornomorya. Specifically, in the platform slope, where crystalline basement comprises the basic horizon, the VES method application may support solutions to the basement relief mapping, as well as tectonics of the sedimentary cover.

In the central trough part VES capacities are limited since the basic electric horizon may change its stratigraphic anchoring from Paleozoic hanging-wall up to Jurassic top.

In the south-western part of territory VES method can be applied for mapping of Upper Jurassic gypsum-anhydrite sequence.

Based on quality analysis of EFS data the basic geo-electric horizon was identified in various geo-electric zones and the range of tasks was defined which can be solved by this method. It was assumed that this method also can be applied to study internal structure of Paleozoic units.

Over 1968-1971 Suvorovska electric survey group of "Dniprogeofizika" trust had conducted regional and planar works by EFS method. Two geo-electric horizons were established of which one is confined to the hanging-wall of Paleozoic sediments (electric compound) and the second one (magnetic compound) is located inside Paleozoic column or is related to Precambrian basement. The planar works had showed EFS method capacities for mapping over the fields of Paleozoic extrusives intersected by deep drill-holes in Tatarbunarskiy ledge.

In view of oil-gas-bearing perspectives, the seismic surveys (MRW, CMRW) were also conducted in the studied area.

Seismic surveys by MRW commenced in Fore-Dobruja in 1949. The studies have been performed by various organizations: Moldavian geophysical expedition, "Ukrgeofizrozvidka" trust, West-Ukrainian geophysical expedition, Moldavian geological department, "Dniprogeofizika" trust [25-28, 32, 34, 43, 44, 50-53].

As a result, the central part of Jurassic depression is outlined, tectonic schemes for horizons of certain reflecting plates were designed, the regional uplift of Jurassic sediments in the northern direction was established, and the southern margin of Fore-Dobruja Jurassic trough was mapped.

The studies of CMRW can be divided in two stages. In the first one (1962-1963) the regional studies in Moldova were performed (A.G.Averbukh). The system of observations has been set to identify the single boundary – Paleozoic hanging-wall. It was assumed that the southern part of the area between Prut and Dnister rivers belongs to Scythian plate and Paleozoic sediments over there are deformed and metamorphosed.

Since 1964 CMRW studies had been being conducted by "Dniprogeofizika" trust. In the regional works the ideas on structure of Paleozoic tectonic floor have been developed. By the speed parameters some complexes of Paleozoic rocks were distinguished and regional zones of tectonic break are mapped. After these works, the large intra-platform Jurassic trough was deduced.

It should be noted that CMRW works were conducted under conditions of complete lacking information on the column speed parameters and therefore all regional cross-sections are conventional. In the plots the thick sequence of Mesozoic extrusives intersected by drill-holes in Tatarbunarska field is not indicated; besides that, mistakes are possible in the reflecting boundaries identification in different blocks.

Of the thematic works, the ones should be noted of V.F.Strashko [57] ("Dniprogeofizika" trust). As a result, based on complex analysis of all previous studies the "Geological-tectonic map of pre-Mesozoic units of Western Prychornomorya in the scale 1:200 000" was compiled.

The map sheet territory L-35-XXIX (Tulcha), to the north from Danube River, in the limits of Ukraine, is quite unfavorable for the surface geophysical studies. Just sporadic route observations are conducted over there which cannot be used for the planar geophysical base design in the studies area, and this should be taken into account assessing probability of respective geological developments.

2. STRATIFIED UNITS

The map sheet territory L-35-XXIII (Izmail) and L-35-XXIX (Tulcha) is located within two major geo-structure units of the south-western slope of Eastern-European Platform (EEP) – Moldavian plate and Besarabsko-Chornomorska plate (regions of tectonic-magmatic activation) separated by the zone of regional Chadyr-Lungskiy fault, and created on their basis Jurassic, Paleogene and Neogene troughs (see “Tectonic scheme of pre-Cenozoic units” and geological cross-sections A_1-A_3 to the “Geological map and map of mineral resources of pre-Cenozoic units”).

The region exhibits two-level structure typical for Eastern-European Platform. The lower tectonic level is composed of deformed Archean – Lower Proterozoic rocks (AR-PR_1), and the upper level – of sedimentary rocks of Vendian-Phanerozoic cover.

Within aforementioned major geo-structure units the litho-tectonic zones (LTZ) are distinguished being caused of tectonic regime of geo-structure blocks defined. They have the own history of development, column type and different thickness of sediments, that is, typical features of evolutionary development over entire Vendian-Phanerozoic history (see “Schemes of LTZs”, legends to geological maps of pre-Quaternary and pre-Cenozoic units).

Based on performed litho-facial analysis, three LTZ are distinguished for the sediments of pre-Jurassic cover, from the south-west to north-east: *Nyzhnyodunayska*, *Chervonoarmiyska* and *Dmytrivska*; for Jurassic rocks – single *Pereddobrudzka*; for Middle Eocene sediments which constitute the western (essentially eroded) part of Prychornomorskiy Cretaceous-Paleogene trough – single *Chervonoarmiysko-Dmytrivska*; for Upper Miocene sediments – three ones: *Kagul-Katlabukhska*, *Nyzhnyoyalpukhska* and *Katlabukhska*; for Pliocene sediments – two zones: *Prydunayska* and *Vladychen-Loshchynivska*. Under this principle the stratigraphic columns of pre-Quaternary column are designed and the legends to geological maps are developed.

The stratigraphic subdivisions are based on the “Stratigraphic scheme of Phanerozoic units of Ukraine for the geological maps of new generation (1993)”, and “Basic legends of geological map in the scale 1:200 000 of Prychornomorska Series (1995)”.

The integrated stratigraphic column of the studied area is designed as follows:

PHANEROZOIC
C e n o z o i c   E r a t h e m e
Quaternary System
Holocene /H/

tH – technogenic sediments
e,edH – eluvial and eluvial-deluvial sediments
dH – deluvial sediments
dcH – deluvial-coluvial sediments
pdH – proluvial-deluvial sediments
pH – proluvial sediments
adH – alluvial-deluvial sediments
aH – alluvial sediments
lmlH – estuary-lake sediments

Neo-Pleistocene (upper branch) – Holocene undivided /P_{III}-H/

aP_{III}pč-H – Prychornomorskiy-Holocene climatoliths undivided: alluvial sediments of Danube River flood-land

Pleistocene
Neo-Pleistocene /P/
Upper Neo-Pleistocene branch /P_{III}/

vd,eP_{III} – aeolian-deluvial, eluvial sediments
a^1P_{III}ds – Desnyanskiy ledge; alluvial sediments of the first over-flood terrace
vdP_{III}pč – Prychornomorskiy climatolith; aeolian-deluvial sediments

$eP_{III}df$	– Dofinivskiy climatolith; eluvial sediments
$adP_{III}df$	– Dofinivskiy climatolith; alluvial-deluvial sediments
$lml^1P_{III}df$	– Dofinivskiy climatolith; estuary-lake sediments of the first over-flood terrace
$a^2P_{III}vl$	– Vilshanskiy ledge; alluvial sediments of the second over-flood terrace
$vdP_{III}bg$	– Buzkiy climatolith; aeolian-deluvial sediments
$eP_{III}vt$	– Vytachivskiy climatolith; eluvial sediments
$lml^2P_{III}vt$	– Vytachivskiy climatolith; estuary-lake sediments of the second over-flood terrace
$a^3P_{III}tb$	– Trubizkiy ledge; alluvial sediments of the third over-flood terrace
$vdP_{III}ud$	– Udayskiy climatolith; aeolian-deluvial sediments
$eP_{III}pl$	– Prylutskiy climatolith; eluvial sediments
$lml^3P_{III}pl$	– Prylutskiy climatolith; estuary-lake sediments of the third over-flood terrace

Middle Neo-Pleistocene branch /P_{II}/

vd,eP_{II}	– aeolian-deluvial, eluvial sediments
$vdP_{II}ts$	– Tyasminskiy climatolith; aeolian-deluvial sediments
$eP_{II}kd$	– Kaydatskiy climatolith; eluvial sediments
$a^5P_{II}hd$	– Khadzhybeyskiy ledge; alluvial sediments of the fifth over-flood terrace
$vdP_{II}dn$	– Dniprovskiy climatolith; aeolian-deluvial sediments
$eP_{II}zv$	– Zavadivskiy climatolith; eluvial sediments
$lml^5P_{II}pl$	– Zavadivskiy climatolith; estuary-lake sediments of the fifth over-flood terrace

Lower Neo-Pleistocene branch /P_I/

vd,eP_I	– aeolian-deluvial, eluvial sediments
eP_I	– eluvial sediments
vdP_Itl	– Tyligulskiy climatolith; aeolian-deluvial sediments
eP_Ilb	– Lubenskiy climatolith; eluvial sediments
vdP_Isl	– Sulskiy climatolith; aeolian-deluvial sediments
eP_Imr	– Martonoskiy climatolith; eluvial sediments
eP_Ish	– Shyrokynskiy climatolith; eluvial sediments

Eo-Pleistocene (upper branch) – Neo-Pleistocene (lower branch) undivided /eE_{II}-P_I/

eE_{II}-P_I	– eluvial sediments

Eo-Pleistocene /E_{II}/

$eE_{II}kr$	– Kryzhanivskiy climatolith; eluvial sediments

Eo-Pleistocene – Neo-Pleistocene (lower branch) undivided /E-P_I/

amE-P_I	– alluvial-marine (deltaic) sediments

Neogene System
Pliocene (N_2)

Prydunayska LTZ	*Vladychen-Loshchynivska LTZ*

Upper Pliocene
Akchagylskiy regio-stage

N_2*tg* – terrigenous-clayey sequence	

Lower Pliocene
Kimeriyskiy regio-stage

N_2*pd* – Prydunayska Suite	**N_2*g*** – clayey sequence

Miocene (N_1)

Kagul-Katlabukhska LTZ	*Nyzhnyoyalpukhska LTZ*	*Katlabukhska LTZ*

Upper Miocene
Pontychniy regio-stage
Novorosiyskiy sub-regio-stage

Dunayska sequence **N_1d^4** – fourth sub-sequence of Dunayska sequence	**N_1p** – sequence of sands	**N_1tg** – terrigenous-clayey sequence

Meotychniy regio-stage

N_1d^3 – third sub-sequence of Dunayska sequence	**N_1gt** – clayey-terrigenous sequence	**N_1g** – clayey sequence

Sarmatian regio-stage
Upper Sarmatian sub-regio-stage

N_1d^2 – second sub-sequence of Dunayska sequence	**N_1dl** – Dolynska sequence	**N_1gv** – clayey-limestone sequence

Middle Sarmatian sub-regio-stage

N_1d^1 – first sub-sequence of Dunayska sequence	**N_1l** – Lymanska sequence	**N_1vg** – limestone-clayey sequence

Paleogene System
Eocene (₽$_2$)
Chervonoarmiysko-Dmytrivska LTZ
Middle Eocene

₽$_2$*šh* – Shabska Suite
₽$_2$*ct* – carbonate-terrigenous sequence
₽$_2$*cg* – carbonate-clayey sequence
₽$_2$*c* – carbonate sequence
₽$_2$*t* – terrigenous sequence

M e s o z o i c E r a t h e m e
Jurassic System
Pereddobrudzka LTZ
Upper division (J_3)
Tithonian stage

J_3*čl* – Chadyr-Lungska Suite
J_3*čl*$_2$ – upper sub-suite
J_3*čl*$_1$ – lower sub-suite
J_3*kl* – Kalafatlarska Suite

Kimmeridgian stage
Upper sub-stage

J_3*kn* – Kongazka Suite
J_3*kn*$_2$ – upper sub-suite
J_3*kn*$_1$ – lower sub-suite

Oxfordian – Kimmeridgian stages undivided

$\mathbf{J_3}$***kz*** – Kazakliyska Suite
$\mathbf{J_3}$***kz***$_2$ – upper sub-suite
$\mathbf{J_3}$***kz***$_1$ – lower sub-suite

Middle – Upper divisions undivided ($J_{2\text{-}3}$)
Callovian – Oxfordian stages undivided

$\mathbf{J_{2\text{-}3}}$***bl*** – Bolgradska Suite
$\mathbf{J_{2\text{-}3}}$***bl***$_2$ – upper sub-suite
$\mathbf{J_{2\text{-}3}}$***bl***$_1$ – lower sub-suite

Middle division (J_2)
Bajocian – Bathonian stages undivided

$\mathbf{J_2}$***an*** – Andrushynska Suite
$\mathbf{J_2}$***an***$_3$ – upper sub-suite
$\mathbf{J_2}$***an***$_2$ – middle sub-suite
$\mathbf{J_2}$***an***$_1$ – lower sub-suite

Triassic System
Nyzhnyodunayska LTZ
Upper division (T_3)
Carnian – Rhaetian stages undivided

$\mathbf{T_3}$***ct*** – carbonate-terrigenous sequence

Lower – Middle divisions ($T_{1\text{-}2}$)
Olenekian – Anisian – Ladinian stages undivided

$\mathbf{T_{1\text{-}2}}$***nv*** – Novosilska Suite
$\mathbf{T_{1\text{-}2}}$***nv***$_2$ – upper sub-suite
$\mathbf{T_{1\text{-}2}}$***nv***$_1$ – lower sub-suite

Lower division (T_1)
Induan stage

$\mathbf{T_1}$***t*** – terrigenous red-brown sequence

P a l e o z o i c E r a t h e m e
Devonian System
Nyzhnyodunayska LTZ
Upper division (D_3)
Famennian stage

$\mathbf{D_3}$***or*** – Orlovska sequence
$\mathbf{D_3}$***c*** – carbonate sequence

Frasnian stage

$\mathbf{D_3}$***br*** – Baurchynska Suite

Middle division (D_2)
Eifelian – Givetian stages undivided

$\mathbf{D_2}$***d*** – dolomite sequence

Lower division (D_1)
Lochkovian stage

D_1*kč* – Kuchuluyska Suite

Silurian System
Dmytrivska LTZ
Upper division (S_2)
Ludlowian – Pridolian stages undivided

S_2*pg-zv* – Pugoyska-Zvenigorodska suites undivided

Lower division (S_1)
Llandoverian – Wenlockian stages undivided

S_1*čm-bl* – Chok-Maydanska and Beltsivska suites undivided

Cambrian System
Lower division ($Є_1$)
Dmytrivska and Chervonoarmiyska LTZs

$Є_1$*sv* – Suvorovska Suite
$Є_1$*vš* – Vyshnivska Suite

PRECAMBRIAN

Proterozoic Eonotheme (PR)
Neo-Proterozoic Eratheme (PR_3)
Vendian System (V)
Upper division (V_2)

Chervonoarmiyska LTZ	*Dmytrivska LTZ*
Kotlynskiy horizon	
V_2*kn* – Kanylivska Series	**V_2*kn*** – Kanylivska Series
Redkinskiy horizon	
V_2*mp* – Mogyliv-Podilska Series	
V_2*ng* – Nagoryanska Suite	
V_2*jr* – Yaryshivska Suite	

Description of stratified units, developed in the map sheets L-35-XXIII (Izmail) and L-35-XXIX (Tulcha) (in the limits of Ukraine), is given below.

PRECAMBRIAN

Proterozoic Eonotheme

Neo-Proterozoic Eratheme

Vendian System

Upper division V_2

The upper division of Vendian System, consisting of Mogyliv-Podilska and Kanylivska series, in the studied area is intersected by four deep drill-holes (1B, 1rS, R-20VP, 33) [21, 42] in Dmytrivska LTZ, developed in the southern margin of Moldavska plate, and in Chervonoarmiyska LTZ of Besarabsko-Cornomorska plate of EEP. Drill-holes are located in the area of inhabited localities Dmytrivka village, Bolgrad town, Suvorove village, and Zadunaivka village which is situated a bit away from the eastern map sheet border (see “Tectonic scheme of pre-Cenozoic units” in the scale 1:500 000 and geological cross-section to the map of pre-Cenozoic units). Vendian sediments mainly comprise frequent intercalation of aleurolites, argillites, rarely fine-grained arkosic sandstones, chocolate-brown tuffogenic argillites, and massive siliceous politic tuffs. Features of Vendian sediments suggest for deposition under conditions of shallow-water sea far away from the shoreline where fine-grained clayey-aleuritic material with tuffogenic admixture was introduced to.

The modern distribution of Vendian rocks is clearly controlled by the position of major tectonic units in pre-Jurassic basement. For instance, in Dmytrivska LTZ, located in the far north-east of the area, the distribution area of Vendian sediments spatially coincides with the southern margin of Moldavska plate and in the south-western direction it is bounded by the zone of Chadyr-Lungskiy fault. In this area Vendian is intersected by DH R-20VP [21, 42] (Dmytrivka village) at the depth 2570-2774.5 m, for the length 204.5 m, and is not intersected over entire thickness. The hanging-wall altitude is -2479.4 m. The rocks include alternating sandstones and aleurolites, and being compared with most completed Vendian column in DH Suvorovska 4rS [21, 42] it probably belongs to the upper part of undivided Kanylivska Series. The rocks plunge under the angle 45-50^o, apparently to the south-west, because of influence of Chadyr-Lungskiy fault on the modern position of the cover in this structure. The true thickness of Vendian System intersected by DH R-20VP [21, 42] in Dmytrivska LTZ, taking into account the rocks plunging, is more than 110 m.

In Chervonoarmiyska LTZ, which spatially coincides with the north-western, essentially elevated block of Archean-Proterozoic Suvorovskiy dome, Vendian rocks are almost completely eroded during inversion phases of Herzinian and Early Kimmerian tectogenesis. They are only preserved in the far south-western part of this dome, where they are intersected by DH Bolgradska 1B [42] and Suvorovska 4rS [21, 42] within thin band in the zone of Bolgrad-Suvorovskiy fault, which comprises the boundary between Chervonoarmiyska and Nyzhnyodunayska LTZs (see “Tectonic scheme in the scale 1:500 000” to “Geological map and map of mineral resources of pre-Cenozoic units”).

In DH Bolgradska 1B [42] Vendian System is intersected at the depth 910-1125 m for the length 215 m and consists of dark-green, dense, strong argillites with numerous thin calcite veinlets, with chlorite material admixture.

In DH Suvorovska 4rS [21, 42] the rocks are intersected at the depth 1964-3332 m (thickness 1368 m) and include alternating argillites and aleurolites with fine-grained arkosic sandstone interbeds. Hanging-wall altitude is -1932 m, footwall one is -2528 m. The rocks dip under the angle 35-50^o and apparently plunge towards Nyzhnyodunayskiy block. The true thickness intersected by the well, taking into account the rock dipping angle, is 1090 m.

To the south-west from Bolgrad-Suvorovskiy fault, in Nyzhnyodunayska LTZ, Vendian System is not intersected by drill-holes. Taking into account that Vendian rocks together with Cambrian and Silurian sediments do participate in the Central Dobruja structure (Romania), one can assume that Vendian System in widely developed over entire this structure but is buried at considerable depth and overlain by Devonian, Triassic and Jurassic sediments. These are intersected by numerous drill-holes in this area beneath Quaternary and Neogene sediments.

Vendian rocks lie with sharp stratigraphic and angular unconformity over plagiogranites of Archean – Lower Proterozoic Suvorovskiy complex. They are overlain without visible stratigraphic and angular unconformity by Cambrian sediments (DH R-20VP [21, 42], Dmytrivka village), parti-colored (red, brown-red, reddish-brown shades) Vyshnivska Suite (DH 4rS [21, 42], Suvorove village), and Upper (DH 1B [42], Bolgrad town) and Middle (DH 3rZ [42], Zadunaivka village) Jurassic sediments. Sediments hanging-wall altitudes vary from -809 m in Bolgrad town area to -2479.4 m in Dmytrivka village area. Thus, the difference in the modern position of Vendian System hanging-wall is 1670 m suggesting for vertical movements of individual blocks in post-Vendian times. Maximum thickness of the rocks, intersected by DH Suvorovska 4r [21, 42] is 1090 m.

In the upper division of Vendian System Mogyliv-Podilska and Kanylivska (undivided) series are distinguished. In turn, Mogyliv-Podilska Series is divided into Yaryshivska and Nagoryanska suites. The Upper Vendian stratigraphic subdivisions are described below.

Mogyliv-Podilska Series (V_2mp) is only confidently identified in the south-western part of Chervonoarmiyska LTZ, which spatially coincides with the zone of Bolgrad-Suvorovskiy fault, where in the narrow band the Series is intersected by DH 1B [42] and 4rS [21, 42]. Apparently, Mogyliv-Podilski sediments are also developed in Nyzhnyodunayska LTZ but are buried to considerable depth therein and overlain by Paleozoic and Mesozoic sequences. The Series hanging-wall altitudes vary from -809 m (DH 1B [42]), where they are essentially eroded, to -2528 m (DH 4rS [21, 42]. The Series lies with sharp stratigraphic and angular unconformity over plagiogranites of undivided Archean – Lower Proterozoic Suvorovskiy ultra-metamorphic complex. The rocks are overlain without visible stratigraphic and angular unconformity by Kanylivska Series (DH 4rS [21, 42], depth 2560 m), and with sharp stratigraphic and angular unconformity by Middle Jurassic Lower Bolgradska sub-suite (DH 1B [42]) and Middle Jurassic Andrushynska Suite (DH 3rZ [48]), respectively, at the depth 910 m and 2461 m. Maximum thickness of the Series, taking into account rock dipping angle, is intersected by DH 4rS [21, 42] to 700 m.

The Late Vendian age of the rocks is defined based on correlation with the columns of stratotypic area and remnants of algae *Vendotalnia antiqua* G n i l determinations of M.B.Gnilovska).

Yaryshivska Suite (V_2jr) is only confidently identified in the south-western part of Chervonoarmiyska LTZ, where it is intersected by DH 1B [42], 4rS [21, 42], and to the east from the eastern border of map sheet L-35-XXIII (Izmail), in DH 3rZ [42].

Most complete column of the Suite is intersected by DH 4rS [21, 42] at the depth 2907-3332 m and include argillites and micro-grained aleuro-argillites with thin sandstone interbeds. The rocks are normally penetrated by thin white calcite veinlets.

A r g i l l i t e s are light-grey with greenish shade, often with violet spots, mica, thin-banded, and mainly composed of illite-sericite with minor aleuritic material.

A l e u r o l i t e s are greenish-grey, often with violet spots, quartz, with considerable admixture of argillite compound, thin-banded, strong, dense, often in gradual transitions between argillites and aleurolites. Rock composition: quartz (60-70%), illite-sericite – up to 30%.

S a n d s t o n e s are light-grey with greenish shade, micro-grained, quartz, very dense, strong.

The Suite lies with sharp stratigraphic and angular unconformity over Archean – Lower Proterozoic plagiogranites. It is overlain without stratigraphic interruption by Nagoryanska Suite (DH 4rS [21, 42]), and with sharp stratigraphic and angular unconformity by Middle Jurassic Lower Bolgradska sub-suite (DH 1B [42]) and Andrushynska Suite (DH 3rZ [42]). The Suite hanging-wall altitudes vary in the wide range from -809 m to -2875 m (DH 4rS [21, 42] and -2407 m (DH 3rZ [42]). The maximum thickness of the Suite, taking into account the rock dipping angle, is intersected by DH 4rS [21, 42] to 393 m.

Nagoryanska Suite (V_2ng). In the studied area the Suite is only confidently identified in the south-eastern part of Chervonoarmiyska LTZ, in Suvorove village area, and is intersected by DH 4rS [21, 42] at the depth 2560-2939 m. It is mainly composed of argillites in the lower column part, and in the interval 2840-2939 m with thin aleurolites interbeds.

A r g i l l i t e s are light-grey with greenish shade and greenish-grey rocks, often with violet spots, mica, massive, banded, dense, strong, mainly composed of illite-sericite with minor clastic material of aleuritic size.

The Suite lies stratigraphically conformably over Yaryshivska Suite. It is also stratigraphically conformably overlain by Kanylivska Series. The hanging-wall altitude is -2528 m.

Kanylivska Series (V_2kn) in the studied area is confidently identified in Dmytrivska LTZ and in the far south-western part of Chervonoarmiyska LTZ.

In Dmytrivska LTZ the Series is intersected by DH Dmytrivska R-20VP [21, 42] at the depth 2570-2774 m. It is locally developed and in the south-western direction its distribution is limited by the zone of Chadyr-Lungskiy fault. The well is stopped in the Series rocks, and apparently, by analogy with Vendian columns of Moldavska plate, it overlies Mogyliv-Podilska Series without stratigraphic interruption. It is stratigraphically conformably overlain by Cambrian System. The rocks mainly include sandstone sequence with thin interbeds of aleurolites and aleuritic argillites, dark-grey, in places almost black, with slight greenish shade.

S a n d s t o n e s are grey with pale-pink shade, light-grey with greenish shade, quartz, fine- and medium-grained, dense, very strong. The cement is of contact type. The rocks are normally penetrated by numerous thin almost white calcite veinlets. Sandstones dip under the angle 45-50^o. The maximum thickness intersected by drill-hole is 110 m.

In Chervonoarmiyska LTZ, which from the north-east is bounded by the zone of Chadyr-Lungskiy fault and from the south-west – by the zone of Bolgrad-Suvorovskiy fault, Kanylivski sediments are actually eroded over entire territory and only preserved in Syvorove village area (DH 4rS [21, 42], depth 1964-2560 m), where they consist of alternating argillites and aleurolites with thin sandstone interbeds. In the lower column part, at the depth 2398-2560 m, the rhythmic pile is observed consisting of four layers of aleuritic argillites separated by sandstone interbeds. At the bottom of each rhythm (batch) up to 10 m thick sandstone bed is developed which upward in the column is replaced by the thicker argillite-aleurolite intercalation. The rocks plunge under the angle 30-35^o, apparently towards Nyzhnyodunayskiy block.

A r g i l l i t e s , which mainly constitute the upper column part of Kanylivska Series, are grey with greenish shade, micro-grained, dense, very strong, coarse-banded, platy. Argillites, developed in the lower column part, are mainly grey with greenish shade, with aleuritic quartz admixture, in places with considerable argillite admixture.

S a n d s t o n e s are grey with pale-pink shade, light-grey with greenish shade, quartz, fine- and medium-grained, dense, very strong. The cement is of contact type. The rocks are normally penetrated by numerous thin almost white calcite veinlets.

The Series conformably lies over Nagoryanska Suite of Mogyliv-Podilska Series. It is overlain with erosion and sharp stratigraphic unconformity by the red-colored Cambrian Vyshnivska Suite. The Series hanging-wall altitudes vary from -1932 m (DH 4rS [21, 42] to -2479.4 m (DH R-20VP [42]). The maximum thickness of sediments is intersected by DH 4rS to 596 m.

PHANEROZOIC

Paleozoic Eratheme

Paleozoic Eratheme is composed of limestones and their dolomitized varieties, sandstones, aleurolites, argillites, shales, sheared aleurolites and sandstones. The rocks include limestone and limestone-dolomite facies of shallow-water marine basin; terrigenous and terrigenous-clayey coastal-marine facies; terrigenous and terrigenous-clayey with increased content of coalified matter of fossil origin, and facies of desalinated lagoons and coastal zones with unstable hydrodynamic regime.

In tectonic respect Paleozoic sediments are ascribed to three litho-tectonic zones which differ in the column completeness, thicknesses, lithology and rock lithification degree. The LTZs are distinguished which spatially coincide with the major defined tectonic units. Dmytrivska LTZ belongs to the southern margin of Moldavska plate. Chervonoarmiyska LTZ does spatially coincide with the northern and north-western parts of Gorokhivskiy block, and Nyzhnyodunayska LTZ spatially coincides with Nyzhnyodunayskiy block of Besarabsko-Chornomorska plate (region of tectonic-magmatic activation).

Paleozoic sediments of Dmytrivska LTZ participate in the cover of Moldavska plate and exhibit sub-horizontal rock dipping, platform type of columns, and low thicknesses. In the fault zones the rocks are dislocated and steep enough rock dipping (up to 60-70^o) is observed.

In Chervonoarmiyska LTZ Paleozoic rocks are almost lacking suggesting for extensive upward movements of respective block resulted in the rock erosion in pre-Jurassic time.

Paleozoic sediments of Nyzhnyodunayska LTZ participate in the structure of Nyzhnyodunayskiy block of Besarabsko-Chornomorska plate. In this LTZ Paleozoic rocks are extensively dislocated (with formation of initial thrust-nappe structures like buffer zones at the I-order structures of the Eastern- and Western-European platforms), altered under incipient stages of greenschist facies of regional metamorphism, cut by quartz syenite intrusion, dykes and dyke-like lamprophyre veins, penetrated by quartz, rarely calcite veins. At the pre-Neogene surface Paleozoic rocks are only exposed in the central and north-western parts of Nyzhnyodunayskiy block where they are intersected by numerous drill-holes, and are overlain by Neogene and Quaternary sediments. Over remaining territory these rocks are overlain by thick Triassic and Jurassic sediment. At the modern surface they are only exposed on Kamyana mountain nearby Orlovka village.

In the studied area Paleozoic Eratheme includes Cambrian, Silurian and Devonian systems.

Cambrian System

Lower division

Cambrian sediments in the studied area consist of the lower division and are intersected just by two drill-holes: R-20VP [21, 42] (depth 2391-2570 m) located in Dmytrivska LTZ of Moldavska plate, and 4rS [21, 42] (depth 1296-1964 m) located in the south-western part of Gorikhivskiy block in Besarabsko-Chornomorska plate. The sediments are only involved in the terrigenous sequence – sandstones and argillites with aleurolite interbeds. To the south from Bolgrad-Suvorovskiy fault the Cambrian System is not intersected by drill-holes. Taking into account that Cambrian rocks, like Vendian ones, are developed in Central Dobruja and zone Mechyn of Northern Dobruja (Romania), there are the reasons to think that Cambrian sediments are developed over entire Nyzhnyodunayska LTZ. The Cambrian hanging-wall altitudes vary from -2300.4 m (DH R-20VP [21, 42]) to -1224 m (DH 4rS [21, 42]).

The Cambrian System without interruption lies over the rocks of Upper Vendian Kanylivska Series. Cambrian rocks are overlain with sharp stratigraphic unconformity by Lower Silurian Chok-Maydanska and Beltsivska suites. The maximum thickness of Cambrian System, taking into account the rock dipping, is intersected by DH 4rS [21, 42] (Suvorove village) to 610 m. Two suites are distinguished in Cambrian System – Vyshnivska and Suvorovska.

Vyshnivska Suite (Є$_1$*vš*) is developed in coastal-marine facies. In Dmytrivska LTZ it is intersected by DH R-20VP [21, 42] at the depth 2391-2570 m. It is mainly composed of alternating grey, dark-grey and greenish-grey, polymictic, fine- and medium-grained, strong, non-carbonate sandstones. In the given LTZ the Suite lies without stratigraphic interruption over Upper Vendian Kanylivska Series and is overlain with considerable stratigraphic interruption by Lower Silurian Chok-Maydanska and Beltsivska suites.

In comparison to Silurian sediments, the Suite clearly differs in exclusively terrigenous composition (Silurian sediments are carbonate in composition exclusively), and in comparison to Vendian rocks – in coarser composition where diverse-grained sandstones and aleurolites predominate. The hanging-wall altitude is -2300.4 m. Thickness of the rocks intersected in drill-hole is 179 m. The true thickness, taking into account the rock dipping, is about 80 m. Vyshnivska Suite is divided in two batches.

The lower batch is intersected at the depth 2495-2570 m and is mainly composed of sandstones with minor aleurolites and argillites.

S a n d s t o n e s are grey, dark-grey and greenish-grey, polymictic, fine- and medium-grained, string, non-carbonate, fractured rocks. The clastic material is composed of quartz, feldspar, chlorite and mica flakes, rock fragments. Sandstones contain tuffogenic material and abundant chlorite (up to 20-30%) developed after biotite and through volcanic glass chloritization in extrusive rock fragments.

A r g i l l i t e s are dark-grey to black with greenish shade, dense, in places banded with sliding planes, chlorite-hydromica in composition with minor admixture of micro-grained pyrite. Content of aleurolite material admixture attains 20-25%. The clastic material consists of acute quartz and feldspar grains, chlorite and light mica thin flakes.

The second batch is intersected at the depth 2391-2495 m and is mainly composed of sandstones with interbeds of aleurolites and argillites, rarely limestones.

S a n d s t o n e s are light-grey with pinkish shade, polymictic, fine-grained, strong, in places banded, fractured. The rock banding is observed under the angle 60-70^o to the horizontal core axis. The milky-white calcite veinlets are noted in argillites.

In Chervonoarmiyska LTZ Vyshnivska Suite is intersected by DH 4rD [21, 42] (Suvorove village) at the depth 1830-1964 m. It is mainly composed of sandstones with diverse-grained gravelite interbeds at the bottom. Sandstones are polymictic, parti-colored (red, brown, reddish-brown, brownish-grey shades). The hanging-wall altitude is -1798 m and thickness, taking into account rock dipping, is 110 m. The Suite lies without stratigraphic interruption above Kanylivska Series and is conformably overlain by Lower Cambrian Suvorovska Suite.

Vyshnivska Suite is ascribed to Lower Cambrian based exclusively on its stratigraphic and tectonic position in the column of the area, as well as on the ground of clear correlation with similar columns in the territory of adjacent state Moldova where these rocks are fauna-supported.

Suvorovska Suite (Є$_1$*sv*) is intersected by DH 4rS [21, 42] (Suvorove village area) at the depth 1288-1830 m. This locality belongs to Chervonoarmiyska LTZ of Besarabsko-Chornomorska plate. The Suite is composed of alternating gravelites, rarely coarse- and diverse-grained sandstones with gravelite and conglomerate interbeds, and in the middle and upper column parts – of alternating aleurolites and argillites. Rock coloring is mainly reddish-brown, cherry-red, brown, pink. The hanging-wall altitude is -1224 m. In the given

LTZ the Suite lies without stratigraphic interruption over Lower Cambrian Vyshnivska Suite and with significant stratigraphic interruption and angular unconformity is overlain by Lower Jurassic sediments. Thickness of the Suite, taking into account rock dipping in drill-hole, is about 500 m.

In comparison to Vyshnivska Suite, it is coarser in composition, and to Lower Jurassic sediments it exhibits angular discontinuity and mainly quartz composition of sandstone clastic material. Suvorovska Suite is ascribed to Lower Cambrian based exclusively on its stratigraphic and tectonic position in the column of the area.

Silurian System

In the studied area Silurian System is mainly composed of grey and dark-grey, organogenic, often dolomitic limestones, from micro-crystalline to pelitomorphic, strong, with frequent white calcite veinlets. Some thin argillite interbeds, dark-grey, thin-banded, aleuritic, mica, are observed in limestones.

In facial respect the rocks belong to marine shallow-water facies of platform type. Silurian sediments are quite locally developed. They are intersected by a single drill-hole (R-20VP) [42] in Dmytrivka village area in the far north-eastern part of the territory. From the south-west the rocks are bounded by the zone of regional Chadyr-Lungskiy fault.

The rocks are intersected by DH R-20VP [42] at the depth 2391-2085 m; they plunge down under the angle 60-65^{o}, apparently in the south-western direction, towards Gorikhivskiy block. The rocks stratigraphically unconformably overlie Lower Cambrian sediments and stratigraphically conformably are overlain by Lower Devonian Kuchuluyska Suite. The sediments hanging-wall altitude is -1994.4 m. Thickness of intersected column, taking into account rock dipping, is about 140 m.

Stratigraphic subdivision of Silurian sediments is performed on the ground of the local stratigraphic units – suites. Taking into account the uniform composition and low thickness of Silurian sediments, which are intersected in one drill-hole only, the minimum amount of bio-stratigraphic studies has been conducted with subdivision of sediments just into the lower and upper divisions. More detailed subdivision is actually not possible. According to available stratigraphic scheme, the following subdivisions are distinguished in Silurian sediments: undivided Lower Silurian Chok-Maydanska and Beltsivska suites; undivided Upper Silurian Pugoyska, Ichkerska, Kyshynivska, Varnytska, Trubchynska and Zvenigorodska suites.

Lower division

Llandoverian – Wenlockian stages undivided

Chok-Maydanska and Beltsivska suites undivided (S_1*čm-bl*). The rocks are only intersected by DH R-20VP [42] in Dmytrivka village area at the depth 2141-2391 m. They are exclusively composed of dark-grey, organogenic, pelitomorphic, dolomitized, clayey, strong limestones with numerous milky-white calcite veinlets. Thin dark-grey, thin-banded, dense, mica argillite interbeds, often with sliding surfaces, are observed in limestones. In thin sections under microscope one can observe that limestones are composed of fine calcite grains with clayey material and dolomite admixture (up to 20-25%). Organogenic limestone varieties consist of fine calcite grains and minor clayey material. Limestone groundmass contains remnants of organic material including fine fragments of ostracoda, crinoidea and echinodermata. Pelitomorphic limestone varieties differ from organogenic ones in pelitomorphic texture and lesser content of clastic organogenic material, up to 25-30% in total, irregularly distributed in limestone groundmass.

The distribution area of undivided Lower Silurian Chok-Maydanska and Beltsivska suites spatially coincides with the distribution boundaries of entire Silurian System. In the south-western direction the rocks are cut by the zone of Chadyr-Lungskiy fault. Both suites are stratigraphically conformably overlain by Upper Silurian sediments and with sharp stratigraphic unconformity lie over Cambrian rocks. The hanging-wall altitude of undivided suites is -2050.4 m. The intersected thickness in DH R-20VP [42] is 150 m. The true thickness, taking into account rock plunging under the angle 60-65^{o}, is 120 m.

The age of sediments (Early Silurian) in DH R-20VP [42] is determined after organic remnants: corals – *Halysites catenularis* L., *Dolerorthis rustica* S o w . , ostracoda – *Leperditis aff. hisingeri* S c h i n., brachyopoda – *Eospirifer radiatus* S o w . , *Attypa reticularis.* L., *Gupidula galeata* D a l m., *Spiriter bragensis* W e n., and others.

Upper division

Ludlowian – Pridolian stages undivided

Pugoyska-Zvenigorodska suites undivided (S_2*pg-zv*). These rocks are only intersected by DH R-20VP [42] in Dmytrivka village area at the depth 2085-2141 m. They are exclusively limestones, dark-grey to black, fine-crystalline, dense, strong, with frequent white calcite veinlets and shell fragments and imprints. In thin sections one can observe that limestone groundmass consists of fine calcite grains and minor clayey material irregularly distributed in the rock. The fine rhombohedral dolomite grains are observed over entire rock groundmass. The clastic organogenic material constitutes up to 4% of rock volume and is quite irregularly distributed.

The distribution area of undivided Upper Silurian Pugoyska-Zvenigorodska suites coincides with the boundaries of entire Silurian System. The rocks stratigraphically conformably lie over Lower Silurian sediments and with gradual transitions are overlain by Lower Devonian Kuchulutska Suite. The suites' hanging-wall altitude is -1994.4 m. Thickness of the suites' column, intersected by DH R20VP [42] is 56 m. The true thickness, taking into account rock plunging under the angle 60-65^o, is about 20 m.

The age of sediments, ascribed to Upper Silurian, is determined on the ground of brachyopoda remnants: *Paulina navicula* S o w . , *Chlonetes sbrucsensis var. hotinensis* N i n i f., *Leporditollina exgr. difusa* M e c h., *Tehmidtellina ovata* N o c k . , *Eospirifer radiatus* S o w . , *Sropheodon sp.*, and others.

Devonian System

Devonian System is developed in Dmytrivska LTZ in the far north-eastern part of the territory and in Prydunayska LTZ where it is intersected by few drill-holes beneath Neogene and partly Jurassic systems. In the Devonian System the lower, middle and upper divisions are distinguished (see cross-section A_1-A_3 to "Geological map and map of mineral resources of pre-Cenozoic units").

Lower division

Lochkovian stage

Kuchuluyska Suite (D_1*kč*) is intersected by the only drill-hole R 20VP [21, 42] at the depth 1970-2085 m. The Suite column is exclusively composed of argillites with minor aleurolites and limestone interbeds. In view of composition, development of the Suite had occurred under conditions close to the central portions of the trough located far away from the coastal zone of Devonian sedimentation basin. In the studied area the Suite is locally developed and encountered in the north-west-trending band up to 3 km wide in the north-eastern part of the territory. In the south-western direction the Suite distribution is controlled by the zone of Chadyr-Lungskiy fault and spatially coincides with the boundaries of Cambrian and Silurian systems (see cross-section A_1-A_3 to "Geological map and map of mineral resources of pre-Cenozoic units").

The typical rocks include dark-grey, mica, low-carbonate, strong, banded argillites with white calcite veinlets. Argillite groundmass consists of hydromica with considerable (up to 40%) admixture of aleuritic clastic material and micro-disperse carbonate. Limestones, developed in thin interbeds, are grey, in places with brownish shade, cryptic-crystalline, strong, with white calcite veinlets. The fine shell detritus is frequently observed in argillites. Fine crystals of limonitized pyrite are widespread over entire rock mass. The rocks are notably dislocated and plunge down under steep angle (60-70^o), apparently in the south-western direction, towards Gorikhivskiy block. The Suite stratigraphically conformably lies over Upper Silurian limestones and is overlain with sharp stratigraphic and angular unconformity by Middle Jurassic sediments. The Suite hanging-wall altitude is -1879.4 m. Thickness is 115 m, and taking into account rock dipping angle – about 65 m. The age of Kuchuluyska Suite is determined on the ground of correlation with columns of Aluatska and Saratsko-Tuzlivska LTZs but it is not supported paleontologically.

Middle division

Eifelian – Givetian stages undivided

Dolomite sequence (D_2d) is mainly composed of brownish-grey fine-grained dolomites with limestone interbeds. Development of the sequence, in view of rock composition, had occurred under lagoon and shallow-water marine basin conditions. At the pre-Neogene surface the sequence is not exposed and is intersected by DH 1uL [29, 42] at the depth 821-1051.3 m (Lymanske village). The contact of dolomite sequence with underlaying rocks (apparently Lower Devonian) is not encountered. Sandstone pile, intersected by DH 1uL [29, 42] at the depth 1051.3-1128.3 m, which spatially lies beneath dolomite batch and conventionally ascribed to Middle Devonian, is being considered to be tectonic remnant of Middle Jurassic lower terrigenous sequence, clamped in the zone of Kagulskiy fault activated in post-Jurassic time. The grounds for this conclusion are as follows:

- the rocks are not supported paleontologically;
- Kagulskiy fault zone exhibits extensive upward movements in post-Jurassic times with amplitude up to 1.5 km (exemplified by DH 2uN [20, 42] located in the western coast of Yalpug lake) resulted from Late Kimmerian (Early Cretaceous) inversion phase of tectogenesis;
- there is tight petrographic relationship between the rocks intersected in DH 1uL [20, 42] at the depth 1051.3-1128.3 m and similar rocks intersected by DH R-1kr [42], 075 and 1uL [20, 42] at the depth 561.0-623.5 m. This column type is characteristic for the Middle Jurassic basal layers composed of diverse-grained quartz sandstones;
- occurrence of tectonic contact with overlaying dolomite sequence sediments.

The sequence is stratigraphically conformably overlain by Baurchynska Suite. Thickness of the sequence, taking into account rock dipping, is about 100 m. The typical rocks are dolomites. Petrographic, chemical, petrophysical and geochemical features of the typical rocks are given below in the section on Baurchynska Suite and Upper Devonian carbonate sequence. The age of dolomite sequence is determined on the ground of fauna studies.

In the samples, taken from the depth 917.6, 988.0 and 1016.0 m, V.P.Grytsenko had determined the complex of corals characteristic for Middle Devonian Givetian sediments: depth 917.6 m – *Qerphuropora sp., Ruqosa sp. ind.*; depth 988.0 m – *Tyrqanolites sp., Crassialveolites cf. obtortus* (L e c o m p t), *Thamnopora cf. reticulata* (B l a n v.); depth 1016.0 m – *Favosites cf. qodfussi d'Ozbiny, Remesia cf. tubulosa* K e t t n e r.

Upper division

Frasnian stage

Baurchynska Suite (D_3br) consists of dark-grey, almost black, micro-fine-grained, often dolomitized limestones with dolomite and argillite interbeds. Development of these sediments had occurred under conditions transitional from lagoon to shallow-water marine basin which is evidenced by exclusively carbonate composition of the Suite. At the pre-Neogene surface the Suite is not exposed and is intersected by DH 1uL [20, 42] (depth 413.6-511.0 m, 623.5-821 m). Without stratigraphic interruption it lies over Middle Devonian dolomite sequence and also without stratigraphic interruption and angular unconformity is overlain by Upper Devonian carbonate sequence. The maximum thickness of the Suite is 160 m. The typical rocks are limestones and dolomites. The age of the Suite is defined on the ground of foraminifera complex determinations.

In DH 1uL [20, 42] at the depth 413.6-821.0 the following Frasnian foraminifera are determined: *Parathurammuna insolita* S a b I r , P. *af. elipina* A n t r ., *Parathurammuna dagniase* S u l ., *off. Coldata* B r o n n ., *P. zeniensis* K o t ., *Pasatikhinella sp., Turkmeniella astra* M - M a c l a y , *Eonolutina tuimasensis* L i p .

Famennian stage

Carbonate sequence (D_3c) is composed of limestones with few dolomite interbeds and together with Orlovska sequence rocks constitutes Herzinian tectonic floor of Nyzhnyodunayskiy block. In view of composition, development of this sequence had occurred under conditions of shallow-water marine basin of platform type. The rocks are not exposed at the surface and are intersected by drill-holes beneath mainly Neogene sediments and partly beneath Middle Jurassic Andrushynska Suite to the north of Dolynske and Lymanske villages where they are mapped at the endo-contact part of quartz syenite massif in quite limited area. This tectonic position of Devonian carbonate sequence is explained by geology of respective site. The area, where the sequence rocks are exposed at pre-Jurassic and pre-Neogene surfaces, comprises anticline structure complicated by quartz syenite intrusion, where at the endo-contact intrusion part these rocks are exposed instead of Orlovska sequence in the anticline portions of Reniyska and Lymanska tectonic nappes of Herzinian tectonic floor. One structure is mapped in Dolynske village area and intersected by DH 051, 042 and 096 [42, 48], and the second structure – to the north of Lymanske village where it is intersected by DH 1uD, 052, 040, 078, 062, 075 [42, 48] and 1kr [42] (see "Geological map and map of mineral resources of pre-Cenozoic units").

The rocks are extensively deformed under conditions of initial nappe-thrust structure development, altered at the incipient stages of greenschist facies of regional metamorphism, and cut by quartz syenite intrusive massif as well as syenite and monzonite-porphyry dykes. At the endo-contact part of intrusive massif the carbonate sequence underwent significant metasomatic alteration. From similar rocks of Triassic Novosilska Suite they do differ in higher metamorphic degree, breccia-like rock appearance, abundant calcite veinlets, and extensive pyritization. In view of distinct geology of the area, the rocks of carbonate sequence apparently are developed throughout over entire Nyzhnyodunayskiy block where they are overlain by thick (some kilometers) Triassic and Jurassic sequences. The maximum thickness of carbonate sequence is not determined and after geological data it does not exceed 150 m. The hanging-wall altitudes vary from -419.6 to -575 m.

Carbonate sequence is overlain by terrigenous Devonian Orlovska sequence. Relationships between these two units in the studied area are not clear. The contact between Orlovska sequence shales with Upper Devonian carbonate sequence limestones, intersected in DH 096 [42, 48] to the north-east of Dolynske village, is tectonic nature.

In places of carbonate sequence exposure at pre-Jurassic surface, it is overlain with sharp stratigraphic and angular discontinuities by Middle Jurassic Andrushynska Suite. The contact between two units is intersected in DH 1uD, 1kr [20, 42] and 075 [42, 48]. At the sites of the sequence exposure at pre-Neogene surface it is overlain with sharp angular and stratigraphic unconformities by Middle Sarmatian sediments and the contact with these rocks is intersected by mapping and prospecting drill-holes in the area where these rocks are developed. The rocks of carbonate sequence, exposed at pre-Jurassic and pre-Neogene surfaces, had undergone initial weathering processes expressed in the increased fracturing and rock lightening.

The age of Devonian carbonate sequence is determined after paleontological studies and correlation of rock composition with the columns developed in the area between Prut and Dnister rivers.

In DH 042 [42, 48] (Dolynske village) in limestones O.I.Berchenko had determined limestone algae: depth 450.0-452.1 m – *Stylaella rhomboidae* B e r c h., *Issinella qrandis* T o h u v ., *Rhabdoporella melekesensis* K u l. (abundant); depth 452.1-462.0 m – *Stylaella rhomboidae* B e r c h., *Rhabdoporella melekesensis* K u l.; depth 462.0-475.0 m – *Rhabdoporella melekesensis* K u l., *Rhabdopozella Stylaella rhmboidae* B e r c h, *Issenella devonia*. From these data, the age of carbonate sequence, intersected by drill-holes beneath Lower Jurassic and Neogene sediments to the north of Dolynske and Lymanske villages, is accepted to be Famennian.

L i m e s t o n e s are grey, dark-grey, in places black, spotty, micro-fine-grained, dense, strong, mainly non-banded, somewhere marbled, with irregularly distributed minor clayey and aleuritic material (5-50%), sliding surfaces, and numerous diverse-oriented fractures filled with calcite. Extensive pyritization is confined to fractures. In limestone thin sections the micro-fine-grained texture, spotty and micro-banded structure are determined caused by horizontally-wavy discontinuous aggregates of pelitomorphic carbonate enriched in fine-disseminated pyrite. Aleuritic material is well-sorted and includes quartz grains, in lesser extent feldspars. Quartz grains are normally cataclased, fractured. Fractures are filled with carbonate. Feldspars include sericitized plagioclases, rarely potassium feldspars. In minor amounts (3-5%) siliceous rock fragments and mica flakes are observed. Accessory minerals include epidote, tourmaline, zircon, sphene, anatase, and hornblende. The grains are weakly-rounded, acute, highly corroded by carbonates. The clayey fraction constitutes 10-20% by rock volume and is observed in thin intergrowth with groundmass micro-grained carbonate. Few amounts of coalified fossil organics are contained making the rocks dark-colored.

D o l o m i t e s are grey, dark-grey, in places black, somewhere with greenish shade rocks, micro-fine-grained, spotty, dense. From similar in appearance limestones they actually do not differ. At the sites, underwent extensive dynamo-metamorphism, the rocks are highly-fractured, become breccia-like, and are penetrated by diverse-oriented calcite veinlets. Numerous sliding surfaces are characteristic. After X-ray diffractometer study of the powders, the rock groundmass is composed of dolomite [10]. Chemical composition of dolomites (%): SiO_2 – 8.19; Al_2O_3 – 1.44; Fe_2O_3 – 0.88; TiO_2 – 0.06; CaO – 31.65; MgO – 15.49; P_2O_5 – 0.02; K_2O – 0.27; Na_2O – 0.55; SO_3 – 0.03; LOI – 41.76.

Orlovska sequence (D_3*or*). In the studied area these sequence is ascribed to Upper Devonian; in the map sheet territory it is widely developed in Nyzhnyodunayska LTZ. The sequence is composed of schists, sheared aleurolites and sandstones. Together with Upper Devonian mainly carbonate sequence, Orlovski rocks constitute Herzinian tectonic floor in Nyzhnyodunayskiy block. In the primary fashion, these are flyschoid-type sediments of desalinated marine lagoons developed in the pericratonic part of EEP with alternating sedimentation conditions, which is evidenced by mainly terrigenous composition with interbeds of dark-grey coalified bituminous shales (coaliferous clays, flood-land facies). The rocks are extensively dislocated at the Herzinian and Early Kimmerian stages of tectogenesis and altered under greenschist facies of regional metamorphism. Orlovska sequence is cut by quartz syenite intrusion, lamprophyre (kersantite) dykes and dyke-like bodies, and penetrated by quartz, rarely calcite veins. The schist composition and grey, dark-grey, black rock color are characteristic for Orlovska sequence. Mainly terrigenous sub-facies is mainly composed of sheared aleurolites and diverse-grained quartz sandstones with unclear-expressed schistose structure. All these evidences make the ground to ascribe these rocks to the black-shale formation. The sequence is widely developed in the south-western part of the territory where these rocks constitute anticline cores of Early Kimmerian structures in the central and north-western parts of Nyzhnyodunayskiy block. At the surface the rocks are only exposed on Kamyana mountain in Orlovka village area occurring in the small cliff outcrop on the left bank of Kamyane mouth where these rocks are being mined by the quarry.

In the central and north-western parts of Nyzhnyodunayskiy block the sequence is intersected by numerous drill-holes beneath Neogene-Quaternary sediments. Over there, Orlovska sequence constitute Dolynska, Novosilska and Ferapontievska anticlines of Early Kimmerian tectonic sub-floor (see "Tectonic scheme in the scale 1:500 000" to the geological map of pre-Cenozoic units). At pre-Neogene surface the rocks are being mapped in three up to 0.5 km wide bands of north-western extension. Besides that, they are also exposed in Orlovskiy block where overlaying sediments were completely eroded because of upward movements in post-Jurassic time. After geophysical surveys and drilling, in adjacent territory these rocks are apparently developed in Izmail-Vladychenskiy block, where they are overlain by Ntiassic and Jurassic rocks, and also in Prydunayskiy block in Kugurluy lake area, where these rocks are overlain by thick (some kilometers) Triassic carbonate-terrigenous sequence. Orlovska sequence lies with indefinite relationships over Upper Devonian carbonate sequence, and with sharp stratigraphic and angular unconformity it is overlain by reddish-brown Lower Triassic terrigenous sequence; at the sites of its exposure at pre-Neogene surface with sharp stratigraphic and angular unconformity it is overlain by Neogene sediments; in some places in Orlovka village area it is overlain by Quaternary sediments.

At the sites of Orlovska sequence exposure at pre-Neogene, pre-Quaternary surfaces and at the modern surface the rocks are altered by weathering expressed in increased fracturing and lightening. The weathering processes are most prominent in the column of Kamyana mountain where the sequence is exposed at the surface, and in the column of DH 29 g/k [21, 42]. These are the upper schist horizons in the quarry which are reddish-brown, brown and brownish-grey; with depth the rocks become greenish-grey and greenish, and at the groundwater level they gradually get their typical grey and dark-grey color. Orlovska sequence is intersected by drill-holes beneath Neogene and Quaternary sediments. Most complete columns are known from DH 1sO [42, 48], 6pO [42] in Orlovka village area, and DH 070-073 [48, 42] nearby former Ferapontiy monastery. The typical column of Orlovska sequence is intersected by DH 6pO [42] drilled during EGSF-200 and located in 2 km to the south of Nagirne village of Reniyskiy area.

In the gravity fields Orlovska sequence is not expressed separately. Together with Devonian carbonate sequence and complex of intrusive and dyke rocks of Herzinian tectonic floor it makes linear positive gravity anomalies caused by relatively higher density of Devonian rocks in comparison to the sediments of younger tectonic complexes developed in the area. In magnetic fields Orlovska sequence is not expressed because of insufficient differentiation of magnetic susceptibility of involved lithologies.

The typical rocks in Orlovska sequence column include schists, sheared aleurolites and sandstones.

S c h i s t s are quartz-sericite-chlorite, quartz-chlorite-sericite and quartz-less; they are most developed in Reniyska facial sub-zone. In Orlovsko-Novosilska facial sub-zone the terrigenous range rocks are mainly developed – sheared aleurolites and sandstones. Visually these are dark-grey, almost black, micro-grained dense rocks with distinct micro-schist structure, silk shine at schistose surfaces, and mat surface in cross cut, often with fine folding. Schists are composed of thin and very thin (0.5 mm) chlorite-sericite and quartz interbeds, which rhythmically alternate highlighting their primary thin-banded or micro-banded structure. In places, where the rocks are altered by weathering (lightened), they become greenish-grey, rarely reddish-brown, well expressed in the quarry nearby Orlovka village. In thin sections the schists exhibit micro-grained, grano- and lepido-granoblastic texture. Sericite and chlorite are regularly distributed in the rock or are accumulated in thin lens-shaped interbeds with one or other mineral predomination. Fractures and weakened zones in the rock are filled with pure crystalline quartz. Major rock-forming minerals include sericite, chlorite, quartz and albite. Minor carbonate and metamorphic organic matter of coal and (or) bitumen range are often observed. Numeric relationships of components in the rock vary in the wide range and transitional varieties are observed between the schists and other rocks involved. From another hand, relationships between layered silicates are being changed very often in these rocks: from varieties where sericite strongly predominates to the rocks composed of chlorite group minerals. Sericite is colorless or with slight greenish shade; it occurs in very fine flakes. Chlorite is green, slightly transparent in green (Ng) and yellowish-green (Np) shades, and it almost does not differ from sericite occurring in parallel intergrowth with the latter. Chemical composition of the schists (%): SiO_2 – 51.63-79.42; TiO_2 – 0.34-0.85; Al_2O_3 – 7.23-16.54; Fe_2O_3 – 0.12-2.97; FeO – 5.96-7.26; MnO – 0.84; MgO – 0.52-2.90; CaO – 0.7-3.65; Na_2O – 0.53-4.09; K_2O – 1.74-4.61; P_2O_5 – 0.07-0.41; SO_3 – 0.01-1.3; CO_2 – 2.66-6.73; LOI – 0.94-3.26.

A l e u r o l i t e s, together with sandstones and subordinated schists, are developed in Orlovsko-Novosilska facial sub-zone. The rocks are grey, rarely light-grey, fine-grained, sheared, thin-banded with frequent (very fine) mica and quartz-mica dark-grey interbeds. The rocks are mainly composed of quartz with minor sericite and chlorite. Cement is of regeneration, contact and porous types.

S a n d s t o n e s are quartz and feldspar-quartz; they are developed in Orlovsko-Novosilska facial sub-zone only. The rocks are grey, fine- and diverse-grained, dense, slightly sheared. The clastic material consists of quartz and grey feldspars. Cement is of contact and porous types, composed of regeneration quartz and fine-flaky aggregate of chlorite and sericite.

Limestones are locally developed in the studied area. They are found in a quarry nearby Orlovka village in the lens-shaped interbeds up to 20 cm thick within schist sequence which is essentially deformed. Besides that, similar rocks are intersected by DH 29 g/k, 1s [21, 42] drilled in the same area, and DH 055 [48, 42] drilled in Dolynske village area. Macroscopically these are dark-grey, brownish-grey, fine-grained, dense, strong, massive-schistose rocks. Schistosity is caused by thin interbeds enriched in sericite and chlorite. At the schistosity surfaces these rocks get silver-green shade and silk shine. The thin (1-3 mm) fractures in the rocks are oriented in various directions and filled with milky-white crystalline calcite. Under microscope the rock texture is fine-grained (glomeroblastic), in places diverse-grained (heteroblastic). Major rock-forming minerals include calcite and quartz. Plagioclase (5-10%), chlorite and sericite are observed in minor amounts. Of the other carbonates, dolomite is most common. Numeric relationships between quartz and calcite vary in the wide range and by these reasons a series of transitional varieties is distinguished between the rocks with different quartz and calcite content and typical metamorphosed limestones (75-90% of calcite). Calcite crystal-blasts are always idiomorphic in relation to quartz. Calcite is manganese-bearing and exhibits increased birefringence number (n = 1.662-1.666). Quartz is observed in pure, without inclusions, isometric grains with polygonal contours; quartz grain are always lesser than calcite ones in size. Plagioclase is albite with up to 12-13% of anorthite component. Albite grains are pure, with polysynthetic twins by albite or albite-Carlsbad rule. Chemical composition of limestones (%): SiO_2 – 53.46; TiO_2 – 0.27; Al_2O_3 – 5.29; Fe_2O_3 – 1.88; MnO – 0.65; MgO – 0.47; CaO – 18.57; Na_2O – 2.71; K_2O – 1.13; P_2O_5 – 0.06; SO_3 – 0.28; LOI – 15.11.

The hanging-wall altitudes of Orlovska sequence vary from +2 m (outcrop 100, Kamyana mountain in Orlovka village area) to -436.5 m (DH 047 [41, 42], Dolynske village area). The maximum thickness of sediments, intersected by drill-holes, is 433 m (DH 1sO [48, 42]) and 163 m (DH 6sO [42]). The average thickness intersected by drill-holes does not exceed 20 m. The actual thickness of these rocks in the studied area is not defined. By geological data, the true thickness of the sequence does not exceed 1500 m.

To date, there is no common opinion on the age of Orlovska sequence. The age determination for this stratigraphic unit has its own history and is mainly based on results of palinological investigations, study of conodonts, and relationships with underlaying and overlaying stratigraphic units. B.V.Timofeev (1958) in the samples selected from the schists in Orlovskiy quarry, had determined micro-fossil complex of Late Riphean age. Based on these determinations, taking into account metamorphic patterns, Orlovska sequence for a long time had been being correlated with the Riphean green schists of Central Dobruja developed in the basement of Mizian plate. Radiological studies of samples from Orlovskiy quarry conducted in 70-80th of the last century by K-Ar method had yielded wide range of rock age values (470, 360, 336, 300 Ma) which did not get proper interpretation.

In 1979 E.O.Aseeva had conducted micro-paleo-phytological analysis of 12 schist samples and 3 con-sedimentation limestone samples selected from Orlovskiy quarry. In few amounts but in all samples diverse spores of Devonian land plants are identified (determinations of E.T.Lomaeva), and besides that, Devonian conodonts were determined in limestones: *Palmatolepis marginifera* H e l m s, *Polygnatus aff. delicates ulerich et* B a s s l e r i (determinations of O.M.Lypnyagov).

In 1987 during GM-50 [48] in five of 11 samples selected from outcrop nearby Orlovka village V.I.Avkhimovich had determined numerous spores. The sample 985 from outcrop 100 [48, 42] comprises greenish-grey schists from the outcrop bottom:

Ar. Chacotriletes sp., Retusotriletes communis, N a u m., *R. simplex* N a u m., *Dictyotriletes vimineus* N e k r., *Arshacozonotriletes notatus* N a u m. *var. microspinosus* T s e h i b r., A. *variabilis* N a u m., *Stenozonotriletes conformis* N a u m., *S. extensus* N a u m., *S. formosus* N a u m., *Lophozonotriletes curvatus* N a u m., *Humenozonotriies rygsosus* N a u m., *H. elvanensis* N a u m., *H. radiatus* N a u m. *var. poljessicus* K e d o., *H. spociosus* N a u m., *H. lupinovitchi* A v c h.

Defined composition of spores is characteristic for Upper Devonian Lower Famennian sediments. Occurrence of the varieties like *Dictiotriletes vimineus* N e k r. in the complex which are zone-type for the boundary sediments of Fransian and Famennian stages, and *Hymenozonotriletes speciosus* N a u m., *H. radiatus* N a u m. *var. poljessiccus* K e d o, which are only known at Lower Famennian bottom, suggests for Early Famennian age of sediments. The sample 1257 [48, 42] comprises grey schists. Few spores of appropriate preservation are identified: *Lihcospora pusilla* (I b r.) S o m e r s., *Densosporites inassus* N a u m., B y v s c h., D a n., *D. goniacantus* (W a l t z.) B y v s c h., *D. aculeatus* P l a u t. *emend* N u m n., *Cingulizonates bialatus* (W a l t z.) K e d o. This spore set is characteristic for Lower Carboniferous Visean sediments. The sample 1258 [48, 42] comprises grey schists. Single spores are found characteristic for Lower Carboniferous Visean sediments: *Densosporites dentatus* (W a l t z.) P o t. et K r e m p., *D. goniacantus* (W a l t z.) B y v s c h.. The sample 1259 [48, 42] comprises grey clayey limestone. Few spores of appropriate preservation characteristic for Lower Carboniferous Visean sediments are identified: *Lihycosporapusilla* (I b r.) S o m e r s., *Densosporites variabilis* (W a l t z.) B y v s c h., *D. goniacantus* (W a l t z.) B y v s c h., *D. dentatus* (W a l t z.) P o t. et K r e m p., *D. gibberosus* (N a u m. e t B y v s c h.) B y v s c h. *Trilobozonotriletes incisotrilobus* N a u m. et I s c h. Sample 1253 [48, 42] comprises grey schists with limestone lenses. Few spores of appropriate preservation characteristic for Lower Carboniferous Visean sediments are identified: *Lycospora pusilla* (I b r.) S o m e r s., *Densosporites gibberosus* N a u m. et B y v s c h. B y v s c h., *D. variabilis* (W a l t z.) B y v s c h., *Cingulizonates bialatus* (W a l t z.) K e d o., *Granulatisporites subintortus* (I s e h.) L u d., *Dictatisporites rauserac* N a u m. et B y v s c h., *Calamospora sp., Convolutispora sp.* Single re-deposited Famennian spores are noted: *Lophozonotriletes curvatus* N a u m., *Stenozonotriletes conformis* N a u m.

In the samples selected from core DH 025 and 039 [48, 42] for palinological analysis, abundant coalified fossil matter is identified. In DH 039 [48, 42] in the samples selected from dark-grey coalified schists with characteristic silk shine, O.K.Shchegolev at the depth 467.0 m had found angustifolia Lycopodium – *Lepidodendropsis*, characteristic for Late Devonian – Early Carboniferous. In DH 047 [48, 42] (depth 467 and 515.5 m) V.V.Ogar had determined *Crinoidea* segments; in the sample from depth 465.0 m – *Rugosa* of inappropriate preservation. Except V.V.Ogar, other authors had ascribed the rocks containing mentioned remnants to Upper Paleozoic.

Comparing the columns of Orlovska sequence developed in Nyzhnyodunayska LTZ with the columns in Aluatska and Saratsko-Tuzlovska LTZs located to the north from studied area, the following is established. In Aluatska LTZ the Upper Devonian column (Baurchynska Suite and carbonate sequence) consists of chemogenic-lagoon type sediments exclusively – fine-grained, often dolomitized, aphanitic limestones without organic remnants. In Saratsko-Tuzlovska LTZ the chemogenic-lagoon type of Upper Devonian sediments (Burnaska sequence) is developed (alternating limestones, dolomitized limestones, dolomites, gypsum-anhydrites). And in Dolynske village area only, which is located to the south of Bolgrad-Suvorovskiy regional fault, Upper Devonian column contains reef-type limestones with corals and marine fauna. Presented description of columns in the area between Prut and Dnister rivers suggests for lagoon and shallow-water marine conditions of sedimentation of chemogenic limestone-dolomite-gypsum-anhydrite range, which predominated over the south-western slope of Eastern-European Platform. The sharp litho-facial differences of Olrovska sequence columns from Upper Devonian columns in other LTZs of Fore-Dobruja can be resulted from facies analogues point of view, that is, their deposition had occurred under different conditions (geosyncline trough in case of Orlovska sequence and fore-geosyncline trough in case of its age analogues). The need in Orlovska sequence age adjustment is unequivocal nevertheless.

Mesozoic Eratheme

Triassic System

Triassic System is composed of pebble-stones, gravel conglomerates, sandstones, aleurolites, limestones, dolomite limestones and dolomites. It is mainly developed in the south-western part of the area where participates in structure of Nyzhnyodunayskiy block and is extended over the distance of 60 km in the north-western direction with the band up to 50 km wide. The north-eastern boundary of Triassic System is controlled by Bolgrad-Suvorovskiy fault and follows the line of inhabited localities Vynogradne village (to the north), Bolgrad town, Zhovtneve village, Suvorove village, and then abruptly, under the angle 70-80^{o}, turns up direction towards north-east along Zakhidno-Kugurluyskiy fault and goes away the map sheet territory. Apparently, considerable part of Triassic System to the north of its modern boundary was eroded in pre-Jurassic time because of extensive block uplifting. The south-western boundary is set by the line Luncaviţa-Consul

(Romania). The north-western boundary is known to the north-west from Reni town where it is cut by Galats-Tyraspilskiy regional fault zone. In the south-eastern direction the sediments are extended outside the studied area.

Triassic rocks are essentially deformed as a result of Early Kimmerian phase of tectogenesis widely developed in Western-European Platform, to the west from the studied area, and in Skifsko-Turanska plate (Steppe Crimea). The rocks are clamped into flat asymmetric north-west-trending folds complicated by reverse faults and thrusts and cut by diabase dykes.

In Nyzhnyodunayskiy block the rocks with sharp stratigraphic and angular unconformity lie over Upper Paleozoic sediments involved in Herzinian tectonic floor.

By the age of sediments, which overlie Triassic System, two blocks are distinguished: the first one, Prydunayskiy, where they are overlain by Neogene and Quaternary systems, and the second block, Izmail-Vladychenskiy, where Triassic System is buried at the great depth and overlain by Jurassic, partly Paleogene, Neogene and Quaternary systems. Their position is caused by tectonic regime of the territory in post-Jurassic time resulted in essential uplifting of Prydunayskiy block by the system of north-west-trending faults, which, in turn, had caused complete erosion of Jurassic sediments in this block. Taking into account the columns of DH 2uN [20, 42] and 6g/kI [21, 42], the vertical movements amplitude exceeds 1000 m.

At the surface Triassic sediments are only exposed in the area of former Ferapontiy monastery where they are mapped in the minor (50×50 m) cliff outcrop of Novosilska Suite limestones in the swamped flood-land of Danube River.

The maximum thickness of Triassic System according to calculations is about 4000 m. The maximum thickness of sediments intersected by drill-holes is 300 m (DH 2uN) [20, 42] and 500 m (DH 3g/k) [21, 42]. The hanging-wall altitudes of Triassic sediments vary from +2.5 m (former Ferapontiy monastery area) to -447.5 m in DH 091 [48, 42] located to the west of Reni town. The modern hypsometric position of Triassic hanging-wall directly depends on the erosion patterns in specific blocks.

Triassic System is studied most complete and in details in Prydunayskiy block where it is intersected by numerous drill-holes beneath Neogene and Quaternary systems.

In gravity field the sites of Triassic sediments are expressed in the negative linear gravity anomalies. This is well prominent in Reni town area and Lymanske village where little differences are noted in the buried relief because of lesser density of Triassic rocks in comparison to the underlaying rocks of Herzinian tectonic sub-floor. In magnetic fields Triassic sediments are not expressed because of low magnetic susceptibility (see “Map of local gravity anomalies in the scale 1:500 000”).

Based on litho-tectonic analysis, two LTZs are distinguished for Triassic sediments – Nyzhnyodunayska and Chervonoarmiyska. The modern distribution of Triassic System and the columns directly depend on the erosion degree in particular blocks caused by the regional uplifting movements. Specifically, to the north and north-west from Reni town Triassic sediments are completely eroded. In the area from Reni town towards south-east by line Novosilske village – former Ferapontiy monastery Upper Triassic is eroded and Lower and Middle Triassic rocks only are exposed at pre-Neogene-Quaternary surface. Further to the south-east, in Kugurluyskiy block, Triassic sediments are most preserved. The lower, middle and upper divisions are distinguished in Triassic System.

Lower division

Induan – Olenekian stages undivided

Terrigenous red-brown sequence (T_1t). In the map sheet area Lower Triassic includes terrigenous sequence only. The full description of the latter is given below.

The sequence comprises the basal layers of Triassic System. It is composed of red-brown gravel and pebble conglomerates, sandstones and aleurolites representing sub-continental facies of molassa type. Red-brown rock coloring as well as arkosic and polymictic composition of clastic material is characteristic. The sequence is developed over entire territory of Triassic depression and its distribution boundaries coincide with the boundaries of Triassic System. Of the Triassic units this sequence is most widespread although it is not exposed at the surface and is intersected by numerous drill-holes in Prydunayskiy block beneath Neogene and Quaternary sediments. After geophysical and drilling data in adjacent territory [42] the sequence apparently is also widely developed in Izmail-Vladychenskiy block, where the sequence is deeply buried and overlain by Jurassic, partly Paleogene, Neogene and Quaternary systems. In Prydunayskiy block, in the northern limbs of Plavnenska and Prydunayska synclines, the rocks are exposed at pre-Neogene surface in the bands of the north-western extension up to 2 km wide. The rocks with sharp angular and stratigraphic unconformity lie over Devonian Orlovska sequence and are overlain (stratigraphically conformably) by the lower sub-sequence of

Novosilska Suite composed of limestones, dolomite limestones and dolomites. Most complete column reflecting relationships of terrigenous sequence with underlaying and overlaying sediments is intersected by DH 027N [48, 42].

C o n g l o m e r a t e s are gravel, pebble and gravel-pebble. Macroscopically these are dense, non-carbonate rocks with chaotic, rarely coarse-banded structure. Rock color is brown and red-brown, in places with lily shade. The grey and greenish-grey coloring is observed in the varieties underwent weathering and occurring directly beneath Neogene cover. The rock is composed of acute-rounded fragments of sheared sandstones, aleurolites, schists, quartz, cemented by red-brown aleurites-sandy-clayey mass with minor chlorite and sericite. Cement is of porous and basal types, aleurite-sandy-clayey in composition.

S a n d s t o n e s are diverse-grained, coarse-banded, dense, strong, mainly red-brown. They are composed of acute-rounded grains of feldspar, quartz, fragments of schists, aleurolites and sandstones. Numeric relationships of clastic material of various composition vary in the wide range; by these reasons sandstone composition varies from polymictic varieties to arkosic ones and essentially depends on the source regions of clastic material.

A l e u r o l i t e s are diverse-grained, coarse-banded, dense, strong, with minor sand material, red-brown, cemented by clayey cement of porous and basal types.

The sediments are not completely intersected by drill-holes over their entire thickness. The maximum thickness does not exceed 25-30 m. The true thickness of this sequence after geological data is about 1200 m (see geological cross-section to “Geological map and map of mineral resources of pre-Cenozoic units”). The rocks do not actually contain fauna remnants. Taking this reason into account, the Lower Triassic age of terrigenous sequence is mainly defined after their tectonic position in the column of the given area.

Lower – Middle divisions

Olenekian – Anisian – Ladinian stages undivided

Novosilska Suite ($T_{1\text{-}2}nv$). The Suite is distinguished in the lower and middle undivided divisions of Triassic System based on litho-tectonic analysis; it is divided, in turn, in the lower and upper sub-suites.

Lower sub-suite ($T_{1\text{-}2}nv_1$). This includes sediments of marine shallow-water limestone facies and mainly composed of limestones, in lesser extent – dolomite limestones. Exclusively carbonate composition, massive structure, and micro-grained rock texture are the distinct features of the lower sub-suite. In comparison to the upper sub-suite, similar in composition, the lower one differs in higher carbonate composition. The lower sub-suite is developed over entire territory of Triassic depression and its distribution boundary coincides with the boundary of entire Triassic System. At the surface these sediments are only exposed in the area of former Ferapontiy monastery in the minor cliff outcrop in the swamped part of Danube River flood-land. The rocks lie over Lower Triassic terrigenous red-brown sequence with gradual transition. The contact is intersected by DH 027N [48, 42]. The sub-suite is stratigraphically conformably overlain by the upper sub-suite of Novosilska Suite.

In Prydunayskiy block (Kagulskiy and Orlovsko-Novosilskiy second-order blocks) located to the north-west from Zakhidnokugurluyskiy fault, which strikes to the south-east of Novosilske village and former Ferapontiy monastery, the lower sub-suite constitutes the cores of asymmetric syncline structures extended in the north-western direction in the bands 3-4 km wide and intersected by numerous drill-holes beneath Neogene and Quaternary cover sediments. In the anticlines and in the area of Orlovka-Nagirve villages the lower sub-suite is eroded. In Kugurluyskiy second-order block, located to the south-east from Zakhidnokugurluyskiy fault, and also in Izmail-Vladychenskiy block, after geophysical and drilling data, as well as drill-hole data from adjacent areas (DH 2uN) [20, 42], the lower sub-suite is apparently developed throughout and is overlain by Upper Triassic sediments being most preserved from erosion. The typical column rocks include limestones, dolomite limestones, and rarely dolomites.

L i m e s t o n e s are aleuritic, clayey, often dolomite, light-grey, grey to dark-grey, micro-grained, dense, strong, non-banded. In thin sections the micro-banded structure is observed in places caused by horizontally-wavy discontinuous interbeds of pelitomorphic carbonate.

D o l o m i t e s are aleuritic, clayey, light-grey, in places dark-grey, micro-grained, dense, strong, with unclear micro-banded structure; macroscopically they do not differ from limestones.

The hanging-wall altitudes of lower sub-suite, exposed at pre-Neogene and pre-Quaternary surfaces, vary from +2.5 to -447.5 m (DH 091) [41, 42]. Thickness of sediments, after geological data, attains 1400 m.

Upper sub-suite ($T_{1\text{-}2}nv_2$). The upper sub-suite is composed of dolomites and dolomite limestones representing marine limestone-dolomite facies. The upper sub-suite composition is mainly dolomitic. From the similar in composition rocks of the lower sub-suite these ones differ in banded structures. The upper sub-suite sediments are not exposed at the surface and are intersected by drill-holes 2uN [20, 42], 072, 022 [48, 42] beneath Neogene rock sequence. In comparison to the sediments of lower sub-suite these rocks are less widespread and at pre-Neogene surface are exposed in the area of Plavni and Novosilske villages and to the south of Kugurluy lake. The upper sub-suite stratigraphically conformably lies over lower sub-suite and is stratigraphically conformably overlain by Upper Triassic carbonate-terrigenous sequence. The contact with underlaying and overlaying sequences is not intersected by drill-holes in the studied area.

The most completed column of upper sub-suite is intersected by DH 072 and 022 [48, 42]. In DH 072 beneath Neogene sediments at the depth 302-453 m the sequence of light-grey micro-grained, in places extensively crushed dolomites, is intersected. The thickness of intersected column is 151 m (see "Geological map of pre-Quaternary units").

D o l o m i t e s are most widespread rocks in the upper sub-suite column. These are light-grey, grey, in places dark-grey, micro-grained, dense, strong, banded rocks. At the top dolomites are normally coarse-banded.

The column of upper sub-suite is not intersected over full thickness by drill-holes. After geological data, its thickness is about 300 m.

Novosilska Suite in term of composition is well correlated to the similar Triassic sediments in Tulcea zone (Romania). Over there, these rocks are exposed at the surface, well studied and fauna-supported. The carbonate sequence in Tulcea zone of Northern Dobruja, based on paleontological data, is ascribed to the upper parts of Anisian and Ladinian stages. In Kiliyska LTZ (outside the studied territory) Novosilska Suite is correlated to the sediments of Vylkivska Suite composed of limestones with scarce marl, sandstone and aleurolite interbeds. Thickness of Vylkivska Suite attains 918 m.

The age of Novosilska Suite is mainly based on paleontological data and clear correlation with similar sediments in the stratotypic area of Northern Dobruja and adjacent areas. In DH 2uN [20, 42] at the depth 1001-1023 m N.A.Efimova had determined foraminifera: *Glomospira cf. Denga* (P a n t i č*), Glomospira sp., Glomospira ex gr. regularis* L i p i n a, *Glomospira densa* (P a n t i č), *Glomospira off. densa* (P a n t i č). At the depth 1044-1267 m: *Mendrogpira pusilla* (H o), *Glomospirella off. triphoonensis* B a n d, Z a n i n, B r o n., *Glomospirella facilis* (H o), *Glomospirella sp., Glomospira sp.* After determinations of N.A.Efimova, the rocks at the depth 1044-1267 m contain varieties *Meandrospira busilla* (P a n t i č), which belong to upper part of Lower Triassic, and the rocks at the depth 1001-1023 m contain the variety: *Glomospira densa* (P a n t i č) which belongs to lower part of Middle Triassic.

L.D.Kiparysova in the samples from well drilled to the south from Novosilske village had determined the remnants of gastropoda *Naticopsis sp, Worthenia*, and bivalvia *Gervilia sp., Anodonthophora sp.* Taking into account above reasons, the age of Novosilska Suite is accepted to be Lower-Middle Triassic.

Upper division

Carnian – Rhaetian stages undivided

Carbonate-terrigenous sequence (T_3ct) completes Triassic System column in the studied area. It is mainly composed of dark-grey, non-banded, dense carbonate aleurolites. In the lower part of column intersected by DH 016 [48, 42] (to the south of Kugurluy lake) alternating limestones and aleurolites are encountered. Upward in the column the rocks become massive, non-banded, uniform, with distinct elongated-spotty structure.

Carbonate-terrigenous composition, non-banded structure, uniform appearance of the rocks comprises their distinct features. From similar in composition Middle Jurassic rocks of Andrushynska Suite they differ in carbonate composition.

Carbonate-terrigenous sequence is not exposed at the surface and is intersected by drill-holes 015, 016, 020, 021 (to the south of Kugurluy lake) and 030, 033 [41, 42] drilled in the area of Plavni and Novonekrasivka villages beneath Middle and Upper Sarmatian sediments (see "Geological map of pre-Cenozoic units").

Upper Triassic carbonate-terrigenous sequence is developed in the Kugurluy lake area to the south-east from the zone of Zakhidnokagulskiy fault, where they are overlain by Neogene System. Apparently, these sediments are widely developed in Izmail-Vladychenskiy block, where Triassic surface is observed at significant depth and is overlain by thick Jurassic sequence, if they are preserved from erosion. To the north-west from Zakhidnokugurluyskiy fault, in Prydunayskiy block, the carbonate-terrigenous sequence is eroded because of considerable (up to 2000 m) upward movements.

The carbonate-terrigenous sequence lies stratigraphically conformable over Novosilska Suite and with sharp stratigraphic and angular discontinuity is unconformably overlain by Middle Jurassic terrigenous sequence. The contacts with underlaying and overlaying units are not intersected in the studied area. In places, where carbonate-terrigenous sequence is exposed at pre-Neogene surface, the sequence with sharp stratigraphic and angular discontinuity is overlain by Middle and Upper Sarmatian sediments.

The most typical columns are intersected by DH 021, 020, 030 and 033 [41, 42].

A l e u r o l i t e s are dark-grey, quartz, dense, very strong, non-banded, in places with unclear discontinuous banding rocks cemented by carbonate and clayey-carbonate cement, in places cut by calcite veinlets.

The hanging-wall altitudes of carbonate-terrigenous sequence, exposed at pre-Neogene surface in Kugurluy lake area, vary from -165 m (DH 016) [41, 42] to -251.5 m (DH 030) [48, 42] and depend on the modern hypsometric position of particular tectonic blocks and their erosion degree. Thickness of the sequence after geological data is about 1000 m.

By composition and fauna remnants carbonate-terrigenous sequence is well correlated with Upper Triassic flysch formation of Northern Dobruja. In Tulcea zone it is composed of sandstones with distinct rhythmic. The thickness is about 1000 m therein. The sequence is mainly developed in the western part of Tulcea zone and contains *Daonella* imprints indicating Triassic age of this formation. The sequence without interruption in sedimentation lies over marls containing *Gladiscites din.* and indicating Early Norian age of the rocks. In Mechin zone carbonate-terrigenous sequence is correlated with Nalbandski layers comprising Upper Triassic flysch formation. Nalbandski layers are composed of sandstones and argillites with prominent rhythmic patterns of sediments typical for flysch formations. The columns of Northern Dobruja do mainly correspond to the coastal zone with reinforced hydrodynamic regime whereas columns intersected by drill-holes in the studied area reflect deeper-water part of Late Triassic basin.

In comparison to the columns of Saratsko-Tatarbunarska area the carbonate-terrigenous sequence is correlated with Trudivska Suite (outside map sheet area) composed of alternating sandstones, aleurolites, argillites, marls and limestones. The sequence is observed stratigraphically higher of Novosilska Suite and with sharp stratigraphic and angular unconformity is overlain by Jurassic and Neogene sedimentary sequences.

The age of carbonate-terrigenous sequence is mainly based on fauna remnants studies as well as on defined tectonic and stratigraphic position of this sequence in the column and good correlation with similar sediments of adjacent areas in Tulcea zone of Northern Dobruja and Saratsko-Tatarbunarska area.

In the samples, selected from the core of DH 020, 031, 030 [41, 42], L.F.Romanov had determined *Daonella lammeli Mojsisov* characteristic for Upper Triassic.

The column of carbonate-terrigenous sequence, intersected by DH 016 [48, 42], includes marls, limestones, argillites and aleurolites and contains re-crystallized mollusc remnants which cannot be determined. The uniform sequence of dark-grey aleurolites which is observed below and contains imprints of *Daonella lammeli Mojsisov* is well correlated with Triassic Carnian and Norian stages of Tulcea zone in Northern Dobruja.

Jurassic System

In the studied map sheet area Jurassic System includes the following facies: marine sandy-clayey, marine carbonate and carbonate-clayey, lagoon-marine evaporate and sub-continental terrigenous-clayey. The rocks are developed over almost entire territory except the far south-western part where these sediments are almost completely eroded and only preserved in minor remnants in the area of former Ferapontiy monastery being “clamped” in tectonic break zones. The south-western boundary of Jurassic sediments follows the line of inhabited localities Dolynske – Nagirne (to the south) – Novosilske – Nova Nekrasivka villages and further to the south of Izmail town. This boundary is of tectonic origin and comprises the system of reverse faults with upward movement amplitude more than 1300 m expressed in post-Jurassic time and confirmed by drilling (DH 1uD, 2uN [20, 42], 6g/kI [21, 42]) (see “Geological map of pre-Cenozoic units”).

Deposition of Jurassic sediments had occurred under conditions of the north-eastern part of broad trough encompassed considerable territory of the western and south-western slope of Eastern-European Platform. The trough development process had involved entire territory which belongs to Besarabsko-Chornomorska plate (region of tectonic-magmatic activation) and significant portions of Moldavska plate slopes. In post-Jurassic time the territory to the south-west of the modern distribution area of Jurassic System as well as Central and Northern Dobruja were essentially uplifted and Jurassic sediments are almost completely eroded over there.

Over complete thickness Jurassic sediments are intersected by few drill-holes, mainly in Moldavska plate and Gorikhivskiy block which spatially belongs to Besarabsko-Chornomorska plate. The rocks lie with significant stratigraphic and angular discontinuity over Archean – Lower Proterozoic plagiogranites, Vendian, Cambrian, Devonian, Carboniferous sequences and various stratigraphic units of Triassic indicating considerable tectonic re-arrangement of the territory in the period from Triassic to Middle Jurassic. The rocks are stratigraphically unconformably overlain by Eocene and Upper Miocene (Neogene) sediments. The depth of Jurassic surface intersected by drill-holes is 149 m (DH 094) [41, 42] in the south and 1748 m (DH R 20VP [21, 42], Dmytrivka village) in the far north of the territory. The hanging-wall altitudes vary from -151 m (DH 094) to -1657 m (DH R 20VP) [21, 42]. Thickness of Jurassic System varies from zero in Prydunayskiy block, where it is completely eroded, up to 2334 m (DH 1P) [21, 42] in Gorikhivskiy block. The total thickness of Jurassic System is 4200 m being caused by sharp changes in thickness of specific stratigraphic units. Distribution of straton thickness and Jurassic System hanging-wall altitudes indicate essential vertical downward movements in specific blocks at the stage of sedimentation, and upward movements at the stage of trough inversion, when significant portion of Jurassic column was eroded. The deepest trough part does spatially coincide with the north-eastern part of Gorikhivskiy block. The most elevated part of the trough belongs to Prydunayskiy block where Jurassic sediments are preserved in minor remnants.

Based on litho-tectonic analysis of Jurassic sediments, the Pereddobrudzka LTZ is distinguished, which spatially corresponds to the major tectonic elements – Moldavska plate, Gorikhivskiy and Nyzhnyodunayskiy blocks. In Jurassic System, Andrushynska, Bolgradska, Kazakliyska, Kongazka and Chadyr-Lungska suites are distinguished.

Middle division

Bajocian – Bathonian stages undivided (J_2bj-bt)

Andrushynska Suite (J_2*an*) includes marine clayey-terrigenous facies exclusively: carbonatized argillites, aleurolites and diverse-grained sandstones. The Suite is only intersected by few drill-holes in Gorikhivskiy block and southern part of Moldavska plate, mainly in the northern part of the studied area (see "Geological map of pre-Cenozoic units"). In the southern part of the area the Suite is only intersected in the zone of Kagulskiy fault which controls the south-western boundary of Jurassic System sediments and where these rocks are exposed at pre-Neogene surface and intersected by drill-holes in the areas of Lymanske village (DH 1uD [20, 42] and others), Plavni village (DH 2uN) [20, 42], and Izmail town (DH 6k/gI) [21, 42]. Over the full thickness they are only intersected by some drill-holes in Gorikhivskiy block and southern part of Moldavska plate (DH R 20VP [21, 42], Dmytrivka village). Of the other Jurassic stratigraphic subdivisions Andrushynska Suite is most widely developed; its south-western boundary coincides with the boundary of entire Jurassic System and is bounded by the zone of post-Jurassic fault. The Suite with angular unconformity lies over Archean – Lower Proterozoic plagiogranites, Vendian, Devonian, Carboniferous and Triassic sediments suggesting for significant tectonic re-arrangement of the territory at the boundary between Late Triassic and Middle Jurassic. The Suite with stratigraphic unconformity is overlain by Bolgradska Suite and Neogene Middle Sarmatian sediments. The depth of Andrushynska Suite surface varies from 149 m (DH 094) [41, 42] in the south to 1748 m (DH R 20VP [21, 42], Dmytrivka village) in the north of the studied area. The hanging-wall altitudes vary from -151 m (DH 084) in the south margin of Nyzhnyodunayskiy block to -1657 m (DH R 20VP) [21, 42] in the south margin of Moldavska plate. Thickness of the Suite varies from first meters in the south to 2524 m (DH 1CH, 2CH, 1P, 2P, 3P and 1G [21, 42]) in the area of Chervonoarmiyske and Gorodne villages in Gorikhivskiy block. The thickness distribution of the Suite and the modern position of its surface suggest for considerable vertical motions of specific blocks, both at the stage of trough development and afterward at the inversion stage. Based on detailed litho-facial analysis of Andrushynska Suite coupled with complex results of well logging data three sub-suites are distinguished – the lower, middle and upper.

Lower Andrushynska sub-suite (J_2*an*$_1$). The rocks belong to marine clayey-terrigenous facies. They include argillites, aleurolites and diverse-grained sandstones and are only developed in the central and northern parts of Gorikhivskiy block (see "Tectonic scheme in the scale 1:500 000"). In the south-western direction the boundary of sediments is limited by the system of faults to the south of Chervonoarmiyske and Banivka villages. The northern sub-suite distribution boundary is limited by Chadyr-Lungskiy fault zone, Dmytrivka village area, and the eastern and south-eastern boundaries are limited by the zone of Novonekrasivsko-Novokamyanskiy fault (Kamyanka village area). In the north-western direction sub-suite is extended outside the map sheet area into adjacent Moldova. Sub-suite lies with angular discontinuity over Archean – Lower Proterozoic plagiogranites and is overlain with slight interruption, expressed in coarse-clastic rock layer, by Middle Andrushynska sub-suite. The maximum depth of sub-suite surface (2862 m) is intersected by DH 1g [21, 42], the minimum one is 2760 m (DH 1CH [21, 42], Chervonoarmiyske village). The hanging-wall altitudes: maximum one is -2733 m (DH 1P [21, 42]), and minimum one is -2635 m (DH 1G [21, 42]). The maximum thickness is 654 m (DH 1CH, 2CH [21. 42], Chervonoarmiyske village).

Middle Andrushynska sub-suite (J_2*an*$_2$). The rocks, like Lower Andrushynska sub-suite, are ascribed to marine clayey-terrigenous facies. They mainly include carbonate argillites, aleurolites and diverse-grained sandstones. Development of sub-suite, in comparison to the lower sub-suite, had occurred in more stable hydrodynamic environments evidenced by fine-grained clastic material involved. The hanging-wall depth is as follows: maximum – 1967 m (DH 1G [21, 42]), minimum – 1078 m (DH 2P [21, 48]). The hanging-wall altitudes: maximum is -1847 m (DH 1P [21, 42]), minimum is -1039.7 m (DH 2P [21, 42]. The maximum thickness is 954 m (DH 1CH [21, 42]). The thickness distribution of Middle Andrushynska sub-suite and the modern position of its hanging-wall suggest for considerable vertical motions of specific blocks, both at the stage of trough development and afterward at the inversion stage.

Upper Andrushynska sub-suite (J_2an_3). The rocks belong to marine clayey-terrigenous facies of Jurassic trough. They include low-carbonate argillites, aleurolites and rarely fine-clastic sandstones. Of the other subdivisions of Andrushynska Suite the upper sub-suite is most distributed (see "Geological map of pre-Cenozoic units"). The south-western boundary coincides with the boundary of entire Jurassic System and follows the line of inhabited localities Lymanske-Nagirne-Plavni-Novosilske-Novonekrasivka and further to the east to the south of Izmail town where it is cut by fault zone. Sub-suite lies without sharp stratigraphic discontinuity over Middle Andrushynski sediments, with sharp stratigraphic and angular unconformity over Devonian sediments, and over various stratigraphic subdivisions of Triassic System. Sub-suite with stratigraphic discontinuity is overlain by Eocene and Upper Miocene sediments. The surface depth is as follows: minimum – 149 m (DH 094 [42, 42]) in the south, maximum – 1748 m (DH R 20VP [21, 42]). The hanging-wall altitudes: minimum is -151 m (DH 094 [48, 42]), maximum is -1657 m (DH R 20VP [21, 42]). The maximum thickness of sub-suite is 916 m and is intersected by DH 1G [21. 42] (Gorodne village).

Description of most widespread rocks of Andrushynska Suite is given below.

A r g i l l i t e s are dark-grey, black, dense, uniform, non-banded, in places aleuritic, sandy, carbonate, with interbeds of aleurolites, sands, sandstones, rarely re-crystallized limestones, with coalified fossil remnants. After the thermal analysis data, the clay minerals include hydromica with admixture of carbonate, quartz, organic matter. Aleuritic and sand admixture (0.01-0.5 mm) is mainly composed of quartz, in lesser extent of feldspar and flint. Of the heavy fraction minerals in minor amounts are observed (0.01-0.1 mm): garnet, ilmenite, tourmaline, leucoxene, zircon, pyrite, biotite, iron hydroxides. In single grains are known chlorite, sillimanite, apatite, amphibole, magnetite, epidote.

A l e u r o l i t e s are quartz, dark-grey to black, light-grey, in places with brownish shade, dense, strong, uniform, non-banded, with interbeds of argillites, sandstones, limestones, siderite nodules. Cement is clayey, carbonate-clayey.

S a n d s t o n e s are feldspar-quartz, polymictic, quartz, fine-, medium-, coarse- and diverse-grained, gravelous, light-grey, grey, dark-grey, greenish-grey, normally dense, strong, in places thin-banded, wavy-banded. The banding is caused by alternating interbeds of various granulometric composition, argillites and aleurolites. Sandstones in places are pyritized, contain inclusions of coalified and pyritized organic matter, admixture, interbeds and lenses of gravel-pebble material up to 3 cm in size, consisting of quartz, syenite, sandstones, aleurolites, argillites, limestones. Somewhere carbonate and pyrite-carbonate veinlets up to 3 mm thick oriented under the angle 20-50^o to the core axis and irregular siderite nodules up to 5 cm in size are observed. Cement is mainly siliceous, regenerative, rarely clayey-aleuritic of basal and porous types.

G r a v e l i t e s and conglomerates are grey, light-grey, dark-grey, dense, strong, mainly non-banded, in places with argillite and aleurolites interbeds. The clastic material is up to 5 cm in size of various rounding degree, consisting of quartz, feldspars, syenites, sandstones, aleurolites, argillites. Cement is siliceous or sandy-clayey of basal type. In gravelites and conglomerates pyritization is noted in pods, films by crack walls, lenses and bunches up to 2-3 mm in size, in places more. Somewhere carbonate and pyrite-carbonate veinlets up to 3 mm thick oriented under the angle 30-75^o to the core axis are observed.

The age of Andrushynska Suite is defined after paleontological studies data. According to conclusion of L.F.Romanov, the mollusc fauna in samples selected from drill-holes 038, 044, 054 [41, 42] belong to the zone *Garantiana garantiana*, that it, lower parts of Upper Bajocian. It is evidenced by endemic variety *Phaenodesmia sobetski* (R o m.) known in the territory between Prut and Dnister rivers from the sediments of this age only. Mollusc fauna *Bositra buchi* (R o e m e r .), determined in DH 049, 053 [41, 42] suggest for Late Bajocian – Early Bathonian age.

In the rock sample, selected from the core of DH 049 [48, 42], R.I.Leshchukh had determined variety *Posidonia buchi* (R o e m e r.), and on this ground conclusion is made on Late Bajocian – Early Bathonian age of sediments.

In the samples, selected from the core of DH 044, 049 [48, 42], G.G.Yanovska had determined Filicinae spores close to the spores of modern families: *Dichsoniceae, Dipteridaceae, Osmundaceae, Kenkia*. The pollen is also determined with the forms of *Pinaceae* family. On the ground of these data conclusion is made on Middle Jurassic, apparently Bajocian age.

In the samples, selected from DH 041 [48, 42], E.O.Aseeva had determined highly corroded and deformed Filicinae spores, Gymnospermae and cicada pollen: *Delitoidospora compacta* B a r c h., *Toroisporites vulgaris (maI.)* B a r c h., *Toroisporis sp., Cicadopites sp., Piccapollemites sp., Pinuspollenites sp., Heliosporites sp*. In the same drill-hole at the depth 441.3 m I.M.Yamnychenko had determined fauna *Phacnodesmia cf.*

circumfluens J o m n. On the ground of data obtained conclusion is made of Middle Jurassic (probably Bajocian) age of sediments.

In the samples from DH 044 [48, 42] K.V.Dykan had determined the complex of pelecypoda and ammonites: *Parkinsonia sp., Gonioma sp., Phaenodesmia ex gr. arrinsis* R o m a n o v , *Pleuromya ex gr. goldfussi* R o l l i o r , *Nuculana sp., Oxytoma cf. scarburgensis* R o l l i o r , *Astarte cf. orbicularis* S o m e r b y, *Entolium cf. demissum* P h i l l i p s , *Thracia ex gr. lata* (G o l.), *Gonioma sp., Nucula ex gr. endorae* O r b i n y . , *Pleuromya cf. goldfussi* R o l l i o r . On the ground of data obtained conclusion is made concerning Middle Jurassic (Late Bajocian – Early Bathonian) age of the rocks.

In drill-hole 2CH [21, 42] (Chervonoarmiyske village) in sediments ascribed mainly to the Lower and Middle Andrushynska sub-suites the complex of Late Bajocian – Early Bathonian molluscs was determined [1].

Taking into account unequivocal conclusions after paleontological studies as well as clear correlation by lithology with the even-aged sediments in stratotypical area of Fore-Dobruja Jurassic trough, the age of described sediments is defined to be Middle Jurassic (Bajocian –Bathonian).

Middle – Upper divisions undivided

Callovian – Oxfordian stages undivided

Bolgradska Suite (J_{2-3}*bl*) is composed of reefogenic limestones and argillite-like clays with minor, mainly at the column bottom, terrigenous rocks – aleurolites and diverse-grained sandstones. Their deposition had occurred under conditions of transgressive stage of marine basin development at the boundary of Middle and Upper Jurassic. Over there, in Bolgradskiy time the shallow-water marine basin conditions were established with normal water salinity evidenced by the sedimentation features as well as fauna and micro-fauna complexes.

The Suite is not exposed at the surface and is intersected by numerous drill-holes over almost entire territory except the south-western uplifted part where the Suite was completely eroded in post-Jurassic time. The south-western boundary of modern Suite distribution follows the line of inhabited localities Dolynske, Nagirne, Plavni, Novonekrasivka, Izmail and almost completely coincides with the distribution boundary of Andrushynska Suite, which is bounded by Izmailskiy and Kagulskiy fault zones. In the north-western, northern and south-eastern directions the Suite is extended outside the studied area. The Suite with significant interruption in deposition lies over Middle Jurassic Upper Andrushynska sub-suite and over most part of its distribution is overlain by Kazakliyska Suite, and at the sites of essential erosion – by Upper Miocene sediments. The modern boundary of the Suite distribution, column completeness, thickness distribution and modern hanging-wall position directly depend on the motions of specific tectonic blocks in post-Jurassic time and, respectively, on erosion depth.

The Suite hanging-wall altitude varies from -257.7 m (DH 28 [21, 42] in Matroska village area to -1429.4 m (DH R 20VP [21, 42] in Dmytrivka village area; the depth is 254.7 and 1520 m respectively suggesting for amplitude of vertical motions in certain blocks in post-Jurassic time. The maximum Suite thickness attains 478 m (DH 4rS [21, 42]) in Suvorove village area. The Suite is distinguished for the first time in the stratotype (DH r-21 [21, 42] where its thickness is up to 440 m. Based on detailed litho-facial analysis the lower and upper sub-suites are distinguished.

Lower Bolgradska sub-suite (J_2bl_1) is exclusively composed of reefogenic limestones with subordinate, mainly in the lower column part, terrigenous rocks including aleurolites and diverse-grained sandstones. The hanging-wall altitudes vary from -251.7 m (DH 18 [21, 42] in Matroska village area to -1506.4 m (DH R 20VP [21, 42] in Dmytrivka village area; the depth is 254.7 m and 1597 m respectively. The maximum thickness of sub-suite is intersected by DH 4rS [21, 42] to 340 m. With the minor interruption sub-suite lies over Andrushynska Suite and is overlain with gradual transition by the Upper Bolgradska sub-suite.

Upper Bolgradska sub-suite (J_2bl_2) is mainly composed of argillite-like clays with minor limestone interbeds indicating marine basin shallowing at the final stage of Bolgradska Suite deposition. The hanging-wall altitudes vary from -271 m (DH 6k/g [21, 42]) in Izmail town area to -1429.4 m (DH R 20VP [21, 42) in Dmytrivka village area); the depth is 287 m and 2520 m respectively. The maximum sub-suite thickness is intersected by DH 1rCH [21, 42] in Chervonoarmiyske village area to 259 m. Sub-suite lies without interruption over limestones of Lower Bolgradska sub-suite and is overlain with essential interruption by Kazakliyska Suite.

L i m e s t o n e s are grey, dark-grey, yellowish-grey, greenish-grey, mainly re-crystallized, fine-micro-grained, strong, in places clayey pelitomorphic, often fractured, breccia-like, with interbeds of marls, argillites, aleurolites, sandstones, and somewhere contain thin, diverse-oriented calcite veinlets and pyrite dissemination.

A r g i l l i t e s are grey, dark-grey, light-grey, brown, in places with reddish-brown and brown-yellow spots and interbeds, often aleuritic, carbonate, low-siliceous, with interbeds of quartz fine-grained sandstones and aleurolites under clayey and carbonate-clayey cement and re-crystallized, organogenic, organogenic-oolite, dolomitized limestones with scarce thin calcite and iron oxide veinlets.

A l e u r o l i t e s are quartz, grey, dark-grey, mainly fine-grained, in places sandy, low-carbonate, dense, strong, somewhere banded because of argillite interbeds. Cement is clayey, carbonate-clayey, clayey-carbonate. In places carbonate veinlets up to 0.5 mm thick and pyrite pods are developed. Aleurolites are not widely distributed in the studied area and in certain places they substitute argillites and are observed in the interbeds in argillites and limestones.

S a n d s t o n e s are quartz, feldspar-quartz, mica-feldspar-quartz, light-grey, grey, dark-grey, greenish-grey, fine- and diverse-grained, in places aleuritic, dense, strong, somewhere banded because of occurring argillite and aleurolite interbeds. Cement is clayey, carbonate-clayey, siliceous, of basal and porous types. In places thin calcite veinlets are observed.

In Bolgradska Suite aleurolites, argillites and sandstones few geochemical anomalies of silver, chromium, manganese, lead, titanium, zinc, molybdenum and lithium are encountered.

The age of Bolgradska Suite does correspond to Kallowean and Oxfordian of the common (international) stratigraphic scale based on correlation links and lithology similar to the rocks intersected in Dnistersko-Prutskiy stratotypical area, as well as on the ground of mollusk fauna determinations: *Lithacoceras spongiphillus* M o e s., *Bositra buchi* (R o e m e r .), *Posidonia buchi* R o e m e r ., *Entolium demissum* P h i l l i p s ., *Perisphinctes bifurcatum* Q u e n s t ., *Lithacoceras spongophillum* M o e s c h., *Glochiceras sp.*

Upper division

Oxfordian – Kimmeridgian stages undivided

Kazakliyska Suite (J_3kz) in the territory of map sheets L-35-XXIII (Izmail) and L-35-XXIX (Tulcha) mainly consists of chemogenic limestones and parti-colored (grey, brownish-grey and brown shades) argillite-like clays. Their development had occurred under conditions of retrograde stage of shallowing marine basin far away enough from the shoreline which is evidenced by limestone and clay sediments and fauna and micro-fauna complexes. The Suite is not exposed at the surface and is only intersected by drill-holes. It is developed throughout entire Fore-Dobruja LTZ. The south-western boundary of the modern Suite distribution follows the line of inhabited localities Bolgrad town – Topolyne-Krynychne-Ozerne-Novosilske-Novonekrasivka-Sofyan villages and is controlled by the zones of Skhidnoyalpugskiy and Sofyanskiy faults. To the south-west from this line the Suite is completely eroded (see “Geological map and map of mineral resources of pre-Cenozoic units”).

The Suite lies without stratigraphic interruption over Bolgradska Suite and is overlain with slight interruption by Kongazka Suite while in places where the latter is eroded – by Upper Miocene sediments. The modern distribution boundary of the Suite and its modern hanging-wall position directly depend on the motions of specific blocks in post-Jurassic time (Late Kimmerian phase of tectogenesis).

The Suite hanging-wall altitudes vary from -292.4 m (DH 111 [42]) in Zhovtneve village area and up to -1299.4 m (DH R 20VP [21, 42]) in Dmytrivka village area. The maximum thickness of sediments is 251 m (DH 3P [21, 42], Chervonoarmiyske village area).

Kazakliyska Suite (in Kazakliya village, Moldova) was initially distinguished by B.S.Slyusar as Kazakliyski layers [3]. As the “Suite” it i distinguished in the given territory for the first time. The stratotype is established in DH 338 [42], depth 976.2-760.0 m in the northern part of Kytay lake where the Suite thickness is up to 200 m. In comparison to the stratotype, the columns of Kazakliyska Suite in the studied area are somewhat higher in thickness, more complete, and specific conditions of sedimentation.

Based on detailed litho-facial analysis the lower and upper sub-suites are distinguished in Kazakliyska Suite. Description of these stratigraphic subdivisions is given below.

Lower Kazakliyska sub-suite (J_3kz_1) is mainly composed of chemogenic limestones with argillite, aleurolite and sandstone interbeds indicating complex hydrodynamic conditions of sedimentation. Sub-suite is developed almost everywhere in the Fore-Dobruja LTZ. The modern distribution in the western part is bounded by the zone of Skhidnoyalpugskiy fault and in the southern part by the zone of Sofyanskiy fault. To the south and south-west from this fault zone and also in Vynogradivka village area the given sediments are completely eroded.

The hanging-wall altitude varies from -268.3 m (DH 206 [21, 42], Zaliznychne village) to -1506.4 m (DH R 20VP [21, 42], Dmytrivka village area). The maximum thickness of sub-suite is intersected by drill-hole 1CH [21, 42], Chervonoarmiyske village area) to 134 m. It lies without interruption over Bolgradska Suite and is overlain by Upper Kazakliyska sub-suite. In places of erosion it is overlain with stratigraphic unconformity by Kongazka Suite. The age of sub-suite is determined to be Late Oxfordian on the ground of paleontological data.

Upper Kazakliyska sub-suite (J_3kz_2) is mainly composed of grey, greenish-grey and blue-gray argillites, in places with brownish shade, carbonate, somewhere flinted, dense, diverse-strength and lithification degree, often banded, with limestone, aleurolite and fine-grained quartz sandstone interbeds. Sub-suite composition suggests for sedimentation under conditions of shallowing marine basin. In comparison to Lower Kazakliyska sub-suite the Upper one is less developed and in the area of Dmytrivka village it is eroded at all.

The hanging-wall altitudes vary from -287.3 m (DH 40 [42], Larzhanka village) to -945.5 m (DH 3P [21, 42], Chervonoarmiyske village area). The maximum thickness in excess of 203.8 m is intersected by DH 37 [42] in Loshchynivka village area. Sub-suite is overlain by Kongazka Suite with slight interruption and in the area of Krynychne, Kalanchak and Ozerne villages – by Middle Sarmatian sediments with considerable stratigraphic unconformity; with gradual transition it lies over Lower Kazakliyska sub-suite. The age of sub-suite is accepted to be Middle-Late Kimmeridgian on the ground of paleontological studies.

The Kazakliyska Suite rock description is given below.

L i m e s t o n e s are light-grey, grey, yellowish-grey, re-crystallized, micro- and fine-grained, organogenic, detritus, dense, strong, in places cavernous, breccia-like, somewhere dolomitized, flinted, in places with aleurite, sand and clay admixture, with argillite, aleurolite and sandstone interbeds. Described limestones constitute Lower Kazakliyska sub-suite. In the Upper Kazakliyska sub-suite limestones are limited in volume and other macroscopic appearance. These are mainly red-color, parti-colored rocks, often with breccia-like structure. Limestones are re-crystallized, from micro- to coarse-grained, organogenic, often fractured, contained in the fragments cemented by carbonate or clayey-carbonate matter, often with sand and aleurite admixture. Fractures are filled with calcite. Aleurite and sand admixtures in limestones are mainly composed of quartz, in lesser extent of feldspars and flint. Of the heavy fraction minerals in minor amounts the following minerals are observed: garnet, ilmenite, tourmaline, leucoxene, rutile, zircon, chlorite, pyrite, biotite and apatite.

A r g i l l i t e s are dark-grey to black, light-grey, greenish-grey, bluish-grey, in places with brownish shade, carbonate, somewhere flinted, dense, of various strength and lithification degrees, often banded, with fine-grained quartz sandstone, aleurolite, limestone, dolomite interbeds.

A l e u r o l i t e s are quartz, fine-grained, red-brown, brownish, greenish-grey, bluish-grey, with clayey-carbonate cement, in places with limestone and dolomite interbeds.

The age of Kazakliyska Suite (Oxfordian-Kimmeridgian) is based on clear correlation with similar sequences of adjacent territories where these sediments are completely enough supported by fauna. In the studied map sheet area, the fauna complex was determined in drill-holes which corresponds to the Upper Jurassic: mollusks – *Lithacoceras cf. spongiphillum* M o e s . , *Entolium nummalaris* (F. W a l d c h e i m), *Monotis lacunosa* Q u e n s t e d t , *Chlamys sp., Ammonitida sp., Dacroloma sp., Lytoceras sp., Astarte sp.*

Kimmeridgian stage

Kongazka Suite (J_3kn) is composed of chemogenic limestones, dolomites, gypsums, anhydrites, gypsum-anhydrites and parti-colored argillite-like clays with minor development, mainly at the bottom layers, of terrigenous rocks including aleurolites, diverse-grained sandstones and conglomerates. Development had occurred under conditions of the shallowing north-eastern part of Jurassic trough in lagoon-marine sedimentation environments with mainly evaporitic sedimentation.

The Suite is widely developed in the northern and eastern parts of the studied area. In the remaining territory it is almost completely eroded and only preserved in the remnants in the areas of Tabaky village, to the east of Ozerne village, and in Loshchynivka village area. At the surface these rocks are not exposed and only intersected by numerous drill-holes. The rocks with slight interruption lie over Kazakliyska Suite. Over most part of the territory they are overlain by Chadyr-Lungska Suite. At the sites of essential erosion they are overlain by Upper Miocene sediments. The modern distribution boundary of Kongazka Suite, the column completeness, and erosion depth respectively, thickness distribution and modern hanging-wall position directly depend on the motions of individual tectonic blocks in post-Jurassic time (Late Kimmerian tectogenesis phase). The Suite hanging-wall altitudes vary from -220 m (DH 19 [42], Sofyan village), to -997.4 m (DH R 20VP [21, 42], Dmytrivka village) indicating for significant amplitude of some blocks vertical motions in post-Jurassic time. The maximum thickness of sediments is intersected DH 401 [21, 42] and 18s [50, 42] to 651 m. For the first time Kongazka Suite was distinguished in 1968 by V.F.Moroz (after Kongaz village, Moldova). The stratotype is defined in the well 136k, depth 990-1117 m, drilled in Svitle village, Komratskiy area, Moldova. The maximum thickness is estimated to 127 m [9].

In comparison with the stratotype, the columns of upper Kongazka Suite intersected by drill-holes in the studied area are more complete and more than five times thicker (650 m) the stratotype column exhibiting specific sedimentation conditions and clear interruption inside the Suite. The age of Kongazka Suite is accepted to be Oxfordian-Kimmeridgian based on paleontological studies, position in the Jurassic System column, and relationships with underlaying and overlaying units.

Based on detailed litho-facial analysis, the lower and upper sub-suites are distinguished.

Lower Kongazka sub-suite (J_3kn_1) in the lower part mainly consists of parti-colored, fine-grained, massive dolomites, often with banded structure, in places with clay, gypsum and anhydrite admixtures, pods and inclusions. Besides that, thin limestone, gypsum, anhydrite and gypsum-anhydrite interbeds are observed. Higher in the column mainly dolomite column is replaced by the clayey one. The typical column of Lower Kongazka sub-suite is intersected by DH 11s [59, 42] at the depth 586.2-781.1 m (Banivka village are). The column features suggest for deposition under conditions of marine lagoon with increased salinity where dolomite sedimentation predominated in the beginning and then conditions had been progressively changed mainly towards lagoon shallowing with transition to the clayey sedimentation type with increased NaCl concentration. Sub-suite is only developed to the north-east from the line of Bolgrad town – Suvorove village. With interruption it lies over Kazakliyska Suite and is overlain by Upper Kongazka sub-suite.

The hanging-wall altitudes vary from -282.0 m (DH 101 [42], Vasylivka village) to -1141.4 m (DH R 20VP [21, 42], Dmytrivka village). The maximum thickness of sub-suite is intersected by DH 401 in Suvorove village area.

Upper Kongazka sub-suite (J_3kn_2) is composed of gypsums, anhydrites, gypsum-anhydrites and parti-colored argillite-like clays which complete the column of Upper Kongazka sub-suite; thin dolomite interbeds are observed somewhere. Terrigenous rocks include aleurolites, diverse-grained sandstones and gravelites which are mainly developed in the basal layers. These column features indicate sedimentation of the lower part under conditions of marine lagoon with increased water salinity where evaporitic deposition had predominated. With time sedimentation conditions had been changed towards lagoon desalination with gradual transition to mainly clayey sedimentation type. The distinct feature of upper sub-suite, in contrast to the lower one, is mainly sulphate (gypsums, anhydrites, gypsum-anhydrites) sedimentation type. The Upper Kongazki rocks are developed in all litho-facial zones, mainly in the northern and eastern parts of territory. Over remaining territory they are almost completely eroded and are mapped in minor remnants in Tabaky village area, to the east of Ozerne village, and in Loshchynivka village area. They lie with slight interruption, expressed in terrigenous rock interbeds, over Kazakliyska Suite and Lower Kongazka sub-suite. The unit with slight interruption is overlain by Chadyr-Lungska Suite and in places where they are eroded – by Eocene and Upper Miocene sediments. The hanging-wall altitudes of Upper Kongazka sub-suite vary from -280 m (DH 19 [42], Sofyan village area) and up to -997.4 m (DH R 20VP [21, 42], Dmytrivka village). The maximum thickness of Upper Kongazka sub-suite sediments is intersected by DH 18s [21, 42] in Sofyan village area to more than 337.6 m). The sediments thickness increasing from the north-east to south-west indicates that maximum territory subsidence in Late Kongazkiy time had occurred in Nyzhnyodunayskiy block. The most typical columns of Upper Kongazka sub-suite are intersected by DH R 20VP [21, 42] in Dmytrivska LTZ and DH 13s, 17s, 18s [50, 42] (Sofyan village area).

A n h y d r i t e s are blue-grey, brownish-grey, grey, dark-grey, fine-micro-grained, in places with gypsum, dolomite, clay admixtures, pods and inclusions, with clay, gypsum, gypsum-anhydrite, dolomite, limestone, rock salt, aleurolite interbeds causing banded structure. The rocks often are fractured with fine leaching hollows. Fractures are diverse-oriented, filled with gypsum, clay, carbonate. The banding is coarse, medium and thin to sheeted, horizontal, and wavy.

D o l o m i t e s are cream, grayish-brown, brown, grey, dark-grey, blue-grey, red-brown, greenish-grey, pelitomorphic, micro- and fine-grained, massive and banded, in places with clay, gypsum, anhydrite, and aleurite admixture, pods and inclusions, somewhere flinted. Banded structures are caused by dolomite intercalation with other rocks, anhydrites first of all. The interbeds of gypsum-anhydrites, gypsums, dolomitized limestones, clays are observed in subordinated amounts. The banding is from thin, sheeted to coarse one. Dolomites are fractured in places. Fractures are diverse-oriented and filled with gypsum and calcite.

A r g i l l i t e s are reddish-brown, grayish-brown, brown, parti-colored, blue-grey, grey, dark-grey, dense, carbonate, in places with dolomite, anhydrite, gypsum, gypsum-anhydrite, aleurolite, and fine-grained sand interbeds. In places fractures filled with gypsum are observed.

A l e u r o l i t e s are quartz, light-grey, grey, dark-grey, bluish-grey, grayish-brown, brownish, reddish-brown, parti-colored, mainly micro-grained and fine-grained, rarely coarse-grained, dense, in places with admixture, pods, inclusions and interbeds of gypsums, anhydrites, dolomites, in places fractured. Fractures are diverse-oriented, mainly 1-2 mm wide, filled with selenite and anhydrite. Thin-banded structure is frequently observed caused by alternating diverse-color rocks. Cement is clayey, carbonate-clayey.

S a n d s t o n e s are quartz, feldspar-quartz, greenish-grey, light-grey, brown, blue-grey, fine- and fine-medium-grained, in places aleuritic, with gypsum nodules, pods and bunches, with clay and aleurolite interbeds, in places fractured. Fractures up to 5 mm wide are filled with selenite. Cement is clayey, clayey-carbonate,

carbonate-gypsum of basal and porous types. The banded structure is often observed caused by alternating rocks of various composition or sandstones of various colors and granolumetric composition.

Other rocks in Kongazka Suite, occurring in the interbeds, include gypsums, gypsum-anhydrites, limestones, and rock salt.

G y p s u m s are white, grey, with brownish, pinkish, yellowish, bluish shades, light-grey, smoky-grey, grey, pink, brown, maroon, from micro-, fine-, medium- to coarse-, diverse-, and giant-grained, in places thin-fibrous. The crystals are columnar, prismatic, platy and sheeted, occurring in various crystal aggregates. Fractures up to 3 cm wide filled with selenite and clay are observed in the gypsums.

G y p s u m - a n h y d r i t e s are pinkish-grey, brownish-grey, light-grey, grey, bluish-grey, micro-, fine-, diverse-grained and fibrous, in places with clay admixture, somewhere fractured. Fractures up to 1 cm wide, diverse-oriented, are filled with selenite and clay.

R o c k s a l t is light-grey, grey, in places with pinkish shade, mainly coarse-grained, rarely medium-coarse-grained and giant-grained, normally with clay and terrigenous material admixture, with up to 4 cm thick fine-grained anhydrite interbeds. The rock salt is encountered in DH 17s [59, 42] in 0.1-3.95 m thick interbeds in anhydrites and gypsum-anhydrites.

L i m e s t o n e s are clayey, pelitomorphic, light-grey, dark-grey, grayish-cream, massive, with flora and fauna detritus, with diverse-oriented thin calcite veinlets. In places these rocks are observed in 0.5-11 m thick interbeds.

In DH 17s [59, 42] and r-1 [42] the flora and fauna forms are determined: *Labirintina sp., Spirocyclinidae sp., Textularia sp., Epistomina sp., Nodobacularia cf. verneuilind off. doneziand* D a l n . , *Spirolina sp., Ammobaculites sp., Classopollis classoides* P f l u g., *Classopollis minor* P o c. *et* J a n., *Classopollis sp.*; on this ground the age of Kongazka Suite is accepted to be Kimmeridgian.

Tithonian stage

Chadyr-Lungska Suite (J_3*čl*) completes Jurassic System column. It is mainly composed of parti-colored normally clayey gravelites, diverse-grained sandstones and aleurolites. Deposition of these rocks had occurred under sub-continental conditions at the final stage of Jurassic trough development, where terrigenous material from surrounding elevated sites had been input and deposited in the fan and minor-river fore-delta facies, as it is evidenced by the clastic material features, banding and coarse-clastic rocks – conglomerates, gravelites, chlidolites, and so forth.

The stratotype is defined in DH 136 [42], depth 770-990 m, drilled in Baymakliya village (Moldova). The Suite is widely developed only in the territory limited from the south and south-west by the zone of Bolgrad-Suvorovskiy fault. To the south from this tectonic unit (in Nyzhnyodunayska LTZ) the rocks are essentially eroded and only preserved in some, most subsided blocks. The Suite lies with slight erosion over Kongazka Suite and is overlain with significant erosion, depending on the block tectonics, with regional stratigraphic unconformity, and in places with slight angular unconformity, by Eocene and Upper Miocene sediments.

The most complete column of the Suite is preserved from erosion in Dmytrivka village and south-eastern part of Vynogradne village area only. The Suite hanging-wall altitudes vary from -176.4 m (DH 12 [42], Vynogradne village) to -457 m (DH R 20VP [21, 42], Dmytrivka village). The maximum thickness of sediments is intersected by DH R 20VP [21, 42] in Dmytrivska LTZ to 540 m.

The Suite distribution boundaries, its column completeness, thickness distribution and modern hanging-wall position directly depend on the development of tectonic blocks in post-Jurassic time (Late Kimmerian phase of tectogenesis). Based on detailed litho-facial analysis and geophysical logging data, the lower and upper sub-suites are distinguished in the Suite.

Lower Chadyr-Lungska sub-suite (J_3*čl*$_1$) is mainly composed of aleurolites and sandstones with subordinate argillite-like clays. The maximum thickness of sub-suite is intersected by DH 12 [42] in Chervonoarmiyske and Vynogradne village areas to 427 m. The lower sub-suite lies with slight erosion over Kongazka Suite and is overlain with gradual transition by the upper sub-suite. In places of essential erosion it is overlain with stratigraphic and slight (2-5^o) angular unconformity by Eocene and Middle Sarmatian sediments.

Upper Chadyr-Lungska sub-suite (J_3*čl*$_2$) is mainly composed of argillite-like clays with aleurolites interbeds and is quite locally developed. The rocks are only preserved from erosion in minor sites in Dmytrivka village area, in the most subsided block, and in Vynogradivka village area where they occur in small erosion remnant. The maximum thickness of sediments is intersected by DH 20VP [21, 42] in Dmytrivka village area to 230 m. The upper sub-suite lies with gradual transition over lower sub-suite and is overlain with stratigraphic and slight (3-5^o) angular unconformity by Eocene and Neogene sediments.

C l a y s are argillite-like, parti-colored (light-brown, light-grey, yellowish-grey, greenish-grey, bluish-grey, brownish-grey, dark-grey, brownish, red-brown, brick-red, brown, ocherous), often carbonate, aleuritic, sandy, dense, in places banded and lumpy, with interbeds of sands, sandstones, aleurolites, limestones, marls, and with gypsum inclusions and veinlets.

Aleurolites are quartz, parti-colored (red-brown, brownish, bluish-grey), mainly micro-grained, rarely fine- and coarse-grained, sandy, often banded, with inclusions and admixture of gypsum, anhydrite, with interbeds of sandstones, gypsums, clays. The banding is caused by other rock interbeds or intercalation of diverse-color aleurolites.

Sandstones are feldspar-quartz, mica-quartz, polymictic, red-brown, brownish, pink-grey, bluish-grey, light-grey, brownish-grey, greenish-grey, fine-, medium- and diverse-grained, with gypsum inclusions and veinlets. Cement is clayey, gypsum, carbonate-clayey, clayey-gypsum. The rocks contain clay and aleurolites interbeds.

Limestones are light-grey, grey, white, greenish-grey, with brick-red spots, dense, strong, in places clayey, flinted, with sandstone and clay interbeds. The rocks are rarely observed in 0.85-13.0 m thick interbeds in argillite-like clays.

Sands are quartz, light-grey, grey, fine-grained, in places diverse-grained, clayey, occurring in 3.0-10.5 m thick interbeds in argillite-like clays. In DH R-1 [48, 42] at the depth 310-340 m foraminifera are determined: *Textularia ex gr. gepivata* S c h w a g e r . , *Nodobacularia cf. bulbifera* P a a l s o w, *Cristellaria cf. angustissima* W i s h .

Cenozoic Eratheme

Cenozoic Eratheme is composed of clays, marls, limestones, aleurites, loams, mud. The shallow-water marine clayey, terrigenous-clayey, carbonate-clayey and carbonate-terrigenous facies, in lesser extent the coastal-marine terrigenous, clayey-terrigenous, and continental facies are developed. The rocks of Cenozoic Eratheme are developed throughout in the area laying with angular and stratigraphic unconformity over Jurassic, Triassic, Devonian systems, as well as over intrusive rocks, which constitute Herzinian, Early Kimmerian and Late Kimmerian tectonic sub-floors in the south-western margin of Eastern-European Platform. The greatest intersected thickness of these rocks is 550 m in the north-eastern part of studied area in Vynogradne village (DH 26 [42]). The hanging-wall altitudes vary from 2.4 m in the south to 175.5 m in the north, at the watershed plain. In the studied area Cenozoic Eratheme includes Paleogene, Neogene and Quaternary systems.

Paleogene System

Middle Eocene

Middle Eocene consists of marls, aleurolites, clays, limestones, sandstones. The following facies are distinguished: coastal-marine carbonate-terrigenous, shallow-water-marine carbonate-clayey, carbonate-terrigenous and clayey low-carbonate.

The rocks are developed in the eastern and northern parts of map sheet L-35-XXIII (Izmail) in Chervonoarmiysko-Dmytrivska LTZ. They are intersected by DH 103, 109, 112, R 3P, 236, R 20VP, 403, 11s, 1g/k, 4g/k [21, 42, 59] drilled with core sampling by Paleogene rocks. Besides that, in some drill-holes (R 1P, 1CH, 1R, 1G, 110, 106, 34, 404) [21, 42] Paleogene sediments are distinguished after logging data. The primary distribution boundary of Middle Eocene basin, in the authors' opinion, has been controlled by Bolgradskiy and Karasulakskiy faults. In post-Eocene time, because of the territory inversion, Middle Eocene sediments were partly eroded. These rocks lie with angular and stratigraphic unconformity over Jurassic Kazakliyska and Kongazka suites and are transgressively overlain by Neogene sediments. Thesediments hanging-wall latitudes vary from -240.5 m in the central part of Gorikhivskiy block to -359.4 m outside the latter; thickness is 13.2-130.0 m, increasing in the northern direction towards the basin deepening. In addition, great thickness is observed in the blocks which did not undergo post-sedimentation uplifting and are more or less completely preserved from erosion.

Based on the litho-facial analysis the authors had defined in the Middle Eocene the following units: terrigenous, carbonate, carbonate-clayey, carbonate-terrigenous sequences and Shabska Suite.

Terrigenous sequence (₽$_2t$) consists of the coastal-marine sediments – sandstones which are developed over entire area of Middle Eocene sediments distribution and constitute their lower part. At the pre-Neogene surface sandstones are exposed in the narrow band along the distribution boundary of Middle Eocene sediments. The maximum thickness is 21 m. Higher in the column the coastal-marine sediments are overlain by shallow-water marine sediments of carbonate sequence, and in places where the latter is lacking, it is transgressively overlain by the Middle Sarmatian rocks.

S a n d s t o n e s are quartz, glauconite-quartz, fine-grained, grey, strong, with clayey-carbonate cement.

Carbonate sequence ($₽_2c$) consists of shallow-water marine basin sediments – organogenic and oolite limestones developed over entire distribution area of Middle Eocene sediments and are less developed in comparison with the Eocene terrigenous sequence. The maximum thickness is 14 m.

L i m e s t o n e s are organogenic, oolitic, re-crystallized, sandy, clayey, grey, greenish-grey.

In the carbonate and terrigenous sequences in DH 4g/k [21, 42] and 236 [21, 42] were determined molluscs: *Clamys sp.*; ostracoda: *Bairdia subdeltoidea* M u n s t e r., *Schuleridea sp., Lenticulina sp.*; foraminifera: *Discociclina sp., Elphidium sp., Nummulites sp.*, and orbitoides.

By lithology and large nummulite occurrences aforementioned rocks do correspond (according to "Stratigraphic Code of Ukraine" (1997)) to Middle Eocene Simferopolskiy horizon which in Prychornomorska depression consists of nummulite limestones and glauconite-quartz sandstones with nummulites.

Carbonate-clayey sequence ($₽_2cg$) is developed in the facies of shallow-water marine basin consisting mainly of greenish-grey marls. Carbonate-clayey sequence is developed over almost entire distribution area of Eocene sediments. The rocks lie without visible interruption over carbonate sequence and are overlain by carbonate-terrigenous sequence, and in places where the latter is eroded it is transgressively overlain by Middle Sarmatian sediments. The maximum thickness of carbonate-clayey sequence is 32 m.

Carbonate-terrogenous sequence ($₽_2ct$) comprises shallow-water marine facies of Middle Eocene basin and consists of aleurolites which higher in the column are gradually changed by relative deeper-water zone with carbonate clays of Shabska Suite. The rocks are developed over almost entire distribution area of Middle Eocene rocks and in lesser extent than in carbonate-clayey sequence because of their erosion in post-Eocene time. The rocks are overlain by Shabska Suite, and in places where the latter is eroded, they are transgressively overlain by Middle Sarmatian rocks. The maximum thickness is 31 m.

Shabska Suite ($₽_2šb$) is developed in the facies of shallow-water marine basin – mainly carbonate clays. It is only preserved from erosion in the northern part of territory in Dmytrivka village area. The maximum thickness is 33 m. The Suite lies without visible interruption over carbonate-terrigenous sequence and is transgressively overlain by Middle Sarmatian sediments.

M a r l s are greenish-grey, light-grey, white, in places clayey, aleuritic, sandy, dense, strong, non-banded. The rock groundmass is composed of pelitomorphic calcite and hydromica with minor silica. The clastic material attains 25% and mainly consists of acute grains of quartz, rarely feldspar, glauconite, mica, pyrite. In minor amounts the sponge spicules are observed as well as frequent foraminifera shells.

A l e u r o l i t e s are grey, greenish-grey, in places sandy with clayey-carbonate and carbonate-clayey cement, dense, strong. The clastic material includes acute and acute-rounded grains of quartz and rarely feldspars, glauconite, muscovite, pyrite. Cement is composed of pelitomorphic carbonate and thin-flaky hydromica. Texture is aleurolitic, in places aleuro-pelitic.

C l a y s are carbonate, in places sandy, greenish-grey, green, yellow-brown in spots.

The terrigenous-carbonate sequence is well expressed in the gamma- and electric logging plots where all lithology features are reflected.

In the terrigenous-carbonate sequence, according to previous works [6, 14], foraminifera complex was determined: *Acarinina rotundimarginata* S u b b., *Globigerapsis subconglobatus* C h a l., *Globigerina turkmenica* C h a l., and others, which correspond to Middle Eocene Novopavlivskiy, Kumskiy and Alminskiy horizons. By analogy with adjacent map sheet L-36-XXIV (Kiliya) where analogues in lithology and thickness Middle Eocene rocks are well fauna-supported, the authors believe that the marls and aleurolites of carbonate-clayey and carbonate-terrigenous sequences do correspond to Middle Eocene Novopavlivskiy and Kumskiy horizons, and the clays of Shabska Suite – to Alminskiy horizon [41].

Neogene System

This unit is composed of clays, aleurolites, limestones, sands, sand-gravel sediments and reddish-brown chlidolites. The following facies are distinguished therein: marine clayey, carbonate-clayey, terrigenous-clayey and carbonate-terrigenous; coastal-marine terrigenous, clayey-terrigenous; lagoon clayey; molassoid fore-mountain of accumulative plains and alluvial clayey-terrigenous and terrigenous.

Neogene System is developed over almost entire territory except some minor sites in Orlovka village and former Ferapontiy monastery areas where it was eroded in Quaternary time. The rocks with sharp angular and stratigraphic unconformity lie over Devonian, Triassic and Jurassic sediments and with erosion are overlain by Quaternary sediments. The hanging-wall altitudes of Neogene sediments vary from -67 m in Danube River flood-land to +144.5 m in the north at the watershed plain. The surface relief of Neogene sediments is of erosion origin and has been formed because of cuts in Quaternary period. The maximum thickness of sediments is 503 m in Vladychen village area (DH 12) in Vladychenska depression.

Miocene and Pliocene divisions are distinguished in Neogene System. Miocene division consists of its upper sub-division which, in turn, is divided into Sarmatian, Meotychniy and Pontychniy regio-stages.

Pliocene division includes the lower and upper sub-divisions. The lower sub-division does correspond to Kimeriyskiy and the upper one to Akchagylskiy regio-stages.

Based on detailed litho-facial analysis of sediments in the south-western limb of Upper Miocene trough three litho-facial zones (LTZs) are distinguished in Miocene: Kagul-Kugurluyska, Nyzhnyoyalpugska and Katlabukhska, and two LTZs in Pliocene – Prydunayska and Vladychen-Loshchynivska.

Miocene division

Sarmatian regio-stage
Middle Sarmatian sub-regio-stage

Middle Sarmatian sub-regio-stage is composed of clays, limestones, aleurolites, sands, sandstones with brown coal interbeds, marls, reddish-brown chlidolites. The rocks are grouped in the following facies: shallow-water marine clayey, carbonate-clayey; coastal-marine terrigenous; coastal-marine and lagoon terrigenous-clayey; molassoid facies of more-mountain accumulative plain. Specific features of Middle Sarmatian sediments include grey-color appearance of marine sediments, mainly carbonate-clayey composition of shallow-water marine facies, as well as reddish-brown color and non-sorted mode of the rocks in the facies of fore-mountain accumulative plain.

Middle Sarmatian sediments are developed over almost entire studied territory and are only lacking in the southern part, in Kagul-Kugurluyska LTZ where the denudation and clastic material removal area was located in Sarmatian time. The southern boundary of Middle Sarmatian sediments modern distribution in the plane follows the northern margin of Prydunayskiy block with the complex relief forms. At the modern surface the Middle Sarmatian rocks are not exposed and are intersected by numerous drill-holes. These rocks with sharp angular and stratigraphic unconformities lie over Devonian and Triassic sediments, as well as with sharp stratigraphic, and in the sites of flexures and faults – with angular unconformity over Middle and Upper Jurassic sediments; they are conformably overlain by Upper Sarmatian sediments (see cross-section A_1-A_3 to "Geological map of pre-Quaternary units").

The hanging-wall altitudes vary from -131.7 m (DH 15) [42] in the northern part, in Gorikhivskiy ledge, to -395.7 m (DH 091) [41, 42] in the south-west, in Vladychenska depression. The thickness intersected by drill-holes, varies from 11 m (DH 079) [41, 42] in the south-west to 184 m (DH 11) [42] in the central-eastern part, in Vladychenska depression. The surface relief, thickness of Middle Sarmatian sediments, as well as facies distribution are influenced by the syn-sedimentation and post-sedimentation faults resulted in the normal faults and flexures with displacement amplitude up to 60 m developed in the given rock sequence. In the northern part of territory the erosion-denudation processes had also participated in the relief formation, thickness of sediments and facies distribution.

Three sequences are distinguished in Middle Sarmatian regio-stage, which gradually substitute one another in the north-eastern direction: the first sub-sequence of Dunayska sequence, Lymanska and limestone-clayey sequences.

First sub-sequence of Dunayska sequence (N_1d^1) consists of the fore-mountain accumulative plain rocks and is developed in Kagul-Kugurluyska LTZ which spatially coincides with Prydunayskiy block with very complicated relief. In genetic respect, the fore-mountain accumulative plain rocks mainly include proluvial and deluvial-proluvial sediments arranged in the fan system originated from the mountain structure (Northern Dobruja) and directly adjoined the Middle Sarmatian marine basin shoreline. The rocks include aleuritic, sandy clays and red-brown, orange-yellow-brown, parti-colored chlidolites with gruss, gravel and pebble admixture, with interbeds of acute-rounded gravelites and conglomerates, polymictic, diverse-grained, gravelous sands and sandstones. The clastic material composition depends on the source region bedrocks being eroded in Middle Sarmatian time. Specifically, in Orlovka and Novosilske village area where slightly metamorphosed Devonian-Triassic rocks are developed (schists, limestones, aleurolites, argillites, sandstones, conglomerates) the clastic material consists of these rocks. In Reni town area the clastic material consists of intrusive rocks, mainly granitoids, which are developed in this area in Romania territory.

The most complete column of given sub-sequence are intersected by DH 04 and 091 [41, 42]. In DH 04 drilled in 2.5 km to the west from Novosilske village western outskirt, at the depth 260-337 m the rhythmic red-brown terrigenous rock sequence is intersected. The rhythmic patterns are mainly two-fold, in some rhythms – three-fold. In the column intersected by DH 04 [41, 42] seven rhythms are distinguished. At the rhythm footwall mainly coarse-clastic rocks are observed and higher in the column the bottom horizon is gradually replaced by the finer-grained material while specific rhythm column is capped by aleuritic clays. In general the batch expresses weak sorting and low rounding of clastic material suggesting for its insufficient transportation. The most typical rocks intersected by DH 04 [41, 42] include coarse chlidolites, fine chlidolites, clayey aleurolites, aleuritic clays. Below the rock description is given.

Coarse chlidolite is brown with slight reddish shade, chaotic structure, dense rock consisting of acute-rounded gravel (up to 50%) with minor addition of fine pebble of sedimentary rocks cemented by reddish-brown aleurite-sand-clay cement of basal and porous types. The terrigenous material mainly includes the fragments of schists, sheared aleurolites and sandstones, rarely quartz fragments.

Fine chlidolite is parti-colored (reddish-brown, brown, orange-yellow shades), non-banded, dense. The rock consists of the mixture of clayey, aleuritic and fine-grained sandy particles.

Aleuritic clays are reddish-brown, orange-yellow with reddish-brown spots, non-banded, dense. Content of aleuritic material varies in the wide range. In some places aleuritic clays are replaced by aleurolites with clayey cement.

Lymanska sequence (N_1l) is developed in Nyzhnyoyalpugska LTZ. It is composed of coastal-marine and lagoon facies and intercalation of coastal-marine and lagoon sediments is frequently observed in the column.

The coastal-marine rocks include sands and sandstones, quartz, feldspar-quartz, fine- and diverse-grained with gravel and pebble, grey, brownish-grey, blue-grey, greenish-grey, often aleuritic, clayey, with gravelite interbeds. Cement of sandstones is clayey and carbonate-clayey.

Lagoon sediments include aleurolites and clays with thin (0.01-2.65 m) brown coal interbeds.

Limestone-clayey sequence (N_1vg) is developed in Katlabukhska LTZ and mainly consists of oolite and detritus limestones as well as carbonate clays with aleuritic and sandy material admixture, which contain salty-water mollusc fauna suggesting for these rocks development under conditions of shallow-water salty marine basin and hot climate. Occurrence of dark-grey and black clay and aleurolite interbeds enriched in organic matter in the south-western part, as well as brown coal interbeds, suggests for development of these sediments under conditions of shallow-water marine basin.

Aleurolites are quartz, grey to dark-grey and black, greenish-grey, bluish-grey, with clayey and carbonate-clayey cement, in places sandy with sand, sandstone and brown coal interbeds.

Clays are greenish-grey, bluish-grey, grey, black in interbeds, in places aleuritic, sandy, with thin brown coal interbeds, somewhere with aleurolite, aleurites, sand and limestone interbeds. After X-ray phase analysis data, the clays are kaolinite-montmorillonite-hydromica and montmorillonite-kaolinite-hydromica in composition, with admixture of chlorite, quartz, mica, feldspars, gypsum, and siderite.

After thermal analysis data, the clays of shallow-water marine facies are hydromica, montmorillonite-hydromica in composition, with admixture of iron hydroxides and organic matter.

Limestones are organogenic, oolitic, oolite-organogenic, re-crystallized, in places clayey, pelitomorphic, light-grey, grey, white, greenish-grey, black, with greenish-grey, light-grey, white, dense marl interbeds up to 1 m thick.

The age of Middle Sarmatian marine and lagoon sediments is determined after the fauna complex which includes molluscs: *Mactra fabreana* Orb., *M. vitaliana* Orb., *M. podolica* Eichw., *M. tapesoides* Sinz., *Cerastoderma fittoni* (Orb.), *C. obsoletum nefandum* (Koles.), *C. desperatum* (Koles.), *Paphia tricuspis* (Eichw.), *P. gregaria* (Partsch) Goldf., *Donax dentiger* Eichw., *Tapes gregarius* Goldf., *Trochus podolicus* (Dub.) Pusch. (determinations of A.L.Chepalyga); foraminifera: *Elphidium macellum* (F. et M.), *E. aculeatum* (Orb.), *Porosononion subgranosus* (Egg.); ostracoda: *Xestoleberis elongata* Schn.

The age of red-color continental sediments is determined by the direct correlation with the normal-marine columns.

Upper Sarmatian sub-regio-stage

Upper Sarmatian sub-regio-stage consists of clays, aleurolites, sands, sandstones, marls, limestones, red-brown chlidolites. The sediments are grouped into facies: shallow-water marine carbonate-clayey, coastal-marine carbonate-terrigenous-clayey, molassoid facies of fore-mountain accumulative plain. Upper Sarmatian sediments are characteristically grey-colored and carbonate-clayey in case of marine rocks whereas sediments of fore-mountain accumulative plain are red-brown and non-sorted. From the Middle Sarmatian marine sediments they differ in more clayey composition and mollusc fauna complex.

Upper Sarmatian sediments are developed over almost entire studied area and are only lacking in the southern part where the rocks of Herzinian – Early Kimmerian tectonic sub-floor are elevated. At the modern surface and pre-Neogene surface these rocks are not exposed and are intersected by numerous sediments beneath Meotychni and Pliocene sequences. The rocks lie stratigraphically conformably or transgressively with minor interruption in sedimentation over the Middle Sarmatian rocks, and with sharp angular and stratigraphic unconformity – over Triassic and Jurassic sediments. In turn, Upper Sarmatian rocks are transgessively with interruption overlain by Meotychni sediments, and with the deep erosion – by the Kimeriyski and Akchagylski sediments.

The hanging-wall altitudes of Upper Sarmatian sediments vary from +19 m (DH 1G) [42] in the north to -249 m (DH 091) [48, 42] nearby western outskirt of Reni town. In the surface relief of Upper Sarmatian sediments the tectonic and denudation processes are reflected. Displacement amplitude in flexures is 60 m. The maximum thickness of sediments is 195 m (DH 1G) [42] in the north of the area, in Dmytrivska depression.

Three sequences are distinguished in Upper Sarmatian sediments which gradually replace one another in the north-eastern direction: the second sub-sequence of Dunayska sequence (facies of fore-mountain accumulative plain), Dolynska sequence (coastal-marine facies), and clayey-limestone sequence (shallow-water marine facies).

Second sub-sequence of Dunayska sequence (N_1d^2) is only developed in the south and south-west of the studied area, in Kagul-Kugurluyska LTZ. In genetic respect, the rocks of fore-mountain accumulative plain comprise deluvial and deluvial-proluvial sediments arranged in the system of large fans originated from the Northern Dobruja mountain structure, and include aleuritic and sandy clays, red-brown, orange-yellow-brown, parti-colored chlidolites, with gravel and pebble admixture, with interbeds of gravelites and conglomerates, and polymictic, diverse-grained, gravelous sands and sandstones. Composition of terrigenous material depends on the composition of rocks underwent denudation and removal in Late Sarmatian time; they include fragments of schists, limestones, aleurolites, argillites, sandstones, granitoids, as well as quartz and feldspar grains. By composition the rocks are similar to those constituting the Middle Sarmatian facies of fore-mountain accumulative plain and described above. The thickness of the sequence is from some meters to 190 m.

Dolynska sequence (N_1dl) in the lateral direction substitutes the rocks of second sub-sequence. It is developed in the south-western and southern parts of the area in Nyzhnyoyalpugska LTZ. The sequence consists of clays with interbeds of aleurolites, sands, sandstones, limestones, marls, and rarely brown coal. The maximum thickness is 190 m.

Clayey-limestone sequence (N_1gv) is developed over entire Katlabukhska LTZ and consists of clays with aleurolites, sand, limestone, marl interbeds, and limestones.

C l a y s are greenish-grey, bluish-grey, with interbeds of dark-grey and black ones. In the coastal-marine facies clays admixture of aleurites, sand, carbonate, interbeds of aleurolites, fine- and diverse-grained sands and sandstones, limestones, marls, and rarely brown coal are contained. In composition they are hydromica, hydromica-kaolinite, chlorite-hydromica-montmorillonite. The shallow-water marine facies clays in composition are hydromica, montmorillonite-hydromica and contain interbeds of aleurolites, fine-grained sands, limestones and marls.

A l e u r o l i t e s are grey, light-grey, greenish-grey, bluish-grey, ocherous-yellow, fine-, coarse- and diverse-grained, in places sandy, carbonatized, somewhere banded; at the layer bottom often contain gravel and pebble (up to 10 cm) of sedimentary rocks: schists, argillites, aleurolites, and sandstones. Cement is clayey. The clastic material mainly consists of quartz. In subordinate amounts the light-fraction minerals include feldspars, muscovite, and flint. Of the heavy-fraction minerals, the garnet, ilmenite, tourmaline, leucoxene, staurolite, rutile, zircon, pyrite, chlorite, amphibole, magnetite, epidote, celestine, and sphalerite are contained in minor amounts.

S a n d s a n d s a n d s t o n e s are quartz, feldspar-quartz, grey, light-grey, greenish-grey, bluish-grey, yellowish-grey, fine-, medium-, coarse- and diverse-grained, in places aleuritic, with gravel, pebble and debris of quartz, feldspars, sedimentary and igneous rocks. The sands often contain clay material admixture. Cement of sandstones is variable: clayey, carbonate, carbonate-clayey, of basal and porous types, in places quartz, regenerative.

L i m e s t o n e s are organogenic, oolitic, pelitomorphic, re-crystallized, grey, light-grey, white, in places clayey, aleuritic, sandy, dense and friable.

M a r l s are greenish-grey, grey, light-grey, white, non-banded, in places lumpy, aleuritic, sandy, with gravel and gruss of quartz, sandstone and flint. These rocks are locally developed in interbeds in clays and limestones.

The age of coastal-marine and marine sediments is determined after the fauna complex. Molluscs: *Mactra bulgarica* T o u l a., *M. caspia* E i c h w ., *M. df timida* Z h i z h., *M. podolica* E i c h w ., *Af. nalivkini* K o l e s ., *M. crassicolis* S i n z., *Solen subfragilis* E i c h w ., *Psilunio subhornssi* (L a s v .), *Cuclopotomida sp., Anisus* (G y r a u l u s) *trochiformis kleini* G o t t. cf. W e n z., *Theodoxus sp., Bithynia sp., Neopisidium sp.* Foraminifera: *Ammonia beccarii L., Porosononion subgranosus* (E g g.), *Elphidium macellum* (F. et M.), *E. crispum* (Z.). Ostracoda: *Cyprideis torosa* (J o n e s).

The age of red-color continental sediments is determined by direct correlation with the Middle Sarmatian normal-marine columns.

Lithology of sediments and fauna composition suggest for the shallow-water marine basin in Late Sarmatian time. The distribution of thickness and terrigenous material in shallow-water marine facies indicate expansion of Late Sarmatian transgression outside the given territory from the north to south and south-west. In turn, the clastic material input was directed from the south and south-west to the north and north-east.

Meotychniy regio-stage

Meotychniy regio-stage is composed of clays, aleurites, sands, sandstones, limestones, chlidolites. The rocks are grouped into the facies: clayey shallow-water marine basin, coastal-marine terrigenous-clayey, molassoid fore-mountain accumulative plain. Specific features of Meotychniy regio-stage include mainly clayey composition of shallow-water marine and coastal-marine facies, as well as red-brown and brick-red color and non-sorting of the rocks in the zone of fore-mountain accumulative plain. From the Upper Sarmatian sediments they differ in more clayey composition and mollusc fauna complex, and from the overlaying Novorosiyskiy sub-regio-stage – in the clayey composition and also mollusc fauna complex.

Meotychni sediments had primarily covered entire map sheet territory except some minor sites in the areas of Orlovka village and former Ferapontiy monastery where the rocks of Herzinian and Early Kimmerian tectonic floors were exposing at the surface in Metychniy time. As a result of pre-Kimeriyskiy and pre-Akchagylskiy deep erosion cuts, Meotychniy regio-stage was eroded over significant part in the south of the area and is only preserved in some erosion remnants.

The rocks of Meotychniy regio-stage are not exposed at the surface and intersected by numerous drill-holes beneath Pliocene sequences. These rocks transgressively and stratigraphically conformably lie over Upper Sarmatian sediments, and with sharp stratigraphic unconformity – over Triassic and Jurassic rocks. In turn, they are transgressively with slight erosion are overlain by Novorosiyskiy sub-regio-stage, and stratigraphically unconformably, with deep erosion – by Kimeriyski and Akchagylski sediments.

The hanging-wall altitudes of Meotychniy regio-stage vary from +74 m (DH 1G) [21, 42] in the north to -223.7 m (DH 064) [48, 42] in the south-west in Danube River flood-land and depend on the modern tectonic position of particular sites and their erosion degree. Neo-tectonic processes are expressed in post-sedimentation flexures with 30-60 m displacement amplitude. The maximum thickness of sediments is 79.9 m (DH 2 [42], to the south of Bolgrad town).

In the map sheet area, three sequences are clearly distinguished in Meotychniy regio-stage which replace one another in the south-eastern direction: the third sub-sequence of Dunayska sequence (facies of fore-mountain accumulative plain), terrigenous-clayey sequence (coastal-marine facies), and clayey sequence (facies of shallow-water marine basin).

Third sub-sequence of Dunayska sequence (N_1d^3) is developed in Orlovka village area, former Ferapontiy monastery and Novosilske village area where it is mapped in the erosion remnants. In genetic respect, the fore-mountain accumulative plain sediments mainly include proluvial and proluvial-deluvial sequences which constitute the peripheral portion of large fan at the Northern Dobruja horst foothill directly adjoined Meotychniy marine basin shoreline. The rocks include aleuritic and sandy clays, red-brown, orange-yellow-brown, parti-colored chlidolites with gruss, gravel and pebble admixture, and interbeds of gruss-stones, gravelites, conglomerates, polymictic, diverse-grained, gravelous sands and sandstones. Terrigenous material consists of quartz and fragments of sandstones, aleurolites and schists. The clayey fraction mainly consists of smektite and hydromica with minor chlorite, nontronite, kaolinite.

Clayey-terrigenous sequence (N_1gt) is developed in the south and south-west in Nyzhnyoyalpukhska LTZ. The sequence comprises alternating bluish-grey, greenish-grey, grey, dark-grey to black clays, in places aleuritic, sandy, and aleurolites, sands and sandstones up to 72 m thick. In composition the clays are hydromica or kaolinite-montmorillonite with admixture of quartz, feldspars, calcite, dolomite, and gypsum [42].

Clayey sequence (N_1g) is developed over entire territory of Katlabukhska LTZ (see “Scheme of LTZs location” (Miocene)). It is composed of blue-grey, greenish-grey, grey, dark-grey to black clays, in places aleuritic, sandy, with scarce aleurolites, sand and limestone interbeds. In composition the clays are montmorillonite, hydromica, montmorillonite-hydromica, with iron hydroxide, carbonate, quartz, calcite admixture.

A l e u r o l i t e s are quartz, mica-quartz, grey, often with orange-yellow iron hydroxide spots, orange-yellow, fine- and diverse-grained, in places sandy with carbonate nodules, non-banded, somewhere horizontal- and thin-horizontal-banded. Cement is clayey.

S a n d s a n d s a n d s t o n e s are quartz, mica-quartz, feldspar-quartz, grey, light-grey, dark-grey, greenish-grey, blue-grey, often with orange-brown and orange-yellow iron hydroxide spots; from fine- to coarse- and diverse-grained, with gruss, gravel and pebble (up to 50%) of quartz, feldspars, sandstones, schists, granitoids. In places sands and sandstones are aleuritic, clayey, thin- and oblique-banded, with carbonate nodules. Cement of sandstones is clayey, carbonate-clayey, in places siliceous. It should be noted that coarse- and diverse-grained varieties with gruss, gravel and pebble are mainly observed in the coastal-marine facies sediments.

L i m e s t o n e s are light-grey to white, grey, in places with orange-yellow iron hydroxide spots. Limestones are mainly pelitomorphic, often clayey, in places organogenic and partly re-crystallized, mainly friable, somewhere strong, non-banded, in places lumpy.

Meotychniy age of marine sediments is determined after the fauna complex. Molluscs: *Congeria novorossica* A n d r u s ., *Psilunio novorossicus* (S i n z .), *P. Radiatodentatus* S i n z ., *Abra tellinoides* (S i n z .), *Dosinia maeotica* A n d r u s . , *Valvata variabilis* F u c h s., *Congeria sp., Vahata sp., Mytilaster sp., Theodoxus crenulatus* (K l e i n .), *Dreissena sp.* (determinations of P.F.Gozhyk, A.L.Chepalyga). Ostracoda: *Cyprideis littoralis* (B r.), *Caspiocypris labiata* (Z a l .) [48].

The age of red-color fore-mountain accumulative plain rocks is determined by means of direct correlation with Meotychni normal-marine columns as well as by occurrence of interruptions expressed in the horizons of coarse-grained rocks.

Pontychniy regio-stage
Novorosiyskiy sub-regio-stage

Novorosiyskiy sub-regio-stage is composed of clays and aleurolites with brown coal interbeds, sands, sandstones, limestones. The rocks are developed in the following facies: shallow-water marine carbonate-terrigenous and clayey, coastal-marine terrigenous, fore-mountain accumulative plain coarse-clastic. Specific features of Novorosiyskiy sub-regio-stage include grey-color appearance, terrigenous-clayey and carbonate-terrigenous composition, occurrence of thin-banded (sheeted) structures in marine rocks; red-color appearance and mainly clayey composition of fore-mountain accumulative plain sediments. From the rocks of Meotychniy regio-stage they well differ in terrigenous-clayey and carbonate-terrigenous composition, thin-banded structures, and mollusc fauna complex. From the overlaying mainly clay Kimeriyski sediments they differ in composition and mollusc fauna.

Novorosiyskiy sub-regio-stage had primarily covered entire studied area except some minor sites in the areas of Orlovka village and former Ferapontiy monastery where the rocks of Herzinian and Early Kimmerian tectonic floors were exposing at the surface in Novorosiyskiy time.

Later on, because of pre-Kimeriyskiy, pre-Akchagylskiy and Quaternary deep erosion cuts, Novorosiyskiy sub-regio-stage was partly or completely eroded over significant areas, especially in the southern part of the territory. The rocks are intersected by numerous drill-holes and exposed in the banks of Yalpug and Katlabukh lakes, on the slopes of minor river valleys and big gullies in the northern part of map sheet area. The rocks stratigraphically conformably and transgressively lie over Meothychniy regio-stage sediments and with sharp angular and stratigraphic unconformity over Triassic System rocks; they are overlain stratigraphically unconformably with deep erosion by Kimeriyskiy, Akchagylskiy regio-stages and Quaternary System.

The hanging-wall altitudes of Novorosiyskiy sub-regio-stage vary from +145.5 m (DH 32) [42] in the north to -145.2 m (DH 1r) [42] in the south-west, in Danube River flood-land, and depend on the modern tectonic position of certain sites and their erosion degree. Tectonic benches in the surface relief of Novorosiyskiy sub-regio-stage are almost not expressed because of superimposed extensive erosion processes. The maximum thickness of sediments in the area is 119.3 m in DH 19 [42] (to the south of Reni town).

Three litho-facial sequences are confidently distinguished in Novorosiyskiy sub-regio-stage: the fourth sub-sequence of Dunayska sequence (fore-mountain accumulative plain facies), sequence of sands (coastal-marine facies), and terrigenous-clayey sequence (shallow-water marine facies).

Fourth sub-sequence of Dunayska sequence (N_1d^4) is only preserved from subsequent erosion in the areas of Orlovka village and former Ferapontiy monastery where the rocks are mapped in minor erosion remnants. This sequence is mainly composed of red-color clays with admixture of diverse-grained polymictic sands, aleurites, and fine gruss. In genetic respect these sediments comprise proluvial-deluvial rocks which constitute partly swamped peripheral parts of large fans at the Northern Dobruja foothill and directly adjoined in the past to the Novorosiyskiy basin shoreline. Thickness of the sequence varies from 0 to 100 m.

Sequence of sands (N_1p) is preserved from erosion in the narrow band along the south-western distribution boundary of Novorosiyskiy sub-regio-stage (Nyzhnyoyalpukhivska LTZ). This sequence consist of quartz, light-grey, medium-fine-grained sands with shell detritus and interbeds of clays, aleurolites with clayey cement, and detritus limestones. In the north-eastern direction the sequence of sands is gradually changed by terrigenous-clayey sequence developed in another, Katlabukhska LTZ.

Terrigenous-clayey sequence (N_1tg) in the south of the area (Katlabukhska LTZ) consists of grey, light-grey aleurolites with clayey cement, often banded and thin-banded to sheeted, with interbeds of clays, fine-grained quartz sands and sandstones, chemogenic limestones and brown coal 0.1-1.05 m thick. Thin banding is caused by thin (up to 3 mm) interbeds of aleurolites, fine-grained sands and fine detritus. In the northern part the shallow-water marine sediments include from bottom to top: 1) blue-grey, greenish-grey, grey clays with black clay interbeds with fossil detritus; 2) quartz, fine- and diverse-grained, light-grey, yellowish-grey, white sands with shell detritus; 3) detritus, light-grey, grayish-yellow limestones, in places strong, re-crystallized; 4) grey, light-grey aleurolites with clayey cement and interbeds of fine-grained quartz sands, sandstones and chemogenic limestones. The sands, aleurolites, clays do facially replace one another, often alternating, and comprise the common terrigenous-clayey column.

In the outcrops 33, 20, 10 [42] in the areas of Vynogradivka, Tabaky, Dmytrivka villages the black and grey clay interbeds up to 0.5 m thick with fresh-water mollusc fauna are observed. The contacts between clays and sands are irregular, wavy, and suggest for interruption in sedimentation.

The clays of Novorosiyskiy sub-regio-stage in composition are hydromica, montmorillonite, montmorillonite-hydromica, hydromica-montmorillonite, with calcite, quartz, iron hydroxide and gypsum admixture.

The sands are mainly quartz in composition and the light-fraction minerals include flint, feldspars, and muscovite. The heavy-fraction minerals are contained in minor amounts and include garnet, ilmenite, tourmaline, leucoxene, staurolite, rutile, zircon, chlorite, pyrite, kyanite, sillimanite, iron hydroxide, epidote, and biotite. In the single grains apatite, amphibole, magnetite and monazite are observed.

The age of sediments is determined after the fauna complex. Molluscs: *Pseudocatilluspseudocatillus* (Barb.), *Congeria amygdaloides novorossica* (Sinz.), *C. novorossica* Sinz., *Prosodacna littoralis* Eichw., *Dreissensia tonuissima* Sinz., *D. simplex* Barb., *Monodacna pseudocatilus* Barb., *M. caspia pontica* (Eichw.), *Hydrobia novorossica* Sinz., *Hydrobia sp., Melanopsis esperi* Fer., *Fagotia esperi* Fer., *Unio portafericus* Andrejescu, *U. rumanus* Tourn., *Limnocardium odessaea* (Barb.), *Limnocardium cf. subodessae* (Sinz.), *Viviparus sp., Zagrabica sp.* (determinations of P.F.Gozhyk, V.M.Semenenko, A.L.Chepalyga). Ostracodes: *Cyprideis littoralis* Br., *Pontoniella acuminata* (Zal.), *P. acuminata pontica* (Agal.), *Loxoconcha eichwaldi* Liv., *Mediocytherideis sp., Caspiocypris sp., C. labiata* (Zal.), *Candoniella suzini* Schn., C. *subellipsoida* (Shar.), C. *acronasuta* (Liv.), *T. truncata* (Schn.), *T. pracarerbaid janica* (Agal.), *T. pontica* (Liv.), *Caspiolla ossoinae* (Kr.), *Cypria tocorjescui* Hang., *Cyprideis punctillata* Br.

The age of red-color fore-mountain accumulative plain rocks is determined by means of direct correlation with Novorosiyskiy sub-regio-stage normal-marine columns as well as by occurrence of interruptions at the footwall of these sediments expressed in the horizons of coarse-grained rocks.

Lithology of sediments and fauna complex suggest for the shallow-water desalinated marine sediments in Early Pontychniy time. The dark-grey and black clay, brown coal interbeds could be formed under conditions of the coastal accumulative plain indicating the short-term sea level oscillations in Early Pontychniy time. At the end of this time the continental regime had been established over the studied area and entire Fore-Dobruja [17]. In the Late Pontychniy time and Pliocene in the given territory the red-color rocks were developing which comprise weathering crust after Lower Pontychni sediments developed under conditions of arid-humid sub-tropic climate [29, 30].

Pliocene division

Kimeriyskiy regio-stage

This unit consists of clays, aleurolites, and sands, including the following facies: desalinated marine basin pass, coastal pass zone, desalinated lagoon, and minor river fore-delta. Development of sedimentary sequences had occurred under conditions of narrow marine pass connecting Dacian and Kimeriyskiy sedimentation basin, on the background of general uplifting of erosion basis. Specific features of Kimeriyskiy regio-stage include mainly grey-color appearance and terrigenous-clayey composition. From the rocks of Novorosiyskiy sub-regio-stage they differ in the lacking of thin-banded and sheeted structures and change in the mollusc complex; from Meotychniy regio-stage and Upper Sarmatian sub-regio-stage – in the sandy rock composition, and from Akchagylskiy sub-regio-stage – in micro- and fine-graining and well sorting of the sandy sequences.

Kimeriyskiy regio-stage was initially developed in the southern and central parts of the area filling erosion cut (pass) between the Dacian and Black Sea basins emerged in pre-Kimeriyskiy time. Erosion cut width is up to 15 km and relative depth up to 170 m. The general cut orientation from the north-west to south-east does spatially coincide with the modern direction of Danube River valley. Inside this erosion valley Novorosiyskiy sub-regio-stage, Meotychniy regio-stage, and partly, to the depth up to 30 m, Upper Sarmatian sub-regio-stage were eroded. The modern bottom of maximum cut is observed at the altitudes -241.8 m (DH 082 [48, 42], to the south of Reni town) and -161.0 m (DH 065 [48, 42]), -165.1 m (DH 081 [48, 42]), -167.6 m (DH 31 [42]) in the area of Nagirne and Novosilske villages. The bottom inclination in the south-western direction had occurred because of Dacian trough development which had encompassed the north-western part of the territory. In view of plunging amplitude of Sarmatian, Meotychni and Novorosiyski sediments, subsidence amplitude is about 100 m. The first bench is being mapped by Kagul lake and the second one by Buzhorul gully. Due to post-Kimeriyski cuts (pre-Akchagylskiy and Quaternary times), Kimeriyski sediments were eroded in the southern, northern and eastern parts of their distribution area.

Kimeriyskiy regio-stage is intersected by numerous drill-holes and is exposed by the banks of Kagul, Yalpug lakes, on the slopes of minor rivers and big gullies. With deep erosion it lies stratigraphically unconformably over Novorosiyskiy sub-regio-stage, Meotychniy regio-stage, and Sarmatian sub-regio-stage. Stratigraphically conformably, with deep cut, it is overlain by sandy-gravelous sequences of Akchagylskiy regio-stage, and also stratigraphically unconformably, with deep erosion, by Quaternary System. The hanging-wall altitudes of Kimeriyskiy regio-stage vary from -138.1 m (DH 076) to the south of Reni town to -105.0 m (DH 113) to the north of Zaliznychne village and depend on the modern tectonic position of certain sites and erosion degree over post-Kimeriyskiy time. In the surface relief of Kimeriyskiy regio-stage pre-Akchagylskiy and Quaternary cuts are well expressed. Pre-Akchagylskiy cut had caused general descending of the surface of these sediments to -130 m in the south-western direction, towards the deepest cut. In the lake, minor river, big gully valleys, where Late Quaternary cut depth is 10-30 m, the rocks of Kimeriyskiy regio-stage were eroded in the northern and eastern parts of their distribution area. In the southern direction these cuts are ceased because of general descending of the surface of Kimeriyskiy regio-stage sediments and are not expressed in the relief. The syn-sedimentation normal fault are also expressed in relief emerged in Kimeriyskiy time in the south-western part of the territory and had affected thickness of sediments. The rocks are being mapped along Buzhorul gully and Kagul lake. Displacement amplitude is 60 and 40 m respectively. The maximum thickness of Kimeriyski rocks is 140 m (DH 091) [48, 42] in the south-west nearby Reni town. Kimeriyskiy regio-stage includes two sequences which gradually substitute one another in the north-eastern direction: Prydunayska Suite (desalinated marine basin pass facies) and clayey sequence (desalinated lagoon facies).

Prydunayska Suite (N_2*pd*) (desalinated marine basin pass facies) is developed in the south and south-west of map sheet area in Prydunayska LTZ. The rocks include quartz, light-grey, mainly fine-grained, normally well-sorted, strew sands with interbeds of clays and aleurolites with clayey cement. In the coastal zone abundant detritus and mollusc shells are contained.

Clayey sequence (N_2*g*) (desalinated lagoon facies) is developed in Vladychen-Loshchynivska LTZ, mainly in Vladychenska depression (see “Scheme of LTZs location”), and is mainly composed of clays and aleurolites, in places with interbeds of fine-grained, quartz, clayey sands. Somewhere rhythmic intercalation of clays and aleurolites or clays, aleurolites and sands is observed.

C l a y s are grey, blue-grey, dark-grey, black, with numerous orange-brown iron hydroxide spots, to parti-colored, dense, viscous, non-banded, often aleuritic, gypsumized, carbonatized in various extents. In the northern part of the distribution area the clays are red-brown by some interbeds, and often at the bottom of Kimeriyski sediments they are highly carbonate and in places are substituted by marls and clayey limestones, containing shell detritus. In composition the clays are hydromica, montmorillonite-hydromica, montmorillonite, with calcite, dolomite, quartz, feldspars, mica, iron hydroxide, and organic admixture. Under aleuritic material content of 50% and more the clays become a l e u r o l i t e s with clayey cement, mainly quartz in composition, fine- and diverse-grained. By color they are similar to clays being grey, blue-grey, dark-grey, black, parti-colored, red-brown, gypsumized, carbonatized.

In the north-western part of Kimeriyski sediments distribution area the minor river avant-delta facies is distinguished which gradually substitutes lagoon facies and consists of quartz, light-grey, yellowish-grey, mainly fine-grained s a n d s with clay and aleurolite interbeds.

The age of sediments, which are ascribed by the authors to Kimeriyskiy regio-stage, is well determined after the fauna complex. Molluscs: *Viviparus ovidii nasonis* B o g . , *V. cf. Bifarcinatus* B i e l z . , *V. stefanescui* S a b b a . , *V. mammatus* S a b b a . , *Psilwtio sp., Limnocardium sp., Theodoxus sp., Congeria sp., Pisidium sp., Planorbarius sp., Gyraulus sp., Fagotia pterochila onuchia* M u l l . , F. *parumbarui* B r u s., *Prosodacna (Psilodon) haneri* (K o b .), *Pachydacna cobalcesni* F o n t . , *Dreissensia sp.* Ostracoda: *Ilyocyprisgibba* R a m d . , *I. aspera* N e g., *Candona elongata* S c h n., *C. Neglecta* S a r s., *C. trilbeti* K r s t., *Cyprinotus sp., Trachyleberis pontica* (L i v .), *Cytherissa bogatschovi* (L i v .), *Cyprideis littoralis* (B r.), *Cyprinotus sp.*

The fauna remnants were determined in the course of GM-50 [48] as well as in previous works of V.V.Bogachev, P.F.Gozhyk, V.G.Chyrka. These authors had examined abundant Dacian (Pliocene) mollusc complex in the core of drill-holes in Reni town area.

Akchagylskiy regio-stage

This unit mainly consists of fine-medium-grained and fine-coarse-grained (with diverse-grained gravel and pebble admixture), clayey, dense sands developed in the river course and flood-land alluvium facies. Deposition of terrigenous sequences had occurred under conditions of under-flooded mouth part of large river on the background of general erosion basis uplifting. Specific features of these sediments include dark-grey and grey rock color, coarse-clastic composition, total non-sorting of clastic material, and clayey composition. From the similar in composition underlaying Kimeriyski sediments they differ in coarser-clastic composition, weak sorting of clastic material, and clay content; from the underlaying sediments of Upper Sarmatian sub-regio-stage, Meotychniy regio-stage, and Novorosiyskiy sub-regio-stage, developed mainly in fore-mountain accumulative plain facies they differ in clear lithological features; from the overlaying Quaternary alluvial sequences they also differ in lithology. At the footwall of Quaternary sediments the basal layers are normally developed composed of sand-gravel rocks with pebble, rarely cobble admixture. These rocks are more sorted and contain less amount of clay material.

Akchagylski sediments are only developed in the south-west of studied area (see “Geological map and map of mineral resources of pre-Quaternary units”). They fill up erosion cut developed in the pass between Dacian and Black Sea basins at the boundary of Kimeriyskiy and Akchagylskiy times. The total extension of paleo-cut is from the north-west to south-east and coincides with the modern direction of Danube River valley. The pass width was from 4 to 8 km, the cut depth – about 150 m. The modern position of maximum paleo-cut depth is at the altitudes -135 m to the south of Reni town, -138 m in between Orlovka and Nagirne villages, and -148.5 m to the south from Kugurluy lake (DH 020) [48, 42]. The general descending in the cut depth to the south-east is observed. In the given paleo-valley the rocks of Kimeriyskiy regio-stage, Meotychniy regio-stage, and partly Upper Sarmatian sub-regio-stage had underwent extensive erosion.

Due to Quaternary cuts development (to the altitudes -50…-60 m), the upper column part of Akchagylskiy regio-stage is eroded. The north-eastern distribution boundary is set by the southern outskirt of Reni town, Dolynske and Nagirne villages, to the north of Novosilske village, and then to the south-east to Sulynske mouth of Danube River. The south-western boundary is located outside the studied area.

Akchagylskiy regio-stage is not exposed at the surface and is intersected by numerous drill-holes to various depths beneath thick Quaternary cover. The rocks stratigraphically unconformably with deep erosion do lie over Kimeriyskiy regio-stage, Upper Sarmatian sub-regio-stage, Meotychniy regio-stage, Triassic and Devonian; these are overlain stratigraphically unconformably with erosion by the Middle and Upper Neo-Pleistocene alluvial sequences. The hanging-wall altitudes vary from +23.5 m (DH 065) to +61.4 m (DH 077) [48, 42] and fully depend on the hanging-wall erosion degree in Quaternary time. In the surface relief of Akchagylskiy regio-stage the Upper Neo-Pleistocene cut of Danube River, Kagul lake, Yalpug lake are well expressed. The cut depth from the modern surface is about 60 m. The maximum thickness of sediments is 102.6 m (DH 013 [48, 42], to the south of Novosilske village). The rocks comprise the common terrigenous-clayey sequence (river course and flood-land alluvium facies) developed in Prydunayska LTZ only.

Terrigenous-clayey sequence (N_2tg) fills up pre-Akchagylskiy cut and is mainly composed of diverse-grained (fine-coarse-grained) sands with diverse-grained gravel and fine pebble admixture. Most typical columns of Akchagylski river-course facies are intersected by drill-holes 082 [48, 42] in Reni town area, drill-holes 07, 018, 023, 025, 08 [48, 42] to the north of Orlovka village, drill-holes 011, 012, 027 [48, 42] in the former Ferapontiy monastery area, and drill-holes 015, 016, 020, 024 [48, 42] to the south of Kugurluy lake.

S a n d s are light-grey, grey, ash-grey, quartz, siliceous-quartz, often with mica, from fine-medium-grained to diverse-grained, with up to 50% admixture of diverse-grained gravel and fine pebble in the interbeds, normally clayey, dense, weakly-sorted, in places replaced by sandstones with clayey cement. Under gravel content more than 50%, the sands become gravel and gravel-pebble sediments, sandy, clayey. The gravel and pebble is up to 5 cm in size, various rounding degree, composed of quartz, re-deposited sandstone nodules. Major rock-forming mineral of sands include quartz, flint, muscovite. In the minor amounts feldspar, rock fragments, calcite, garnet, ilmenite, staurolite, epidote, amphibole are observed. In single grains tourmaline, leucoxene, rutile, zircon, chlorite, pyrite, kyanite, magnetite, celestine, iron hydroxide are noted.

C l a y s are grey, light-grey, dark-grey with greenish, bluish, blue, yellow shades, in places black, dense, viscous, aleuritic, sandy, non-banded, horizontally-banded, lumpy, in places with orange-brown iron hydroxide spots, carbonate nodules up to 3 cm in size, wood remnants, mollusc shells and shell detritus. After thermal analysis data (DH 25k [21, 42], mineral composition of clays is mixture of hydromica and montmorillonite.

A l e u r o l i t e s are light-quartz, grey, light-grey, dark-grey, from fine-grained to diverse-grained, dense, with clayey cement, non-banded, horizontally-banded, with carbonate nodules up to 2-3 mm in size.

The age of Akchagyskiy regio-stage is determined after the fauna complex. Molluscs: *Fagotia esperi* F e r . , *Fagotia sp., Valvata piscinalis* M u l l . , *Valvata sp., Bithynia spoliata* S a b b a , *Lithoglyphus neymayri* B r u s . , *Lithoglyphus sp., Melanopsis bergeroni* S a b b a , *M. esperoides* S a b b a , *M. rumanee vireete* S a b b a , *M. (Lyreea) cf. onusta* S a b b a , *Melanopsis sp., Dreissensia polymorpha* P a l l . , *Dreissensia sp., Congeria augustiformis var., Prosodacna aff. munieri* S a b b a ., *Viviparus sp., Unio sp., Planorbis sp., Didacna sp., Hydrobia sp.*

Quaternary System

Quaternary sediments are developed almost everywhere and only lacking in some steep slopes where pre-Quaternary rocks are exposed at the surface. The sediments include various genetic types: aeolian-deluvial, eluvial, alluvial, alluvial-marine, estuary-lake, deluvial, deluvial-coluvial, alluvial-deluvial, proluvial, proluvial-deluvial, and technogenic, which are grouped into continental sub-aerial and sub-aqueous facies of the southern loess plain in the back-glacier zone. The total thickness of Quaternary sediments varies from 0.1 to 83.6 m; the minimum thickness is observed at the steep slopes while the maximum one – at the modern watershed plains and Danube River flood-land.

The Pleistocene and Holocene divisions are distinguished in Quaternary System. Pleistocene includes undivided Eo-Pleistocene – Lower Neo-Pleistocene rocks and Neo-Pleistocene section, which in turn is divided into the branches: the lower, middle and upper ones. Description of all types of Quaternary sediments distinguished in the studied map sheets is given below (see “Geological map and map of mineral resources of Quaternary sediments”, cross-sections A_1-A_3).

Pleistocene division

Eo-Pleistocene – Lower Neo-Pleistocene

Undivided Eo-Pleistocene – Lower Neo-Pleistocene rocks include alluvial-marine (deltaic) sediments /amE-P_I/ which are widely developed in the area. These sediments are only lacking in the south and south-east where they were eroded in the Early and Late Neo-Pleistocene, and also in places where modern erosion network is developed. The northern boundary of their distribution is well expressed in geomorphologic respect and coincides with Chadyr-Lungskiy fault. The rocks are intersected by numerous drill-holes and are exposed on the slopes of Buzhorul gully nearby Dolynske village, on the left bank of Kagul lake, from Nagirne village up to the State border with Moldova, in fragments on the right bank of Kagul lake, on the banks of Yalpug, Katlabukh lakes and on the slopes of some river valleys, gullies and gorges in the northern part of territory. The rocks lie over sands and clays of Upper Miocene Prydunayska Suite and Lower Pliocene clayey sequence, as well as over Upper Miocene sandy and terrigenous-clayey sequence; over most part of their distribution these rocks are overlain by all sub-aerial climatoliths from Sulskiy to Holocene, and on the slopes and in gullies – by various genetic types of Upper Neo-Pleistocene and Holocene. The depth is from 0.1 m on the gully slopes up to 48 m at the watershed plains. The uneroded hanging-wall altitudes vary from -5.9 m in the south-east to +157 m in the north; the footwall – from -21.5 m in the south-east to +145 m in the north. The high difference between hanging-wall and footwall altitudes is caused by irregular differentiated territory uplift in Quaternary period. The thickness at watershed plains varies from 47 m in the south to 4 m in the north (see geological cross-section by line A_1-A_3 to “Geological map and map of mineral resources of Quaternary sediments”).

The rocks are developed in the river-course and flood-land facies. The river-course facies constitute the lower column part and consist of sands, gravel-pebble sediments and conglomerates. Higher in the column and in direction from the modern erosion cuts towards watershed plains the river-course facies are gradually changed by the flood-land facies consisting of clays, clayey aleurites, loams, with horizons of the former red-brown hydromorphic soils. In the northern part of map sheet territory, in Kalchevo village area, beneath red-brown clays the gypsums and gypsumized clays are observed which apparently had been formed under conditions of small closed basin. In the north-eastern direction the river-course facies pinch out and deltaic rocks therein consist of the flood-land facies only.

C o n g l o m e r a t e s a n d g r a v e l - p e b b l e s e d i m e n t s do mainly constitute the basal layers of river-course facies and also are observed in the lenses and interbeds within sand batch. Their thickness varies from 0.1 to 5-6 m. Gravel and pebble composition: quartz, brown and black flint, carbonates, sandstones. Prevailing size of clastic material is from 1 mm to 5 cm. Admixture of diverse-grained flint-quartz sand and the clay, sand and clayey aleurites interbeds and lenses from 0.1 to 1.5-2 m thick are often contained. Conglomerates are strong, cemented by carbonate material. By strike they are replaced by flint-quartz, diverse-grained, gravelous sandstones with carbonate cement or by the non-cemented gravel-pebble sediments.

S a n d s are quartz, mica-quartz, feldspar-quartz, flint-quartz, mica-flint-quartz, feldspar-flint-quartz, light-grey to white, rarely yellowish-grey, orange-yellow, diverse-, coarse-, medium-grained but mainly fine-grained, in places aleuritic, clayey, horizontally- and oblique-banded, in places with flint, quartz and carbonate gravel and pebble, with nodules of sandstones with carbonate cement of various forms and types – from some millimeters to 1 m. The heavy-mineral fraction includes few amounts of garnet, ilmenite, tourmaline, leucoxene, staurolite, rutile, zircon, chlorite, kyanite, sillimanite, biotite, amphibole, magnetite, epidote, celestine, and iron hydroxides. The single grains of pyrite and monazite are observed. The greatest thickness of sands attains 30 m. The lower part of sandy batch is normally composed of coarse-grained varieties which higher in the column are replaced by diverse-grained, medium- and fine-grained, clayey ones.

A l e u r i t e s are light-grey, blue-grey, greenish-grey, yellowish-grey, pale-yellow, clayey, in places sandy, dense, normally non-banded, in places horizontally-banded, with iron hydroxide spots, with manganese hydroxide black dendrites, films and beans up to 3 mm in size, carbonatized.

C l a y s are grey, yellowish-grey, blue-grey, in places dark-grey, brownish-grey, in the upper column part red, brownish-red, often aleuritic and sandy, non-banded, with numerous iron hydroxide spots, manganese hydroxide films, dendrites and beans up to 5 mm in diameter, with aleurites and sand interbeds. Carbonatization, in places very extensive, is frequently observed. The clays are chlorite-hydromica-montmorillonite, hydromica-chlorite-montmorillonite, montmorillonite, hydromica, with admixture of quartz, feldspars, calcite, carbonate, kaolinite, mica, dolomite, gypsum, iron hydroxide grains.

L o a m s are red-brown, yellow-pale, pinkish-pale, brownish-pale, in places with grey spots (primary coloring), light, medium, heavy, dense, carbonatized. Through the spotty varieties the pale-yellow and red-brown loams are substituted by clayey aleurites or sandy-aleuritic-clayey grey and blur-grey rocks. The clay minerals are mainly montmorillonite and hydromica, rarely chlorite. Aleurite-sandy fraction mainly consists of quartz, rarely feldspar and mica grains. Besides that, calcite, gypsum and siderite are also observed, apparently of secondary origin.

G y p s u m is light-grey, coarse-crystalline and fibrous, arranged in “rose”-shaped druses up to 30 cm in size. The maximum thickness of gypsum batch attains 2 m; the contacts with host grey and red-brown clays are gradual.

After paleontological study data, the rocks contain Khaprovskiy, Tamanskiy and Tyraspolskiy mammal complexes (Eo-Pleistocene – Early Neo-Pleistocene), Apsheronski molluscs and ostracoda [8], as well as Tyraspolskiy complex molluscs (Early Neo-Pleistocene) [48]. The findings of older mammal fauna complexes are mainly confined to the basal layers of river-course facies or sand-gravel interbeds in sands which may indicate the odd-age river-course passes in the delta. Occurrence of saline-water Apsheronski ostracoda in the rocks (*Ilyocypris gibba* (R a m d o h r), *Il. biplicata* (K o c h .), *Candona neglecta* S a r s., *C. Candida* M u l l . , *Caspiolla lobata* L i v e n t . , *C. balcanica* (Z a l.), *limnocythere exgr. luculenta* L i v e n t . , *Limnocythere sp., Loxoconcha petasa* L i v e n t . , *Cypria sp.* – determinations of G.F.Shneyder), and saline-water Tyraspolskiy complex molluscs (*Didacna cf. baericrassa* P a v l . , *D. ex gr. tschaudae* A n d r u s . – determinations of K.D.Mikhaylesku), suggest for the link with Guriyskiy and Chaudynskiy marine basins. Besides that, at the southern and northern outskirts of Nagirne village abundant complex of micro-teriofauna is determined [12], which, according to the authors’ conclusion (V.Yu.Ratnykov, A.I.Krokhmal), coupled with fine mammal and mollusc fauna, may correspond to the end of Lubenskiy and beginning of Zavadivskiy time. By the geological observations, sub-aqueous sediments from the southern outskirt of Nagirne village to the border with Moldova are overlain by Sulskiy, Lubenskiy, Tyligulskiy and Zavadivskiy climatoliths with c distinct features (described below). Thus, the age of given sediments, according to the valid stratigraphic scheme of Quaternary sediments, is defined to be Eo-Pleistocene – Early Neo-Pleistocene.

Upper Eo-Pleistocene – Lower Neo-Pleistocene

Undivided Upper Eo-Pleistocene – Lower Neo-Pleistocene eluvial sediments /eE_{II}-P_I/ are widely developed and observed in the distribution limits of Eo-Pleistocene – Lower Neo-Pleistocene alluvial-marine sediments being a bit less distributed, and are lacking in the south of studied area and at the Upper Neo-Pleistocene – Holocene erosion cuts. The rocks are intersected by numerous drill-holes and exposed on the slopes of lakes, river valleys and big gullies. The rocks lie over Eo-Pleistocene and Lower Neo-Pleistocene alluvial-marine sediments and replace the latter by strike, normally in the direction from the modern cuts to watershed plains. The rocks are overlain by Lower Neo-Pleistocene aeolian-deluvial and eluvial sediments and on the slopes by Upper Neo-Pleistocene – Holocene sediments of various genetic types. The thickness at the watershed plains is 0.2-11.5 m. The depth is from 0.1 m on the slopes to 48 m at watershed plains. The hanging-wall altitudes are from 5.3 m in the south-east to 161.2 m in the north. The rocks include red-brown clays and loams and comprise suitable marker horizon. In places, especially in the southern part, the unit is being divided into climatoliths: Kryzhanivskiy (Upper Eo-Pleistocene – eE_{II}), Shyrokynskiy, and Martonoskiy (Lower Neo-Pleistocene – eP_I).

Eo-Pleistocene section
Upper Eo-Pleistocene branch

Kryzhanivskiy climatolith /$eE_{II}kr$/ consists of eluvial sediments including red-brown clays, rarely loams, with clayey sand and sandy loam interbeds. The clays are red-brown, brick-red, low-ductile, viscous, lumpy, in places carbonatized in various extents, with sliding surfaces. After thermal analysis data content is hydromica with admixture of montmorillonite, quartz, carbonates, iron oxides and hydroxides. The depth is 0.1-53.0 m, thickness – 0.5-6.0 m, mainly 1-2 m.

Neo-Pleistocene section
Lower Neo-Pleistocene branch

Undivided Lower Neo-Pleistocene eluvial sediments /eP_I/ are developed in the central and northern parts of the area and lacking in the south and at the Upper Neo-Pleistocene – Holocene erosion cuts. They are intersected by numerous drill-holes and exposed on the slopes of lakes, river valleys and big gullies. The rocks lie over Eo-Pleistocene and Lower Neo-Pleistocene alluvial-marine sediments and replace the latter by strike. The rocks are overlain by Lower Neo-Pleistocene aeolian-deluvial and eluvial sediments and on the slopes by Upper Neo-Pleistocene – Holocene sediments of various genetic types. The thickness at the watershed plains is 1.5-7.0 m. The depth is from 0.1 m on the slopes to 35 m at watershed plains. The hanging-wall altitudes are from 22.5 m in the south-east to 145 m in the north. The sediments include red-brown clays and loams. The clays are red-brown, in places with light-grey spots, dense, viscous, non-banded, often highly carbonatized, with manganese hydroxides. The loams are red-brown, rarely brown, heavy, dense, carbonatized, often with fine (up to 2 mm) manganese hydroxide nodules. These sediments are correlated with Shyrokynskiy and Martonoskiy climatoliths.

Shyrokynskiy climatolith /P_Ish/ consists of eluvial sediments and mainly composed of clays, rarely red-brown loams, in places with quartz, fine-grained sand inclusions. The clays are red-brown, brick-red, brown, low-ductile, viscous, dense, lumpy, with friable carbonate inclusions, sliding surfaces, rarely aleuritic. After thermal analysis the clays are hydromica, hydromica-montmorillonite with admixture of quartz, carbopnates, iron oxides and hydroxides. The depth is 0.1-50.0 m, thickness – 0.3-3.1 m, mainly 1.0-2.5 m.

Martonoskiy climatolith /eP_Imt/ consists of eluvial sediments including red-brown clays and loams. The clays are red-brown, dense, with solid carbonate inclusions up to 2 cm in size, with frequent manganese hydroxide films, beans and dendrites. The loams are red-brown, brown, heavy, in places medium. The clayey fraction, after thermal analysis data, consists of hydromica, montmorillonite, iron hydroxide. The depth is 0.1-48.0 m, thickness – 0.2-3.6 m, mainly 1-2 m.

Lower Neo-Pleistocene aeolian-deluvial and eluvial sediments /vd,eP_I/ are widely developed and observed in the limits of Eo-Pleistocene – Lower Neo-Pleistocene alluvial-marine sediments being a bit less distributed, and are lacking in the south of studied area and at the Upper Neo-Pleistocene – Holocene erosion cuts. The rocks are intersected by numerous drill-holes and exposed on the slopes of lakes, river valleys and big gullies. The rocks lie over Eo-Pleistocene and Lower Neo-Pleistocene alluvial-marine sediments and are overlain by Middle Neo-Pleistocene aeolian-deluvial and eluvial sediments and on the slopes by Upper Neo-Pleistocene – Holocene sediments of various genetic types. The thickness at the watershed plains is from 1 m in the central-eastern part to 16 m in the south-west, mainly 3-10 m, which gradually decreases in the north-eastern direction. The depth is from 0.2 m on the slopes to 42.0 m at watershed plains. The hanging-wall altitudes are from 5.3 m in the south-east to 161.2 m in the north. The rocks are divided into Sulskiy, Lubenskiy and Tyligulskiy climatoliths. These units can be distinguished quite confidently because of their certain stratigraphic position in the column between characteristically red-brown former soil horizons of Zavadivskiy and Martonoskiy climatoliths and distinct internal structure.

Sulskiy climatolith /vdP_Isl/ consists of aeolian-deluvial loess-like, pale-yellow, pale, brownish-pale, light and medium, dense, porous, carbonatized loams; in places greenish-yellowish-grey clays with manganese hydroxide beans (pod sediments). Clay minerals include hydromica and montmorillonite. Aleurite-sand fraction (0.01-0.25 mm) mainly consists of quartz, in lesser extent feldspars and flint. The depth is 0.2-42.0 m at altitudes from -3.9 m to 157.5 m. Thickness is 0.5-8.0 m, normally 2.5-5.0 m.

The highest thickness amongst all Lower Neo-Pleistocene aeolian-deluvial sediments and brown, red-brown former soil layer from 0.2 to 0.5 m thick at the bottom are the distinct features of this climatolith. The soil in places is weakly expressed or lacking; in the eastern and northern parts of the area where thickness of Sulskiy climatolith is decreased, this soil is not found at all.

After paleomagnetic study data (right bank of Buzhorul gully to the north of Dolynske village), the loams mainly exhibit reverse polarization although in the middle part some samples yielded direct polarization. Clear reverse polarization is noted in the lower part from the former soil horizon (V.G.Bakhmutov, 2005 [42]).

Lubenskiy climatolith /e$P_I$lb/ consists of eluvial sediments including brown, light-brown and red-brown, medium and heavy, dense, porous, carbonatized; in places brown clays with grey and greenish-grey shade (pod sediments). Clay minerals include hydromica and montmorillonite. Aleurite-sand fraction (0.01-0.25 mm) mainly consists of quartz and flint. The depth is 0.2-36.0 m and altitudes from -2.4 to 160.5 m. The thickness is 1.0-9.2 m, normally 3.0-5.0 m.

Specific feature of the given climatolith is several horizons of former soils (from 2 to 4) separated by interbeds of loess-like, pale, pale-yellow, brown-pale loams from 0.2 to 2.0 m thick. The thickest interbeds of loess-like loams are observed in the south-western part of the area. In addition, Lubenskiy climatolith is the thickest one of Neo-Pleistocene eluvial sediments. In the north-eastern direction the gradual thinning of Lubenskiy climatolith is observed, the loess-like loam interbeds disappear, and former soils become red-colored, probably, because of superimposed soil-forming processes of Zavadivskiy time.

After paleomagnetic study data, the upper loam part of Lubenskit climatolith exhibits exclusively direct polarization whereas samples from the lower part indicate alternating direct and reverse magnetization with predomination of the latter.

Tyligulskiy climatolith /vd$P_I$tl/ consists of aeolian-deluvial loess-like, pale, yellowish-pale, brownish-pale, pinkish-pale, light, medium, rarely heavy, dense, porous, carbonatized loams. In places yellowish-greenish-grey, pale, dense clay is observed with manganese hydroxide beans and dendrites. Clay fraction in loams consists of hydromica or mixture of montmorillonite and hydromica with quartz and iron hydroxide admixture. The depth is 0.2-35.0 m and altitudes from 5.3 to 161.2 m. The thickness is 0.5-6.8 m, mainly 1.5-3.0 m. In the north-eastern direction thickness of Tyligulskiy climatolith is decreasing and somewhere it is pinched out at all or completely re-worked by the soil-forming processes in Zavadivskiy time.

Middle Neo-Pleistocene branch

Middle Neo-Pleistocene aeolian-deluvial and eluvial sediments /vd,eP_{II}/ are developed in sub-aerial cover of the fifth over-flood terrace and Eo-Pleistocene – Lower Neo-Pleistocene deltaic plain. They are lacking in the south of territory within modern erosion network where these sediments were eroded in Middle-Late Neo-Pleistocene and Holocene. The rocks are intersected by numerous drill-holes and exposed on the slopes of lakes, river valleys and big gullies. The rocks lie over estuary-lake sediments of the fifth over-flood terrace, Lower Neo-Pleistocene aeolian-deluvial and eluvial loams and clays, and at the watershed plains are overlain by Upper Neo-Pleistocene aeolian-deluvial and eluvial sediments and on the slopes – by Upper Neo-Pleistocene – Holocene sediments of various genetic types. The thickness is from 1.0 to 13.2 m, mainly 4-8 m. The depth is from 0.2 m on the slopes to 33.0 m at the watershed plain. The hanging-wall altitudes at the watershed plain are from 11.5 m in the south-east to 168.2 m in the north. The unit is divided into Zavadivskiy, Dniprovskiy, Kaydatskiy and Tyasminskiy climatoliths.

Zavadivskiy climatolith /eP_{II}zv/ consists of eluvial sediments including automorphic and hydromorphic former soils. Hydromorphic former soils were developing after estuary-lake sediments of the fifth over-flood terrace whereas automorphic soils are developed in the sub-aerial cover of Eo-Pleistocene – Lower Neo-Pleistocene deltaic plain.

The rocks include red, brownish-red, red-brown, medium and heavy, dense, porous loams, carbonatized in various extents. In places soils consist of red, red-brown, dense, viscous clays with carbonate and carbonate-manganese nodules. Clay minerals include montmorillonite and hydromica with quartz and goethite admixture. The light fraction of all classes (95-100%) is mainly composed of quartz with minor feldspars and flint. The depth is 0.2-40.0 m and altitudes from 8 to 163 m. The thickness is 0.4-5.6 m, mainly 1.5-3.0 m. In the northern part of studied area Zavadivski and Lubenski soils merge into the single soil horizon while Tyligulski loess-like loams are pinched out.

The bright-red or brownish-red color is the specific feature of Zavadivski former soils. This is suitable marker horizon more or less persistent in thickness and by strike; the boundary between Lower and Middle Neo-Pleistocene is set by the footwall of this horizon.

Dniprovskiy climatolith /vdP_{II}dn/ consists of aeolian-deluvial loess-like, pale-yellow, pale, light, medium, dense, porous, highly carbonatized loams. Carbonates are white and occur in the films on the pore walls as well as in the friable and solid nodules up to 2.5 cm in size. Clay minerals include hydromica and montmorillonite. The light fraction of all classes (95-100%) is mainly composed of quartz, in lesser extent flint fragments and feldspars. The depth is 0.2-34.8 m and altitudes from 9.5 to 165.5 m. The thickness is 0.8-6.4 m, mainly 3.5-5.0 m in the south-west, 2-4 m in the south-east, and 1-2 m in the north. In general, the thickness gradual decreasing is observed from the south-west to north-east.

The extensive carbonatization, much higher than in other aeolian-deluvial sediments, comprises specific feature of Dniprovskiy climatolith. In addition, at the watershed plains it always lies over red-brown Zavadivski former soils.

Kaydatskiy climatolith /eP_{II}kd/ consists of eluvial sediments including brown, reddish-brown, grayish-brown, brownish-grey, medium and heavy, dense, porous, carbonatized loams. In places reddish-brown, light-brown, brownish-grey, dense, viscous clays are noted with manganese hydroxide films and spots, carbonatized. Somewhere in the southern part of the area two soils are observed in the column: the upper brown, reddish-brown, and the lower darker with grayish shade. Clay fraction of loams includes hydromica and montmorillonite or mixture of these minerals. The light fraction of all classes (90-100%) consists of quartz, feldspars, flint fragments. The depth is 0.2-33.0 m and altitudes from 11.5 to 168.2 m. The thickness is 0.4-4.7 m, prevailing – 1.0-2.5 m.

The difference between Kaydatski soils and underlaying eluvial rocks is that the grey shades appear in the rocks and they are relatively thinner. In some cases the column characteristically contains two soils which differ in color one from another.

Tyasminskiy climatolith /vdP_{II}ts/ consists of aeolian-deluvial loams and is the thinnest Neo-Pleistocene climatolith. Because of low thickness which varies from 0.25 to 3.8 m, mainly in the range 0.7-2.5 m, Tysminski sediments are not persistent by strike or either not preserved in places or completely re-worked by the soil-forming processes in Prylutskiy time. The depth is 0.4-30.0 m and altitudes from 12.2 to 166.2 m. The loams are loess-like, yellowish-pale, pale, brownish-pale, light, medium, dense, porous, carbonatized. Clay fraction includes hydromica, montmorillonite, or the mixture of these minerals. The aleurite-sand fraction (0.01-0.5 mm) is mainly composed of quartz with minor feldspars, muscovite, iron and manganese hydroxides.

Khadzhybeyskiy ledge. Alluvial sediments of the fifth over-flood terrace /a^5P_{II}hd/ are developed in the southern part of territory in the area of Plavni and Ozerne villages and apparently belong to the Danube River terrace. The rocks are intersected by numerous drill-holes and exposed in the quarry at the northern outskirt of Plavni village. Terrace socle consists of sands and clays of Prydunayska Suite and Lower Pliocene clayey sequence; it is intersected at the altitudes -5…-26 m and descends in the southern direction. Over most part of distribution area it is overlain by the estuary-lake sediments of the same terrace, and on the slopes – by Upper Neo-Pleistocene – Holocene sediments. The hanging-wall altitudes vary from -5 m to +20.4 m ascending towards the back sutures. The depth is from 0.6 m on the slopes to 47.3 m at the watershed plain. The thickness attains 12-33 m increasing in the southern direction.

Alluvial sediments include quartz and mica-quartz, yellowish-grey, grey, dark-grey sands, from fine- to coarse-grained with gravel and pebble, with up to 3 m thick interbeds of yellowish-grey and greenish-grey clays. Gravel and pebble are of various rounding and consist of quartz, flint, carbonate nodules, sandstones and aleurolites with carbonate cement. In the quarry at the northern outskirt of Plavni village the thin oblique banding is observed in the sands. Diverse-grained sands with gravel and pebble and sand-gravel sediments are confined to the basal layers. Higher in the column and towards the back sutures the sands are substituted by fine-grained varieties and then aleurites with clay interbeds. In DH 29k, in the upper part of sand batch, mollusc fauna is determined: *Dreissensia polymorpha* P a l l . , *Planorbis sp., Fagotia sp.* [23]. Towards the column top and by strike alluvial sediments are gradually substituted by the estuary-lake clays and clayey aleurites.

Zavadivskiy climatolith. Estuary-lake sediments of the fifth over-flood terrace /lml^5P_{II}zv/ are developed in the southern part of territory, in the area of Plavni and Ozerne villages. Terrace is almost everywhere well expressed geomorphologically. The rocks are intersected by numerous drill-holes and exposed in Ozerne village. They lie over alluvium of the same terrace and over most part of their distribution area are overlain by all climatoliths of aeolian-deluvial and eluvial sediments from Dniprovskiy to Holocene, and on the slopes – by Upper Neo-Pleistocene – Holocene sediments of various genetic types. The altitudes of non-eroded hanging-wall vary from 21.5 to 37.8 m ascending towards the back sutures. The depth is from 0.5 m on the slopes to 35.5 m at the watershed plain. The thickness attains 16.0-23.8 m. The total thickness of estuary-lake and alluvial sediments of the fifth over-flood terrace is 34.5-49.0 m increasing in the southern direction.

The estuary-lake sediments include clays and aleurites. The clays are yellowish-grey, grey, in the upper column part grayish-yellow, pale, sandy, aleuritic, carbonatized, with 0.3-6.0 m thick aleurite and sand interbeds. In compositions the clays are hydromica, chlorite-hydromica-montmorillonite, with admixture of quartz, feldspars, mica, calcite grains. Aleurites are yellowish-grey, pale-yellow, clayey, dense, carbonatized.

In the upper column part the former hydromorphic soils of characteristic red and brown-red color are developed after clays and aleurites; like the soils of Martonoskiy climatolith these ones comprise suitable marker horizon. Towards the back sutures amount and thickness of former soil horizons increase while the estuary-lake clays are substituted by sediments characteristic for proluvial-deluvial fans including pale, brownish-pale loams with sand interbeds, and sandy, pale-yellow clays.

In the eastern bank of Yalpug lake, nearby Ozerne village, L.A.Chepalyga and K.D.Mykhaylesku had determined from the estuary-lake sediments the fauna complex of molluscs characteristic for the Middle Neo-Pleistocene lower part: *Didacna poratica* M i h., *D. pontocaspia* P a v l ., *D. sp., Dreissena polymorpha* P a l l ., *Viviparusfasciatus* M u l l ., *V. cf. tiraspolitanus* P a v l ., *Monodacna sp., Turrycaspia (Micromelania) lincta* M i l ., *Fagotia esperi* F e r., *F. acicularis* F e r., *Lithoglyphus fasciatus* M u l l ., *L. naticoides* C. Pf., *Unio pictorum* L., *U. tumidus* R e t s ., *Valvata piscinalis* M u l l ., *Theodoxus danubialis* C. Pf., *T. fluviatilis* L., *T. sp.,* and fine *Corbicula fluminalis* M u l l ., *Pisidium amnicum* M u l l ., *Sphaerium rivicola* Leach. The fine mammal fauna is also determined over there: *Arvicola mosbachensis* S c h m i d t g e n ., *Eolagurus sp., Golagurus sp., Lagurus transiens* J a n o s s y, *Microtus cf. arvalinus* H i n t o n. [48].

Paleontological studies, stratigraphic position of estuary-lake sediments beneath Dniprovskiy climatolith and occurrence of red-color former soil horizons, characteristic for Zavadivskiy climatolith, suggest for Zavadivskiy age of these sediments.

Upper Neo-Pleistocene branch

Upper Neo-Pleistocene aeolian-deluvial and eluvial sediments /vd,eP_{III}/ are widely developed in the studied area and only lacking at the modern erosion cuts. The rocks are intersected by numerous drill-holes and exposed on the slopes of lakes, river valleys and big gullies. The sediments lie over estuary-lake rocks of the first, second, third over-flood terraces, as well as Middle and Lower Neo-Pleistocene aeolian-deluvial and eluvial loams and clays being overlain by Holocene sediments. The thickness at watershed plain is from 1.0 to 33.7 m gradually decreasing in the north-eastern direction. The hanging-wall altitudes vary from 3.5 m in the south-east to 175.2 m in the north. The sediments are subdivided into Prylutskiy, Udayskiy, Vytachivskiy, Buzkiy, Dofinivskiy and Prychornomorskiy climatoliths.

Prylutskiy climatolith /eP_{III}pl/ consists of eluvial sediments including hydromorphic and automorphic former soils. Hydromorphic former soils are developed after estuary-lake sediments of the third over-flood terrace whereas automorphic ones are developed in sub-aerial cover of the fifth over-flood terrace and Eo-Pleistocene – Early Neo-Pleistocene deltaic plain. The rocks include loams, in places clays, brown and light-brown, often with reddish shade. In places two soils are observed: the upper reddish-brown and the lower grayish-brown developed in transitional period between the warm and cold stages. The loams are medium and heavy, dense, porous, carbonatized. The clay fraction in loams consists of hydromica with montmorillonite admixture. Aleurite-sand fraction (0.01-0.5 mm) is mainly composed of quartz, in lesser extent feldspars and flint. The depth is 0.5-25.0 m and altitudes from 13.1 to 168.3 m. The thickness is 0.3-3.5 m, mainly 0.7-2.5 m.

Macroscopically Prylutski eluvial sediments differ from Kaydatski ones in a bit brighter reddish shade of the upper soil. In places where Tyasminski loams pinch out, Prylutski soils merge with Kaydatski ones into apparently common soil horizon. Kaydatski and Prylutski former soils are the thinnest Neo-Pleistocene eluvial sediments.

Udayskiy climatolith /vdP_{III}ud/ consists of aeolian-deluvial loess-like, pale, yellowish-pale, grayish-pale loams, in the upper and lower layer parts brownish-pale, light and medium, dense, porous, carbonatized, in places with inclusions of fine-crystalline gypsum. Clay minerals include hydromica and montmorillonite. The depth is 0.5-30.0 m and altitudes from 6.0 m to 163.8 m. The thickness is 0.4-6.8 m, mainly 1-5 m. The highest thickness is noted in the south-western part of territory and in places where the third over-flood terrace sediments are developed. Close to the northern boundary of the studied area Udayski loams in places are almost completely re-worked by the soil-forming processes in Vytachivskiy time.

Vytachivskiy climatolith /eP_{III}vt/ consists of eluvial sediments including hydromorphic and automorphic former soils. Hydromorphic former soils are developed after estuary-lake sediments of the second over-flood terrace whereas automorphic ones are developed in sub-aerial cover of the fifth over-flood terrace and Eo-Pleistocene – Early Neo-Pleistocene deltaic plain. The rocks include brown, dark-brown, reddish-brown, medium and heavy, dense, porous, carbonatized, in places manganetized loams. Somewhere reddish-brown and dark-brown clays are observed. The clay fraction in loams consists of montmorillonite and hydromica. The depth is 0.5-26.0 m and altitudes from 8.5 to 171 m. The thickness is 0.2-6.5 m, mainly 1-3 m; the highest thickness is observed in the southern and south-western parts of territory. Over there, the pale, brownish-pale, loess-like loam interbed from 0.2 to 0.8 m thick is often observed. The upper soil is reddish but a bit darker than in the soils of Prylutskiy climatolith.

Buzkiy climatolith /vdP_{III}bg/ consists of aeolian-deluvial loess-like, pale, yellowish-pale, light, medium, dense, porous, columnar loams, carbonatized, often with inclusions of fine-crystalline gypsum. Clay minerals include hydromica, montmorillonite, or mixture of these minerals. The depth is 0.5-16.0 m and altitudes from 6.3

m to 172.7 m. The thickness is 0.5-13.5 m, mainly 3-10 m. The highest thickness is noted in the south-western part of territory and in places where the second and third over-flood terrace sediments are developed, at the lower hypsometric levels. Buzkiy climatolith is one of the thickest Neo-Pleistocene loess horizons.

Dofinivskiy climatolith /eP_{III}df/ consists of eluvial sediments including hydromorphic and automorphic former soils. Hydromorphic former soils are developed after estuary-lake sediments of the first over-flood terrace whereas automorphic ones are developed in sub-aerial cover of the second, third and fifth over-flood terrace and Eo-Pleistocene – Early Neo-Pleistocene deltaic plain. The rocks include reddish-brown, brown, brownish-grey, dark-grey, heavy, medium, in places light, dense, porous, carbonatized loams. The clay fraction consists of montmorillonite and hydromica. In the southern part of territory two soils are often observed in the column: the upper reddish-brown and lower brownish-grey or dark-grey. In the outcrops of Yalpug lake right bank (to the north of Plavni village) one can observed the gradual layering of brownish-grey Dofinivskiy soil, firstly for three former soil horizons consisting (from bottom to top) of dark-grey, brownish-grey and light-brown loams. Then the soil horizons do split into the upper light-brown and lower dark-grey ones, and the grey-pale loam interbed gradually appears in between. The thickness of Dofinivskiy climatolith increases respectively. The depth is 0.5-11.0 m and altitudes from 7.5 to 173.3 m. The thickness is 0.2-6.3 m, mainly 1.0-2.5 m.

Prychornomorskiy climatolith /vdP_{III}pč/ consists of aeolian-deluvial pale, yellowish-pale, in the upper column part brownish-pale, mainly light, rarely medium, dense, porous, carbonatized loams, in places gypsumized. Often in the middle part of loess-like loams 1-2 horizons observed composed of weakly-expressed soils, light-grey and grey-brown, 0.2-0.7 m thick, extensively carbonatized in the lower part. In composition they almost do not differ from other Pleistocene climatoliths. Clay minerals include hydromica and montmorillonite. Aleurite-sand fraction (0.01-0.25 mm) includes the following minerals: light fraction – quartz (up to 90%), feldspars, muscovite, flints; heavy fraction – garnet, ilmenite, tourmaline, leucoxene, staurolite, rutile, zircon, chlorite, pyrite, kyanite, biotite, amphibole, magnetite, epidote, sphene, iron and manganese hydroxides, and rock fragments.

Prychornomorskiy climatolith is most developed of all Neo-Pleistocene climatoliths; with the blanket it covers sediments of the first over-flood terrace, Dofinivski alluvial-deluvial and eluvial sediments, on the slopes – older Neo-Pleistocene rocks. It is overlain by Holocene eluvial and eluvial-deluvial sediments. The depth is 0.1-2.5 m and altitudes from 3.5 m to 175.2 m. The thickness is 1.0-12.5 m, mainly 3-7 m. Together with Buzkiy climatolith it is one of the thickest Neo-Pleistocene loess horizons.

Trubizkiy ledge. Alluvial sediments of the third over-flood terrace /a^3P_{III}tb/ are developed in the southern part of territory, in between Kagul and Yalpug lakes, in the area of Nagirne and Orlovka villages. They are intersected by numerous drill-holes. The rocks lie over Lower Pliocene clayey sequence, Upper Miocene terrigenous-clayey sequence, and Upper Miocene Dunayska Suite chlidolites. They are overlain by estuary-lake sediments of the same terrace. The footwall altitudes vary from -17 m to -36 m. The hanging-wall altitudes vary from -11.4 m to -32.2 m. The depth is from 35.0 to 63.5 m. Thickness is 1.2-22.5 m.

Alluvial sediments include mica-quartz, mica-flint-quartz, light-grey, blue-grey, from fine- to diverse-grained sands, clayey in the upper part and with flint and quartz gravel and pebble in the lower part. The iron hydroxides often occur making sands ocher-yellow, brown. Higher in the column alluvial sediments are gradually replaced by the estuary-lake ones.

Prylutskiy climatolith. Estuary-lake sediments of the third over-flood terrace /lml^3P_{III}pl/ are developed in the southern part of territory in between Kagul and Yalpug lakes, in the area of Nagirne and Orlovka villages. Terrace is well geomorphologically expressed and comprises almost flat table gently descending from the north to south. The rocks are intersected by numerous drill-holes and exposed in the eastern bank of Kagul lake. The sediments lie over alluvial rocks of the same terrace and are overlain by all aeolian-deluvial and eluvial climatoliths from Udayskiy to Holocene, or Dofinivski alluvial-deluvial and estuary-lake sediments. The non-eroded hanging-wall altitudes vary from 2.5 to 17.2 m descending in the southern and western directions. The depth is from 21.8 to 34.5 m. The thickness attains 10.0-31.3 m. The total thickness of estuary-lake and alluvial sediments of the third over-flood terrace is 25-40 m and the highest values are observed in the southern part of their distribution area.

Estuary-lake sediments mainly include grey, dark-grey, yellowish-grey, blue-grey, greenish-grey, carbonatized clays, in places sandy, aleuritic, with orange-brown and films of iron hydroxides and black manganese hydroxide dendrites. Often the clays contain lenses and interbeds of quartz, mica-quartz, fine-grained, clayey sands and clayey, yellowish-grey, blue-grey, dense aleurites with iron hydroxides. In places the clays are replaced by aleurites by strike. The clays by mineral composition are hydromica-montmorillonite and chlorite-hydromica-montmorillonite, with admixture of quartz, feldspar, mica, calcite, dolomite grains.

In the upper column parts 1-2 horizons of brown or brown with reddish shade hydromorphic former soils are observed. The soils are developed after estuary-lake clays and clayey aleurites, as well as after pale, grayish-pale and dark-grey loams, which occur at the top of sediments, replace clays and aleurites, and comprise the high flood-land and deluvial fan sediments.

In the estuary-lake sediments the following remnants are determined: molluscs – *Lithoglyphus naticoides* C. P f e i f., *Unio sp., VaWatapiscinalis* M u l l ., *Anodonta sp., Paludina sp., Viviparussp.*; ostracoda *Cyclocypris triangula* N e g ., *Ilyocypris bradyi* S a r s ., *Il. aspera* N e g ., *Il. gibba* (R a m d .), *Cypria elongata* S c h n., *Candona Candida* (M u l l .), *C. neglecta* S a r s ., *Candoniella albicans* (B r .), *C. subellipsoida* S c h a r ., *Caspia candonaeformis* (S c h w .) [21, 23, 46]. Occurrence of saline-water molluscs and ostracoda suggest for connection with sea basin. Apparently, estuaries were forming in the given area in Middle and Late Neo-Pleistocene during sea transgressions which subsequently, under regressions, became closed basins and underwent desalination.

Estuary-lake sediments are overlain by Udayskiy climatolith which lies over these rocks without stratigraphic interruption. The contacts of Udayski loess-like loams with underlaying hydromorphic soils are gradual, the surface of the third over-flood terrace sediments beneath Udayski loams is flat, without evidences for erosion, and thickness and column of overlaying eluvial and aeolian-deluvial loams are persistent. Thus, the age of described estuary-lake sediments is determined by the authors to be Prylutskiy.

Vilshanskiy ledge. Alluvial sediments of the second over-flood terrace /$a^2P_{III}vl$/ are developed in the south-eastern part of territory, in the western bank of Yalpug lake, in 3 km to the north from Plavni village and in between Yalpug and Kotlabukh lakes. The rocks are intersected by numerous drill-holes and exposed in the banks of Yalpug lake. The sediments lie over Lower Pliocene clayey sequence, Upper Miocene terrigenous-clayey sequence, Eo-Pleistocene and Lower Neo-Pleistocene rocks, and are overlain by estuary-lake sediments of the same terrace. The footwall altitudes vary from +4.0 to -47.4 m descending in the southern direction. The hanging-wall altitudes are from -25.2 m to +16.5 m. The depth is from 10.2 m on the slopes to 51.2 m at the watershed plains. The thickness is 1-24 m.

Alluvial sediments include quartz, mica-quartz, grey, light-grey, yellowish-grey sands, from fine- to diverse-grained, in the lower part with flint, quartz, limestone, sandstone gravel and pebble up to 5-6 cm in size. In places intercalation of diverse-grained sands with sand-gravel sediments is observed. The banding types are quite variable: horizontal, oblique, wavy, and in places intercalation of various banding types is noted. In the upper column parts the sands are always fine-grained, clayey. Higher in the column alluvial sediments are gradually substituted by estuary-lake rocks.

Vytachivskiy climatolith. Estuary-lake sediments of the second over-flood terrace /$lml^2P_{III}vt$/ are developed in the south-eastern part of territory, in the western bank of Yalpug lake, in 3 km to the north from Plavni village and in between Yalpug and Kotlabukh lakes. The terrace is almost everywhere geomorphologically expressed and in view of its distribution contour it comprises Yalpug and Katlabukh lakes and Danube River terrace. The rocks are intersected by numerous drill-holes and exposed in Yalpug lake banks. They lie over alluvial sediments of the same terrace and actually everywhere are overlain by the sediments of Buzkiy, Dofinivskiy, Prychornomorskiy and Holocene climatoliths. The hanging-wall altitudes vary from 0.4 m to 27.0 m descending towards the modern cuts. The depth is from 0.4 m on the slopes to 21.4 m at the watershed plains. The thickness is 5-39 m. The total thickness of estuary-lake and alluvial sediments of the second over-flood terrace varies from 10 m to 57 m and the highest values are observed in the southern part of their distribution area.

Estuary-lake sediments are mainly composed of grey, yellowish-grey, greenish-grey, carbonatized, in places aleuritic, sandy clays with brown, ocher-yellow iron hydroxide spots and manganese hydroxide dendrites. The clays contain lenses and interbeds from 0.3 to 4.0 m thick of clayey, grey, blue-grey aleurites and quartz, mica-quartz, light-grey, yellowish-grey, mainly fine-grained sands, and in places lenses and interbeds of sand-gravel sediments up to 0.5 m thick are observed. In the upper column part, in outcrops, the gradual substitution of clays and aleurites by pale, brownish-pale, grayish-pale loams of sub-aerial appearance. Towards terrace back sutures the loam interbeds become more persistent by strike, their amount increases and the upper part of estuary-lake clays, sands and aleurites is gradually substituted by pale, grayish-pale, brownish-pale, greenish-pale loams, in places with admixture and thin interbeds of sand, somewhere horizontally-banded, with fauna, and with 1-3 horizons of hydromorphic former soils consisting of clays and medium, heavy, brown, light-brown, reddish-brown loams. Clay minerals in clays, loams and aleurites include montmorillonite and hydromica. Aleurite-sand fraction is mainly of quartz composition, and admixture of flint, feldspars, mica, iron and manganese hydroxides, and rock fragments is observed. The heavy fraction minerals in minor amounts include garnet, ilmenite, tourmaline, leucoxene, staurolite, rutile, zircon, chlorite, kyanite, amphibole, magnetite, epidote, celestine, sphene; in addition, pyrite, sillimanite, apatite and monazite are noted in the single grains.

In the outcrop of second over-flood terrace in the west bank of Yalpug lake, in 5 km to the south from the southern outskirt of Kotlovyna village, K.D.Mykhaylesku had determined the Late Neo-Pleistocene mollusc fauna complex: *Didacna danubica* M i h ., *D. cf. ultima* P p v ., *Dreissena polymorpha* P a l l ., *Hypanusplicatus*

(E i c h w .), *Valvata piscinalis* M u l l . , *Viviparus fasciatus* M u l l . , *Viviparus ex gr. fasciatus* M u l l . , *Coretus corneus* L., *Lymnaea stagnalis* L.

In 3 km to the south of Ozerne village L.A.Chepalyga and K.D.Mykhaylesku had determined the age of fauna found to be Late Neo-Pleistocene: molluscs – *Corbiculafluminalis* M u l l . , *Viviparus fasciatus* M u l l . , *Viviparus contectus* M i l . , *Dreissena polymorpha* P a l l . , *Valvata piscinalis* M u l l . , *Lithoglyphus naticoides* C. P f e i f., *Unio pictorum* L., *Unio tumidus* R e t z . , *Theodoxus danubialis* C. Pf., *Sphaerium rivicola* L e a c h . , *Fagotia esperi* F e r . , *Pisidium amnicum* M u l l . , *Didacna poratica* M i h . , *D. cf. danubica* M i h . , *D. cf. uzunlarica* M i h . , *Anodonta piscinalis* M u l l . , *Coretus corneus* L., *Planorbis planorbis* L., *Lymnaea stangnalis* L.; and the fine mammals – *Arvicola ex gr. terrestris* L a c e p e d e , *Microtus ex gr. arvalis* P a l l . , *Microtus sp.* [48].

Ostracoda include the following types: *Ilyocypris gibba* (R a m d .), *Il. bradyi* S a r s . , *Candoniella subellipsoida* (S h a r.), *C. albicans* (B r .), *Cytherissa bogatschovi triformis* L i v . , *C. lacustris* S a r s . , *Hemicytheria sicula* (B z .), *Candona neglecta* S a r s . , *Cypria candonaeformis* (S c h w.), *Trachyleberis pseudoconvexa* (L i v .), *Caspiola gracilis bacuana* Z u b . , *Cyprideis littoralis* B r . , *Darvinula stevensoni* (B r . e t R o b .) [22].

Estuary-lake sediments are overlain by Buzki loams without stratigraphic interruption, without erosion, and therefore the age of these sediments are defined by the authors to be Vytachivskiy.

Desnyanskiy ledge. Alluvial sediments of the first over-flood terrace /$a^1P_{III}ds$/ are confined to the modern large erosion cuts and respectively developed along Danube River valley and by the banks of Kagul, Yalpug and Katlabukh lakes. The rocks are intersected by numerous drill-holes and exposed in cliffy banks of lakes, big gullies and Danube River. The sediments with erosion lie over Upper Miocene terrigenous-clayey sequence, Prydunayska Suite and Lower Pliocene clayey sequence, Upper Pliocene terrigenous-clayey sequence, and the older Neo-Pleistocene sub-aqueous sediments. At the watershed plains the rocks are overlain by estuary-lake sediments of the same terrace or the loess-like loams of Prychornomorskiy climatolith, and on the slopes – by Holocene sediments of various genetic types. The socle altitudes vary from -31.9 m to +41.0 m descending in the southern direction. The hanging-wall altitudes vary from -32.3 m in the south to +54.4 m in the north. The depth is from 0.3 m on the slopes to 40 m at the watershed plains. The thickness is 1.0-27.5 m.

Alluvial sediments include feldspar-quartz, flint-quartz, often with mica, fine-, medium-, coarse- and diverse-grained sands, often with admixture and interbeds of gravel and pebble; sand-gravel sediments; gravelites. Gravel and pebble composition: flint, quartz, aleurolites, sandstones with carbonate cement. The rounding is variable, prevailing grain size is from 1 mm to 5-6 cm. In the upper part of alluvial sediments the sands are mainly fine-grained, clayey, with clay and clayey aleurites interbeds. In the outcrops the horizontal and oblique banding is observed and in places large carbonate nodules of sandstones are noted. The heavy mineral fraction (0.1-0.5 mm) consists of garnet, ilmenite, tourmaline, leucoxene, staurolite, rutile, chlorite, pyrite, kyanite, sillimanite, apatite, biotite, amphibole, magnetite, epidote, monazite, celestine, sphene, and iron hydroxides. Higher in the column alluvial sediments are gradually substituted by estuary-lake rocks.

Dofinivskiy climatolith. Estuary-lake sediments of the first over-flood terrace /$lml^1P_{III}df$/ are confined to the modern large erosion cuts and developed respectively along the Danube River valley and by the banks of Kagul, Yalpug and Katlabukh lakes. Terrace is almost everywhere well expressed geomorphologically in the flat or gently inclined towards the modern cuts tables up to 2-3 km wide in the area of Lymanske, Orlovka, Novosilske, Plavni, Vladychen, Novonekrasivka, Kosa, Krynychne villages. The rocks are intersected by numerous drill-holes and exposed in the cliffy banks of lakes, big gullies and Danube River. They lie over alluvial sediments of the same terrace. At the watershed plain the rocks are overlain by loess-like loams of Prychornomorskiy climatolith and on the slopes – by Holocene rocks of various genetic types. In the outcrop in 3 km to the north of Plavni village and in the outcrop in 1.5 km to the north of Novonekrasivka villages the contacts between the first and second over-flood terraces have been observed. In the right bank of Kagul lake, in some outcrops to the north from Lymanske village the contacts between the first over-flood terrace and Eo-Pleistocene – Lower Neo-Pleistocene deltaic plain have been observed. The hanging-wall of these sediments is located at various hypsometric levels because of irregular neo-tectonic and modern tectonic uplift of the territory. The minimum uneroded hanging-wall altitude is -0.5 m in the south and slowly ascends in the northern direction to +37.5…+40 m. To the north of Vladychen village the sediments hanging-wall relative sharply ascends to +50…+55 m. However, estuary-lake and alluvial sediments of the first over-flood terrace are preserved in the small remnants over there which are not expressed in the map scale. The depth is from 0.3 m on the slopes up to 13.5 m at the watershed plains. The thickness is 4-29 m. The total thickness of estuary-lake and alluvial sediments vary from 3.8 to 49.6 m increasing in the southern direction.

Estuary-lake sediments are mainly composed of grey, light-grey, greenish-grey, yellowish-grey, blue-gray, in places aleuritic, sandy clays, and mica-quartz, grey, ash-grey, blue-grey, yellowish-grey, dense, clayey aleurites. The rocks are often carbonatized and contain brown, orange-brown iron hydroxide spots. In places estuary-lake sediments consist of quartz, fine-grained, clayey, grey, yellowish-grey sands or alternating sands, clays and aleurolites described above. Towards terrace back sutures clays and aleurites are gradually substituted by pale, brownish- and grayish-pale, dense, porous, carbonatized in place horizontally-banded loams with sand interbeds and shell detritus. The clays in composition are hydromica-montmorillonite, hydromica with admixture of chlorite, kaolinite, calcite, dolomite, gypsum, siderite. The column of estuary-lake sediments is completed with the former hydromorphic soils, which in the southern of map sheet are locally developed and thin, but towards terrace back sutures the number of horizons increases up to 4. The former soils are brown, grayish-brown, dark-grey, almost black. They consist of clays or medium and heavy loams depending on the rocks they are developed from. In the outcrops to the north of Plavni and Novonekrasivka villages the facial substitution of the first over-flood terrace sub-aqueous sediments by Dofinivski alluvial-deluvial and eluvial sediments is observed indicating the time and forming conditions for the upper part of estuary-lake sediments at least.

In the outcrops in Kosa, Plavni and Lymanske villages, in the upper part of estuary-lake sediments the Upper Neo-Pleistocene molluscs are determined: *Planorbisplanorbis* L., *Planorbis sp., Coretus corneus* L., *Didacna sp., Dreissena polymorpha* P a l l . , *Litoglyphus naticoides* C . P f e i f . , *Fagotia esperi* F e r., *Viviparus fasciatus* M u l l . , *V. contectus* M i l., *Valvata piscinalis* M u l l . , *Hellicella striata* L. (determinations of K.D.Mykhaylesku) [48].

The authors accept the age of estuary-lake sediments to be Dofinivskiy. These rocks everywhere without stratigraphic interruption are overlain by Prychornomorski loess-like loams, contain black and dark-grey hydromorphic soils, which are not typical for the older climatoliths, and Late Neo-Pleistocene mollusc fauna in estuary-lake sediments.

Dofinivskiy climatolith. Alluvial-deluvial sediments of gullies, ravines, valley slopes and proluvial-deluvial fans /adP_{III}df/ are developed along the modern slopes of gullies, ravines, minor river valleys, Danube River, and lakes. Often these sediments are expressed geomorphologically in relief where they constitute gentle (0.5-3^o) inclined Upper Neo-Pleistocene slopes; in places where modern erosion-denudation processes are active these sediments are not expressed in the relief and on the steep slopes are eroded at all or are quite locally developed and thin making unable their indication in the scale of map and cross-sections. The rocks are intersected by numerous drill-holes and exposed in many places over entire territory. The sediments lie with erosion over older Neo-Pleistocene, Eo-Pleistocene, Neogene rocks and Lower Carboniferous Orlovska Suite schists. The rocks are overlain by loess-like loams of Prychornomorskiy climatolith or Holocene eluvial-deluvial sediments. These rocks are facially replaced by the first over-flood terrace sediments. The thickness varies from 0.2 m to 36.0 m, mainly 5-25 m. The footwall altitudes are -20.8…+138.5 m descending in the southern direction. The hanging-wall altitudes are from 0.5 m in the south to 163.1 m in the north. The depth is from 0.1 m on the slopes to 13.0 m at the watershed plains.

Composition of alluvial-deluvial sediments depends on the rock lithology underwent erosion but in general they in consist of brownish-pale, grayish-pale, rarely yellowish-pale, reddish-brown, dense, porous, carbonatized loams, often with horizons (up to 5-6) of weakly expressed grey, brown and brownish former soils. Often loams contain significant admixture and interbeds of quartz sands, flint and quartz gravel and fauna fragment inclusions. In the lower part and by strike at the contacts with estuary-lake sediments the loams can be substituted by pale, grey, greenish- and blue-grey aleurites with clayey cement, often with ocher iron hydroxide spots, in places horizontally-banded, which, in turn, are substituted by the sands or sand-gravel-pebble sediments, in places horizontally- and oblique-banded. The sands are flint-quartz, feldspar-flint-quartz, often with mica admixture, grey, yellowish-grey, pale-yellow, normally non-sorted, diverse-grained, clayey. Gravel and pebble consist of quartz, flint, sandstone with carbonate cement, and carbonate nodules. The fauna is determined in the basal layers and in age does correspond to the rocks underwent erosion.

Alluvial-deluvial sediments with erosion lie over loess-like loams of Buzkiy climatolith and are overlain by Prychornomorski loess-like loams. Their transition into Dofinivski estuary-lake facies of the first over-flood terrace is gradual and footwall does not descend below the footwall of estuary-lake sediments. By these reasons the authors do think that these sediments have been formed in Dofinivskiy time.

Upper Neo-Pleistocene – Holocene

Alluvial sediments /aP_{III}-H/ are developed in the south of studied territory, constitute Danube River flood-land, and underlie Holocene estuary-lake sediments of Kagul, Yalpug, Kugurluy, Katlabukh lakes. They are intersected by numerous drill-holes. With erosion they lie over Neogene rocks and Orlovska Suite schists. The thickness varies from 0.3 to 71.0 m, mainly 10-60 m. The hanging-wall altitudes vary from +2.5 m in Danube River flood-land to -42 m at the lake bottoms; the footwall altitudes are from -3 m to -67 m. The column is composed of (from top to bottom): brownish-pale, light-grey, medium and heavy, lumpy loams with plant roots, up to 2 m thick; mica-quartz, clayey, grey, ash- and blue-grey aleurites, with orange-yellow iron hydroxide spots, in places horizontally-banded, with lenses and interbeds of blue-grey, fine-grained quartz sands from 1 mm to 10 m thick; quartz, mica-quartz, mica-flint-quartz, grey, blue-grey, yellowish-grey, aleuritic, clayey, from fine- to diverse-grained sands with flint and quartz gravel and pebble, with up to 13 m thick lenses and interbeds of sand-gravel-pebble sediments and blue-grey and grey clays. Heavy mineral fraction (0.01-0.5 mm) includes garnet, ilmenite, tourmaline, leucoxene, pyrite, kyanite, sillimanite, apatite, biotite, amphibole, magnetite, epidote, iron hydroxide. The sands constitute alluvial facies whereas clays, loams and aleurites – the flood-land one.

The following mollusc complex is determined in the rocks: *Didacna cf. pseudocrassa* P a v l., *Corbiculla fluminalis* M u l l., *Dreissena polymorpha* P a l l., *Valvata piscinalis* M u l l., *Lithoglyphus naticoides* C. P f e i f., *Lithoglyphus neymayri* B r u s., *Lithoglyphus sp., Monodacna caspia* E i c h w., *Monodacna sp., Fagotia esperi* F e r r., *Fagotia sp., Sphaerium rivicola* L e a c h., *Theodoxus sp., Bithynia sp., Valvata sp., Planorbis sp., Unio sp, Vtviparussp.,* as well as ostracoda: *Cypria elongata* S c h n., *Candoniella subillipsoida* S c h a r., *Candoniella albicans* (B r.).

Holocene division

Estuary-lake sediments /lmlH/ are developed in the southern part of territory and also constitute the bottom of modern lakes. They lie over Upper Neo-Pleistocene – Holocene alluvial sands and aleurites and facially substitute the latter. The highest thickness is 46 m. The hanging-wall altitudes vary from 2.5-5 m in the south to 5-12 m in the north. The lowermost footwall altitude is -43 m. The rocks are intersected by drill-holes and exposed in outcrops by the left bank of Yalpug lake, in the areas of Topolyne, Oksamytne villages and Bolgrad town. Relatively high hanging-wall altitude of Holocene estuary-lake sediments in the northern part of territory is caused by the modern territory tectonic uplifting providing multi-phase cuts development in Holocene time. The rocks exhibit mixed lithology with alternating loams, clays, sands, aleurites, muds, shells.

L o a m s are dark-grey, pale, brownish-pale, heavy and medium, with interbeds of diverse-grained sands with detritus, occur in the upper column part in places adjoining the slopes, and comprise alluvial-deluvial sediments of the valley slopes. Thickness is 0.6-5.0 m.

C l a y s are grey, pale-yellow, dark-grey, black, blue-grey, greenish-grey with orange-yellow and brown iron hydroxide spots, dense, viscous, lumpy, banded, in places aleuritic, sandy, carbonatized, with lenses and interbeds of peat, clayey aleurolites, fine-grained quartz sands. After thermal analysis data, clays are hydromica with montmorillonite in composition.

A l e u r i t e s are quartz, grey, blue-grey, with orange-yellow iron hydroxide spots, clayey, dense, carbonatized.

M u d s are dark-grey, almost black, soft, in places sandy.

Sands are quartz, light- and blur-grey, yellow, strew, in places clayey, from fine- to diverse-grained, with quartz, flint and shell gravel and pebble. The rocks are observed in the lenses and interbeds up to 10 m thick, and also in the coastal part of estuary-lake sediments.

The following mollusc complex is determined in the rocks: *Dreissena polymorpha* P a l l., *Fagotia esperi* F e r r., *Lithoglyphus naticoides* C. P f e i f., *Theodoxus danubialis* C. Pf., *Valvata sp., Planorbis sp., Unio tumidus* R e t z., *Unio sp., Viviparus cf. fasciata* M u l l., *Paludina sp., Corbicula sp.*, and also ostracoda: *Ilyocypris gibba* (R a m d), *Il. bradyi* S a r s., *Il. aspera* N e g., *Il. gibba var. nistruensis* N e g., *Cyclocypris globosa* S a r s., *Candoniella albicans* (B r)., *Leptocythere bacuana* Z i v., *L. pediformis* S c h o r., *Candona neglecta* S a r s., *Caspiolla gracilis var. bacuana* Z u b., *Cyprideis sp.*

Alluvial sediments /aH/ are developed in the minor river valleys: Karasulak, Tashbunar, Velykiy and Maliy Katlabukh; the rocks are intersected by drill-holes. With erosion they lie over Neogene rocks and facially substitute Holocene estuary-lake sediments. The column (from to to bottom) includes: pale, grayish- and brownish-pale, dark-grey, medium, heavy, dense loams; grey, greenish- and blue-grey, yellowish-grey, aleuritic, sandy, dense, viscous clays; clayey, grey, greenish- and blue-grey, yellowish-grey, sandy, dense aleurites; mica-quartz, yellowish-grey, aleuritic, clayey, mainly fine-grained sands with re-deposited shell detritus. Transitions between the rocks are almost always gradual. It should be noted that this column structure is not uniform and various rock combinations are observed although at the column bottom relatively coarser-grained sediments are always developed. The thickness is 4.0-18.3 m, mainly 10-15 m. The hanging-wall altitudes vary from 5 to 89 m, the footwall ones – from -9.3 to 84.0 m.

Alluvial-deluvial sediments /adH/ constitute the bottom and lower slope parts in gullies and ravines; they facially substitute Holocene alluvial and estuary-alluvial sediments. The rocks are intersected by numerous drill-holes. They are variable in lithology and typically not sorted. In the gully upper courses, where alluvial-deluvial sediments overlie Neo-Pleistocene sub-aerial eluvial and aeolian-deluvial rocks, the loams predominate in composition, pale, brownish- and grayish-pale, dark-grey, light, medium, heavy, dense, porous, carbonatized.

Down the course, where gullies cross Neogene and Quaternary sandy-clayey rocks, composition of alluvial-deluvial sediments changes respectively. In the upper column parts they consist of pale-yellow, brownish-yellow, dark-grey loams or grey, black, blue-grey clays with orange-yellow iron hydroxide spots and manganese hydroxide dendrites, in places banded. Lower in the column the loams and clays are gradually replaced by quartz, flint-quartz, brown, grey, yellowish-grey, from fine- to coarse-grained sands with flint, quartz, carbonate gravel and pebble. The thickness of sediments varies from 0.4 m in the upper gully courses to 24.4 m in the mouths. The hanging-wall altitudes are from 5 m in the south to 165 m in the north. The minimum footwall altitude -19.4 m is positioned below the footwall altitude of the even-aged alluvial and estuary-lake sediments indicating their Holocene age.

Deluvial sediments /dH/ do cover river valley, ravine, and lake slopes more then 3^{o} steep. Lithology completely depends on the rock composition involved in denudation and removal. In the upper and middle slope parts the upper portion of modern black-earth is being removed and deluvial sediments mainly consist of re-deposited Holocene soils, in places with admixture of sands and carbonate nodules, somewhere thin-banded, friable (eluvial-deluvial sediments). Their thickness is 0.1-0.5 m. In view of low thickness and throughout development on the slopes, Holocene eluvial-deluvial sediments, like eluvial ones, are omitted from the map of Quaternary sediments. In the lowermost slope portions thickness of deluvial sediments is increased, except re-deposited black-earth (visible thickness up to 4 m), and they consist of light-brown, brownish-pale, brown, yellow-brown, light, medium, heavy, lumpy, thin-banded, friable loams with admixture, lenses and interbeds of sands, clays, and sand-gravel sediments. Gravel consists of flint, quartz, and carbonate nodules. Thickness of deluvial sediments in the lower slope parts varies from 1.2 to 9.0 m. They are observed everywhere in the narrow band up to 50-100 m wide along the slope foothills but in the map scale are not expressed and only shown together with alluvial-deluvial sediments.

Deluvial-coluvial sediments /dcH/ are developed on the steep gully, lake, ravine land-slide slopes (more than $8\text{-}10^{o}$). In the map of Quaternary sediments the objects are shown which are expressible in the given map scale. In the upper land-slide parts retained succession of layers is observed, mainly sandy-clayey sediments of Quaternary terraces and Upper Miocene terrigenous-clayey sequence. The lower land-slide part is destroyed and composed of friable non-sorted rocks – mixture of clays, loams, aleurites, sands, gravel, pebble, and modern black-earth. Land-slides are active and stabilized, overlain by deluvial sediments, consisting of dark-grey, pale-brown, reddish-brown loams, often with admixture of sand, gravel and pebble of flint, quartz, and carbonates. Visible thickness of deluvial-coluvial sediments is up to 10 m.

Proluvial-deluvial sediments /pdH/ are developed at the foothills of large gully and minor river valley slopes eroded with ravines. Removal of sandy-clayey material is being driven by temporary flows from the minor gullies and ravines and deposition in the cones where proluvial-deluvial fans are being formed consisting of mainly unsorted rocks – mixture of loams, clays, aleurites, sands, gravel and pebble, with one or another variety predomination. Rock color is brownish-pale, grayish-pale, grey, dark-grey. They are distinguished by geomorphologic evidences and airborne image deciphering. In the map the objects are shown which are expressible in the given map scale.

Fan proluvial sediments /pH/ are distinguished after geomorphologic observations and airborne image deciphering in the mouths of major gullies adjoining Kagul and Yalpug lakes. The rocks overlie Holocene estuary-lake sediments and consist of unsorted, grey, dark-grey, blue-grey aleurites-sand-clayey rocks with brown iron hydroxide spots and detritus admixture as well as flint and quartz pebble. Thickness is up to 4.5 m.

Holocene eluvial and eluvial-deluvial sediments /e,edH/ include modern soils developed everywhere and lacking at the steep slopes where they are removed by temporary flows. The rocks contain humus material, salt films and veinlets, carbonate nodules, numerous mole and worm passes. In the upper part the rocks are normally dark-grey, almost black, sandy-light-loamy and dusty-heavy-loamy, friable, lumpy, with plant roots. Deeper the soils become lighter and dense. Most dense soils with highest thickness and heavy “grain size” are observed in the river flood-lands, lakes, and gully bottoms. Granulometric composition of modern soils is related to the soil-forming rock. The humus content is 1.41-3.58%, carbonate 2.3-9.3%. After thermal analysis, the soils consist of mixture of hydromica, quartz, organic material, iron oxides, carbonates, minor montmorillonite. Thickness of Holocene soils is from 0.1 to 2.5 m, mainly 0.5-1.0 m.

Technogenic sediments /tH/ are related to the modern human activities and divided into large-planar, low-planar and linear. The large-planar one are observed in the towns and other inhabited localities whereas low-planar – at the landfills, filled quarries, cemeteries, strews for water-pump stations. The linear ones constitute railroad and motor-way strews, filled trenches, grooves, pond dams, Troyaniv arch. These are composed of displaced material of modern soil, Quaternary loams, clays, sands, Quaternary and Neogene limestones. Thickness is 0.5-5.0 m.

3. NON-STRATIFIED UNITS

Geological development succession of non-stratified units in the studied area is as follows:

M e s o z o i c   E r a
***Triassic Period* (T)**

T_3*fr* – Ferapontievskiy complex of minor intrusions

P a l e o z o i c   E r a
***Carboniferous Period* (C)**

C_{1-2} – association of hydrothermal-vein rocks
C_{1-2}*dl* – Dolynskiy complex (sk)[1]
C_1*rn* – Reniyskiy complex

P r e c a m b r i a n

Archean – Lower Proterozoic undivided (AR-PR_1)

AR-PR_1*sv* – Suvorovskiy complex
(see legend to "Geological map of pre-Cenozoic units").

Precambrian

Archean – Lower Proterozoic undivided

Suvorovskiy complex (AR-PR_1*sv*)

The oldest rocks in the studied area are those constituting crystalline basement in the south-western margin of Eastern-European Platform (EEP) including undivided Archean – Early Proterozoic ultra-metamorphic rocks. In the studied area the rocks of Suvorovskiy complex are only intersected by few drill-holes in the northern part of territory, in the area of Bolgrad town, Chervonoarmiyske, Gorodne, Vynogradne, Zadunaivka and Suvorove villages. The rocks constituting EEP basement are intersected by the following drill-holes: 1B [21, 42] (Bolgrad town) at the depth 1125-1704 m; 4rS [21, 42] (Suvorove village) at the depth 3332-3434 m; 1CH [21, 42] and 2CH [21, 42] (Chervonoarmiyske village) at the depth 3414-3500 m and 3474-3661 m; R 1P [21, 42] (Gorodne village) at the depth 3407-3518 m. In addition, outside the map sheet area two more wells are drilled which had intersected EEP crystalline basement rocks – 1r [42] (Vynogradne village) at the depth 1739-1987 m and 3r [42] (Zadunaivka village) at the depth 2800-2920 m (see "Geological map of pre-Jurassic rocks" in the scale 1:500 000 and cross-section A_1-A_3 to "Geological map of pre-Cenozoic units").

Archean – Lower Proterozoic rocks of crystalline basement include biotite and in lesser extent amphibole-biotite plagiogranites developed in the north-western, northern and partly central parts of Suvorovskiy dome (well known from publications as "Gorikhivska" straight arch) comprising major tectonic unit of pre-Riphean folded complex in the area. In the part of this structure, bounded from the north-east by Chadyr-Lungskiy, and from the south-west by Bolgrad-Suvorovskiy faults, the rocks of Precambrian folded complex are essentially "uplifted", do not have Paleozoic cover, and are exposed at pre-Jurassic surface (see cross-section to "Geological map of pre-Cenozoic units").

In DH 1CH, 2CH [21, 42] (Chervonoarmiyske village) and R 1P [21, 42] (Gorodne village) the rocks of Suvorovskiy complex are exposed at pre-Jurassic surface and are overlain by Middle Jurassic Andrushynska Suite; in DH 1B [21, 42] (Bolgrad town) Precambrian rocks are overlain by Vendian Mogyliv-Podilska Series; in

[1] sk - skarns

DH 4rS [21, 42] (Suvorove village) the folded complex rocks are overlain by Vendian and Lower Cambrian sediments and are not exposed at pre-Jurassic surface.

The maximum thickness of Archean – Lower Proterozoic rocks intersected by drill-holes is 582.0 m (DH 1B [21, 42], Bolgrad town). The hanging-wall altitudes vary from -1024 m to -3348 m. Thus, elevation difference is 2324 m indicating significant amplitude of vertical motions caused mainly by descending movements of single geological blocks at the stage of Jurassic trough development.

The rocks of pre-Riphean folded complex are also developed to the north from Chadyr-Lungskiy fault zone where they constitute the basement of Moldavska plate and are intersected by numerous drill-holes. Specifically, DH R 20VP [21, 42] located in this structure in the territory of map sheet L-35-XXIII (Izmail) is stopped in Vendian rocks and not reached crystalline basement rocks.

Most typical Archean – Lower Proterozoic rocks include biotite plagiogranites transitional to adamellites with low potassium feldspar content; these ones are intersected by DH 1B [42] (Bolgrad town), 2CH [21, 42] (Chervonoarmiyske village), R 1P [21, 42] (Gorodne village), and DH 1r [21, 42] (Vynogradne village) and 3rZ [42] (Zadunaivka village) located very close to the eastern map sheet border. The second rock type comprises amphibole-biotite palgiogranites and is intersected by the only DH 4rS [21, 42] in Suvorove village area. Below description of major rock types is given.

Biotite plagiogranites are mainly greenish-grey, normally extensively cataclased and with weathering signs. The rock is mainly composed of plagioclase with minor potassium feldspar (60-65%), quartz (25-30%) and biotite (up to 10%). Chemical composition of plagiogranites from DH 1B (Bolgrad town) (%): SiO_2 – 69.02-74.67; TiO_2 – 0.17-0.66; Al_2O_3 – 13.27-15.70; Fe_2O_3 – 0.41-2.98; FeO – 0.62-2.10; MnO – 0.06-0.07; CaO – 0.79-2.73; MgO – 0.63-1.07; K_2O – 1.26-3.76; Na_2O – 1.14-4.45; P_2O_5 – 0.03-0.07; S – traces; SO_3 – traces; CO_2 – 0.32-1.60; H_2O – 0.30-0.16; LOI – 1.21-2.49.

Amphibole-biotite plagiogranites are greenish-grey, full-crystalline. Texture is hypidiomorphic, structure banded caused by alternating relatively light bands mainly composed of quartz and plagioclase, and dark-green or dark-grey bands with increased content of opaque minerals – amphibole and biotite.

Paleozoic Era

Carboniferous Period

Reniyskiy complex

Reniyskiy complex of this age cuts Devonian and Carboniferous. It is composed of *gabbro* ($\nu C_1 m$), *pyroxenites* ($\upsilon C_1 m$), and *kersantite* dykes ($k\chi C_1 m$). Minor gabbro and pyroxenite bodies are intersected by drill-holes 040 (depth 492.5-496.2 m) and 071 (depth 461.6-482.0 m) [48, 42] in the south-western part of territory. They are confined to the southern contact of Dolynskiy intrusive syenite massif with host rocks. Emplacement of gabbro and pyroxenites had occurred in tectonically weakened zone before syenite massif as it is evidenced by gabbro and pyroxenite xenoliths in syenites. These rocks cut Middle-Upper Devonian and Lower Carboniferous sedimentary rocks and contain xenoliths of the latter. Xenoliths are mainly acute-shaped, from 1-3 mm to 1.5-3.0 cm in size. Their content varies from 5-10 to 30-40%. The contacts of gabbro and pyroxenites with host rocks and xenoliths are almost clear, with little (up to 10 mm) zones of shearing and re-crystallization in the endo- and exo-contact portions.

Gabbro ($\nu C_1 m$) is greenish-grey, grayish-green and pinkish-greenish-grey, mesocratic, in places melanocratic, fine-grained, fine-medium-grained, diverse-grained, often microclinized, fractured, cataclased, in places sheared. The rocks are cut by numerous syenite and pegmatite veins and quartz-microcline veinlets; at the contacts with these rocks gabbro are brecciated, sheared and re-crystallized. Structure is massive, in places schistose, breccia-like. Gabbro is composed of plagioclase (10-50%) which corresponds to labrador, and monoclinic pyroxenes (50-90%). In places olivine and hornblende grains and biotite flakes are observed. Texture is gabbroic, hypidiomorphic, in schistose varieties nematoblastic. The contacts between mesocratic and melanocratic varieties are gradual. Plagioclase microclinization processes are widespread in gabbro up to complete substitution by microcline. The latter is often pelitized and occurs in single phenocrysts, bunches, veinlets up to 2-3 cm thick. Chemical composition of gabbro from DH 040 [21, 42] (%): SiO_2 – 43.88; TiO_2 – 0.76; Al_2O_3 – 11.70; Fe_2O_3+FeO – 7.41; MnO – 0.09; MgO – 4.69; CaO – 10.0; Na_2O – 2.01; K_2O – 4.74. By petrochemical parameters from normal gabbro they differ in higher K_2O content and respectively higher for mafic rocks value of Na_2O+K_2O = 6.75, and low serial index ratio Na_2O/K_2O = 0.42, which are caused by the late microclinization, in general related to the emplacement of Dolynskiy intrusive syenite massif.

Petrophysical parameters of gabbro are given in Table 3.1 indicating their low-magnetic high-density properties in comparison with the felsic and intermediate rocks.

Table 3.1. Petrophysical parameters of igneous rocks.

Reference	Rock name	Number of samples	Density – σ, kg/cm^3			Magnetic susceptibility – χ, n×10^{-6} CI units			Residual magnetization – In, n×10^{-3} A/m	
			min.	max.	avg.	min.	max.	avg.	min.	max.
48, 42	Syenite	14	2.56	2.86	2.68	75	9000	2175	6	1150
48, 42	Gabbro	2	2.72	2.88	2.80	56	89	72	1	17
48, 42	Pegmatite	3	2.55	2.63	2.59	2124	3403	2559	243	613
48	Kersantite	3	2.77	2.78	2.78	32	38	36	0	0.7
48	Diabase	9	2.53	2.85	2.72	29	2500	460	0	260

In DH 040 the anomalies of rubidium oxide – 0.024% and lithium oxide – 0.0068%, are related to microclinized gabbro.

Plagioclase pyroxenites (υC$_1$*m*) are greenish-dark-grey, fine-grained rocks, which occur in fine xenoliths, from 0.5 to 5.0 cm in size, in syenites. They are composed of monoclinic pyroxene (90%) and plagioclase (10%). Somewhere in syenites fine (up to 1 cm) pyroxenite xenoliths are observed where monoclinic pyroxene grains are cemented by ore mineral. Chemical composition of pyroxenites from DH 040 (%): SiO_2 – 37.2-39.36; TiO_2 – 0.8-1.17; Fe_2O_3 – 9.76-12.0; MnO – 0.15-0.17; MgO – 8.03-8.74; CaO – 12.61-14.93; Na_2O – 0.28-0.51; K_2O – 0.70-1.11. By petrochemical parameters pyroxenites belong to the rocks under-saturated in silica, increased K_2O content, and respectively low serial number ratio, which may be caused by the different composition of rock-forming minerals, their irregular contents, and secondary alteration related to the influence of Dolynskiy intrusive syenite massif. High mafic coefficient (K_ϕ = 55-58%) may be related to high magnetite content. By the value of alumina coefficient (0.28-0.37) the rocks are classified to be low-alumina.

The age of pyroxenites has been defined on the ground of relationships with host rocks. They cut Middle-Upper Devonian sediments and therefore are younger. From another hand, they are relatively older than syenites of Lower-Middle Carboniferous Dolynskiy intrusive massif.

Kersantites (kχC$_1$*m*). The dykes of kersantites are intersected by drill-holes 036, 077, 1sO [48] and exposed in the quarry in Orlovka village. In DH 036 the rocks are intersected at the depth 288-291 m in a dyke 3 m thick. In DH 077 the dyke is intersected at the depth 187.5 m and 47.5 m are drilled over these rocks up to the depth 235 m. Dyke thickness in Orlovka quarry is from 1.5 to 4.0 m, and in DH 1sO located over there from 0.4 to 1.5 m. On this ground one can assume that drill-hole 077 had followed the dyke by dip. Kersantites everywhere cut Orlovska sequence rocks and are clearly confined to the zones of tectonic breaks resulted in crushing, cataclasm and milonitization of the rocks as well as extensive secondary processes. According to previous observations, kersantite dykes nearby Orlovka village were split into series of blocks which are displaced relatively each other. The contacts of kersantites with host rocks are clear and the rocks are sheared and brecciated at the contacts (see outcrop 100 in the "Geological map of pre-Cenozoic units") [42].

Macroscopically kersantites are grayish-green, greenish-grey, brownish-grey, porphyry-like, with fine-grained groundmass. Phenocrysts consist of feldspars, amphibole and biotite. The groundmass is feldspar, quartz-feldspar. Structure is massive, rarely schistose, breccia-like. The rocks are everywhere cut by diverse-oriented quartz-carbonate, carbonate and quartz-barite veinlets from 0.1 to some centimeters thick. Petrographic description of kersantites at Orlovka village, which is given below, is provided by V.M.Bobrynskiy [2] and is presented briefly.

Microtexture of kersantites is porphyry. Porphyry phenosrysts consist of intermediate plagioclase (0.1-0.8 mm) and biotite (0.5-2.0 mm). Almost all igneous minerals in the rock are completely or partly replaced by secondary minerals. Mineral composition (%): plagioclase – 39, biotite – 31, amphibole – 10, quartz – 13, apatite – 4, fluorspar – 1, magnetite – 2. Secondary minerals: ferrous chlorite, iron-magnesium chlorite, iron-magnesium carbonates, iron hydroxides, sericite, albite and quartz.

Petrophysical parameters of kersantites are given in Table 3.1 indicating the rocks are low-magnetic and exhibit stable physical properties.

In the quarry in Orlovka village the barium, manganese, nickel and chromium anomalies are related to kersantites.

A.K.Boyko had determined the age of kersantites to 290 Ma which corresponds to the end of Carboniferous period [42, 48].

Dolynskiy complex ($C_{1-2}dl$)

In the map sheet territory Dolynskiy complex includes the same-named massif of quartz syenites (qξ) and syenites (ξ); vein derivates – quartz monzonite-porphyries (qμ$C_{1-2}dl$), pyroxene-hornblende syenites (ξ), quartz-microcline veinlets (qmi$C_{1-2}dl$) and microcline, pyroxene-microcline pegmatites (p$C_{1-2}dl$); hydrothermal-metasomatic and metamorphic rocks – skarns and skarned rocks (sk$C_{1-2}dl$), marbles and calciphyres paragenetically linked with Dolynska intrusion (see "Geological map and map of mineral resources of pre-Cenozoic units").

Dolynskiy massif is located in the south-western part of territory to the north from Dolynske and Lymanske villages. The northern part is located outside Ukraine in the territory of Moldova. In the plane the massif is oval-shaped and by its long axis is oriented to the north-east. Dimensions in the studied area are 9.0-9.5×2.0-2.5 km, and square is about 25 km^2. In cross-section this is apparently stock-like body with steep (70-90°) walls. It is intersected by drill-holes 040, 043, 046, 050, 071, 079, 089, 093, 095 [42, 48], 18, 19 [21, 42] (in the course of mapping over Izmail map sheet by Reniyska GEE in 1955) at the depth 440.0-587.7 m beneath Middle Sarmatian and Middle Jurassic sediments. In addition, DH 1u [21, 42] in 3 km to the south from the massif the dykes of pyroxene-hornblende syenites and quartz monzonite-porphyries are intersected in Middle-Upper Devonian carbonate rocks, which in the authors' opinion, are directly related genetically with Dolynskiy intrusive syenite massif.

Intrusion had been emplaced into tectonically weakened zone. The host rocks for syenites are Middle-Upper Devonian limestones and dolomites, schists of Orlovska sequence, and minor bodies of gabbro and pyroxenites. The contacts of intrusive with host rocks are different in the plane and cross-section. The southern contact in the plane is strait, gentle, slightly turned towards host rocks. In the cross-section this is steep, quite wavy line. The zone of contact-altered rocks varies in thickness from first meters to 700-750 m. At the contact of syenites with gabbro and pyroxenites the former are sheared, re-crystallized, contaminated and hybridized; at the contact with limestones and dolomites these are marbles, skarns and skarned rocks described below. Apophyses, vein and dykes into host rocks and xenoliths of the latter in the intrusive massif are characteristic. At the final stages of massif development the pegmatite dyke-vein bodies and quartz-microcline veinlets were emplaced.

Ideas on the structure of Dolynskiy massif are mainly induced from observed anomalous magnetic and gravity fields. According to magnetic survey, in general structure is oval-shaped (26×10 km) with long axis extended in the north-eastern direction; the internal structure in complex, zonal-concentric. The central part of massif, in comparison to the peripheral flanks, exhibits decreased magnetic field. It is especially prominent in the map of local magnetic anomalies where the central massif part looks like the oval-shaped area (10×5 km) with low δZ_a field values, while structure contour is highlighted by almost continuous chain of increased local anomalies 100-1500 nTl; each anomaly also exhibits its own distinctions. The highest-amplitude magnetic anomaly is located in the south-western part (more than 1500 nTl) where the ring-shaped second-order magnetic anomaly is also distinguished (see "Map of anomalous magnetic field ΔTa" in the scale 1:500 000).

In the gravity field intrusion is not clearly expressed. Positive local anomalies δg_a with some breaks surround entire external contour of the massif. The central part is expressed in the local minimum δg_a. It is interesting that maximum value of local maximums, more than 3 mGal, is noted in the symmetric corners of intrusion, in its north-western and north-eastern parts, where gravity anomalies in these two cases only completely coincide with magnetic maximums. The drilling data and gravi-magnetic survey results allow explaining observed anomalous field. Magnetic anomalies of highest amplitude, which coincide with local δg_a minimums, are mainly caused by quartz syenites, which exhibit maximum magnetization (χ = 2000-4000 $n \times 4\pi \times 10^{-6}$ CI units) and minimum density values at the same time (σ = 2.66 g/cm^3). Syenites of the massif (σ = 2.74, χ = 550 $n \times 4\pi \times 10^{-6}$ CI units) and contact-altered rocks (gabbro and syenites) (σ = 2.78, χ = 150-300 $n \times 4\pi \times 10^{-6}$ CI units) do cause progressive decreasing of magnetic and respective increasing of gravity fields.

In view of above, in general one may conclude on certain petrographic zonation in intrusion, where in the central part mainly quartz syenites are developed, whereas syenites and contact-altered rocks are confined to the peripheral portions. Two noted local isometric areas where local magnetic and gravity fields coincide are probably caused by minor diorite or gabbro intrusions with high magnetization.

Results of Dolynskiy intrusive modeling using magnetic survey data suggests in favor of idea on the common anomaly-forming object, heterogeneous in composition (by physical properties) and internal complicated tectonic structure. The flanks of intrusive over entire perimeter are periclinal and flat enough dipping (30-40°). The depth to the object top along calculated profiles varies in the range 400-800 m. The denser rocks are confined to the endo-contact zones of intrusive. The object bottom attains the depth 5 km at least. On the ground of interpretation data, it looks likely that Dolynskiy massif at the first development stage (postorogenic phase of Herzinian geosyncline) had comprised the common dome-shaped intrusive of syenite composition. Further on (during Kimmerian orogenesis) it was split into separate tectonic blocks of various shapes and sizes although in general it has retained its primary oval shape.

According to drilling data [48], in the central part Dolynskiy massif is composed of quartz syenites, in the peripheral part biotite, pyroxene-biotite and hornblende syenites are intersected, and at the contacts with host gabbro and pyroxenites – melanocratic pyroxenites, contaminated and hybridized, including pyroxene, biotite-pyroxene, amphibole-pyroxene varieties. The rock description of Dolynskiy intrusive massif is given below.

Quartz syenites (q$\xi C_{1\text{-}2}$*dl*) are intersected by drill-holes 18 and 19 during the map sheet Izmail mapping by Reniyska GEE in 1955. Petrographic description is performed by A.A.Chumakov [18]. Macroscopically these are medium-grained, in places porphyry-like, pinkish-grey rocks with parallel orientation of tabular and prismatic potassium feldspar crystals causing trachytoid structure of syenites. In the fresh cut the rocks exhibit characteristic iridescence due to shining of cleavage planes in unaltered feldspar crystals. Texture is prismatic-grained, hypidiomorphic, and caused by prismatic and tabular feldspar crystals and xenomorphic mesostatic quartz habitus. The rocks composition (%): albite-oligoclase – 40-45, orthoclase-microperthite – 45-50, quartz – 7-10, and monoclinic pyroxene of pigeonite-hedenbergite range – 2-5%. Accessory minerals include apatite, sphene, zircon, tourmaline, topaz, magnetite, and fluorspar. The later, apparently epi-magmatic hydrothermal minerals include hornblende of pargasite type. Plagioclase is characteristically zoned with narrow albite peripheral rim. The twins are under albite and albite-Carlsbad rules. Potassium feldspar is two-axis, negative, with Carlsbad twins. According to V.M.Bobrynskiy [2], quartz syenites contain single crystals of light-green alkaline amphibole 0.5-0.3 mm in size with optical constants of magnesium hastingsite, and accessory minerals include sphene in idiomorphic rhombohedral crystals (0.07-0.1 mm), xenomorphic magnetite, apatite, zircon, tourmaline and fluorspar.

Biotite, augite-biotite, hornblende syenites ($\xi C_{1\text{-}2}$*dl*) by their structure-texture properties almost do not differ from those described above. In places coarse-grained and coarse-medium-grained varieties are observed. Opaque mineral contents vary in the range 10-20% and quartz – 0-5%. In *melanocratic contaminated syenites* opaque mineral contents attain 40%. They mainly include monoclinic pyroxenes, and biotite and amphibole are contained in minor amounts. Quartz content is 0-3%. Secondary minerals include carbonates, developed after pyroxene and fill up fractures, epidote, and saussurite. After mineralogical analysis of bulk samples, the following mineral contents are estimated: magnetite – 0.008-1.818 kg/t, apatite – up to 1.459 kg/t, galena – 0.02-0.01 kg/t, barite – up to 0.002 kg/t, native copper – 0.001 kg/t, fluorspar – 0.002 kg/t, as well as moissanite, bornite, barite-celestine, sphene, graphite, and other minerals [48]. Chemical composition of the rocks described above is given in Table 3.2 indicating that by chemical composition these rocks are close to alkaline syenites [7], belong to potassium-sodium series (Na_2O/K_2O = 0.47-0.77), high-alumina and very high-alumina (al' = 1.3-2.7), with agpaite coefficient K_a = 0.5-0.7 and iron-magnesium coefficient f' = 6.2-11.5. High iron-magnesium ratio is resulted from the high opaque minerals content. The contact-altered contaminated melanocratic, in places microclinized, pyroxene syenites differ in lower SiO_2, higher in MgO and CaO contents, and in places exhibit decreased Na_2O and increased K_2O contents.

Geochemical parameters of syenites are given in Table 3.3. After results of spectral analysis, the positive geochemical specialization of Dolynskiy massif syenites (see Table 3.3, syenites) is defined for for Ba, Be, Pb, Cr, Co, Mo, V, Cu, Zn, Ag, Sc, and negative – for Sn, Ti, Mn, Nb, Ga, Ni, Zr, P, Sr, Ge, Li.

In almost all rock varieties of Dolynskiy intrusive massif increased content of rubidium oxide is encountered to 0.019-0.09%. With the rubidium content increasing the content of lithium and potassium also increases while sodium content decreases.

It is defined through the biotite and feldspar monofraction analysis that potassium feldspars are rubidium mineral-concentrators (Table 3.4).

Distribution of chemical elements in the rocks of massif is uniform enough, both in lateral and vertical directions. At the same time, some regularities are observed, typical for mafic rocks. Specifically, tin, bismuth, vanadium and ytterbium exhibit uniform distribution. At the same time, from the massif center to the contacts titanium content decreases and zirconium and silver contents increase. The tungsten mineralization point as well as anomalies of molybdenum, silver, chromium, tin, scandium, lithium, copper, cobalt, nickel, manganese, zinc, beryllium, and phosphorus are related to syenites.

The age of Dolynskiy intrusive complex is determined on the ground of direct and indirect evidences. The complex cuts paleontologically-supported Middle-Upper Devonian rocks including Orlovska sequence and has clear active contacts with these rocks accompanied by diverse skarn development; with erosion the complex is overlain by Middle Jurassic Andrushynska Suite. Thus, the lower age boundary of Dolynskiy massif is not older than Early Carboniferous, and the upper one – not younger than Middle Jurassic.

Table 3.2. Chemical composition of syenites, %.

Reference	Sample number	SiO_2	TiO_2	Al_2O_3	Fe_2O_3+ FeO	MnO	MgO	CaO	Na_2O	K_2O
Syenites										
42, 48	043-155	61.13	0.33	16.82	4.76	0.10	1.57	1.26	3.78	7.93
42, 48	043-157	60.21	0.44	16.68	5.13	0.09	1.83	1.42	3.75	7.71
42, 48	043-158	57.85	0.35	15.20	3.97	0.11	1.85	4.90	3.51	6.90
42, 48	043-161	58.76	0.46	16.26	5.03	0.10	2.17	2.13	3.67	7.38
42, 48	043-162	59.42	0.39	16.64	4.67	0.10	1.91	2.07	3.87	7.57
42, 48	043-156	59.58	0.53	16.21	6.06	0.10	1.94	1.37	3.67	7.77
42, 48	050-157	57.97	0.62	14.09	6.29	0.12	3.85	3.77	3.06	4.12
42, 48	050-175	54.64	0.64	13.54	6.56	0.13	4.03	5.41	2.95	3.85
42, 48	050-162	57.25	0.62	14.05	6.59	0.12	4.32	3.18	3.01	4.06
42, 48	079-110	54.22	0.56	15.78	3.70	0.13	6.24	4.90	3.36	5.88
42, 48	079-116	56.51	0.441	16.61	2.14	0.08	3.59	4.55	4.10	7.12
Contaminated syenites										
42, 48	071-14	50.28	0.76	16.69	5.24	0.13	3.21	3.08	0.64	11.58
42, 48	071-21	50.95	0.67	13.19	5.15	0.12	5.91	5.38	0.64	10.14
42, 48	071-32	48.29	0.59	14.11	3.73	0.15	4.70	7.49	1.38	10.42
42, 48	071-24	45.32	0.68	13.56	3.53	0.17	4.71	8.55	0.80	9.47
42, 48	071-37	49.57	0.65	13.06	4.76	0.16	5.61	7.63	1.62	9.46

Table 3.3. Geochemical parameters of magmatic rocks from Dolynskiy massif and Feropontievskiy complex [48, 42].

Chemical elements	Average content of element, % × 10^{-3}	
	Syenites - $\xi C_{1\text{-}2}dl$	Diabases – $\beta T_3 fr$
Ba	73.2	31.0
Be	0.191	-
Pb	2.72	0.189
Sn	0.261	0.134
Ti	263	291
Mn	58.4	52.1
Nb	0.929	0.946
Ga	1.83	0.739
Cr	5.76	12.8
Ni	2.03	4.09
Co	1.38	1.28
Mo	0.151	0.657
V	11.7	5.68
Cu	6.13	3.23
Zn	7.68	3.91
Zr	20.7	6.43
Ag	0.576	0.168
Y	1.09	1.27
Yb	0.109	0.138
P	155	44.9
Sr	13.3	-
Gc	0.125	0.125
Sc	0.824	1.33
Li	1.04	1.09

Table 3.4. Results of chemical analysis of mineral monofractions from syenites [42, 48].

Sample number	Mineral	Content, %		
		Li_2O	Rb_2O	Cs_2O
046-152a	K-feldspar	0.0062	0.0753	<0.0005
046-152b	Biotite	0.0234	0.0142	<0.0005
093-14a	Biotite	0.015	0.0135	<0.0005
093-14b	K-feldspar	0.0056	0.092	0.012

In the course of GM-50 [48] in the Institute of Geological Sciences, UNAS, the absolute age determinations by K-Ar method were performed for quartz syenite samples (A.K.Boyko). The age of Dolynskiy massif syenites is estimated to 195 Ma, which corresponds to Early Jurassic Pliensbachian time, and in authors' opinion is not correct apparently just corresponding to the time of "rejuvenation", which coincides with the final phase of Early Kimmerian tectogenesis, widely expressed in the studied area, and accompanied by emplacement of massifs (in Tulcea zone, Romania) and dyke-like diabase bodies. Taking into account that Tulcea zone intrusive rock age is defined to be Middle Carboniferous, as well as reasons mentioned above, the age of Dolynskiy intrusive complex is accepted by the authors to be Early-Middle Carboniferous[1].

Petrophysical parameters of syenites are given in Table 3.1. High magnetic susceptibility is caused by essential magnetite concentration in the rocks – 1.749-1.818 kg/t in the central part of massif. The rock density oscillations are related to the superimposed dynamo-metamorphism.

Melanocratic, fine-grained, green *pyroxene-hornblende syenites*, intersected by DH 1uD [20, 42] at the depth 909-914, are though to be in tight genetic and age relations with syenites described above; they cut fauna-supported Middle-Upper Devonian limestones, and comprise the derivates of the major massif.

Quartz monzonite-porphyries ($q\mu C_{1\text{-}2}dl$) are intersected by DH 1uD [20, 42] in the west bank of Kagul lake, in 1 km to the north from Lymanske village, at the depth 843-866 m in limestones and dolomites of Middle-Epper Devonian carbonate sequences and apparently comprise derivates of Dolynskiy intrusive syenite massif. At the contact with quartz monzonite-porphiries the host carbonate rocks are modified into magnesium skarns. Their petrographic description is given by V.F.Moroz [10] and is briefly presented below.

Visually these are porphyry, greenish-grey, massive, fractured rocks with dense, fine-crystalline groundmass. Fractures are filled with secondary, later minerals (pyrite, calcite, quartz). Macroscopically in quartz monzonite-porphiries large feldspar phenocrysts are well visible, as well as finer porphyry inclusions of opaque mineral replaced by green chlorite. Much rarely fine rounded phenocrysts of transparent quartz are noted.

Under microscope in quartz monzonite-porphyries well-prominent porphyry texture is observed. Porphyry inclusions contain plagioclase, quartz, biotite and hornblende replaced by secondary minerals. Amount of phenocrysts in the rock varies from 15-20 to 45-50% and in average is 32-35% by rock volume. Mineral composition (%): plagioclase – 72.7, quartz – 5, biotite and pseudomorphs after hornblende – 2.8, ore minerals and apatite – 1.5.

Plagioclase (intermediate oligoclase No. 16-20 – sodium andesine No. 30-35, albite, oligoclase-albite) in phenocrysts occurs in tabular and prismatic, polysynthetically twinned crystals from 0.4 to 5 mm long and from 0.2 to 2.5 mm wide. Quartz in phenocrysts is rarely observed and in the rocks only confined to the dyke footwall. Therein quartz occurs in highly crushed, rounded grains up to 0.4-0.6 mm across. Biotite is observed in phenocrysts in few amounts in the tables from 0.65 to 2.5 mm long and from 0.25 to 1.7 mm wide, being often replaced by chlorite and carbonate. Secondary alteration of biotite is also accompanied by sphene, leucoxene and rutile. Pseudomorphs after opaque mineral are filled with chlorite, calcite, sphene, leucoxene and other titanium minerals, which occur in various combinations and numeric relations. Of accessory minerals, monzonite-porphyries normally contain apatite, pyrite, titanomagnetite, magnetite, and fluorspar.

The rock groundmass is fine-crystalline, in places micro-graphic, essentially feldspar (79.5%) with minor quartz (6.7%) and fine grains of opaque mineral (1.2%). Of the feldspars, plagioclase and potassium feldspar occur in roughly equal amounts. The later minerals include carbonate, chlorite, apatite and sphene.

Chemical composition of monzonoite-porphyries (%): SiO_2 – 59.2; TiO_2 – 0.45; Al_2O_3 – 13.08; Fe_2O_3 – 2.92; FeO – 2.87; MgO – 2.68; CaO – 5.07; MnO – 0.1; Na_2O – 3.63; K_2O – 3.2; LOI – 4.82; Total – 2.32; $S_{tot.}$ –

[1] There are many reasons to consider the age of Dolynskiy massif igneous rocks not Early-Middle Carboniferous but Late Triassic - Early Jurassic, connected with the final stage in Early Mesozoic development of Northern Dobruja structures in the Early Kimmerian phase of folding. This assumption well agrees with radiogenic age data for quartz syenites (195 Ma) obtained by A.K.Boyko. At the same time, the issue of age determination for intrusive complexes and hydrothermal-metasomatic rocks, distinguished in the map sheet and developed in Nyzhnyoprutskiy bench and Fore-Dobruja, requires further more detailed studies.

0.93 (depth 857.2-860.7 m). As one can see from above data, the rock exhibits relatively high for monzonite silica and decreased alumina content, as well as low iron oxides and magnesium and normal for monzonites relatively high total alkali content (6.83%).

Recalculation of chemical analysis into mineralogical norms after A.Ritman [13] (%): magnetite – 1.43; sphene – 0.74; pyrite – 1.48; amphibole – 14.29; clinopyroxene – 3.71; orthoclase – 29.34; oligoclase – 33.89; quartz – 15.09; color index – 21.65.

The age of quartz monzonite-porphyries is determined on the ground of relationships with host Middle-Upper Devonian rocks, which are cut, and younger rocks respectively.

Quartz-microcline veinlets (qmiC_{1-2}*dl*) are encountered in DH 040 [42, 48]. They cut gabbro and syenites in various directions and are 1-3 cm thick. The contacts with host rocks are clear and gradual. Gabbro and syenites at the contacts are microclinized, sheared and re-crystallized. The zone of contact-altered rocks is 0.5-1.5 cm thick. The veinlets are mainly composed of microcline, in lesser extent quartz, which is arranged in aggregates up to 0.5 cm in size in the middle part of veinlets. Rarely amphibole, biotite and pyroxene grains are observed. Chromium, nickel, molybdenum and strontium anomalies can be related to quartz-microcline veinlets. They cut gabbro and syenites and therefore are the younger rocks.

Microcline and pyroxene-microcline pegmatites (pC_{1-2}*dl*) are pink, dark-pink, coarse-grained, medium-coarse-grained, with pegmatoid texture, they cut gabbro, syenites and Middle-Upper Devonian carbonate rocks. The contacts with host rocks are clear, the host rocks at the contacts are microclinized, sheared and re-crystallized. Pegmatites are intersected by drill-holes 040 (depth 518-521.5 m) and 043 (depth 455-455.5 m, 459.5-467.1 m) [42, 48]. Mineral composition (%): microcline – 90-99 in tabular crystals up to 1 cm in size; pyroxene (1.0-10), black, in places of extensive chloritization – greenish-grey; pyrite and pyrrhotite (up to 1) occur in fine (up to 1-1.5 mm) pods and thin veinlets which cut the rock in various directions. Petrophysical parameters of pegmatites are given in Table 3.1. In DH 040 [48, 42] the anomalies of rubidium oxide, lithium oxide, molybdenum, lead are related to pegmatites. They cut gabbro and syenites, contain their xenoliths, and therefore are the younger rocks in comparison to the latter.

Hydrothermal-metasomatic and contact-metasomatic rocks related to development of Dolynskiy intrusive massif include skarns and skarned rocks (skC_{1-2}*dl*), marbles and calciphyres. They are observed in the exo-contact zone of Dolynskiy intrusive massif where these rocks are developed through the interaction of magma or magmatic and other alumosilicate rocks with dolomites and limestones under influence of high-temperature magmatogenic solutions and thermal impact. The rocks are intersected by drill-holes 040, 075, 078 [48, 42] and 1uD [20, 42]. Most complete metasomatic and contact metamorphic processes are noted in DH 040 [48] and 1uD [20, 42].

In DH 040 [42, 48] at the depth 492.5-540 m limestones of Upper Devonian carbonate sequence are intersected, which are cut by syenites, gabbro and pegmatites, and under influence of intrusion and dykes they were re-crystallized into marbles with exo-skarn development.

Skarnation process is not developed over entire rock mass but is selective. Specifically, in the hanging-wall block of pegmatite dyke (depth 518.0-521.5 m) the marble occurs while in the footwall block skarnation degree increases away from the contact attaining the peak with skarn formation at the depth 522.4-531.6 m, and then the process is ceased in the reverse order up to transition into marble occurring at the contact with gabbro dyke.

Epidote-carbonate skarn macroscopically is greenish-grey with pinkish shade, spotty, fine-grained. Under microscope texture is hetero-blastic, in places cogged. The rock is composed of carbonate (60-70%), epidote (30-35%), which is being replaced by serpentine. In the interstices and inside calcite grains fine garnet (0.5-1.0%), ore mineral, sericite grains and quartz bunches are noted.

In drill-hole 1uD [20], the contact-altered rocks include magnesium skarns, marbles and marbled limestones, which are described in details by V.F.Moroz [10]. The brief description is given below.

Magnesium skarns are intersected by DH 1uD [20] at the depth 760-843 m and 1000-1050 m and located in dolomite limestones and dolomites of Middle-Upper Devonian carbonate sequence. Both infiltration and diffusion (bi-metasomatic) skarn types are encountered. The first ones are distinguished at the contact zone of quartz monzonite-porphyry dyke with Middle-Upper Devonian dolomites, and the second ones are encountered lower down at the base of carbonate rocks, at the contact with underlaying terrigenous rocks. The lower column part of carbonate rocks is altered by metasomatic process in lesser extent and consists of pyroxene- and amphibole-phlogopite marbles and marbled limestones. Between the dykes of quartz monzonite-porphyries (depth 844.0-865.6 m) and pyroxene-amphibole syenites (909.4-914.0 m) prehnite-bearing marbles are also noted. Metasomatic zonation in the skarn structure and composition is weakly expressed because of superimposed later post-magmatic mineral-forming processes. In the infiltration skarns just the marginal zones of magnesium-skarn column are most completely developed including the zone of marbled carbonate rocks and zone of calciphyres. Of the diffusion skarns, the diopside skarns are widely developed, which are partly or completely replaced by amphiboles of tremolite-actinolite range and talc.

Talc-actinolite and talc-actinolite-diopside metasomatites are confined to the basal part of the Middle-Upper Devonian sequence of limestones and dolomites where the latter are more and more enriched in terrigenous quartz and are gradually substituted by carbonate sandstones first and then by quartzites. In the column of DH 1uD [20, 42] the zone of this gradual transition about 50 m thick in encountered at the depth 1000-1050 m and almost completely consists of talc-actinolite and talc-actinolite-diopside metasomatites, where in places thin (up to 0.5-1.0 m) interbeds of altered limestones and quartz sandstones with primary calcite cement are rarely observed.

Talc-actinolite rocks are observed over entire column of this zone but in the most extent in its upper part at the depth 1002.6-1030.0 m. Visually these are grayish-green and dark-grey, in places almost black, highly deformed, brecciated rocks with numerous discontinuous fractures filled with coarse-crystalline calcite and other secondary, later minerals. Major minerals include amphibole of tremolite-actinolite range, talc, and calcite. Some rock varieties contain essential amount of terrigenous quartz (10%). Amount of amphibole in the rocks varies in wide range but amphibole permanently predominates over talc and calcite. Two latter minerals comprise products of later low-temperature transformations of amphibole. From the tremolite replacing products, besides talc and calcite, quartz is also developed. Of the accessory minerals, zircon, orthite and sphene are frequently developed in talc-tremolite rocks. Thin, up to 0.5-1.0 mm wide veinlets in the rock are almost completely filled with these minerals.

Talc-actinolite and talc-actinolite-diopside metasomatites, developed below, are connected with gradual transitions. There is no clear boundary between these varieties although amount of pyroxene suddenly increases from the depth 1030 m and further down it becomes prevailing mineral. Some rock varieties at the depth 1045-1049 m are almost completely composed of diopside. Diopside rocks are noted directly at the contact of carbonate rocks with underlaying quartzite-like sandstones, and talc-actinolite rocks – at some distance away from. Thickness of diopside zone is about 20 m.

Visually talc-actinolite-diopside metasomatites are dense, massive, highly fractured, brecciated, light-greenish-grey, crystalline rocks with variable composition of clastic quartz. Diopside is observed in short-prismatic crystals and isometric-irregular grains from 0.5 to 2.0 mm across. Most of diopside is extensively replaced by thin-fibrous amphibole (tremolite) and talc up to complete pseudomorphs. In some cases diopside replacement by talc is observed with development of quartz and calcite.

Talc-actinolite-diopside metasomatites contain frequent thin (up to 0.5-1.0 m) interbeds of fine-grained quartz sandstones where primary carbonate cement is not preserved and substituted by aggregate of fine diopside grains and cluster hornblende.

The acid leaching in diopside rocks is very extensive. Besides mentioned changes, the total rock silicification is observed and appearance of sulphides and chlorite. Sulphide content attains 30-50% by rock volume. Of these sulphides, pyrite is most developed. In minor amounts glaucodot and arsenopyrite are observed. The total thickness of the zone of sulphide mineralization is about 17 m.

Chemical composition of talc-actinolite and talc-actinolite-diopside metasomatites is given in Table 3.5 where one can find that metasomatites contain very low alumina (0.47-2.44%) and sum of alkali (0.0-0.64%). Iron oxide (3.04-4.46%) and protoxide (3.02-4.76%) contents are also low. These features of chemical composition suggest for respective rocks development under conditions of low migration capacities of alumina, iron and alkali.

Microscopic studies allow conclusion that talc-actinolite-diopside rocks comprise diffusion (bi-metasomatic) skarns developed at the contact of dolomite with low-clayey quartz sandstones. As to the talc-actinolite rocks, they are mainly developed after previously formed skarns. Few actinolite masses substitute carbonate rocks in the transition zone to skarns.

In DH 18 [21, 42] located in 3 km to the south-west from Vladychen village, at the depth 502 m, in Middle-Upper Devonian dolomites the phlogopite mineralization is encountered with pyrrhotite and pyrite, which is apparently related to the skarnation processes at the contact of granodiorite-porphyry and monzonite intrusion with Middle-Upper Devonian dolomites in the area of Suvorove village, in Moldova territory, in 2.5 km to the west from the State border. Dolomites are penetrated by the dense network of curvilinear, very thin (2-5 mm) fractures, where central part is filled with phlogopite, pyrrhotite, pyrite and calcite. In parallel to fractures the narrow (up to 50 mm) bands of host dolomite are observed where dolomite is almost completely replaced by serpentine aggregate. Relicts of higher-temperature minerals are not found in these rocks. On this ground one can assume that phlogopite and serpentine are developed through migration of solutions enriched in silica, alumina and potassium, along fractures in dolomites. Directly at the contact of granodiorite-porphyries with metasomatically altered host carbonate rocks increased concentrations of lead (0.1-0.2%) and bismuth (0.03%) are encountered. They are related to the occurrences of galena bunches and very fine needle and prismatic cosalite or galenobismuthite crystals in the rocks. After spectral analysis data, carbonate rocks in the exo-contact zone of the massif are enriched in molybdenum (0.0005%), chromium (0.02%), copper (0.01-0.03%), lead (0.015%), zinc (0.04-0.05%), strontium (0.06%), barium (0.3%), lithium (0.01%), phosphorus (0.1%), silver (0.3 g/t), gold (0.005-0.012 g/t). By mineralogical analysis in the rocks are estimated: zircon – 0.002 kg/t, barite – 0.003 kg/t, as well as apatite, sphene, galena, ilmenite, siderite, graphite, barite-celestine, and bornite [48].

Table 3.5. Chemical composition of talc-actinolite and talc-actinolite-diopside metasomatites from the column of DH 1uD [20, 42], weight %.

Components	Talc-actinolite metasomatites		Talc-actinolite-diopside metasomatites	
	depth 1002.8-1006.3 m	depth 1029.8-1032 m	depth 1036.6-1040.8 m	depth 1049.2-1053.6 m
SiO_2	50.33	53.9	52.04	51.63
TiO_2	0.34	0.64	0.18	0.11
Al_2O_3	0.67	0.47	2.44	1.33
Fe_2O_3	3.04	4.36	4.38	4.46
FeO	4.1	3.66	3.02	4.76
MnO	0.4	0.4	0.388	0.39
MgO	19.25	16.01	13.78	9.82
CaO	12.16	12.65	15.79	15.46
Na_2O	0.13	0.13	0.21	-
K_2O	-	-	0.43	-
SO_3	2.78	2.35	5.64	3.22
LOI	9.26	7.63	8.38	11.69

Marble is macroscopically light-grey, medium-grained, medium-coarse-grained, in places with well expressed banding, caused by occurrence of thin (1-2 mm) bands composed of brownish-grey calcite with opaque minerals. Under microscope texture is granoblastic, hetero-granoblastic, with elements of cogged one. The rock is composed of carbonate with well expressed cleavage by rhombohedron, grain size 2-4 mm, where aggregates of fine (0.1-0.3 mm) isometric grains of carbonate are frequently observed, which apparently did not undergo re-crystallization under metasomatism. Scarce serpentine aggregates are confined to micro-cracks and cleavage surfaces. Sericite is developed after carbonate. Rarely quartz bunches, sphene and ore mineral grains are noted. Chemical composition of marble (%): SiO_2 – 3.15; TiO_2 – 0.12; Al_2O_3 – 1.19; Fe_2O_3 – 0.54; FeO – 0.14; MnO – 0.01; MgO – 0.61; CaO – 51.55; Na_2O – 0.28; K_2O – 0.32; P_2O_5 – 0.12; SO_3 – 0.13; LOI – 41.00; total – 99.16.

Calciphyres are encountered above the dyke of quartz monzonite-porphyries in DH 1uD [20, 42] at the depth 760-843 m. In the upper, external zone, calciphyres adjoin dolomite-calcite marbles. In the lower, core zone, they are separated from quartz monzonite-porphyries by thin zone of clinochlore-amesite-phlogopite and pyroxene-feldspar rocks. The thickness of calciphyres intersected by drill-hole is 83 m. Visually these are dense, uniform or greenish-grey, light-grey, fine-crystalline rocks with massive or often spotty structure. After microscopic study data, mineralogical composition is as follows: calcite, dolomite, phlogopite, spinel, amesite, clinochlore, serpentine, forsterite, and corrensite. In few amounts the minerals of humite group, talc, pyrite, pyrrhotite, barite, and borates(?) are noted. Amount of silicate minerals and spinel varies from 9.1 to 16.9%.

Chemical composition of calciphyres from the external zone at the depth 760-762 m is as follows (%): SiO_2 – 15.04; TiO_2 – 0.29; Al_2O_3 – 5.48; Fe_2O_3 – 2.04; FeO – 1.09; MnO – 0.059; MgO – 13.44; CaO – 31.0; Na_2O – 0.27; K_2O – 0.83; SO_3 – 0.19; LOI – 29.6; total – 99.329.

Of the ore minerals, directly related with calciphyres and marbles [48, 42], most frequent are pyrite, pyrrhotite, sphalerite, galena and chalcopyrite. The scarce ore minerals include glaucodot, arsenopyrite and native gold.

Association of hydrothermal-vein rocks

This group includes *quartz* (qC_{1-2}), *carbonate-quartz* ($caqC_{1-2}$), *quartz-barite* ($qbaC_{1-2}$), *quartz-carbonate* ($qcaC_{1-2}$), *carbonate* (caC_{1-2}) *veins and veinlets* which are widely developed and cut all varieties of sedimentary and igneous rocks of Herzinian tectonic floor. Thickness of veins and veinlets varies mainly in the range 0.5-7.0 mm – 0.2-0.3 m, in places up to 3 m. The thickest (0.1-3.0 m) are quartz and carbonate-quartz veins mainly confined to the rocks of Orlovska sequence (DH 011, 018, 023, 071, 073, 1sO [42, 48], 59k, 62k

[23, 42], 6P [42]). The veins and veinlets cut host rocks in various directions, conformably and unconformably to the general schistosity. They are variable in shape: simple linear or discontinuous, complex branch, network with swells, in places lens-shaped and irregular separations are observed. Concentration of vein material is normally confined to the weakened, fractured zones. Quartz in quartz veins is milky-white or light-grey, semi-transparent, sugar-like, contain host rock xenoliths. Carbonates are mainly composed of calcite, rarely iron-magnesium carbonates are noted. Mineral aggregates are of fine- or micro-grained texture, and monomineral calcite – in places coarse-grained one.

In the abandoned quarry in Orlovka village baritization vein up to 1 m thick is encountered which comprises the system of contiguous quartz-barite veinlets 1-2 cm thick and confined to the endo-contact zone of kersantite dyke. Barite mineralization point with $BaSO_4$ content 40% is confined to the same zone. Therein, in the quarry, in different year in quartz veins the anomalous contents of manganese (0.7-1.0%), lead (0.015-0.02%), copper (0.07%), and gold (0.0065-0.01 g/t) were determined.

In DH 6P [42], in fracturing zone at the depth 329.2-331.5 m, in calcite vein sulphide mineralization is encountered with zinc mineralization point, and high-contracted lead anomaly (0.05%). Sulphides (40-50%) mainly include pyrite (98%), rarely sphalerite (1%), galena (1%), and chalcopyrite (grains).

In addition, in pyrite-calcite vein the anomalous copper (0.008%), manganese (0.3%) and gold (0.02 g/t) contents are determined.

Apparently, the anomalous gold content (0.003-0.05 g/t) in DH 6p, 011, 07, 047, 1sD [48, 42], 59k [23, 42] is related to quartz, quartz-carbonate and carbonate-quartz veinlets.

In DH 1uD [20], the native gold is found in the bulk sample from marbled limestone with prehnite and calcite veinlets at the depth 900 m. Gold intergrowth with transparent calcite and quartz in association with well-grained pyrite crystals indicate that gold is tightly related to the quartz-calcite veinlets developed in the late, low-temperature stage of hydrothermal alteration of the host carbonate rocks. Admixtures in gold include mercury (0.2-0.6%), nickel (0.1-0.3%), lead and manganese (0.1%), Silver content varies from 10.2 to 24.3%.

It is determined that given hydrothermal-vein rocks cut all low-metamorphosed sedimentary and igneous rocks in Herzinian tectonic floor and do not occur in the younger Triassic and Jurassic rocks; on this ground the age of this rocks is defined to be Early-Middle Carboniferous.

Mesozoic Era

Triassic Period

Ferapontievskiy complex of minor intrusions (T_3*fr*)

In the authors' opinion, this complex include diabases intersected by drill-holes 014 [48, 42] and 029 [48, 42] at the depth 50-56 m to the south-west from Orlovka village, where they cut limestones of Lower-Middle Triassic Novosilska Suite. The contacts with host rocks are clear, sharp. The host rocks and diabases at the contact are extensively crushed, cataclased and milonitized. Fractures are filled with calcite. Limestones in the contact zone are slightly re-crystallized.

Macroscopically diabases are greenish-grey, mainly medium-grained, in places fine- and medium-grained, massive, somewhere unclear-porphyry, penetrated by the dense network of thin carbonate veinlets. In some places fine vesicles are noted filled with pale-pink calcite. Under microscope the rock is full-crystalline, with diabase texture, composed of plagioclase, rhombic and monocline pyroxenes. Plagioclase is observed in the laths 1.0-1.5 mm long, as well as twinned crystals, and is composed of andesine. Pyroxene fills the interstices between plagioclase grains and is observed in small grains whose primary shape is weakly preserved. Quartz occurs in thin, diverse-oriented veinlets. By chemical composition (Table 3.6) diabases are uniform enough, silica-undersaturated, with high iron and magnesium oxide contents.

Table 3.6. Chemical composition of diabases, %.

Sample number	SiO_2	TiO_2	Al_2O_3	Fe_2O_3+ FeO	MnO	MgO	CaO	Na_2O	K_2O
014-15	37.88	1.71	12.18	12.02	0.22	8.06	10.16	0.89	0.26
014-17	36.83	1.38	11.3	10.39	0.16	12.17	7.42	2.41	0.07
029-21	38.12	1.28	12.77	12.43	0.14	8.93	7.92	2.69	0.73
029-38	39.47	2.82	11.15	15.43	0.19	9.12	5.97	0.79	0.37

Diabases belong to potassium-sodium and sodium series (Na_2O/K_2O = 2.1-34.4), low-alumina (al' < 0.75), iron-magnesium index f' = 21.79-27.37, ferrous coefficient is irregular – K_ϕ = 47-63, ratio K_2O/TiO_2 – 0.05-0.57, which corresponds to tholeiitic basalts and dolerites [7].

Geochemical parameters of diabases are given in Table 3.3 where one can see positive geochemical specialization for Ba, Ti, Mn, Cr, Zr. By spectral analysis in diabases from DH 014 [48, 42] increased content of vanadium (0.015%), nickel (0.0015%) and molybdenum (0.00015%) is determined.

Physical properties of diabases vary in the wide range (Table 3.1). The density is 2.53-2.85 g/cm^3, average – 2.72 g/cm^3; magnetic susceptibility – 29-2500×4π×10^{-6} CI units, average – 38×4π×10^{-6} CI units; residual magnetization is 0-260×10^{-3} A/m , average – 3.5×10^{-3} A/m . From DH 029 [48, 42] two determinations are available where magnetic susceptibility attains 1300 and 2500×4π×10^{-6} CI units, and residual magnetization – 117 and 260 ×10^{-3} A/m. Perhaps, this variability is related to the changes of magnetite content, and density variations – with the rock crushing degree.

The diabase dykes cut fauna-supported rocks of Lower-Middle Triassic Novosilska Suite and therefore are younger of the latter. There are no other data on the rock age.

4. TECTONICS

In tectonic respect, the map sheet territory L-35-XXIII (Izmail), L-35-XXIX (Tulcha) belongs to the south-western slope of Eastern-European Platform (EEP) and is typically two-folded, with Precambrian crystalline basement and platform cover (see “Scheme of major tectonic units in the studied area and adjacent territories at pre-Jurassic surface” – Fig. 4.1, and “Tectonic scheme of pre-Cenozoic units” in the scale 1:500000).

The lower tectonic level (basement) is composed of extensively dislocated Archean – Lower Proterozoic ultra-metamorphic rocks. The upper tectonic level (sedimentary cover) consists of Vendian, Paleozoic, Mesozoic and Cenozoic units. In the western direction EEP by the deep-seated fault zone (Mechyn zone, in Romania territory) adjoins Central Dobruja, structure of the epi-Kimmerian Western-European Platform (WEP), and in the southern and south-eastern directions – with West-Chornomorska depression.

The reasons to distinguish Besarabsko-Chornomorska plate and to define the boundary between EEP and WEP by Mechyn zone (Romania) are presented in the geological report [42]. Tectonic zonation of the territory is performed on the ground of historic-geological method using all available geological information.

Based on the complex geological re-interpretation of geophysical data [25-28, 31-36, 38, 43-45, 49-55, 57, 60-62], specifically, results of planar gravity and magnetic surveys, seismic studies, satellite image processing, and results of morphometric analysis, in the EEP south-western slope (I-order structure) Moldavska and Besarabsko-Chornomorska plates (II-order structures) are distinguished. In turn, the III-order – floors (basement and cover) and IV-order structures – sub-floors (Baikalian, Caledonian, Herzinian, Early Kimmerian, Late Kimmerian, and Alpine) are distinguished in the II-order structures. Description of plicative structures, individual major blocks and faults is given for the distinguished sub-floors. Description of negative tectonic structures (trough and depressions) is given above in the description of litho-tectonic sedimentary complexes involved in the structure of tectonic floors and sub-floors of the basement and sedimentary cover.

Moldavska plate comprises the oldest plate structure in the EEP south-western margin. This is a major block of Precambrian consolidation, which through the troughs emerging in Vendian was involved in the western peri-cratonic subsidence and developing under platform regime. The sedimentary cover therein consists of Vendian, Cambrian, Silurian, Lower Devonian, Jurassic, Cretaceous, Paleogene, Neogene and Quaternary sediments. In view of geological setting of the major sedimentary complexes, the territory of Moldavska plate over Vendian and entire Phanerozoic time was developing under the stable enough tectonic regimes. In the studied map sheet just the far southern part of Moldavska plate is expressed with Kyshynivska syncline and is mapped in the north-east-trending band up to 3 km wide in the area of Dmytrivka village. In the south-western direction it is cut by the zone of Chadyr-Lungskiy regional fault.

Besarabsko-Chornomorska plate[1] is distinguished in the EEP south-western slope for the first time. Its northern and north-eastern boundary follows the zone of Chadyr-Lungskiy regional fault where the plate adjoins the southern margin of Moldavska plate. In the south-western and western directions this plate is extended outside the territory of Ukraine into Romania where it is cut by the deep-seated fault zone (Mechyn zone). In the north-western direction the plate pinches out at the contact with Berladskiy dome. In the north-eastern direction the plate is essentially broaden and extended towards the Black Sea south-western offshore where is adjoins West-Chornomorska depression. Like Moldavska plate, this structure is the oldest plate unit in the EEP. This is also major block of Precambrian consolidation and in relation to the Vendian miogeosyncline troughs development in the modern WEP it was involved in the western peri-cratonic subsidence under platform regime.

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[1] Tectonic zonation, suggested by the authors, considerably differs from the traditional one. Conclusion, that Nyzhnyoprutskiy bench - the north-western plunge of Northern Dobruja (in the authors' terminology - southern part of Nyzhnyodunayskiy block of Besarabsko-Chornomorska plate), and adjacent Romanian part of the latter, do belong to the EEP, is in contradiction to the study degree of this very complicated region. The distinct authors' ideas are also in contradiction to the modern factorial geological-geophysical material and non-typical EEP features - occurrence of extensive Late Paleozoic - Triassic magmatism, Herzinian age of crystalline basement in Nyzhnyoprutskiy bench (composed of greenschist metamorphic complexes), position in the entire Chornomorsko-Krymska epi-orogenic zone (Scythian plate), and others. Arguing against the idea that Nyzhnyoprutskiy bench belongs to the latter (in other versions - to Northern Dobruja orogen), the authors does not support also Paleozoic marginal trough - Fore-Dobruja. Scientific analysis of all available information, conducted over last years (E.I.Patalakha et al, 2002, "Tectonic map of Ukraine in the scale 1:1 000 000", 2005; Tectonics of Ukraine, 1988, and others), indicates that structure, defined in the given volume as Besarabsko-Chornomorska plate and bounded in the south by Kagul-Georgievskiy fault, comprises typical marginal trough developed in front of Northern Dobruja orogen because of Herzinian tectogenesis. From another hand, there are no reasons to disclaim tectonic status of this structure - *(Ed.)*.

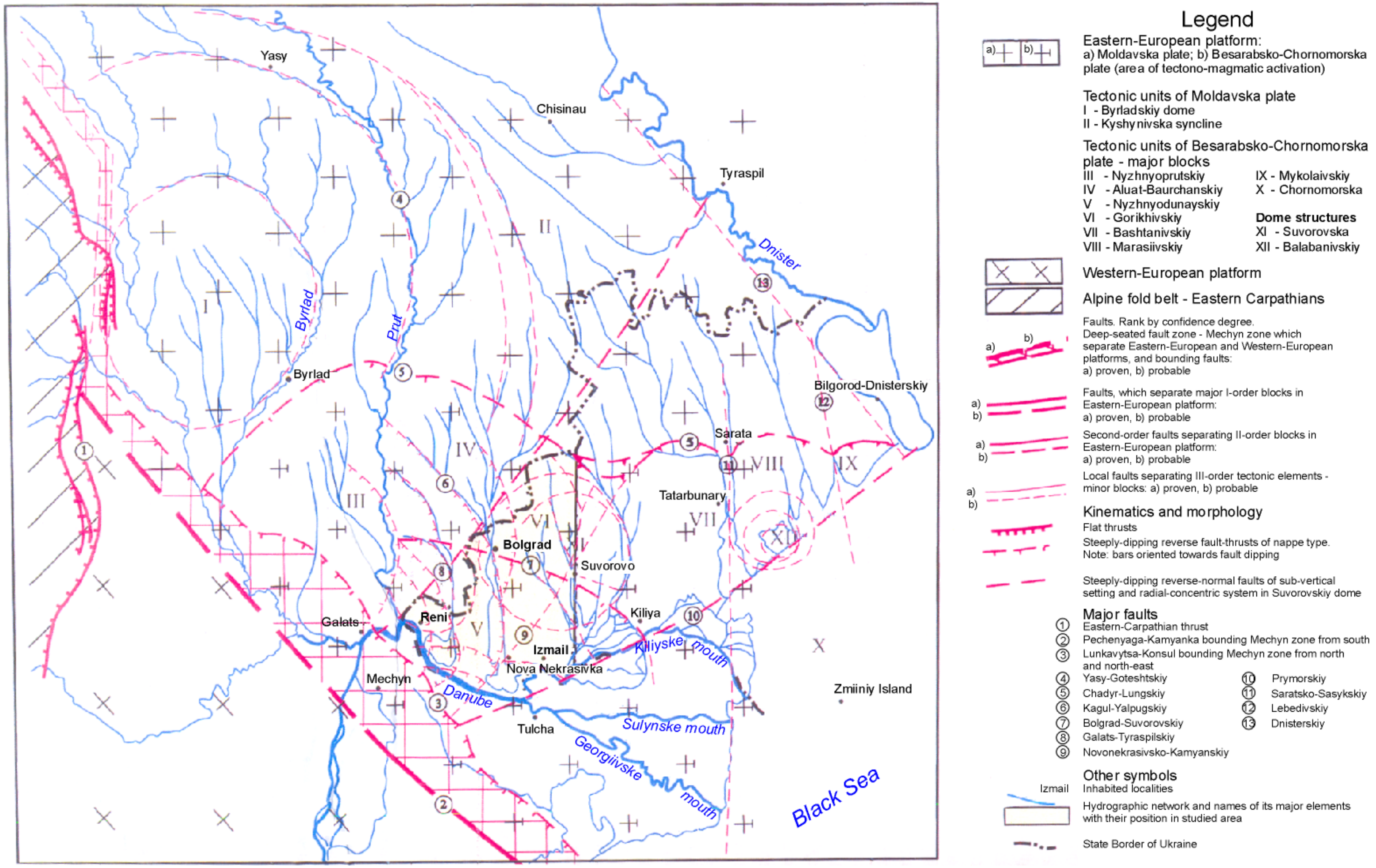


Fig. 4.1. Scheme of major tectonic units in the studied area and adjacent territories at pre-Jurassic surface.

In the plate, sedimentary cover consists of Vendian, Paleozoic, Mesozoic and Quaternary units. In contrast to Moldavska plate, however, this region was developing under more extensive tectonic regime. Thickness of sedimentary cover over there, in comparison to Moldavska plate, is 5-6 times higher indicating more extensive subsidence of the area at the stage of troughs development. In the region, vertical block motions are higher (up to 4 km), being descending at the stage of troughs development, for instance, Triassic thickness therein is about 4000 m, Jurassic one up to 3500 m (see "Stratigraphic column"), and ascending at the inversion stage of territory development. Comparing geological columns of Nyzhnyodunayskiy and Nyzhnyoprutskiy blocks with the boundary by Galats-Tyraspolskiy fault (see Fig. 4.1), one can see that in the latter block Triassic rocks, up to 4000 m thick, are completely eroded, indicating respective amplitude of ascending motions about 4000-5000 m. The cover rocks are essentially deformed because of Herzinian, Early Kimmerian and Late Kimmerian tectogenesis, altered by initial phases of regional metamorphism, and cut by quartz syenite intrusion, the dykes and dyke-like bodies of lamprophyres and diabases. In adjacent territory (Saratsko-Tatarbunarskiy block), at the Upper Permian level, volcanic activity is noted. All mentioned examples suggest for the regime of tectonic-magmatic activation of the region, especially during Herzinian and partly Early Kimmerian tectogenesis. The boundary between Moldavska and Besarabsko-Chornomorska plate is set by the zone of Chadyr-Lungskiy regional fault.

Based on the analysis of litho-tectonic complexes developed in the area, Gorikhivskiy and Nyzhnyodunayskiy basement blocks are distinguished in Besarabsko-Chornomorska plate.

Gorikhivskiy block is square-shaped being 40×40 km in size. From the north-east it is bounded by the zone of Chadyr-Lungskiy fault, and from the south-west – by the zone of Bolgrad-Suvorovskiy fault. In the north-western and south-eastern directions it is bounded by the zones of Galats-Tyraspilskiy and Novonekrasivsko-Kamyanskiy faults respectively. In the sedimentary cover of Gorikhivskiy block Jurassic, partly Paleogene and Quaternary units are developed. Paleozoic and Triassic rocks are lacking over there; apparently they were eroded in pre-Jurassic time.

Nyzhnyodunayskiy block looks like broad enough north-east-trending band up to 40 km wide in the north-western part and up to 60 km in the south-eastern direction. The north-eastern boundary with Gorikhivskiy block follows the zone of Bolgrad-Suvorovskiy fault. In the south-western direction this block is extended outside the territory of Ukraine into adjacent Romania and is bounded by the deep-seated fault zone (zone Machyn). In the north-western direction the block is extended into the neighboring Moldova and by the zone of Galats-Tyraspilskiy fault adjoins Nyzhnyoprutskiy block. In the south-eastern direction the block is extended outside the studied area. In contrast to Gorikhivskiy block, in Nyzhnyodunayskiy block are widely developed Devonian rocks and Triassic sediments up to 5500 m thick, which with stratigraphic and angular unconformities are overlain by Jurassic, Neogene and Quaternary units. Apparently, the Vendian and Lower Paleozoic rocks are developed in the given block but they are during to considerable depth and not intersected by drill-holes. Description of tectonic structure in the basement and cover is given below separately.

The first- and second-order tectonic breaks, Chadyr-Lungskiy and Bolgrad-Suvorovskiy respectively, are distinguished based on the complex interpretation of geophysical materials, drilling data, satellite image processing, and results of morphometric analysis.

Chadyr-Lungskiy fault by the complex of evidences is classified to be the first-order regional-type break separating major structures in the EEP south-western slope – Moldavska and Besarabsko-Chornomorska plates. The fault is located in the far north of the territory (Dmytrivka village area) and is extended in the north-eastern direction over the distance of 7 km. According to geophysical data re-interpretation, prospecting and mapping drilling data and analysis of litho-tectonic complexes developed from the both sides of the fault, this break, from the kinematic point of view, is reverse-normal fault with sub-vertical dipping and essential amplitudes (up to 3 km) of alternating vertical motions. Thickness of the fault zone (apparently) does not exceed 500 m. In the "Map of local anomalies of gravity field Δg" the fault zone is well expressed in the high-gradient zone (see frame-off outlets to the "Geological map of pre-Cenozoic units").

Bolgrad-Suvorovskiy fault, by analogy with Chadyr-Lungskiy one, by the complex of evidences, is classified to be the major regional break, but lower order, separating the second-order blocks in Besarabsko-Chornomorska plate – Gorikhivskiy and Nyzhnyodunayskiy blocks. The fault is located in the central part of the studied area and is extended in almost sub-latitudinal direction along 40 km from Bolgrad town (in the west) to Suvorove village (in the east).

According to the geophysical materials re-interpretation [42], prospecting drilling data, satellite image processing, morphometric studies and analysis of litho-tectonic complexes developed by both sides of the fault, from the kinematic point of view the fault apparently comprises normal-reverse break with sub-vertical dipping or light inclination to the south-west under the angle 15-20^{o}. The fault zone is mainly composed of cataclasites (DH 1rB) [42] and exhibits significant (up to 5 km) vertical alternating motions. In the "Map of local gravity anomalies – $\Delta g_{loc.}$" the fault is well expressed in the high-gradient zone. Thickness of the zone after geological data does not exceed 500 m.

Tectonics of crystalline basement

The major "pre-plate" tectonic element of crystalline basement is Suvorovskiy dome. In the plane this is regular ring structure 50-55 km across with the center in Suvorove village area and occupies the northern, central and partly southern part of the studied area. The internal structure of Suvorovskiy dome includes the system of radial faults. Structure is distinguished for the first time after satellite image processing and morphometric studies. Suvorovskiy dome is most clear expressed, especially its northern part, in the satellite image of KATE-200 type, 0.60-0.70 mcm range.

Later on, during the litho-facial map design for major Neogene tectonic units and geological maps for Jurassic System, it was found that certain fragments of Suvorovskiy dome are mainly expressed in the boundaries of specific subdivisions, sharp changes in sediment thickness, flexure bends, and in some places with faults developed in the cover rocks.

With the north-west-trending Bolgrad-Suvorovskiy fault structure is divided into almost equal two parts. The north-eastern part is elevated (Gorikhivskiy black) and Paleozoic sediments are lacking over there being developed in Herzinian tectonic floor in Nyzhnyodunayskiy block. The Cambrian sediments with red-brown Suvorovska sequence are developed in the Late Baikalian tectonic sub-floor and intersected by DH 4rS [21, 42] in the far south-eastern, most subsided part of this block, and are essentially eroded.

The south-western part of Suvorovskiy dome in Nyzhnyodunayskiy block by the zone of Bolgrad-Suvorovskiy fault is buried to significant depth beneath the sedimentary sequence constituting Herzinian and Early Kimmerian tectonic sub-floors. The oldest rocks which overlie Suvorovskiy dome are Vendian sediments intersected by drill-holes mainly at the periphery of the northern and central parts of this structure. The youngest overlaying rocks are Middle Jurassic sediments of Andrushynska Suite.

Suvorovskiy dome is composed of plagiogranites and their gneissose varieties apparently developed over most of the studied area. Since in the deep-seated fault zone (Mechyn zone, Romania) the mafic gneisses of meso-zonal facies are exposed at the modern erosion surface, which lie over Precambrian gneisses and gneissose granites[1], it can be concluded that in Precambrian basement of the southern part of Nyzhnyodunayskiy block the gneisses and gneissose granites are developed in the inter-block structures.

Suvorovskiy dome with the system of radial faults is split into numerous diverse-size blocks subsided to various depths. Based on morphometric analysis and thickness analysis of Jurassic sediments, the following units are distinguished over there: Novokamyanskiy, Bolgradskiy, Gorikhivskiy, Novotroyanivskiy, Dmytrivskiy, and Kalanchakskiy blocks bounded by Vladychenskiy, Vasylivskiy, Golytskiy and Chervonoarmiyskiy concentric-ring faults, and Novonekrasivsko-Kamyanskiy, Staronekrasivskiy, Utkonosivskiy, Katlabukhskiy and Bolgrad-Suvorovskiy radial faults. In the kinematic-morphologic respect, the Archean – Early Proterozoic fault system consists of reverse-normal sub-vertical breaks.

Tectonics of sedimentary cover

In the studied area, the sedimentary cover includes seven litho-tectonic complexes: Vendian – Cambrian, Silurian – Early Devonian, Devonian – Early Carboniferous, Triassic, Jurassic, Pliocene, and Quaternary. Each complex contains certain set of sedimentary sequences (stratons) and separated from the over- and underlaying complex by the regional unconformities and tectonic plane misfits.

Based on the analysis of regional interruptions in sedimentation, relationships between litho-tectonic complexes and distinct patterns of their tectonic planes, seven tectonic floors are distinguished in the sedimentary cover: Late Baikalian (Salairian), Caledonian, Herzinian, Early and Late Kimmerian, Early and Late Alpine. Description of the litho-tectonic units in the EEP sedimentary cover is given below.

Late Baikalian (Salairian) tectonic floor

This tectonic element of EEP sedimentary cover is only confidently established in the southern part of Moldovska plate by DH R-20VP [21, 42] (Valya-Perzheyska) and in the south-eastern and south-western peripheral parts of Gorikhivskiy block which belongs to Besarabsko-Chornomorska plate (region of tectono-

[1] Romanian authors consider these rocks to be Late Proterozoic (Riphean?) - *(Ed.)*.

magmatic activation) of EEP and intersected by drill-holes 1B [42] (Bolgradska) and 4rS [21, 42] (Suvorovska), where it is exposed at pre-Jurassic surface.

Late Baikalian tectonic floor includes Vendian-Cambrian marine terrigenous-clayey complex composed of intercalating non-carbonate argillites and aleurolites with fine-grained sandstone interbeds. The complex lies with sharp stratigraphic and angular unconformity over high-grade Archean – Lower Proterozoic rocks developed in the EEP basement indicating significant interruption in sedimentation and essential tectonic re-arrangement in the territory. The complex with stratigraphic unconformity and Ordovician sediments missing from the column but without angular unconformity is overlain by Silurian – Lower Devonian complex indicating stable enough tectonic regime in the region at the boundary of Cambrian and Silurian.

Caledonian tectonic floor

Caledonian tectonic floor of the EEP cover is only confidently established (see cross-section A1-A3, DH R-20VP [21, 42], Dmytrivka village) in the far north-eastern part of the area, in the southern slope of Moldovska plate. However, since Silurian – Lower Devonian sediments are intersected by drill-hole in Zmiiniy Island and in Saratsko-Tatarbunarska litho-tectonic zone, one can conclude that Silurian – Lower Devonian sediments are widely developed in Nyzhnyodunayskiy block although being buried at considerable depth and not intersected by drill-holes.

Caledonian tectonic floor includes Silurian – Lower Devonian litho-tectonic complex composed, in the lower part, of intercalating Middle and Upper Silurian Llandoverian, Wenlockian and Ludlowian dark-grey limestones and Lower Devonian argillites with aleurolite and limestone interbeds. With the stratigraphic unconformity this complex lies over eroded Cambrian surface. Relationships with the overlaying complex are not established. Thickness of the complex is 205 m.

Herzinian tectonic floor

This tectonic unit consists of Devonian litho-tectonic complex. In the lower column part the sequence is distinguished of Middle and Upper Devonian limestones, in places dolomitized, more than 500 m thick. The upper column part is terrigenous-clayey (flyschoid) in composition consisting of Upper Devonian black schists and dark-grey sheared aleurolites, rarely sandstones (Orlovska sequence) up to 1500 m thick.

The rocks of Devonian complex, constituting Herzinian tectonic sub-floor in Nyzhnyodunayskiy and Nyzhnyoprutskiy blocks, are highly dislocated and altered under initial phases of regional-metamorphic greenschist facies, cut by quartz syenite intrusion and lamprophyre (kersantite) dykes and dyke-like bodies, and penetrated by milky-white quartz and calcite veins of quartz-calcite barite and calcite-sulphide (galena, sphalerite, pyrite) composition. The rocks of Herzinian tectonic sub-floor are accompanied by barite occurrences, polymetallic (lead, zinc) mineralization points, and numerous anomalies of gold, silver, and other elements. The internal structure of Herzinian tectonic floor includes initial-phase compression deformations of reverse-normal type and is very similar to the frontal dislocations in the cover of folded Donbas.

Development of these deformations in sedimentary cover, as it is evidenced by the Folded Donbas – tectonic activation structure in the EEP, in only possible under sub-layer (sub-horizontal) detachments along the ductile sequences. This sub-horizontal detachment can be exemplified by the column of outcrop 100 (see “Geological map of pre-Cenozoic units”) [42] on Kamyana mountain nearby Orlovka village, and the column of DH 1sO [42, 48] drilled in the given area. In the outcrop, in the wedge-shaped block the steeply-dipping rocks of Orlovska sequence are exposed consisting of sheared quartz aleurolites and quartz-sericite-chlorite schists with aleuritic limestone interbeds, and is cut by thick cleavage zone. The latter is north-west-trending and plunges in the western direction, towards Dobruja, under the angle 25-30^{o}.

Aforementioned plunging direction of cleavage zone has been previously interpreted by geologists as the dipping of layering. The internal sequence deformations are widely developed in the zone, like fine folding, which is well expressed in limestone interbeds from DH 1sO core samples [42, 48]. The shears are also well visible oriented parallel to the cleavage. Major plicative forms of the single-direction sub-horizontal (tangential) compression of Carpathian type are nappes or thrusts. In contrast to the typical syncline and anticline forms, there are no normal vault cores in the structures of this deformation type. Commonly, the frontal nappe parts are elevated and complicated by reverse-thrust faults whereas opposite nappe side is subsided and looks like syncline. In general the nappe resembles asymmetric anticline complicated by reverse-thrust faults in the frontal part. Normally, the older rocks are exposed at the erosion surface in the frontal parts of these structures.

Herzinian tectonic floor is confidently established in the map sheet area in the central and northern parts of Prydunayskiy block where the rocks of this unit constitute anticlines of Early Kimmerian structures and intersected by numerous drill-holes beneath Neogene and Quaternary sedimentary sequences. The rocks of

Devonian complex are almost completely exposed at pre-Neogene surface in the elevated Nyzhnyoprutskiy block where Triassic sediments are actually eroded.

In view of uniform composition of the upper Devonian complex (sheared aleurolites and schists – Orlovska sequence), interpretation of its internal structure is complicated as far as geophysical methods are not efficient in this case. It was only possible based on morphometric analysis and satellite image processing using drilling data. By means of this composite method, four major plicative structures are distinguished in the area (from west to east): Reniyska, Lymanska, Kotlovynska and Bolgradska nappes (see "Tectonic scheme in the scale 1:500 000 to "Geological map of pre-Cenozoic units"), which, in turn, in places are complicated by the minor nappes. In Dolynske village area Dolynskiy dome is distinguished caused by intrusive quartz syenite massif. Plicative structures – nappes are horseshoe-shaped with the convex side oriented in the eastern direction. The width in the central parts varies from 10 to 20 km which could be resulted from their flat, up to 10^o, plunging in the western direction. Plicative structures are separated by fault zones of reverse-thrust type which are genetically linked with the zone of sub-horizontal compression buried to significant depth. Thickness of these zones, intersected by DH 1uD [20, 42] and 6O [42], does not exceed first tens of meters. The fragment of such a zone in cleavage zone is exposed at the surface in Orlovka village area. The major faults of Herzinian tectogenesis stage include Skhidnoreniyskiy, Kagulskiy, Skhidnoyalpugskiy, Tsentralnodolynskiy and Pivdennodolynskiy breaks.

Early Kimmerian tectonic floor

This tectonic unit is composed of Triassic litho-tectonic complex. Like the Devonian litho-tectonic complex, this one was developing under conditions of peri-cratonic trough in the EEP south-western margin, which spatially coincides with the distinguished Besarabsko-Chornomorska plate with the northern and north-eastern boundary by Chadyr-Lungskiy regional fault (see "Tectonic scheme in the scale 1:500 000 to "Geological map of pre-Cenozoic units").

Triassic complex includes (from bottom to top) the red-brown terrigenous sequence, Novosilska Suite, and carbonate-terrigenous sequence. The lowermost, basal coarse-terrigenous, brownish-red Lower Triassic sequence is composed of gravel-pebble conglomerates, sandstones and aleurolites. Thickness of the sequence after geological data is about 120 m.

Lower-Middle Triassic Novosilska Suite is mainly composed of limestones, dolomitized in the upper part. Thickness of Novosilska Suite is about 1400 m.

Upper Triassic carbonate-terrigenous sequence of flyschoid type is mainly composed of grey and dark-grey, non-banded, calcareous aleurolites with limestone interbeds. Thickness of the sequence is about 1000 m.

The total thickness of entire Triassic complex, constituting Early Kimmerian tectonic sub-floor, is bout 3500-4000 m, indicating significant subsidence amplitude over Triassic time (see stratigraphic column).

Triassic litho-tectonic complex is most completely developed in Nyzhnyodunayskiy block only where these rocks constitute Early Kimmerian tectonic floor and intersected by numerous drill-holes.

The rocks of Triassic LTC, involved in the Early Kimmerian tectonic floor in Nyzhnyodunayskiy block, are deformed into the north-west-trending folds with strike azimuth $220\text{-}300^o$ and cut by numerous faults into separate blocks. Completeness of Triassic complex preservation directly depends on the post-sedimentation development of certain blocks and their vertical motions. In the southern and south-eastern parts of Nyzhnyodunayskiy block synform structures of Early Kimmerian floor look like asymmetric folds with axial surface plunging to the south and south-west under the angle up to 45^o, and subsided portion is complicated by the reverse fault and thrust breaks. This folding type resembles nappe. In the anticlinal portions of these structures Herzinian rocks are exposed at the erosion surface. This type of deformation is developed in Prydunayska and Plavnenska syncline structures, which in the buried slope of Northern Dobruja are exposed at pre-Neogene surface and well intersected by drill-holes. In the northern and north-eastern directions and Kugurluy lake area, after geophysical data, the synform structures progressively become the normal synclines of platform type with the flat, up to 20^o rock dipping in the limbs. After direct observation and on the ground of geophysical data interpretation, in the north-eastern part of Nyzhnyodunayskiy block five synform structures are distinguished: Prydunayska, Plavnenska, Tsentralnoyalpugska, Pivnichnoyalpugska and Kamyanska synclines, and the system of antiform structures: Ferapontievska, Novosilska, Larzhanska, Vladychenska and Novokalanchynska anticlines.

Of the faults emerged at Early Baikalian stage, the following are most prominent: Ferapontievskiy, Novosilskiy, Izmailskiy, Sofyanskiy, Loshchynivskiy and Bolgrad-Suvorovskiy. From the genetic-morphological point of view, these are steeply-dipping reverse-thrust faults. In the gravity fields the faults are expressed in high-gradient zones. Thickness of the zones, after drilling data (DH 027 [42, 48], does not exceed first tens of meters (see cross-section A_1-A_3 to "Geological map of pre-Cenozoic units").

It should be noted essential misfit between tectonic planes of Early Kimmerian and Herzinian tectonic floors. For instance, Herzinian tectonic plane exhibits almost longitudinal orientation of structures with western vergence whereas Early Kimmerian structures are extended in sun-latitudinal direction with respective southern and partly south-western vergence. This misfit in tectonic planes suggests for abrupt (almost by 90^o) change in the sub-horizontal tectonic movements in the region at the stage of Early Kimmerian tectogenesis.

Triassic terrigenous-carbonate-flyschoid complex, developed in Early Kimmerian floor, with sharp stratigraphic and angular unconformity lies over Vendian, Upper Devonian units and Orlovska sequence, indicating essential interruption in sedimentation and tectonic re-arrangement at the boundary of Late Carboniferous and Permian.

Late Kimmerian tectonic floor

Late Kimmerian tectonic floor includes Middle and Upper Jurassic litho-tectonic complex developed under conditions of north-eastern part of Jurassic trough which is most completely developed in Western Europe, Crimea and Caucasus. In tectonic respect, this part of trough had encompassed entire territory of Besarabsko-Chornomorska tectono-magmatic activation region and considerable part of the southern and south-western slopes of Moldavska plate. In geological publications this structure is known under the name Fore-Dobrudja or Moldavskiy trough [56, 76], but in fact this is only north-eastern part of the trough, developed over Middle and Late Jurassic, and encompassed not only studied area, but also adjacent regions – Northern and Central Dobruja, where Jurassic rocks were eroded in post-Jurassic time, and at present they are only mapped in the Middle Jurassic remnants. In the modern plane this structure is expressed in up to 100 km wide band extended in the north-western direction. The north-eastern part of this structure is located outside the studied area in the territory of southern Moldova, and the south-western boundary follows the line of Dolynske – Nagirne – Plavni – Novosilske – Nova Nekrasivka villages and then to the south of Izmail town. Structure is controlled by the system of post-Jurassic reverse faults with amplitude more than 1300 m and is confidently confirmed by the columns of deep drill-holes 1uD, 2uN [20, 42], 6g/kI [21, 42].

Based on detailed litho-facial analysis, five litho-stratigraphic subdivisions – suites are distinguished in Jurassic litho-tectonic complex, described in the section “Stratified units”.

The major tectonic elements of Late Kimmerian floor include the system of numerous flat syncline and anticline forms of platform type. Distinctly, the floor had inherited tectonic elements (synforms, antiforms, system of blocks and faults) of pre-Baikalian, Herzinian and Early Kimmerian tectonic planes in the given territory. By drilling data, essential, up to 1500 m, amplitudes are noted for vertical motions of certain blocks. Specifically, the highest vertical movements had occurred in the south-western part of Jurassic trough where Jurassic system is almost completely eroded (Prydunayskiy block). In Nyzhnyodunayskiy block, from the south-west to north-east, Andrushynska, Bolgradska, Kazakliyska, Kongazka and Chadyr-Lungska suites are sequentially exposed at pre-Neogene surface (see “Geological map of pre-Cenozoic units”).

Position of Chadyr-Lungska Suite indicates that the south-western part of this block underwent essential uplifting in comparison to its north-eastern part.

Jurassic litho-tectonic complex, constituting Late Kimmerian tectonic floor, with the stratigraphic and angular unconformity lies over Archean, Lower Proterozoic, Vendian, Lower and Upper Devonian, Triassic rocks, suggesting for significant interruption in sedimentation and tectonic re-arrangement at the boundary of Late Triassic and Middle Jurassic.

Late Alpine tectonic floor

Late Alpine tectonic floor includes Paleogene, Neogene and Quaternary litho-tectonic complexes, clearly separated by stratigraphic discontinuities and notable interruptions in sedimentation accompanied by essential erosion of previously deposited sequences.

Paleogene litho-tectonic complex includes Eocene carbonate-clayey sediments, mainly fine-grained sandstones, aleurolites and marls. The maximum thickness of this complex is 131 m. Paleogene sediments with considerable stratigraphic, and in places with slight (inclination up to 3^o) angular unconformity lie over various Jurassic sediments. This indicates significant tectonic re-arrangement at the boundary of Late Jurassic and Middle Paleogene. Eocene sediments are essentially eroded and only preserved in erosion remnants in the north-eastern part of territory, precluding any thoughts on the tectonic forms of inversion stage in Paleogene trough.

Neogene litho-tectonic complex includes two sub-units – Upper Miocene and Pliocene. The total thickness of Neogene LTC is about 450 m. Based on analysis of pre-Upper Miocene surface the following tectonic units are distinguished in the south-western limb of Neogene trough – Prydunayskiy block (plunged slope of North Dobruja horst), Vladychen-Loshchynivska depression, Bolgrad-Gorikhivskiy bench, and

Dmytrivska depression. In general, tectonic plane of Neogene stage is inherited from the earlier structures. Specifically, Dmytrivska depression coincides with the zone of Dmytrivskiy block; Bolgrad-Gorikhivskiy bench – with the zone of Gorikhivskiy block; Vladychen-Loshchynivska depression – with the buried part of Nyzhnyodunayskiy block; Prydunayskiy block – with elevated portion of Nyzhnyodunayskiy block.

Tectonic re-arrangement of Late Alpine floor at the stage of inversion was not sufficient. Of that, Atychna phase is most expressed at the boundary of Sarmatian and Meotychniy stages with slight uplifting and flat arch development in Bolgrad-Gorikhivskiy block, where Meotychni sediments overlie Upper Sarmatian sediments with considerable erosion estimated to 50-100 m. The complex underwent more re-arrangement due to Late Pleistocene – Holocene uplifting in the northern part of territory with amplitude 100-120 m, which had finally affected the modern hypsometric position of major uneroded Neogene stratigraphic subdivisions.

Quaternary litho-tectonic complex in the studied area includes two sub-complexes. The first one is composed of loess-like loams with former soil horizons; the complex was developing under conditions of thick glaciers in the northern part of Europe. Thickness of sediments does not exceed 30 m. The second sub-complex is of sub-aqueous origin consisting of alluvial (river course, flood-land), lake, estuary sediments and proluvial-deluvial diverse-grained sands, aleurites with gravelite and clay interbeds. In the studied area seven sub-aqueous stratigraphic subdivisions are distinguished developed in the system of Danube River terraces and its left minor branches Kqagul, Yalpug and Katlabukh. Thickness of single stratigraphic subdivision does not exceed 80 m. Quaternary litho-tectonic complex underwent essential tectonic re-arrangement in Late Quaternary – Holocene time.

Based on structure analysis of uneroded smoothing surfaces of individual Neogene stratigraphic subdivisions, specifically, Eo-Pleistocene – Lower Pleistocene sediments developed over entire territory, and smoothing surface of certain sub-aqueous complexes, considerable uplifting of the northern part of territory is established in relation to its southern part. Amplitude of uplifting is 150-140 m (see “Neo-tectonic scheme” to “Geological map of Quaternary sediments”).

In general, the smoothing surface of Eo-Pleistocene – Lower Pleistocene sediments is monocline inclined from the north to south and complicated by flexure bends.

5. HISTORY OF GEOLOGICAL DEVELOPMENT

In tectonic respect, the map sheet territory L-35-XXIII (Izmail), L-35-XXIX (Tulcha) belongs to Eastern-European Platform (EEP) and, typically for its plates, is two-folded, with basement and platform cover.

Pre-plate period in the territory development, which includes Archean and Early Proterozoic, can be restored in general only because of data lacking. Over that time, which corresponds to pre-Baikalian cycle of tectogenesis, granitization processes had occurred accompanied by extensive potassium and sodium input into the Earth crust. These processes had caused structure and composition transformations in proto-metamorphic basement and extensive thickening of granite-metamorphic layer. Giant granitization and accompanied regional metamorphism and consolidation of pre-Riphean rocks had defined further plate development of EEP. Over that time Suvorovskiy plagiogranite massif had been formed into the dome up to 55 km across with distinct radial-concentric internal structure.

The plate development stage in the EEP south-western margin encompasses essential time span from Late Proterozoic (Vendian) up to Holocene. The oldest structure in the EEP plate development is Dnisterskiy peri-cratonic trough emerged in relation with the active growth of mio-geosyncline troughs (Vendian) where the EEP western and south-western margins were involved. Dnisterskiy peri-cratonic trough, in the modern understanding, included Moldavska plate and Besarabsko-Chornomorska plate (region of tectono-magmatic activation), distinguished by the authors. The boundary between these two structures follows the zone of Chadyr-Lungskiy regional fault. Transition to plate regime was resulted in the re-arrangement of tectonic plane in the region, and outside the studied area, in the zones of tectono-magmatic activation (Volyn and Prydnistrovya), had been accompanied by extensive mafic magma emplacement (Volynian and Podolian flood-basalts).

In the course of continuous sedimentation during Vendian-Cambrian the earliest litho-tectonic cover complex has been developed: sandy-aleurite-clayey sediments with admixture of volcanic material – Mogyliv-Podilska Series (Vendian); marine aleurites-clayey sediments – Kanylivska Series (Vendian), and marine sandy-aleurite-clayey sediments – Cambrian. Thickness of Vendian-Cambrian complex in Moldavska plate is about 400 m and becomes more than three times thicker in the south-western peri-cratonic trough attaining 1300 m. The difference in the thickness of Vendian-Cambrian complex indicates more extensive subsidence of the south-western region in comparison to Moldavska plate. Deposition of Cambrian sediments completes the first stage in the EEP pre-cratonic trough development. In Ordovician time the short interruption in sedimentation had occurred expressed over entire territory of Prydnisterskiy peri-cratonic trough.

Silurian – Early Devonian period comprises the second stage in the development history of given area. Starting from Wenlockian (Silurian) to Emsian (Early Devonian) time, under conditions of the platform-type shallow-water marine basin, the carbonate-clayey Silurian – Lower Devonian litho-tectonic complex had been developed. This complex in the studied area is intersected by drill-holes in Moldavska plate only. Taking into account, however, that Silurian – Lower Devonian sediments are intersected by drill-hole in Zmiiniy Island, in Tatarbunary village area, and zone Mechyn of Northern Dobruja (Fig. 4.1), one may conclude that Silurian – Lower Devonian rocks are also widely developed in Nyzhnyodunayskiy block but are not intersected by drill-holes. The maximum thickness of this complex by drilling data is 205 m. Lack of angular unconformity at the boundary of Vendian-Cambrian and Silurian – Lower Devonian litho-tectonic complexes indicates insufficient tectonic re-arrangement in the region which correspond to Baikalian tectogenesis. At the boundary of Early and Middle Devonian the short-time interruption in sedimentation occurs in the region. Starting from Givetian (Devonian) up to Visean (Carboniferous) time the new sea transgression over the EEP western part had occurred while the northern and north-eastern boundary of this transgression is limited by Chadyr-Lungskiy fault zone. Over Givetian, Frasnian and Famennian times (Devonian) under conditions of shallow-water platform-type marine basin in Dmytrivska and Chervonoarmiyska LTZs the carbonate, often dolomitized, sequence more than 500 m thick was depositing.

At the end of Famennian time in Nyzhnyodunayska LTZ sedimentation conditions had been changed towards marine basin shallowing and under coastal-marine zone or even in the delta the clayey-terrigenous sub-complex was developing, essentially enriched in organic matter, and comprising the upper part of Devonian litho-tectonic complex (Orlovska sequence). Starting from the end of Famennian time the sea basin regression outside the map sheet area was occurring and ever since that time the region was developing under continental conditions. The given sub-complex in the studied area is only developed in Nyzhnyodunayskiy block, where it is intersected by numerous drill-holes, mainly in the anticline portions of plicative structures of Early Kimmerian (Early Jurassic) tectogenesis stage. The contact of Silurian – Lower Devonian and Middle-Upper Devonian complexes, which correspond to Caledonian tectogenesis stage, is not encountered in the studied area but ion adjacent Saratsko-Tatarbunarska field the drilling works had intersected the gradual contact indicating the lack of essential tectonic changes over that time.

In the time span, which corresponds to Early and Middle Carboniferous, the territory underwent Herzinian tectogenesis, most extensively developed in adjacent Western-European Platform. Over that time the EEP south-western slope comprised "buffer" zone between the ancient (Archean – Early Proterozoic) stabilization region and the younger tectonically active geosyncline region. The Middle – Upper Devonian complex together with underlaying complexes underwent the tangential (sub-horizontal) compression from the west to east and partly to north-east. Plicative structures of incipient thrust structure (like Folded Donbas) and the fault system (reverse fault – thrust type) have been formed. The flat nappes with western vergency were the main types of plicative structures. The basement faults were activated and the lamprophyre dykes and dyke-like bodies as well as minor gabbro, syenite and granite massifs were emplaced. At the contact of syenites (Dolynskiy massif) (see "Tectonic scheme in the scale 1:500 000" to "Geological map of pre-Cenozoic units") with Upper Devonian carbonate sequences skarnation and host rock assimilation is noted resulted in the rocks hybridization of magmatic complexes where increased content of gold, silver and other elements is noted. At the final phase of Herzinian tectogenesis the hydrothermal-vein complex was developing including quartz, carbonate, quartz-carbonate-barite veins which control barite and in places polymetallic (galena, sphalerite, pyrite) mineralization. The rocks of Herzinian tectonic floor underwent greenschist facies regional metamorphism. At the inversion development stage (orogenic phase) of the territory the rocks of Devonian complex in places were essentially eroded, especially in the nappe frontal parts, where Middle and Upper Devonian carbonate sequences are brought to the Triassic surface. The Middle-Upper Devonian complex with stratigraphic and angular unconformity is overlain by Lower Triassic terrigenous sequence.

Since the end of Famennian time up to Early Triassic the territory of studied map sheets was developing under continental regime, when denudation processes were widespread, resulted in the area peneplainization by the beginning of Permian-Triassic sedimentation cycle.

Starting from Early Triassic, the territory was involved in the new sedimentation cycle. Subsidence in Triassic time encompasses only south-western part of Eastern-European Platform and spatially coincides with Besarabsko-Chornomorska plate, distinguished by the authors, which is bounded from the north by Chadyr-Lungskiy fault zone. In view of Triassic LTC thickness, the territory subsidence depth was about 4000 m. Triassic period comprises the third stage in the history of plate development in the studied area. At the beginning of trough development the lower basal, coarse-terrigenous, brownish-red Lower Triassic sequence is deposited under sub-continental conditions. It is composed of gravel-pebble conglomerates, sandstones and aleurolites. Thickness of the sequence after geological adapt is about 1200 m (see cross-section to "Geological map of pre-Cenozoic units").

The territory was developing under sub-continental conditions up to beginning of Late Triassic. Over that time, the thick Lower-Middle Triassic carbonate sequence (Novosilska Suite) is deposited. It is mainly composed of limestones and in the upper column parts only their dolomitized varieties appear. Thickness of Novosilska Suite is 1400 m. Triassic sea transgression had apparently encompassed entire territory of Besarabsko-Chornomorska plate, bounded by Chadyr-Lungskiy fault zone, but upon Late Triassic inversion in Gorikhivskiy, Nyzhnyoprutskiy and Aluat-Baurchanskiy blocks (two latter are located to the north-west from the studied area) the carbonate sequence is completely eroded (see "Tectonic scheme in the scale 1:500 000" to "Geological map of pre-Cenozoic units").

Starting from Late Triassic sedimentation conditions have been changed because of sea basin shallowing and its regression away from the territory. Instead of carbonate sedimentation, mainly carbonate-terrigenous sedimentation of flyschoid type had been established. Thickness of respective sequence is about 1000 m. With the Upper Triassic carbonate-terrigenous sequence the territory development under regime of Triassic trough is completed as a result of Early Kimmerian tectogenesis phase. Within period from Late Triassic up to Bajoician time the territory was developing under continental regime. The area underwent essential tangential (sub-horizontal) compression first, in contrast to the descending motions at the trough formation stage, resulted in tectonic, mainly plicative, deformations, affected not only Triassic litho-tectonic complex but also previously formed ones. Triassic sediments are deformed into the south-west-trending folds with azimuth NW 290-300^o. In the south-western part of Nyzhnyodunayskiy block synform structures look like asymmetric folds with main surfaces plunging to the south, south-west under the angle 45^o, and their plunged portions are complicated by reverse fault – thrust breaks. This type of synform structures resembles nappes. In the northern and north-eastern directions and in Kugurluy lake area, after geophysical data, synform structures become the platform-type normal synclines with the flat (angle up to 20^o) rock dipping in the limbs. Plicative tectonic elements of Herzinian development stage – the nappes with different tectonic plane, at this development stage underwent almost cross-wise sub-latitudinal deformations, characteristic for Early Kimmerian tectogenesis stage.

Within given time span emplacement of dyke-like diabase bodies had occurred along tectonic breaks. At the inversion development stage of Triassic trough mainly ascending motions had predominated, which substituted sub-horizontal compression. At the end of inversion (orogenic) development, in the direct relation from the amplitude of ascending vertical motions and in accordance with the activity of denudation processes, Triassic complex was eroded in some blocks. In view of thickness of eroded complex, the amplitude of vertical motions was about 4000-5000 m. As a result of widespread denudation processes, by the beginning of Jurassic transgression the territory had comprised the peneplainized surface, where Archean – Lower Proterozoic and various levels of Paleozoic and Triassic stratigraphic subdivisions were brought up to the pre-Jurassic surface.

Since the Middle Jurassic Bajocian time the territory was involved again into the new sedimentation cycle. In Middle Jurassic Bathonian time, and up to the end of Late Jurassic Tithonian time, Jurassic litho-tectonic complex was developing in the studied area. The rocks of this complex with considerable stratigraphic and angular unconformity lie over pre-Vendian basement, Lower Paleozoic rocks, and various subdivisions of Triassic, indicating essential tectonic re-arrangement and denudation level of the territory since the end of Triassic up to beginning of Jurassic transgression. Development of Jurassic complex had occurred under conditions of the north-eastern part of broad Jurassic trough occupied significant territories of the Central and Western Europe, Crimea and Caucasus. In contrast to Devonian and Triassic transgressions, Jurassic one is expanded not only over Besarabsko-Chornomorska plate but also considerable part of the southern and south-western slope of Moldavska plate. At the beginning of trough development, in Bathonian-Bajocian time, under conditions of normal sea basin, evidenced by fauna and micro-fauna complexes, Andrushynska Suite (Middle Jurassic) up to 2524 m was depositing. In the Suite column terrigenous-clayey sediments predominate including diverse-grained sandstones, aleurolites and argillite-like clays. At the boundary of Bathonian and Callovian times the minor transgression of sea basin is noted away the studied area, which is indicated by the interruption and sharp change in sedimentation at the boundary of Andrushynska (J_2) and Boldgradska (J_{2-3}) suites. Starting from Callovian time, upon minor regression, the new Late Jurassic transgression of sea basin over map sheet territory had occurred. In Callovian and Oxfordian times, under conditions of normal sea basin, Bolgradska Suite up to 478 m thick is deposited consisting of reefogenic limestones and argillite-like clays. Within the time span from Middle Oxfordian up to Middle Kimmeridgian progressive shallowing of sea basin had occurred. Under these conditions Kazakliyska Suite (Upper Jurassic) up to 250 m thick is deposited consisting of alternating parti-colored limestones and argillite-like clays. Since the mid Kimmeridgian time lagoon-marine conditions were established in the area with mainly evaporitic sedimentation. Within this time span Kongazka Suite (Upper Jurassic) up to 651 m thick is deposited consisting of chemogenic limestones, dolomites, gypsums, anhydrites, gypsum-anhydrites, and parti-colored argillite-like clays with minor, mainly in the basal layers, diverse-grained sandstones and aleurolites.

At the beginning of Tithonian time sub-continental sedimentation conditions were established and in delta and proluvial-deluvial fans more than 540 m thick Chadyr-Lungska Suite (Upper Jurassic) was deposited. It consists of mainly parti-colored, normally clayey gravelites, diverse-grained sandstones and clayey aleurolites. Chadyr-Lungska Suite completes the territory development under Jurassic trough regime and the area progressively enters inversion development stage because of commenced Late Kimmerian phase of tectogenesis. Since the beginning of Early Cretaceous the territory underwent slight, in comparison to Early Kimmerian phase, sub-horizontal compression resulted in mainly plicative deformation of Jurassic litho-tectonic complex. Jurassic sediments are deformed into flat enough (up to some degree limb dipping) syncline and anticline folds. In Nyzhnyodunayskiy block the Late Kimmerian deformations had fully inherited tectonic forms of Early Kimmerian tectonic plane. In Gorikhivskiy block Jurassic complex deformations inherit tectonic patterns of Suvorovskiy dome with its distinct radial-concentric internal structure.

At the final phase of inversion stage the territory of Jurassic trough and especially its south-western part underwent essential ascending motions. In some places, for instance, in the zones of Izmailskiy and Kagulskiy faults, the vertical displacement amplitude attains more than 1300 m, as it is evidenced by DH 1uD, 2uN [20, 42] and 6g/kI [21, 42]. Due to extensive block motions and respective denudation extent in the south-western part of Nyzhnyodunayskiy block and in the Northern and Central Dobruja (Romania), Jurassic sediments are almost completely eroded. Since the Tithonian time to Eocene epoch the territory has been developed under continental conditions where denudation processes predominated having been finally resulted in the area full peneplainization by the beginning of Paleogene transgression.

Within period since the end of Tithonian time to the end of Paleocene the territory was developing under continental regime with widespread denudation processes. Since the beginning of Eocene the territory was involved into the new sedimentation cycle.

Since the rocks of Eocene litho-tectonic sub-complex are essentially eroded and overlain by Neogene sediments, it can be concluded that within given time span the territory, at least its north-eastern and partly central part, had occurred in the coastal shallow-water zone of Eocene sea basin, as it is evidenced by mainly terrigenous composition of sediments. At the end of Eocene the territory underwent ascending tectonic motions resulted in sea basin regression and continental regime extended up to the beginning of Late Miocene transgression.

Since the Middle Sarmatian the territory was involved in the new sedimentation cycle under conditions of the south-western part of Late Miocene trough encompassed almost entire western and southern margins of Eastern-European Platform. Essential part of pre-Late Miocene Northern Dobruja horst was also involved in subsidence. In general, in Late Miocene epoch the territory was developing under conditions of the south-western margin of shallow-water epi-continental basin, adjoined Northern Dobruja horst therein, that had affected sedimentation. Within given time span the sediments of partly desalinated sea basin (Early Sarmatian, Late Sarmatian, Meotychniy and Early Pontychniy) were depositing which in the south-western direction are facially replaced by thick sequence of the fore-mountain accumulative plain chlidolites. Under this regime the territory was developing by the mid Pontychniy time.

Because of Late Pontychniy completion in the Late Miocene trough development, which encompasses the time span from Middle Sarmatian to Early Pontychniy (Novorosiyskiy) time and regression of respective sea basin away the studied area, the region was developing under continental regime. Since the mid to late Pontychniy time essential drop in erosion basis had occurred as it is evidenced by the thickness of eroded Pontychni, Meotychni and partly Upper Sarmatian sediments where cut is about 160 m. This considerable descending of erosion basis in Prychornomorya is not related to climatic factors but mainly caused by tectonic re-arrangement in Tethys and para-Tethys in relation to the development of Alpine fold belt [15]. This tectonic re-arrangement had separated and got down Mediterranean and Black Sea basin levels resulted in significant erosion cut. Beginning of Kimmerian (Dacian) time in the history of region is expressed in erosion basis ascending up to the level existed before the Middle Pontychna regression. This erosion basis ascending is caused by the oceanic water breakthrough into Mediterranean and respectively Black Sea basins. Under the pass conditions between Dacian and Black Sea basins the sandy sequence of Kimmeriyskiy regio-stage was deposited. At the final stage of this complex development sedimentation area had been expanded outside the pass and encompassed significant fields to the north of this zone where under conditions of swamped lagoon the sequence of aleuritic dark-grey, grey and greenish-grey clays was developing as the facial analogue of the terrigenous sequence inside the pass.

At the beginning of Akchagylskiy time the next erosion basis drop had occurred in the area, essential enough in view of Kimeriyski sediments erosion extent. The cut is about 140 m and like post-Kimeriyskiy one, pre-Akchagylskiy cut is not related to climatic factors but is mainly caused by tectonic re-arrangement in entire Tethys and para-Tethys. The subsequent time span corresponds to essential erosion basis ascending, almost to the level existed prior to the beginning of mid-Pontychna regression. Over Akchagylskiy time under deltaic conditions thick enough clayey-terrigenous sequences is deposited mainly consisting of clayey diverse-grained sandstones, rarely gravelites, aleurolites and clays. Within the time span encompassing Eo-Pleistocene and partly Neo-Pleistocene phases of Pleistocene epoch the territory was developing under conditions of broad delta expanded over entire area between Prut and Dnister rivers. Under paleo-course conditions the river-course alluvium sequence was deposited therein with characteristic oblique banding. In the swamped areas and in the delta flood-lands mainly clays and clayey aleurolites were depositing. This regime in the studied territory had existed up to the Middle Neo-Pleistocene time and beginning of Sulskiy loess horizon development. Further geological history is caused by periodic climatic changes – cooling and warming. Under climate cooling in the north of Europe, in Scandinavia, thick glaciers had been formed which spread down to the southern regions. Significant water accumulation in glaciers had caused essential, 60-80 m, drop in erosion basis entailing vertical river cuts and finally development of the vertical and horizontal river valley profiles. The climate was cold and dry; the rivers were fed from the glaciers only. Inside river valleys denudation processes essentially exceeded accumulation processes. At the watershed plains over that time the loess horizons of aeolian nature were developing (dust storm sediments). In the warm time spans extensive melting of glacier areas had observed resulted in erosion basis ascending, marine basin climatic transgression and, respectively, thick sub-aqueous sediments deposition in the relief dimples. At the watershed plains, above previously formed loess horizons, the soil complexes were developing indicating considerable interruptions in sedimentation over that time. In total, seven such climatic alternations are confidently distinguished in the map sheet area L-35-XXIII and L-35-XXIX.

6. GEOMORPHOLOGY AND RELIEF-FORMING PROCESSES

The map sheet territory L-35-XXIII (Izmail), L-35-XXIX (Tulcha) is situated in Danube-Dnister terrace plain of Prychornomorska lowland (see “Geomorphologic scheme in the scale 1:500 000” to “Geological map of Quaternary sediments”).

The modern relief development had commenced in Eo-Pleistocene time when the rocks of large alluvial and deltaic plains of ancient river systems were depositing in the studied area. Erosion-accumulative and erosion-denudation-accumulative genetic types of relief are distinguished in the area, which, in turn, consist of simpler forms. In addition, a range of minor relief forms are distinguished which are not expressed in the map scale. The age of mentioned relief forms was determined in accordance with the age of sediments involved thereof or have been formed in relation to various processes defining the relief genetic types and forms.

Erosion-accumulative relief

This one comprises sub-horizontal and gently-inclined forms including Eo-Pleistocene – Neo-Pleistocene terraces, Danube river valley and Late Neo-Pleistocene – Holocene lakes, as well as Holocene minor river flood-lands, gully bottoms and fans. The general inclination of the modern relief surface from the north to south is related to the uplifting process in Southern Fore-Dorbuja commenced in pre-Kimeriyskiy time and occurring up to now, which, in turn, had caused development of accumulative terraces at various hypsometric levels (altitudes). At the same time, Danube River paleo-valley was established confined to the “margin zone” of Eastern-European Platform. The lake, minor river and gully valleys are often confined to the local faults separating the third-order blocks (see “Geomorphologic scheme in the scale 1:500 000” and the legend thereof).

Eo-Pleistocene – Early Neo-Pleistocene deltaic plain (k) is widely developed in the map sheet area and outside. Terrace slope is well expressed geomorphologically and observed to the north of Reni town, Lymanske and Nagirne villages at the contact with the first and third over-flood terraces. Further to the east and south-east, at the contact with the fifth and second over-flood terraces, it is less expressed in the relief. Terrace is embedded in the Neogene rocks of Kimeriyskiy and Pontychniy regio-stages and over most part of their distribution alluvial-marine rocks are overlain by eluvial and aeolian-deluvial sediments. Sub-aerial cover was developing over Early Neo-Pleistocene – Holocene; the surface altitudes are 30-175 m with descending to the south and south-east. The surface altitudes of alluvial-marine sediments are from -5.9 m in the south-east to 157 m in the north; the footwall ones – from -21.5 m in the south-east to 145 m in the north. The high difference in the sediment surface altitudes is caused by irregular differentiated territory uplifting in Quaternary time.

Middle Neo-Pleistocene fifth over-flood estuary-lake-alluvial terrace (j) is composed (from bottom to top) of Middle Neo-Pleistocene – Holocene alluvial, estuary-lake, eluvial and aeolian-deluvial sediments. Sub-aerial cover was developing over Middle Neo-Pleistocene – Holocene; the cover surface altitudes are 50-70 m. The elevation above Yalpug lake water level is 47.5-67.5 m. Terrace is observed in the southern part of the territory and in Plavni and Ozerne village area is well expressed geomorphologically, especially its bench at the contact with the third and first over-flood terraces. The back suture at the contact with Eo-Pleistocene – Early Neo-Pleistocene deltaic plain is less expressed. Terrace socle is composed of Kimeriyski rocks and observed at the altitudes -5...-26 m descending towards the modern cuts. The hanging-wall altitudes of estuary-lake sediments are 21.5-37.8 m ascending towards the back suture. The table width is up to 6.7 km.

Late Neo-Pleistocene third over-flood estuary-lake-alluvial terrace (i) is composed of alluvial, estuary-lake, aeolian-deluvial and eluvial sediments. Sub-aerial cover was developing over Late Neo-Pleistocene – Holocene; the cover surface altitudes are 30-40 m. The elevation above Katlabukh lake water level is 27.5-37.5 m. Terrace is observed in the southern part of the territory and in the area between Kagul and Yalpug lakes, to the north of Orlovka village, and almost everywhere is well expressed geomorphologically. The “table” width attains 9 km and length – 11.5 km. The third terrace is embedded in the fifth one and in the deltaic plain. The socle is composed of Neogene sands and clays and observed at the altitudes -17...-36 m descending in the southern direction. The hanging-wall altitudes of estuary-lake sediments vary from -2.5 m to -17.2 m and also descend to the south.

Late Neo-Pleistocene second over-flood estuart-lake-alluvial terrace (h) is composed of alluvial, estuary-lake, eluvial and aeolian-deluvial sediments. Sub-aerial cover was developing over Late Neo-Pleistocene – Holocene; the cover surface altitudes are 20-50 m. The elevation above water level is 17.5-47.5 m. Terrace is observed in the southern part of the territory, in the area between Kagul and Yalpug lakes, and also in the west bank of Yalpug lake, to the north of Plavni village, and in view of distribution contour it comprises Yalpug lake and Danube river terrace. Terrace is almost everywhere expressed in the relief. The table width is 300-1000 m in the area of Plavni village and 3.0-11.5 km in between Yalpug and Katlabukh lakes. The second terrace is embedded in the deltaic plain and the fifth terrace. The socle is composed of Kimeriyskiy regio-stage rocks and observed at the altitudes +4...-47.4 m. The hanging-wall altitudes of estuary-lake sediments vary from 0.4 m to 27 m. The general descending direction of the hanging-wall and socle is southern and south-eastern.

Late Neo-Pleistocene first over-flood estuary-lake-alluvial terrace (g) is developed in the banks of Kagul, Yalpug and Katlabukh lakes, in the southern part of map sheet territory along Danube river valley, and is composed of eluvial and aeolian-deluvial loams. Sub-aerial cover was developing over Late Neo-Pleistocene – Holocene; the cover surface altitudes vary from 5 m in the south to 50 m in the north. The elevation above water level is 2.5-47.5 m. Different hypsometric levels of terrace surface are caused by irregular modern tectonic uplifting of the territory. In the relief terrace is expressed well enough. The table width varies in the wide range from 200 m to 3.5-4.0 km. The socle is composed of Pontychni, Kimeriyski and Akchagylski (Neogene) rocks and observed at the altitudes -31.9...+41.0 m descending in the southern direction. The hanging-wall altitudes of estuary-lake sediments vary from 0.2 m to 55.0 m. Form the south to north the first over-flood terrace is sequentially embedded in all older Quaternary terraces and Pontychniy regio-stage sediments.

Danube river valley (d, e) is located in the southern part of territory and was formed in Late Neo-Pleistocene – Holocene. The course and flood-land are distinguished therein. The flood-land width is 0.05-8.5 km, surface altitudes are 2.5-5.0 m. The bedrocks include Akchagylskiy, Kimeriyskiy, Pontychniy regio-stage Neogene sediments, as well as Devonian and Triassic schists. The flood-land development time is Late Neo-Pleistocene – Holocene. The course is wavy, in the south-eastern part it consists of several branches (Old Danube, and Sulynske, Kiliyske and Georgievske mouths). The course width is 600-1120 m, river depth – 7-27 m, flow speed – 0.4-0.9 m/s, inclination – 0.0006^{o}, water line altitude – 2.4 m. The course formation time is Holocene.

In the studied area the *Holocene estuary-lake accumulative plain* (f) is widely developed, with surface altitudes 2.5-5.0 m in the southern part and 5-12 m in the north, reflecting irregular modern tectonic uplift of the territory in Holocene. The plain is well expressed in the relief and comprises the bedrock of Kagul, Yalpug, Kugurluy, Katlabukh and other lakes, in places swamped or dried and in the south it is gradually substituted by Danube river valley.

Two lake types are distinguished in the area – continental and flood-land. The continental lakes include Kagul, Yalpug, Katlabukh and Sofyan, which are the flooded river mouths bounded by the elevated continent banks, and are connected with Danube River by the narrow passes. The flood-land lakes are developed in the Danube river flood-land.

Yalpug lake is 192 km^2 in square, 40 km long, and up to 5 km wide. Average depth is 3 m, maximum – 6 m. In the south it is connected with Kugurluy lake. The slopes are erosion-abrasion and abrasion-slide. The coast cliffs are 2-40 m high.

Kagul lake is 92 km^2 in square, from 1 to 9.5 km wide, and up to 3 m deep. The slopes are erosion-abrasion. The coast cliffs are 2-12 m high.

Katlabukh lake is 71 km^2 in square, 21 km long, up to 7 km wide, and up to 4 m deep. The slopes are erosion-abrasion. The coast cliffs are 2-15 m high.

Sofyan lake is located in 4 km to the north-east from Izmail town. The lake is 9 km long, from 300 to 1.5 km wide, and 0.5-2.0 m deep. The lake is least wide and deep in the northern part. The slopes are erosion-abrasion. The coast cliffs are up to 5 m high.

The lake beaches are from 3 to 40 m wide, sand-mud, sand with shell.

A number of gullies and minor rivers with branches do inflow into the lakes and Danube River. The main strike of large gullies and rivers is southern, south-eastern. Most extensive erosion network is observed in the northern part of the territory which underwent highest uplifting in Quaternary time. The river valley and gully shape is V-like and U-like with symmetric and asymmetric cross-wise profile. The length of large gullies is up to 20 km, rivers – up to 50 km. The slopes are from 2-3 to 15^{o} steep. In places the rivers suddenly change the flow direction apparently because of tectonic structure of the territory and modern tectonic motions.

Late Neo-Pleistocene – Holocene minor river flood-lands (a) are composed of alluvial sediments and developed in the eastern part of studied area. The hanging-wall altitudes of the flood-lands vary from 5 m in the south to 89 m in the north. The width is 100-400 m. The relief of surface where rivers flow down is normally calm and gentle-inclined towards the course with the general inclination in the southern direction. The courses are either strait or wavy, often meandering, bifurcating. The width varies from 1 to 8 m, depth – from 0.5 to 1.5 m, and length up to 35 km. The minor river valley orientation is mainly sub-longitudinal and shape is U-like.

Of the minor rivers the biggest one is Katlabukh, extended in sub-longitudinal direction, and in the mouth part bifurcated into two rivers – Velykiy and Maliy Katlabukh. The valleys are trough-shaped with symmetric and asymmetric slopes up to 6^o steep. The course up to 5-8 m wide has permanents water flow and is cut by 1.5 m. The flood-land up to 400 m wide is flat, in places slightly swamped.

Late Neo-Pleistocene – Holocene gully bottoms (b) are composed of alluvial-deluvial sediments. The gully bottom surface altitudes vary from 5 m in the south to 165 m in the north. Their width varies in the wide range from 5-10 m in the upper courses of minor gullies to 350-400 m in the mouth of large ones. The bottom relief is calm, gently-inclined towards the course with general inclination to the south. The courses are either strait or wavy, often with erosion gorges. The width varies from 1 to 10-12 m, depth – from 0.1 to 6.0 m, and length up to 25 km.

Relatively large *Holocene fans* (c) are confined to the mouth parts of big gullies (Chitron, Valya-Mare, Sochilor, Burlacheny). They are well expressed in the relief and comprise low flat slopes up to 960 m long, up to 360 m wide, composed of aleurites-sand-clayey rocks. The hanging-wall altitude of the fans attains 10 m. In addition, the minor fans are characteristic relief forms in the mouth parts of minor gullies and ravines but in the map scale are not expressed.

Erosion-denudation-accumulative relief

This relief types includes slopes of various age and steepness formed through the erosion-denudation and abrasion-slide processes with sediment accumulation mainly in the lower part (see "Geomorphologic scheme in the scale 1:500 000" to "Geological map of Quaternary sediments").

Middle-Late Neo-Pleistocene and Late Neo-Pleistocene erosion-denudation-accumulative slopes (c, d) are developed throughout; they are up to 3^o steep, overlain by eluvial and aeolian-deluvial loams, and comprise the slopes of buried terraces or ancient river valleys, lakes and gullies. The cover was developing in Late Neo-Pleistocene – Holocene.

The slopes of buried river valleys and lakes are formed in Middle and Late Neo-Pleistocene. They normally are well expressed geomorphologically. The slopes of buried gullies are formed in Late Neo-Pleistocene, weakly expressed geomorphologically and gradually replaced by the Late Neo-Pleistocene – Holocene slopes. The slopes were developing above the rocks of various lithology and age. Alluvial-deluvial and deluvial sediments have been deposited in the limbs and lower parts of the slopes of river valleys, lakes and gullies mainly composed of loams with sand, aleurites, gravel and pebble admixture.

Late Neo-Pleistocene erosion-denudation-accumulative slopes (a, b) more than 3^o steep are widely developed in the studied area. They are observed in the river, lake and gully valleys. The upper slope boundary, especially in the upper gully courses, is conventional since their transition into other relief forms is gradual. The slopes are eroded, with gorges and ravines, flat or slightly convex, in the northern part often wavy because of loams sliding over the Eo-Pleistocene – Early Neo-Pleistocene clays, in places slightly hilly. Two slope groups can be distinguished by the erosion degree:

- the slopes developed mainly over clays and loams, slightly eroded by ravines and gorges with deluvial fan accumulation in the lower part;
- the slopes developed mainly over sandy rocks and complicated by extensive ravine erosion with accumulation of proluvial-deluvial fans in the lower part.

Holocene deluvial and proluvial-deluvial fans up to 50-100 m wide are well expressed geomorphologically in the flat slopes gradually substituted by the steeper erosion-denudation slopes. These are composed of materials transported by temporary water flows from the ravines and gullies and washed from the slopes because of planar erosion.

Late Neo-Pleistocene – Holocene abrasion-denudation-slide and erosion-denudation-slide slopes (e) more than $8\text{-}10^o$ steep are distinguished in the banks of Yalpug lake and Buzhorul and Perzheyska gully slopes. The slides are of block type from tens of meters to 500 m long and up to 50 m wide. The height of over-slide benches varies from 3 to 10 m. Up to 3-4 ranges of slide terraces are observed overturned towards non-broken part of the slope. The slides are often overlain by deluvial sediments. In the upper slide parts the primary layer succession is preserved in the Quaternary sand-clayey terrace sediments and Upper Miocene terrigenous-clayey sequence. The lower slide portion is dismembered and composed of friable non-sorted sand-clayey rocks. The slides are active and stabilized and overlain by deluvial sediments. Displacement of slide blocks is observed by the Quaternary and Neogene clays.

Minor relief forms

Four groups of minor relief forms are distinguished: fluvial, lake, gravitation and technogenic. All these ones are well expressed in the relief although some are not expressed in the given map scale and shown with out-of-scale symbols. The age of these minor forms is Holocene (see "Geomorphologic scheme in the scale 1:500 000" to "Geological map of Quaternary sediments").

The fluvial minor relief forms are widely developed in the area and include course-side arches, ravines, gorges, erosion dimples and bottom cuts in the river and gully courses.

Course-side arches (a) have been developed in Danube river flood-land. They are essentially smoothed by the human technogenic activities. The arch width at the foothill is from first tens of meters to 200-250 m and height is 1.0-2.5 m. The shoreline of Kugurluy lake in its south-eastern part is confined to the one of the course-side arches. These forms are oriented along the Danube river course and in Kugurluy lake area they are arranged in the meandering cluster because of river-course move to the south.

Ravines (d) are developed on the slopes of lakes, river and gully valleys, especially those formed over mainly sandy rocks. The length is variable, from 10-20 m to 5 km. These are narrow curvilinear forms with steep, cliffy, high (up to 15 m) sides or slide slopes. The bottom is often filled with rock fragments. The deepest and long ravines are observed in the north of the territory where they are cut into Pontychniy regio-stage (Neogene) sandy rocks. At the beginning phase of their development these are shallow narrow grooves from some tens of meters to 0.5 km long which are mainly ploughed and smoothed.

Erosion dimples (c) are confined to the upper courses of gullies and rivers. The length is from tens of meters to 3 km.

In the northern part of the area the bottom cuts are observed in the river courses related to the modern tectonic uplifting of the territory in Holocene. The cut depth is 2-4.5 m.

The lake minor relief forms includes beaches and spits confined to the coasts of Kagul, Yalpug, Kugurluy and Katlabukh lakes. The beaches are sandy, sandy-muddy, 3-40 m wide. The spits comprise the ridges composed of sandy-clayey-muddy material, in places covered by cane, elevated above the water level by 1-2 m. The length varies from 200-500 m to 2-4.5 km and width from first tens of meters to 500-600 m.

Gravitation minor relief forms include slides, taluses and subsidence funnels. The slides were described above. The taluses are confined to the steep cliffy coasts and formed because of the physical rock weathering. Subsidence funnels are elongated-oval in shape up to 130×450 m in size, and observed to the west from Plavni village at the surface of the fifth over-flood terrace.

Technogenic relief forms are related to the human activities. In the southern part, in Danube river flood-land, a range of dams and channels were constructed, and over entire area the *quarries* (h) of various sizes are observed where construction materials (sand, loam, debris) are being mined. Some quarries are abandoned and filled with water.

In addition, the geomorphologic elements like *terrace back sutures* (b), *abrasion* (g) and *erosion* (f) *benches* are well expressed in the territory. Abrasion benches are developed through the lake abrasion activities; these are 2-40 m high increasing in the northern direction. Erosion benches are observed along Danube river course and are formed by Danube River erosion activity. Their height is 2-18 m.

In the development of various relief forms (morphogenesis) the neo-tectonic factor is prominent, especially its Neo-Pleistocene stage, which in the given area comprises regime of differentiated tectonic uplift. In order to estimate neo-tectonic influence on the modern relief development the method of analysis of deformation in the smoothing accumulative surface is used. This marker surface in the territory is the surface of Eo-Pleistocene – Early Neo-Pleistocene terrace developed almost over entire area except the southern map sheet part where terrace is eroded during Danube river valley cut formation. Based on this surface analysis the authors had designed the "Neo-tectonic map of Neo-Pleistocene time in the scale 1:500 000" (see legend to "Geological map of Quaternary sediments").

In the scheme, two areas are clearly distinguished which differ in the tectonic style. The first area occupies most part of the studied territory with the regime of differentiated tectonic uplift from 0 to 150 m in amplitude in the area of Novi Troyany village in the north of map sheet. The second area, which spatially coincides with Danube river valley and Kagul and Katlabukh lakes, exhibits regime of tectonic subsidence 0-30 m in amplitude. The territory inclination from the north to south is also quite visible, as well as the block structure inherited from previous stages of tectogenesis. This inheritance is expressed in the flat enough flexures and breaks of pre-Baikalian, Herzinian and Early Kimmerian stages of tectogenesis. Specifically, Buzhorul gully valley, the eastern banks of Kagul and Yalpug lakes, as well as some gullies in the are of Bolgrad town, with characteristic horseshoe shape "inherit" Skhidnodolynskiy, Kagulskiy, Skhidnoyalpugskiy and Karasulakskiy faults of Herzinian tectogenesis with distinct arch-shaped morphology and, in general, sub-longitudinal extension. Uplifted block in Reni town and Dolynske, Lymanske and Nagirne village areas inherits Herzinian dome structure caused by Dolynska quartz syenite intrusion and bounded by the zones of Tsentralnodolynskiy and Pivdennodolynskiy faults.

Danube river valley in the interval from Reni town to Izmail town is extended in sub-latitudinal direction; Kytay and Katlabukh lake depressions inherit the zone of differentiated subsidence in the modern tectonic plane of the territory. The contours of certain blocks, mainly in the northern part of the territory, as well as Tashbunar, Velykiy Katlabukh river valleys and Perzheyska gully (in Dmytrivka village area) inherit the activated tectonic plane (blocks mainly) and fault system of pre-Baikalian tectonic plane, characteristic for the basement of Besarabsko-Chornomorska plate (region of tectonic-magmatic activation).

7. HYDROGEOLOGY

In hydrogeological respect, the map sheet territory L-35-XXIII (Izmail), L-35-XXIX (Tulcha) is situated in the south-western part of Prychornomorskiy artesian basin ("Hydrogeology of USSR", v. 5, 1971) with complex hydrogeological conditions. The hydrogeological stratification is based on geological-hydrogeological principle (N.M.Frolov, L.A.Ostrovskiy, 1982).

The territory contains a number of water-bearing horizons and complexes confined to the thick sequence of Cenozoic, Mesozoic and Paleozoic sediments. Distribution of major water-bearing horizons and complexes is shown in Fig. 7.1.

The following water-bearing horizons are distinguished in the studied area.

First from the surface water-bearing horizons and complexes

1. *Water-bearing horizon in Holocene alluvial and alluvial-deluvial sediments of minor river and gully bottoms* (a,adH). The water-bearing rocks include loams, sandy loams and sands. Thickness of water-bearing horizon is 1.2-6.0 m, depth up to 8 m, in places more, static level is 0.15-7.4 m, yield – 0.36-28.2 m^3/d, depression – 0.29-2.23 m, water conductivity – 0.5-33 m^2/d, water permeability – 0.2-13.1 m/d. The hanging-wall altitudes vary from 5 to 165 m; minimum footwall altitude is -19.4 m. The waters are mainly fresh, rarely slightly salty, sulphate sodium, sulphate magnesium, chloride-sulphate magnesium, hydrocarbonate sodium. The water-proofs include Quaternary or Neogene clays but commonly gully sediments lie over Neogene-Quaternary water-bearing rocks and direct hydraulic connection occurs therein. The feeding is being performed mainly through atmospheric precipitates and in lesser extent from drainage waters from Quaternary and Neogene sediments. The waters are ground and being used everywhere.

2. *Water-bearing horizon in Holocene estuary-lake sediments of Danube river low flood-land and Kagul, Yalpug and Katlabukh lake shorelines* (lmlH). The water-bearing rocks include aleurites, diverse-grained sands with gravel and pebble at the footwall. Thickness is up to 10 m. The water are ground with level up to 3 m, rarely up to 6 m. Water permeability is 2-10 m/d and more. Water conductivity is 15-100 m^2/d and more. The static level is 0.83-2.0 m, yield – 44.1-86.4 m^3/d, depression – 0.68-2.71 m. The hanging-wall altitudes of water-bearing horizon vary from 2.5 to 12.0 m; footwall ones – up to -43 m. This water-bearing horizon is hydraulically connected with underlaying Neogene horizons and overlying horizons of Quaternary estuary-lake and alluvial sediments of Danube river over-flood terraces. The waters are mainly fresh, sulphate sodium, sulphate magnesium, chloride-sulphate magnesium, hydrocarbonate sodium. The feeding of horizon is being performed through atmospheric precipitates infiltration and from the surface waters of Kagul, Yalpug, Kugurluy, Sofyan, Katlabukh and Danube rivers. The water-bearing horizon is being widely used for water-supplying of inhabited localities and together with the water-bearing horizon in Upper Neo-Pleistocene – Holocene alluvial sediments /aP_{III}-H/ of Danube River it comprises major source for centralized water supplying of Reni and Izmail towns and surrounding villages.

3. *Water-bearing horizon in Upper Neo-Pleistocene – Holocene alluvial sediments of Danube River* /aP_{III}-H/. The horizon is extended along the right bank of Danube River in the band 0.15-3.5 km wide over the distance of 80 km. Water-bearing rocks include diverse-grained aleurolites with gravel and pebble at the bottom. Thickness of water-bearing horizon is about 40-70 m. The waters are ground with level from 0 to 3 m.

Water permeability is 2-20 m/d, water conductivity – 15-120 m^2/d and more, static level – 0.83-2 m, yield – 44-97 m^3/d, depression – 0.68-2.71 m. The hanging-wall altitudes on water-bearing horizon vary from 2.5 to -42 m; the footwall ones – up to -67 m.

Water-bearing horizon is hydraulically connected with underlaying Neogene horizons. The waters are fresh, sulphate sodium, sulphate magnesium, chloride-sulphate magnesium. The horizon is being fed through infiltration of atmospheric precipitates and surface waters of Danube River. Water-bearing horizon is being widely used for centralized water supplying of Reni and Izmail towns.

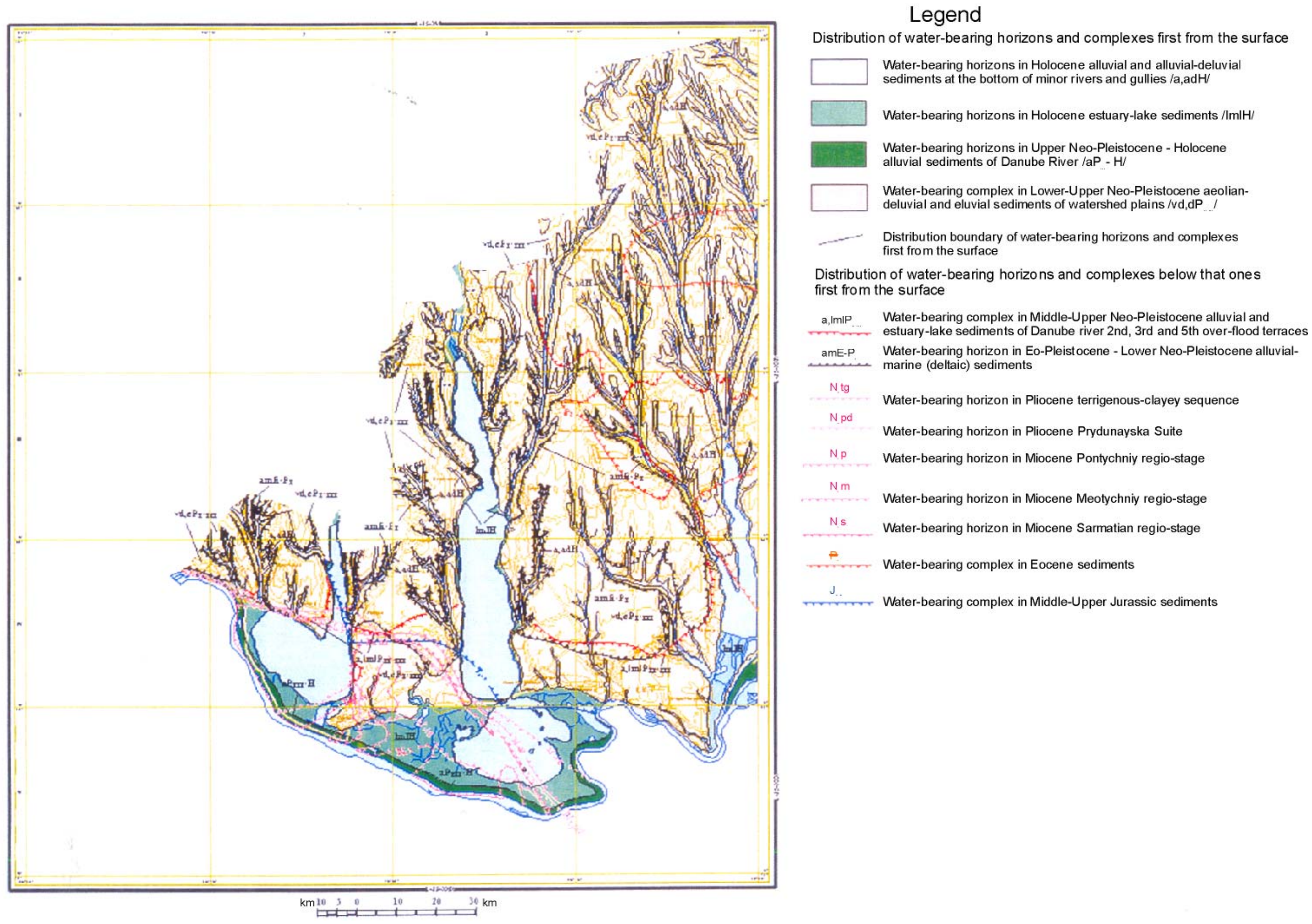


Fig. 7.1. Distribution scheme of major water-bearing horizons and complexes.

4. *Water-bearing complex in Lower-Upper Neo-Pleistocene aeolian-deluvial and eluvial sediments of watershed plains* /vd,eP_{I-III}/. It is widely developed at watershed plains, at the sites of buried over-flood terraces, and is of great value in the irrigation activities. Water-bearing rocks include light, medium and heavy loams. The waters are ground. Thickness of water-bearing sequence varies from 1 to 27 m, water conductivity – 0.27-7.2 m^2/d, water permeability – 0.06-1.1 m/d, static level – 3.8-11.65 m, yield – 0.77-20.3 m^3/d, depression – 0.26-2.76 m. The hanging-wall altitudes of water-bearing horizon vary from 5 to 180 m; the footwall ones – from -3.9 m to 157.5 m. The groundwater level altitudes vary from 169 m to zero. The horizon is being fed from atmospheric precipitates and at the irrigation sites groundwaters get additional feeding through the irrigation inputs. In the south feeding can be received from surface waters. The water are not suitable for drinking water-supplying because of low water content, increased mineralization and high contamination but are being widely used by local inhabitants in technical purposes. By chemical composition the waters are sulphate sodium, sulphate magnesium, chloride-sulphate magnesium, and hydrocarbonate magnesium.

Water-bearing horizons and complexes occurring beneath the first from the surface ones

6. *Water-bearing complex in Middle-Upper Neo-Pleistocene alluvial and estuary-lake sediments of the Danube river over-flood terraces* /a,lmlP_{II-III}/. It is confined to the over-flood terrace sediments developed over broad areas between Katlabukh and Yalpug lakes, in Danube river valley. Water-bearing rocks include fine-micro-grained clayey sands, loams, and sandy loams. In the lake-alluvial sediments the water-permeable and water-proof rocks commonly intercalate. The Danube river over-flood terraces comprise the low-permeable rocks at the top and well-permeable sands with gravel and pebble at the bottom. Filtration coefficients vary from <0.1 to 10 m/d and more. In most cases this water-bearing horizon is hydraulically connected with Neogene horizons and (mainly lower column part) Holocene estuary-lake sediments of Kagul, Yalpug and Katlabukh lakes. The horizon is being fed through infiltration of atmospheric precipitates, flooding waters, inflow from other water-bearing horizons, and at the irrigation sites through the irrigation inputs. The waters are slightly-salty, rarely salty, and are being widely used by local inhabitants in technical and household purposes. Water chemical composition is chloride-hydrocarbonate calcium-sodium, chloride-sulphate magnesium-calcium, sulphate-chloride calcium-magnesium-sodium, and mixed.

7. *Water-bearing horizon in Eo-Pleistocene – Lower Neo-Pleistocene alluvial-marine (deltaic) sediments* /amE-P_I/ is developed in the central and southern parts of map sheet area. Water-bearing rocks include sandy loams, sands, aleurites, in places with gravel and pebble. In the northern part water-bearing horizon is more enriched in clayey fraction and in places these sediments are water-free providing the inter-layer water-proof horizon. In the central and southern parts the rocks include diverse-grained sands with minor gravel and pebble and are overlain by Neo-Pleistocene water-bearing and water-proof sediments making the single complex thereof. Thickness varies in the range 1-20 m and the depth is 10-45 m. The hanging-wall altitudes of water-bearing horizon vary from -5.9 m to +180 m; the footwall ones – from -21.5 m to +145 m. At the sites where horizon contains inter-layer waters, it is being fed by the water transfer through separating layer and hydrodynamic windows. At the sites where horizon is ground, the feeding is being provided through infiltration of atmospheric precipitates, surface waters and irrigation inputs. The waters are slightly-salty, in the Danube portion – fresh, and are being used by local inhabitants in technical purposes and for drinking. By chemical composition the waters are sulphate sodium, chloride-sulphate magnesium, hydrocarbonate-magnesium, and mixed.

8. *Water-bearing horizon in Pliocene terrigenous-clayey sequence* (N_2*tg*) is developed in the southern part of the area. Water-bearing rocks include coarse-grained sands with gravel and pebble. Water conductivity varies from 20 to 443 m^2/d; water permeability – 4-13 m/d, static level – 0.85-27.7 m, yield – 9.76-242 m^3/d, depression – 0.49-8.91 m. The hanging-wall altitudes of water-bearing horizon vary from +23.5 m to -61.0 m; the footwall ones – up to -148.5 m. The maximum thickness of sediments is 102.6 m. By chemical composition the waters are chloride-hydrocarbonate calcium-magnesium and sulphate-hydrocarbonate sodium-magnesium. The water-bearing horizon is being used for water supplying comprising major source for centralized water-supplying of Reni town, Orlovka and Novosilske villages.

9. *Water-bearing horizon in Pliocene Prydunayska Suite sediments* (N_2*pd*). Water-bearing rocks include fine-grained sands with aleurolite interbeds. In the northern and north-eastern directions mainly sandy sequence of Prydunayska Suite (Neogene) is gradually substituted by alternating fine-grained sands and clays. The maximum thickness of water-bearing sediments is 130 m in Reni town area and average thickness in the area does not exceed 60 m, water conductivity is from 20 to 150 m^2/d, water permeability – 4-12 m/d, static level –

0.85-36 m, yield up to 100 m^3/d, depression of level – 0.49-9.3 m. The hanging-wall altitudes of water-bearing horizon vary from -138.1 m to +113 m; the footwall ones – from -167.6 m (Nagirne village) to -241.8 m. Water-bearing horizon is being widely used for water supplying of inhabited localities. By chemical composition the waters are chloride-hydrocarbonate calcium-magnesium and sulphate-hydrocarbonate sodium-magnesium.

10. *Water-bearing horizon in Miocene Pontychniy regio-stage sediments* (N_1p). In Pontychniy regio-stage, based on detailed litho-facial analysis, three local stratigraphic subdivisions are distinguished – the fourth sub-sequence of Dunayska sequence (N_1d^4), sequence of sands (N_1p), and terrigenous-clayey sequence (N_1tg), which substitute one another in the northern direction. Water-bearing horizon is developed everywhere except the river and gully valleys where Pontychni sediments are eroded. Water-bearing rocks include micro-medium-grained sands, aleurites, in places limestones. Over most part of the area Pontychni sediments contain inter-layer waters; the even-aged or Meotychni clays are lower water-proof. The depth of Pontychni waters is 0-15 m in erosion cuts where they often occur at the surface in springs and layers, and up to 30-80 m and more at the watershed plateau, as well as in the south-west of the area in Danube river valley where they are overlain by younger sediments. Filtration coefficient of limestones in Chervonoarmiyske village area attains 21.6 m/d, water conductivity – 108 m^2/d, but major water-bearing rocks are micro-fine-grained sands with filtration coefficient 0.08-1.54 m/d and water conductivity 0.96-25.0 m^2/d. The hanging-wall altitudes of water-bearing horizon vary from +145.5 m to -145.2 m; the footwall ones – from +74 m to -223.7 m. Under water extraction from boreholes and wells the following parameters of Pontychniy water-bearing horizon are obtained (Table 7.1).

Table 7.1. Parameters of Pontychniy water-bearing horizon (Neogene).

Ref.	Hole (w – well, b – borehole)	Thick-ness, m	Water-bearing rock lithology	Static level, m	Yield, m^2/d / Depression, m	Water conductivity, m^2/d / Water permeability, m/d
42	252 (b)	15	fine-grained sand	30.02	24 / 4.78	9.0 / 0.51
42	U (b)	14	limestone	5.56	4.32 / 12.97	108 / 21.6
42	284 (b)	16.3	fine-grained sand	0.76	1.54 / 10.1	25 / 1.54
42	17 (w)	3	micro-grained sand	2.02	4.88 / 0.59	1.89 / 0.63
42	76 (w)	12	aleurite	10.75	0.61 / 23.4	0.96 / 0.08
42	81 (w)	6	aleurite	13.5	2.83 / 0.67	1.08 / 0.18
42	187 (w)	2	micro-grained sand	12.4	9.76 / 0.49	1.6 / 0.8
42	226 (w)	3	micro-grained sand	1.35	29.6 / 2.73	2.81 / 0.97

Almost everywhere in the area the water in Neogene Pontychni sediments are non-pressurized except the sites where Pontychni water-bearing sediments are overlain by thick water-proof Kimeriyski clays where pressure attains 50-100 m. The horizon is being fed through infiltration of atmospheric precipitates, inflow from other water-bearing horizons, and surface waters. The waters are chloride-hydrocarbonate, hydrocarbonate, chloride-sulphate and sulphate-hydrocarbonate. The horizon is of low practical value for water supplying but in the north-western part Pontychniy water-bearing horizon is being widely used for household-drinking water supplying (Bolgrad town, Tabaky, Vynogradivka, Chervonoarmiyske, and other villages), despite of mineralization 2-3 g/dm^3.

11. *Water-bearing horizon in Miocene Meotychniy regio-stage sediments* (N_1m). In Meotychniy regio-stage, based on detailed litho-facial analysis, three local stratigraphic subdivisions are distinguished – the third sub-sequence of Dunayska sequence (N_1d^3), clayey-terrigenous sequence (N_1tg), and clayey sequence (N_1g). The horizon is developed almost everywhere except the sites in Danube river valley where Meotychni sediments are eroded. The sequence is mainly composed of clays containing water-bearing micro-fine-grained sand and aleurolite interbeds and lenses. Thickness of water-bearing interbeds is from some centimeters to several meter, rarely up to 15 m. Almost everywhere is the area the waters of Meotychni sediments are inter-layer except

erosion cuts. Under water extraction from wells the following parameters of Meotychniy water-bearing horizon are obtained (Table 7.2).

The hanging-wall altitudes of water-bearing horizon vary from +74 m in the north to -223.7 m in the south; the footwall ones – from +19 m to -249 m (Reni town area). The maximum thickness of the sediments of this horizon is 79.9 m.

The horizon is being fed through infiltration of atmospheric precipitates and surface waters, as well as through inflow from overlying water-bearing horizons. Because of low water content and mainly high mineralization, the waters are of no practical value but are being used by inhabitants with some wells and springs.

12. *Water-bearing horizon in Miocene Sarmatian regio-stage sediments* (N_1s). In Sarmatian regio-stage fix local stratigraphic subdivisions are distinguished – the first and second sub-sequences of Dunayska sequence ($N_1d^{1,2}$) ascribed in facial respect to the sediments of fore-mountain accumulative plains; the coastal-zone sediments of Miocene sea basin – Lymanska (N_1l) and Dolynska (N_1dl) sequences; the sediments of relatively deep-water part of Miocene basin – limestone-clayey (N_1vg) and clayey-limestone (N_1gv) sequences. The horizon is rich in water and comprises the major water-supplying source over most part of the area. Water-bearing rocks include organogenic, oolitic limestones of various density, cavernous, fractured, re-crystallized, with marl, sandstone, sand, aleurite interbeds. The water-proof includes Sarmatian and Meotychni clays providing regional water-proof 25-35 m thick. The waters are pressurized and pressure height above hanging-wall of water-bearing horizon is from 100 m in the north to 300 m in the south. Thickness of water-bearing rocks varies from 2-5 to 80 m. The hanging-wall altitudes of water-bearing horizon vary from +19 m to -249 m; the footwall ones – from -420 m (Reni town area) to -280 m (to the south of Kugurluy lake). Filtration coefficients vary from some tenths in sand fractions to 15 m/d and higher in cavernous limestones. The waters are chloride-hydrocarbonate, hydrocarbonate, chloride-sulphate and sulphate-hydrocarbonate. The horizon is mainly being fed through infiltration of atmospheric precipitates and surface waters outside the studied area where Sarmatian sediments are exposed at the surface. In lesser extent it is being fed through inflow from overlaying and underlaying water-bearing horizons. The waters of Sarmatian complex are of high practical value as far as they are major water-supplying source in the northern areas of the given territory. To the south increasing of mineralization up to 25-50 g/dm^3 is observed. In Danybe river valley piezometric water level of Sarmatian sediments is often higher of the Earth surface allowing assumption to use Sarmatian waters as the mineral ones. The horizon is developed throughout in the area except the southern part the Sarmatian rocks are eroded by Danube River.

Table 7.2. Parameters of Meotychniy water-bearing horizon.

Ref.	Well number	Thick-ness, m	Water-bearing rock lithology	Static level, m	Yield, m^2/d	Water conductivity, m^2/d
					Depression, m	Water permeability, m/d
42	68	4	aleurite	2.15	5.05 2.75	0.6 0.15
42	88	0.5	fine-grained sand	4.53	13.56 0.43	3.4 1.7
42	109	10	micro-grained sand	11.35	11.66 1.4	8.0 0.8
42	191	2.2	fine-grained sand	2.65	6.8 0.45	4.4 2

13. *Water-bearing complex in Eocene sediments* (₽$_2$). In Eocene, based on detailed litho-facial analysis, five local stratigraphic subdivisions are distinguished constituting Eocene water-bearing complex – terrigenous (₽$_2t$), carbonate (₽$_2c$), carbonate-clayey (₽$_2cg$), and carbonate-terrigenous (₽$_2ct$) sequences and Shabska Suite (₽$_2šb$). Eocene complex sediments are only developed in the north-eastern part of the territory. They include clays with marl, limestone, sandstone interbeds, as well as sandstones and aleurolites. The hanging-wall altitudes of water-bearing complex vary from -240.5 m to -359.4 m; the footwall ones – from -457.4 m (Dmytrivka village area) to -220 m. The maximum thickness of the complex is 130 m. There is no hydrogeological information on the complex in the studied map sheets. Outside the given area the following parameters of similar sediments are determined. Porosity of limestones is 2.5-32.8%, sandstones – 8.3-46.3%, sandy clays – 21.8-46.3%; specific yield is 0.04-0.25 l/s; mineralization – 0.61-31.0 g/dm^3; water type – chloride sodium.

14. *Water-bearing complex in Middle and Upper Jurassic sediments* (J_{2-3}). In the Middle and Upper Jurassic complex, based on detailed litho-facial analysis, five local stratigraphic subdivisions are distinguished

constituting given water-bearing complex – Andrushynska Suite (J_2an), Bolgradska Suite ($J_{2-3}bl$), Kazakliyska Suite (J_3kz), Kongazka Suite (J_3kn), and Chadyr-Lungska Suite ($J_3\check{c}l$). The rocks of Jurassic water-bearing complex are developed over almost entire territory except the far south-western part where they are completely eroded and only preserved in minor erosion remnants. The maximum thickness of water-bearing complex, after drilling data, is 4200 m (DH 1P) [21, 42]. The hanging-wall altitudes of water-bearing complex vary from -151 m (DH 094) [48, 42] to -457.4 m (DH 20rVP) [21, 42]. Water-bearing rocks include aleurolites, limestones, and dolomites. Mineralization varies from 48.5 to 180.0 mg/dm^3, iodine content is 5.9-56.0 mg/dm^3, bromine – up to 277.3 mg/dm^3. The waters are bed-pressurized, static level altitudes are from 2.4 to 210.0 m. Water temperature is up to 40^{o}C.

15. *Water-bearing complex in the non-stratified rocks of pre-Jurassic tectonic floor*. Pre-Jurassic water-bearing complex consists of Vendian, Cambrian, Silurian, Devonian and Triassic sediments including conglomerates, gravelites, sandstones, aleurolites, argillites, schists, limestones and dolomites; non-stratified rocks of Carboniferous Dolynskiy intrusive complex (syenites, quartz syenites) and undivided Archean – Lower Proterozoic ultra-metamorphic rocks of Suvorovskiy complex. Over most part of the territory, mainly in the central and northern parts, the complex altitudes are from -1500 m to -3348 m (Chervonoarmiyske village area), and it is intersected by few drill-holes beneath Jurassic sediments. In Prydunayskiy tectonic block due to extensive upward motions the complex is exposed at pre-Neogene surface with altitudes in the range from -100 m to -440 m in Reni town area, and in the area of former Ferapontiy monastery and Orlovka village it is exposed at the modern surface in the small-scale cliff outcrops (altitude +7 m). Water-bearing horizons are of fracture type, pressurized (except Orlovka village area), the waters are hydrocarbonate magnesium-sodium, chloride sodium. Mineralization attains 61 g/dm^3, iodine content is up to 22 mg/dm^3, bromine – 120 mg/dm^3. Because of high mineralization and low water content the complex is actually out of use.

8. MINERAL RESOURCES AND REGULARITIES IN THEIR DISTRIBUTION

According to metallogenic zonation [42], the map sheet territory belongs to the Dobruja and Fore-Dobruja metallogenic regions. At various depths the minerals are related to pre-Cenozoic, pre-Quaternary, and Quaternary sediments. Over there, brown coal deposit and occurrences are known; Neogene carbonate rocks are being mined for construction materials; river-course facies of deltaic plain are of interest in term of construction sands; Quaternary loams are being used for brick-tile manufacturing. In addition, barite and zinc occurrence is encountered in the area.

All mineral resources belong to four groups: combustible, metallic, non-metallic (ore-chemical, construction raw materials), and groundwaters.

Combustible mineral resources

Solid minerals

Brown coal

Brown coal is locally developed in the area. The bodies are related to Miocene Lymanska and terrigenous-clayey sequences. The coal-bearing rocks include sand-clayey and clayey sediments of costal-marine desalinated swamped lagoons. In the map sheet area Vladychenske brown coal deposit is explored and 6 occurrences are identified.

Vladychenske brown coal deposit (III-3-4, Annex 1) is located nearby Vladychen village, Bolgradskiy area of Odeska Oblast. It is confined to Miocene terrigenous-clayey sequence consisting of clay with single brown coal bed 1.5-0.7 m thick. Average working thickness of the bed is 1.1 m. The depth is 30 m. Coal quality is as follows: moisture – 12.3%, ash content – 26.6%, volatile output – 56.8%, total sulfur – 6.23%. The coal grade is "B3". At the top of coal bed the blue-grey, dense, sandy clays from 1 to 3.5 m thick are developed; at the bottom – the bed of friable shell-stone or sand up to 3-5 m thick with shells. Water-bearing rocks are sandy shell-stone of Novorosiyskiy sub-regio-stage (Neogene) 2.0-3.85 m thick. Deposit is out of production [37].

Reniyskiy brown coal occurrence (IV-2-8, Annex 1) in Miocene Lymanska sequence is located to the north from Lymanske village and explored in 1955. Coal sequence consists of alternating clays, sands, aleurolites and brown coal 0.01-2.65 cm thick. Visually coal comprises brown-black mass composed of fossil remnants, altered in various extents, which are easily being split in thin plates. The fossil remnants are also observed in clay interbeds. In general, high sulfur and ash contents are observed in coal.

Bolgradskiy brown coal occurrence (III-3-2, Annex 1) is confined to Miocene terrigenous-clayey sequence. Brown coal is developed in a bed, often with clay interbeds, from 10-15 cm to 90 cm thick. Average thickness of brown coal is from 2-3 cm to 60-70 cm. The coal bed dipping is almost horizontal with gentle inclination to the south-west under the angle 4-5^{o}. The depth of brown coal bed is from 9.1 to 61.5 m. The bed is commonly overlain and underlain by greenish-grey and dark-grey clay, rarely sands. Coal quality: moisture – 6.7%, ash content – up to 45%, volatile output – 52.9%, total sulfur – 4.9-13%, heating capacity – 5800 Cal, bitumens – 1.75-3.1% [37].

Krynychanskiy-I brown coal occurrence (III-3-3, Annex 1) is located in the area of Krynychne, Zhovtneve, Tabaky villages and Bolgrad town. Brown coal bed is developed in Miocene terrigenous-clayey sequence. Thickness of brown coal bed is 0.1-0.7 m and depth from 22.9 to 51 m. Brown coal quality and parameters: moisture – 6.21%, ash content = 29.93%, volatiles – 59.6%, sulfur – 9.2% [37].

Krynychanskiy-II brown coal occurrence (III-3-5, Annex 1) is located in the eastern bank of Yalpug lake. Brown coal is observed in the lower coal batch, more developed in the southern flank, and the upper less developed one. Thickness of coal in the lower batch is from 0.5 to 1 m with average thickness 0.71 m, depth from 18.9 to 99.1 m (49.2 m in average). Average thickness of coal in the upper batch is 0.58 m, depth from 15.5 to 54.6 m. The square of lower coal batch development in the limits of its working thickness is 2.3 km^2, and the upper one – 1.5 km^2. In general, coal beds are discontinuous and irregularly distributed. Over the coal bed the coal quality is as follows: moisture – 6.21%, ash content – 31.84%, sulfur – 9.2%, bitumen – 1.09% [37].

Vasylivskiy brown coal occurrence (III-4-6, Annex 1) is located nearby Vasylivka village in Bolgradskiy area. Brown coal is confined to Miocene terrigenous-clayey sequence. Coal-bearing sequence consists of dark-bluish-grey to black ductile clays with brown coal interbeds. The average square of coal-bearing sequence is about 120 km^2, it is extended in sub-longitudinal direction being about 13 km long and 9 km wide. The depth is from 4.0 to 52.7 m. The maximum coal development, with coal interbeds from 0.2 to 1.2 m thick, is confined to the south-western part of the area. Coal quality: ash content – 25-32%, total sulfur – 7-8%, carbon – 45%, hydrogen – 5.8%. Under these parameters, the coal can be used as a fuel and in chemical raw materials purposes. Low thickness leaves coal out of commercial value [37].

Karakutskiy brown coal occurrence (III-4-7, Annex 1) is confined to Miocene terrigenous-clayey sequence. Average thickness of the lower batch is 0.1 m and upper one – 0.8 m. Coal quality: moisture – 8.42%, ash content – 30.1%, volatile output – 42.9%, total sulfur – 7.79% [37].

Thus, the following can be concluded. Visually the coal of terrigenous-clayey sequence (Neogene, Novorosiyskiy sub-regio-stage) is identical to the coal of Lymanska sequence (Middle Sarmatian regio-stage). Lymanska sequence occurrence (Karakutskiy) is located in sandy-clayey sediments of coastal-marine and lagoon facies. Vladychenske deposit and occurrences of terrigenous-clayey sequence are located in shallow-water desalinated basin facies. The differences in brown coal quality are caused by the facial affinity of various age occurrences, that is, different conditions of sedimentation. Brown coal stratigraphic levels also differ in geochemical specialization. Sarmatian brown coal is higher in zirconium, scandium, germanium, beryllium, yttrium, and ytterbium contents, whereas Novorosiyskiy brown coal is higher in molybdenum, copper, zinc, barium, silver, and strontium. There are no perspectives to discover major brown coal objects in the given area.

Metallic mineral resources

Non-ferrous and base metals

Zinc

In the map sheet L-35-XXIII, in Lymanske village area, in the course of studied on Fore-Dobruja Carboniferous sediments and their coal-bearing, a zinc occurrence (IV-2-23, Annex 3) is encountered with zinc content 3% in dolomitized marbles, at the clustering sites of numerous veinlets filled with later low-temperature ankerite and quartz. Over there, pyrite, galena, sphalerite and chalcopyrite are observed in the pods and veinlets, in places constituting up to 10-20% by rock volume. Pyrite and sphalerite are prevailing sulphides therein. Sphalerite content is about 7-8%. Galena and chalcopyrite are observed in lesser amounts.

Non-metallic mineral resources

Ore-chemical raw materials

Chemical raw materials

Barite

In abandoned quarry nearby Orlovka village 1 m thick baritization zone is encountered which comprises the system of contiguous quartz-barite veinlets 1-2 m thick confined to the endo-contact zone of kersantite dyke. Veinlets are composed of light-grey quartz and needled barite crystals arranged in the cluster-fibrous aggregates. Barite mineralization is controlled by quartz-barite veins developed at the final stage of Herzinian tectogenesis. By chemical analysis, barite occurrence (V-2-3, Annex 5) is encountered with barite content 40% [42].

Construction raw materials

The list of minerals used in construction purposes is limited in the map sheet area. These are limestones and gravelites comprising raw materials for aggregates, construction sands and brick-tile loams.

Aggregate raw materials

Schists

Orlovske schist deposit (V-2-2, Annex 5) is exhausted to date. It is located in 1.3 km to the west of Orlovka village at Kamyana river mouth. The raw materials include quartz-chlorite-sericite schists of Orlovska sequence (Devonian). The schists consist of rhythmically alternating thin and very thin (0.5 mm) carbonate-quartz and quartz interbeds. The rocks are altered by weathering (lightened) to greenish-grey, rarely reddish-brown color. The schists had been being mined for aggregates to road construction [48].

Limestone

Vynogradivske limestone deposit (II-3-1, Annex 1) is located in 2 km to the north of Vynogradivka village, in the slope of Burlacheny gully. Deposit is composed of limestones and gravelites of Miocene terrigenous-clayey sequence. Limestones are light-grey, brownish-grey, often re-crystallized, from 4.0 to 9.5 m thick. Gravelites are light-grey, composed of pebble and gravel of sedimentary rocks. Thickness of gravelites is up to 2.3 m. Average thickness is 6.5 m, including 0.45 m of gravelites. The overburden rocks include sandy loams, loams and sand 6.1 m thick. Limestones and gravelites are suitable for aggregate manufacturing for the construction and repairing of local roads. Deposit is in production [24].

Sand-gravel raw materials

Construction sand

The sands belong to the widespread raw materials and are being used in various purposes. In the studied area the sands are widely developed and confined to the Neogene and Quaternary subdivisions. In term of construction purposes the sands of Eo-Pleistocene – Lower Pleistocene river-course facies of deltaic plain are of most interest.

Dolynske sand deposit (IV-2-16, Annex 2) is located in 1 km to the west from Dolynske village [24]. The sands lie over irregular surface of Kimeriyski clays. The sands are light-grey, yellow-grey, diverse-grained, quartz and quartz-feldspar with gravel and pebble admixture. The sorting of sands is weak and some interbeds only are composed of well-sorted uniform-grained sands. Average thickness of the sands is 14.3 m, including dry ones – 11.6 m, and wetted – 2.7 m. Thickness of overburden loams is up to 17.8 m. Because of sand low quality and complex mining-geological conditions Dolynske deposit is not foreseen to be developed.

Brick-tile raw materials

Loam

Brick-tile raw materials are one of the most developed minerals in the area. By their quality the overburden loams actually everywhere comply with the requirements to these raw materials. Development of brick-tile raw material deposits is not difficult since the loams are observed almost at the surface. Loess-like loams are mainly used in manufacturing as are. When loams are lean the clay is being added. By the genetic type, the rocks used in brick and tile manufacturing belong to alluvial, aeolian-deluvial and alluvial-deluvial and upper layers of estuary-lake sediments. By mineralogical composition the loams of these natural types belong to montmorillonite-mica group with low quartz content. By chemical composition the loams are uniform: SiO_2 – 56.5-48.5%; Al_2O_3 – 7.3-14.42%, TiO_2 – 0.17-1.03%, CaO – 2.0-9.5%, MgO – 0.45-3.5%. The loams are medium-moderate ductile (ductile number is 3-14%), fusible (refractory is 1100-1160^o), non-sintering, with good foundry properties. Thickness of loams varies from 4.87 to 15.2 m.

To date 12 deposits of brick-tile raw materials are recorded in the area, specifically, 11 deposits in map sheet L-35-XXIII (Annex 2), and 1 deposit in map sheet L-35-XXIX (Annex 4).

Ogorodninske loam deposit (I-4-9, Annex 2) consists of Upper Neo-Pleistocene Prychornomorski aeolian-deluvial and Dofinivski alluvial-deluvial sediments (pale, loess-like loams). Average thickness of raw materials is 7.13 m. Average thickness of overburden is 0.53 m. The raw materials are ductile, with low content of coarse-grained inclusions. The groundwaters are lacking in the sequence. Semi-industrial testing had revealed suitability of loams for "75" class brick manufacturing under SSU 530-54 by means of ductile shaping and imposed drying. Because of low quality of raw materials deposit is not foreseen to be developed [24].

Bolgradske-2 loam deposit (II-3-10, Annex 2) consists of Upper Neo-Pleistocene Dofinivski alluvial-deluvial pale, brownish-yellow loams. Average thickness of raw materials is 13.04 m. Average thickness of overburden is 0.5 m. The loams belong to the group of disperse and coarse-disperse, low-moderate ductile raw materials with low content of coarse-grained inclusion. Semi-industrial testing had revealed suitability of loams for "75"-"100" class brick manufacturing. Deposit is in production [24].

Kalchivske deposit (II-4-11, Annex 2) consists of Upper Neo-Pleistocene aeolian-deluvial and alluvial-deluvial sediments (pale, ductile loams). Average thickness of raw materials is 5.96 m. Average thickness of overburden is 0.35 m. Deposit square is 5.8 hectares. The water-bearing horizon is not intersected. By chemical composition the loams belong to the coarse-disperse low-moderate ductile raw materials with low content of coarse-grained inclusions. Semi-industrial testing had revealed suitability of loams for manufacturing of unit-cast ductile-shaping brick adding 3% of coal. By the strength against compression and bending the samples obtained comply with the modern SSU 530-80 "Brick and ceramic stones". Deposit is out of production [24].

Bolgradske-1 loam deposit (II-3-12, Annex 2) is located in the southern outskirt of Bolgrad town and consists of Upper Neo-Pleistocene Prychornomorski aeolian-deluvial sediments overlaying Dofinivski alluvial-deluvial rocks. Raw materials include pale, brownish-yellow loams, 8.53 m thick in average. Average overburden thickness is 0.44 m. Water-bearing horizon is not intersected. The loams belong to acid raw materials with high color-oxide content, as well as to the group of disperse and coarse-disperse, low-moderate ductile raw materials with low content of coarse-grained inclusions (0-0.43%). Semi-industrial testing had revealed suitability of loams for clay brick manufacturing under natural drying. Deposit is in production [24].

Minzulske loam deposit (III-3-13, Annex 2) is located in 0.3 km from the southern outskirt of Bolgrad town and consists of Upper Neo-Pleistocene Dofinivski alluvial-deluvial sediments (pale-yellow, loess-like loams). Average thickness of raw materials is 9.5 m. Average thickness of overburden is 0.31 m. Water-bearing horizon is intersected in the sandy loams underlaying the raw materials. Semi-industrial testing had revealed suitability of loams for "75"-"100" class, SSU 530-71 compatible, unit-cast brick manufacturing by means of ductile shaping under natural drying and adding 3% of coal. Deposit is in production [24].

Suvorovske loam deposit (III-4-14, Annex 2) is located in the northern outskirt of Suvorove village and consists of Upper Neo-Pleistocene Dofinivski alluvial-deluvial sediments – yellow, loess-like loams, which in the lower part are substituted by yellow sandy loams. Average thickness of raw materials is 4.87 m. Average thickness of overburden is 0.39 m. The square of deposit is 10.99 hectares. Water-bearing horizon is not intersected. Semi-industrial testing had revealed suitability of loams for brick manufacturing with ductile shaping under imposed drying. Brick class is "125" under SSU 530-34. Deposit is in production [24].

Kamyanske deposit (III-4-15, Annex 2) consists of Upper Neo-Pleistocene eluvial and aeolian-deluvial sediments (pale-yellow, yellow-dark-brown, loess-like loams of 7.4 m total thickness). Average thickness of overburden is 0.3 m. The square of deposit is 15 hectares. Water-bearing horizon is not intersected. Semi-industrial testing had revealed suitability of loams for unit-cast brick manufacturing with ductile shaping under imposed drying. Brick class is "75" and "100" under SSU 530-80. The suitability of loams is also established for ceramic brick manufacturing with 18 hollows, "75" and "100" class, under SSU 530-80). Deposit is out of production.

Reniyske loam deposit (IV-2-17, Annex 2) is located in the north-western outskirt of Reni town and consists of Upper Neo-Pleistocene Dofinivski alluvial-deluvial sediments – pale-yellow, brown, yellow-brown, loess-like loams. Average thickness of raw materials is 6.2 m. Average thickness of overburden is 0.5 m. Water-bearing horizon is not intersected. By chemical composition the loams belong to the group of acid raw materials with high content of coloring oxides. The loams also belong to the low-disperse low-moderate ductile raw materials with low content of coarse-grained inclusions. Semi-industrial testing had revealed suitability of loams for "75" and "100" class under SSU 530-80, unit-cast, ceramic brick manufacturing with ductile shaping under natural drying. Deposit is out of production [24].

Orlovske deposit (IV-2-19, Annex 2) consists of Upper Neo-Pleistocene Prychornomorski aeolian-deluvial sediments and estuary-lake rocks of the first over-flood terrace (yellow loams, 8.4 m thick in average). Average thickness of overburden is 0.5 m. Water-bearing horizon is not intersected. Semi-industrial testing had revealed suitability of loams for "75" and "100" class under SSU 530-54 brick manufacturing. Deposit is out of production [24].

Izmailske-III deposit (IV-4-20, Annex 2) is located in the northern outskirt of Izmail town and consists of Upper Neo-Pleistocene Prychornomorski aeolian-deluvial sediments and estuary-lake rocks of the second over-flood terrace. The raw materials include yellowish-pale, yellowish-brown, loess-like loams. Thickness of the layer is 14.57 m. Average thickness of overburden is 0.65 m. Water-bearing horizon is not intersected. Semi-industrial testing had revealed suitability of loams for "75" and "100" class brick manufacturing under SSU 530-54. Deposit is out of production [24].

Izmailske-IV deposit (IV-4-21, Annex 2) is located in 6 km to the east of Izmail town and consists of Upper Neo-Pleistocene eluvial, aeolian-deluvial sediments and estuary-lake rocks of the second over-flood terrace. The raw materials include pale loams of 12.4 m total average thickness. Average thickness of overburden is 0.3 m. Water-bearing horizon is confined to the lower part of loess-like sequence. Semi-industrial testing had revealed suitability of loams for common brick manufacturing with ductile shaping under imposed drying. Brick classes are "75" and "100" under SSU 530-80. Deposit is in conservation [24].

Izmailske-V deposit (IV-4-1, Annex 4) is located in 1 km to the south-east of Izmail town and consists of Upper Neo-Pleistocene Prychornomorski aeolian-deluvial sediments and estuary-lake rocks of the first over-flood terrace. The raw materials include pale, yellow-brown loams 15.2 m thick in average. Average thickness of overburden is 0.4 m. Water-bearing horizon is intersected in the lower part of raw materials. Semi-industrial testing had revealed suitability of loams for "75" and "100" class brick manufacturing. Deposit is in production [24].

Groundwaters

Fresh

Drinking

The territory between Katlabukh and Kagul rivers (map sheets L-35-XXIII, L-35-XXIX) is located in the south-western part of Prychornomorskiy artesian basin with complex hydrogeological conditions. Like the whole basin, the groundwaters over there are confined to all stratigraphic rock complexes, from modern to Paleozoic. The mineral waters developed in the area differ in the forming conditions and chemical composition. These are hydrocarbonate magnesium-sodium, sulphate-hydrocarbonate sodium, chloride-sulphate sodium-magnesium, sulphate-chloride magnesium-sodium, nitrate-sulphate sodium-magnesium, chloride-hydrocarbonate sodium-magnesium, sulphate calcium-sodium, hydrocarbonate-chloride magnesium-sodium waters. By chemical composition, the waters in upper horizons are hydrocarbonate magnesium-sodium or chloride-sulphate sodium-magnesium. Mineralization of water varies in the range 1-3 g/dm^3. Downward in the column the chemical composition of waters gradually changes to hydrocarbonate-chloride magnesium-sodium, in places sulphate calcium-sodium, and mineralization increases. The chemical composition of groundwaters is highly affected by extensive exploitation of horizons, irrigation activities, and fresh water input during spring flooding.

In general, studied area is depleted in groundwaters suitable for household-drinking water supplying. The northern part of the area (Bolgradskiy area) is not supported by water resources. The southern part (Izmailskiy and Reniyskiy areas) are most perspective and rich in water resources. In the perspective fields groundwaters are explored and their reserves are approved under commercial categories. Major data on explored groundwater deposits in the area are given in the Annex 2.

The principal water-bearing horizon, which is of high value for water supplying, is confined to the alluvial sediments of Upper Pliocene terrigenous-clayey sequence in Danube river valley (from Reni town to Izmail town). Izmailske and Reniyske deposits of fresh waters with mineralization up to 1.5 g/dm^3 are explored over there [19, 56]. Water extraction from explored reserves is 33.47 thous.m^3/d. The prognostic reserve module is 97 m^3/d and water extraction is 12 m^3/d. In the northern part of the area, in Bolgradskiy area, Middle Sarmatian and Novorosiyskiy alluvial water-bearing horizons are being exploited. Water extraction is 5.51-10.78 thous.m^3/d. The prognostic reserve module in Bolgradskiy area is 1 and 4 m^3/d. From these data one can see that Bolgradskiy area is weakly-supported (up to 15%) with groundwaters suitable for household-drinking water-supplying. Based on the works conducted over last years for evaluation of prognostic resources of alluvial water-bearing horizon in Danybe river valley, in the area between operating water scoops of Reni and Izmail towns (about 70 km long), exploitation reserves are preliminary assessed. Estimation of exploitation reserves in Izmailske groundwater deposit (IV-4-22, Annex 2) is conducted in three fields: at operating water scoops "Kripost" and "Konservniy zavod", and at the site of detailed exploration "Matroska". These fields are located in the left bank of Danube River and its left branch Velyka Rypida. Water-bearing rocks include Pliocene alluvial diverse-grained sands and gravel-pebble sediments. The waters are being used for household-drinking and industrial-technical water-supplying of inhabitants and enterprises in Izmail town.

Reniyske drinking water deposit (IV-2-18, Annex 2) is located in the left bank of Danube River. Water-bearing rocks include diverse-grained sands with gravel and pebble of Upper Pliocene terrigenous-clayey sequence. Thickness of water-bearing horizon varies from 10-30 m to 60-100 m. Water-bearing horizon is pressurized and non-pressurized. The water type is chloride-hydrocarbonate calcium-sodium. The total water extraction from Pliocene water-bearing horizon by 01.01.2000 was 5 thous.m^3/d. Over 27 years of this horizon exploitation the changes in level, mineralization and chemical composition are stable. Alluvial water-bearing horizon in Danube river valley is the source for water supplying in the entire south-western area of Odeska Oblast, and if necessary it can be used for reserve supplying of Odesa city. Deposit is in exploitation.

9. ASSESSMENT OF THE AREA PERSPECTIVES

Based on the geological mapping and prospecting works in the area [42] a wide range of mineral resources is encountered. Further prognostic assessment of the studied area for some types of mineral resources can be done on the ground of analysis over minerals distribution and ore-controlling factors. Taking into account amount of factorial material and its detailed study, certain mineral types can be divided into potentially perspective and actually prospective. Potentially perspective minerals include those which are weakly studied yet and located in conditions that make their further study and extraction complicated although they are of great interest by all parameters. The actually prospective minerals include those which can be extracted or already being extracted nowadays. These comprise construction raw materials. In the Neogene sediments, the brown coal can be deemed to be potentially perspective. Paleo-geographic environment in Neogene had caused prevailing thin brown coal beds in the area (from 0.02 to 2.65 m), their almost horizontal dipping (up to 5^o), sheeted to lens-like morphology, pinching of the beds, and discontinuity of coal-bearing sediments both in the column and by lateral. According to geological mapping and prospecting data available, the brown coal in the area can be ascribed to the "B_2" class by quality (under work fuel moisture W^r). The B_2 class coal occurring at low depth with economic amounts over small sites can be assessed positively. This coal is suitable for open-cast mining and can offset lack of combustible minerals in the local industry being supplied in briquettes, but since the objects are limited in size and located in the area of large arable lands, they were assessed negatively. Brown coal in Bolgradska field is negatively assessed in term of underground mining. Of the Sarmatian brown coal objects, the underground mining can be geologically and economically substantiated in Reniyska field, meaning Middle Sarmatian productive beds.

In view of above, the coal-bearing is out of commercial value in the given territory because of low-quality (high ash and sulfur content, moisture) thin brown coal beds occurring at considerable depths.

Construction materials including sands and loams are widely developed in the area. The sands are widespread and confined to Neogene and Quaternary stratigraphic subdivisions. In term of construction sand, the Eo-Pleistocene – Lower Pleistocene river-course facies of deltaic plain are most interesting. One deposit is explored but due to low quality of sands and complex mining-geological conditions it is not foreseen to be developed.

The perspectives of territory are related to prospecting for micro- and fine-grained gold in relation with micro-terrigenous sediments – fine-grained sands and aleurolites of both marine and alluvial origin (flood-land and deltaic facies). The recent works in the area of Black Sea offshore had provided promising results. Similar works onshore are underway in the adjacent map sheet L-35-XXIV (Kiliya). Increased interest to the micro- and fine-grained gold prospecting is mainly related to the designing and implementation of new beneficiating technologies with concentrate output containing fine-clastic gold.

Most perspective, in term of micro- and fine-grained gold prospecting, in the studied area are Eo-Pleistocene – Lower Pleistocene micro-grained alluvial sediments of the first over-flood terrace, exposed at the surface, and Holocene sediments of the Danube river flood-land. Alluvial sediments of the Danube river first over-flood terrace are only exposed at the surface in Orlovka village area where in the east bank of Kagul lake the sands are being mined in the minor quarry by local inhabitants. The Eo-Pleistocene – Lower Pleistocene alluvial-marine sediments are more developed. They are being mapped in the north-west-trending band up to 20 km wide and 60 km long. Their northern and north-eastern boundaries follow the line of inhabited localities Bolgrad town, Vasylivka and Suvorove villages, and the southern and south-western boundaries – the line Reni town, Lymanske, Nagirne, Plavni and Ozerne (to the north) villages. In the most part of their distribution area these rocks are overlain by thick enough (up to 40-50 m) sequence of loams and clays. In the banks of Buzhorul and Chytron gullies and in the coastal cliffs of Kagul and Yalpug lakes these rocks are exposed at the surface. The lower column part of Eo-Pleistocene – Lower Pleistocene alluvial-marine sediments is mainly composed of coarse-terrigenous facies including intercalated river-facies gravelites and coarse-grained sands. The upper column part is composed of micro-grained sediments including flood-land facies aleurites, clayey aleurites and fine-grained sands, which are most perspective for micro-grained gold prospecting. Analyzing the territory perspectives for micro- and fine-grained gold prospecting, the columns of Eo-Pleistocene – Lower Pleistocene alluvial-marine sediments are distinguished and recommended for further studies in the area of Dolynske village first of all (outcrop in Buzhorul gully bank) where in the core of drill-holes 635 [22, 42], 200 [48, 42], 211 [48, 42], and 040 [48, 42] single grains of native gold are determined in pot samples under mineralogical studies, and in the area of Nagirne village to the north from the northern village outskirt, where in DH 64k [23, 42], 162 [48, 42], and outcrops 431 [21, 42] and 803 [48, 42] the native gold from 1 to 8 signs is determined. The columns in the areas of Reni town (to the north), Lymanske and Nagirne villages (in the central part and to the north, in the eastern bank cliffs of Kagul lake), Kotlovyna and Krynychne villages (center), and Orlovka village (first over-flood terrace), are also prospective. The perspectives of the Danube river Holocene flood-land sediments are mainly related to the rocks of Danube river river-course side-arch and flood-land adjoining from the east. These sediments are extended in the band up to 200 m wide along the Danube river left bank, from the southern outskirt of Reni town to Izmail town over the distance of 60 km. In the Holocene coarse-terrigenous sediments in the area of former Ferapontiy monastery, to the south of Novosilske village, in the core of drill-holes 59k [23, 42], 61k [23, 42], and 186 [48, 42], single native gold signs are determined at the depth 35-46 m. The perspectives are established for increased placer-type gold content in relation to the Lower Triassic fan coarse-clastic sediments developed under conditions of fore-mountain accumulative plain, nearby the mountain system, where gold grade attains 0.417 g/t (DH 01 [48, 42]). Gold is also encountered in the exo-contact of Dolynskiy intrusive massif in amount up to 0.8 g/t (DH 1u [20, 42]. In all cases the depth of productive complexes is from 100 to 400 m.

10. ECOLOGICAL-GEOLOGICAL SITUATION

Assessment of ecological state of geological environment

In the landscape respect, the territory of map sheets L-35-XXIII (Izmail) and L-35-XXIX (Tulcha) belongs to the steppe group of landscapes in Eastern-European plain, where most part of the territory is occupied by the low seaside plain with thick Anthropogenic cover over Neogene sandy-clayey and limestone sediments with normal low-humus southern black soils. To the north the seaside plain is gradually replaced by the flat slope of Moldavska height. The territory is cut by minor valleys of steppe rivers Kagul, Yalpug and Katlabukh which are gradually replaced by the same-named lakes (desalinated estuaries). The long gullies and the gorge network on their slopes and along steep lake banks are widely developed. The southern part of territory belongs to the terrace sand-loess plain, which towards Danube River is gradually replaced by Danube river flood-land, where Kugurluy lake is located in the eastern part.

The technogenic loading over geological environment (GE) is high enough in the studied area. Prevailing type of the citizens' economic activity in the territory is agriculture. Almost entire surface (except the slopes (protected area) of Kagul, Yalpug, Katlabukh, Sofyan lakes and river and steep gully slopes) is ploughed with extensive agricultural production and in places irrigation. Essential part of the Danube river flood-land is dried and used in agriculture.

Economy of relatively large inhabited localities like Reni aerial center and Izmail town is mainly related to the activities in major river ports specialized in management of diverse cargoes over Danube River. In ecological respect these objects do not provide significant ecological danger. Special ecological studies have not been performed in the territory. Based on the quite limited data obtained from the aerial State administrations and personal observations of the author in the field works, the sketch map of ecological state of geological environment is designed in the scale 1:500 000 (Fig. 10.1), where ecological state of geological environment, allied objects of technogenic loading, the objects of harmful pollutions and dangerous exogenic processes are shown.

Machinery, oil refinery, chemical and metallurgical industries, which essentially affect the geological environment, are lacking in the area. Most significant in Izmail, Reni and Bolgrad towns are municipal enterprises, auto-transport bases, brick plants, agriculture production processing units – conserving factories, vine plants, and so forth, which in general do not provide the threat to the environment.

The landfills of the mentioned towns comprise the most dangerous objects for environment. There are no special enterprises for garbage processing. The landfills are normally abandoned quarries for raw materials (loams) for brick plants. Atmospheric waters in these objects are being contaminated and further penetrate deeper horizons, and finally into the water basins making them contaminated.

Numerous rural inhabitants live in relatively large villages, regularly distributed over entire region. The population is mainly employed in agriculture, including grain production, vinery, gardening, cattle breeding, minor processing industry, in some areas fishing. In those inhabited localities where relatively large cattle breeding complexes are preserved and operate in livestock, sheeps, swines, the tractor factories, mineral fertilizer and pesticide stores are developed. All mentioned objects under their exploitation (violating the norms) provide permanent source of environment contamination. Personal observations in the field suggest that certain part of cattle complex wastes, especially in the rainfall and spring flood periods, is being finally entered Kagul, Yalpug, Katlabukh, and Sofyan lakes.

The mineral fertilizer stores provide certain threat to the environment. Under improper storage these fertilizers are being input into the water reservoirs and underground horizons.

Ecological safety of major water lime in the region, Danube River, in general depends on the nature protection measures in the neighboring states. Specifically, cyanide input from the north of Romania into Tysa river and then in Danube river, had several times essentially affected ecological situation in the region resulted in the mass fish and bird decease. Ecological safety of major lakes – Kagul, Yalpug, Katlabukh, and Sofyan, where large aquifer areas are located outside of Ukraine, in Moldova, where extensive agriculture operations are accompanied by fertilizers, diverse chemicals, herbicides and pesticides, does fully rely on the culture and keeping technological schemes in the given region. For instance, over last two decades the mass fish decease is noted in the basin of these water reservoirs caused by the fertilizer and chemicals rainfall washing-off which finally were dropped in Yalpug and Kagul lakes. Ecological safety of these natural objects fully depends on the agriculture culture not only in Ukraine but also in the neighboring Moldova. Bilateral projects are required to preserve and restore the flora and fauna in these really reserve natural zones.

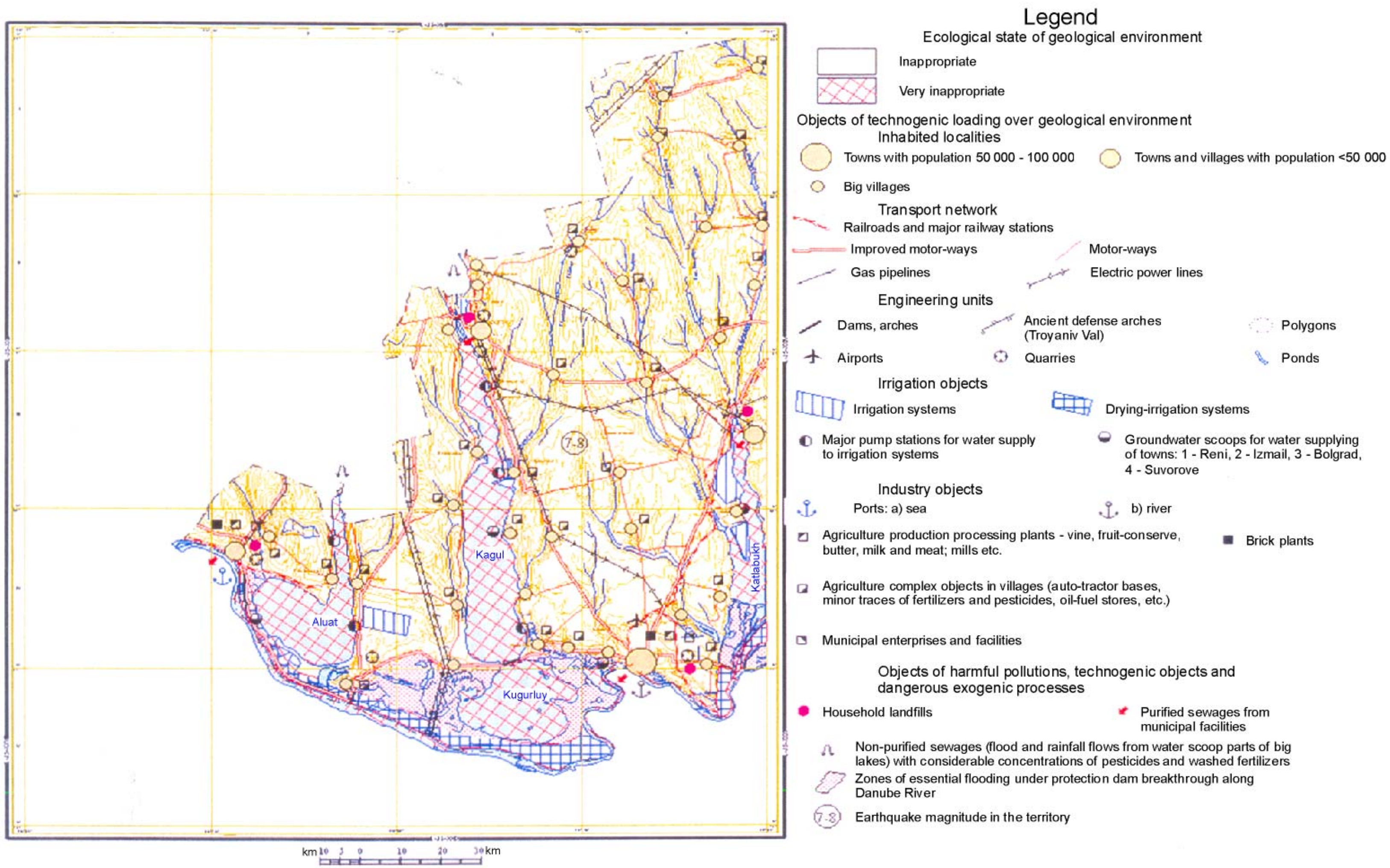
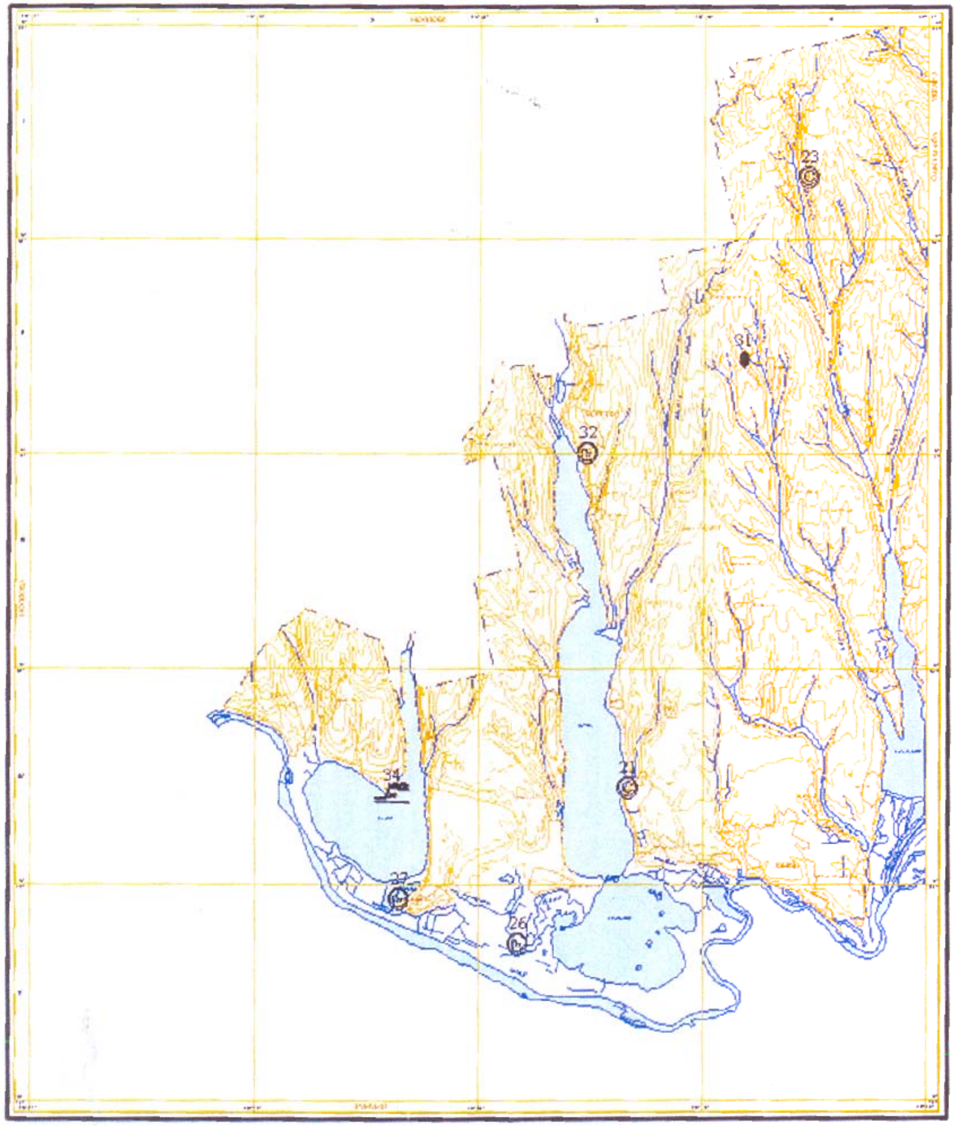


Fig. 10.1. Schematic map of ecological state of geological environment.



Legend

Stratigraphic

Natural and artificial outcrops providing typical columns of various subdivisions and boundary types

Mineralogical

Mineral locations of scientific and cognitive value

Petrologic

Rock locations of scientific and cognitive value

Geomorphologic

Specific relief forms and their complexes: river, lake, marine terraces and their complexes

Fig. 10.2. Sketch map of geological landmark locations.

Of the natural factors essentially influencing ecological-geological state of the territory, two ones are distinguished – tectonic regime in the studied area and geology of sedimentary cover where thick terrigenous rock sequences (sands and aleurites) alternate with clays. Development of the most part of the area under regime of tectonic uplift and thick clay layers in the column is resulted in the dangerous phenomena like slides and collapses. Erosion-denudation processes are also activated with development of gully-ravine system.

The territories developing under regime of tectonic subsidence (Kagul, Yalpug, Katlabukh lakes area, Danube river flood-land) are accompanied by the under-flooding.

Entire territory is ascribed to the 7-8 rank earthquake magnitude (see Fig. 10.1).

Recommendations for ecological-geological studies, rational use and protection of geological environment

Aiming reduction of negative factors influence on the ecological-geological state of environment in the territory related both to the economic activities of inhabitants in the region and natural factors – modern tectonic regime of the territory and geological structure, the following complex of efficient measures should be implemented:

- to remove from agriculture activities the lands located on the slopes of lakes, rivers and gullies;
- to make terraces and forests over mentioned geomorphologic elements aiming reduction of erosion-denudation processes;
- for the territory under progressive tectonic subsidence – Kagul, Kugurluy and Yalpug (south), Katlabukh (south), and Danube river flood-land, the special monitoring is to be established to estimate the area subsidence speed, and based on these observations the complex of preventing measures, related to the territory under-flooding, should be developed;
- in the mouth parts of rivers going to Kagul, Yalpug, Sofyan and Katlabukh lakes the system of dams and ponds is to be foreseen to prevent unpurified sewage drops from minor rivers to the lakes (unique nature objects);
- to improve and make progressively limited the areas of fertilizer and pesticide application which comprise strong ground and surface water contaminating source; to improve and hydraulically isolate their stores; to apply agro-technical measures allowing pesticide refusal;
- to implement the actions preventing destruction of geological landmarks under influence of natural and technogenic factors (Fig. 10.2).

CONCLUSIONS

Design of Derzhgeolkarta-200 map sheets L-35-XXIII (Izmail) and L-35-XXIX (Tulcha) as the modern geological base for planning and development of natural resources, mineral-resource base, scientific-grounded programs of geological exploration, construction, agriculture, subsurface and environment protection is one of the main goals of the Program for regional study of the territory of Ukraine.

Positive results of conducted works include first of all solutions to the problems of stratigraphy, tectonics, regularities in mineral distribution in the given territory, and secondly – definition of the issues which could not be solved in the course of works.

Stratigraphy of Quaternary sediments is studied and integrated, they are subdivided by genetic types and lithology, and their correlation with basic columns of Prychornomorya is performed; the geological map is designed. The subdivision schemes are adjusted for Neogene, Paleogene, Jurassic, Triassic, Devonian, Silurian and Cambrian systems. Litho-tectonic zonation for the territory is conducted and columns correlation over distinguished zones.

The information is given on the age of Orlovska sequence (Devonian). Based on lithological, geochemical, paleontological data, facial and formation analysis, the correlation is made for the columns of Nyzhnyodunayska LTZ with adjacent regions including Nyzhnyoprutskiy block, Mechyn zone of North Dobruja, and Saratsko-Tatarbunarska LTZ. The stratigraphic volume of Upper Kongazka sub-suite sediments is defined and the geological map is designed where their distribution boundaries, thickness and depths are indicated.

Genetic type is adjusted and stratigraphic level of Eo-Pleistocene – Lower Neo-Pleistocene red-brown sequence is defined.

Based on all available geological information, not only for the given area but also adjacent regions, tectonic scheme in the scale 1:500 000 is presented in tectonic respect and new information is obtained for the complex structure in the junction zone of Eastern-European and Western-European platforms. Definition of their boundary and its geological content comprises the key issue in the understanding of the complex tectonic structure in the area between Prut and Dnister rivers. Based on suggested scheme the tectonic zonation is performed for the territory under EGSF-200.

The general two-fold structure of the territory is established. In the basement, on the ground of complex approach, Suvorovskiy dome up to 55 km across is distinguished composed of Archean – Lower Proterozoic plagiogranites; the north-western part of this dome is exposed at pre-Jurassic surface in Gorikhivskiy block.

In the sedimentary cover, Baikalian, Caledonian, Herzinian, Early Kimmerian, Late Kimmerian, and Late Alpine tectonic floors are distinguished. Tectonic patterns are studied for Archean – Early Proterozoic, Herzinian, and Early Kimmerian stages of tectogenesis most clearly expressed in the given territory, in Nyzhnyoprutskiy, Gorikhivskiy and Nyzhnyodunayskiy blocks. The structure features of neo-tectonic and modern tectonic planes in the territory are defined.

Metallogenic zonation of the territory is performed and the territory perspectives in term of minerals are assessed.

The perspectives of Devonian Orlovska sequence and Lower Triassic clastic sequence for fine-disperse gold mineralization prospecting are defined.

The polymetal mineralization point in the area between Nagirne and Orlovka villages is assessed.

Barite occurrence and increased polymetal (sphalerite, galena) mineralization point related to quartz-carbonate veins are distinguished.

Based on the collected, systemized and integrated available geological, geophysical, geochemical and other information using modern computer methods for data gathering, storage and processing the modern GIS database is created for the map sheets L-35-XXIII (Izmail) and L-35-XXIX (Tulcha) under EGSF-200 [42].

Collected factorial material not only provides comprehensive information on geology in the given area but also highlights a range of problems which mainly concern stratigraphic subdivision and tectonics of the territory.

Subdivision of Jurassic System is performed on the ground of local stratigraphic scheme distinguishing Andrushynska, Bolgradska, Kazakliyska, Kongazka and Chadyr-Lungska suites. Historic reasons had caused that all stratified column, first of all, are confined to the south-western part of Jurassic trough, and, secondly, they are located outside Ukraine, in Moldova territory. Detailed studies of Jurassic System in the map sheets L-35-XXIII (Izmail) and L-35-XXIV (Kiliya) using data from deep wells drilled in the course of prospecting for oil, gas and rock salt, had revealed a range of contradictions in comparison to the columns of Southern Moldova.

For instance, the stratotypical column of Andrushynska Suite is eight times less in thickness in comparison with the Middle Jurassic columns in the area of Chervonoarmiyske, Gorodne, Pandakliya (Kalchevo) villages, and may represent the upper part of the column utmost. Similar differences also concern the column of Kongazka Suite (Upper Jurassic) where most complete columns are located in the mentioned map sheet at Kiliya town.

The stratigraphic scheme of Triassic System, involved in the Permian-Triassic litho-tectonic complex in the area between Prut and Dnister rivers, requires essential adjustment. This complex exhibits considerable thickness of sediments and clear enough stratigraphic and tectonic (angular) unconformities with underlaying Upper Paleozoic and overlaying Middle Jurassic sediments. First of all, adjustment concerns definition of thickness for major stratigraphic subdivisions, their litho-facial variability by lateral, definition of clear bio-stratigraphic (leading fauna and micro-fauna complexes) criteria for main litho-tectonic regions of Permian and Triassic systems, including Tulcea zone (Romania), Baurchynska LTZ (Moldova), Nyzhnyodunayska and Saratsko-Tatarbunarska LTZs, area of Black Sea south-western shelf, and definition of typical stratigraphic columns intersected by drill-holes.

There is the need to adjust the stratigraphic scheme of Middle-Upper Devonian rocks constituting Upper Paleozoic litho-tectonic complex of the given area and participating in the Herzinian tectonic floor in the area between Prut and Dnister rivers. Like the Permian-Triassic complex, adjustments first of all concern definition of thickness and confident bio-stratigraphic and litho-facial correlation criteria, taking into account considerable variability of the columns by lateral, characteristic for the south-western slope of Eastern-European platform. Approved stratigraphic schemes of Paleozoic, Triassic and Jurassic systems are outdated and do not match modern requirements. They require improvements taking into account results obtained in the course of EGSF-200 and material preparation to publishing, as well as making changes at the level of the National Stratigraphic Committee of Ukraine.

In order to solve the issue of the location of the boundary between Eastern- and Western-European platforms, which is crucial for the tectonic zonation of the territory, the special studies should be conducted at the level of specialists from respective geological surveys of Ukraine and Romania; the authors of report on EGSF-200 [42] had suggested the “Scheme of main tectonic elements in the studied area and adjacent territories at pre-Jurassic surface”, where mentioned boundary of these two structures (platforms) is set by Mechyn zone and classified as the deep-seated fault zone. This requires further adjustment in term of all available geological information gathering, systematics and re-interpretation, as well as confirmation by geological and geophysical data.

For the first time Besarabsko-Chronomorska plate is distinguished (area of tectono-magmatic activation in the south-western margin of Eastern-European platform) with general basement block structure. Essential enough deformations of sedimentary cover are established in the mentioned plate, mainly at the stages of Herzinian and Early Kimmerian tectogenesis, and occurrences of magmatism (intrusive-dyke complex, extrusive flood-basalt formation), which require special thematic studies to encompass entire structure (including that part which is located in the Black Sea shelf).

The equivocal issues also include geology of the junction zone between Besarabsko-Chronomorska and Moldovska plates, which spatially coincides with the zone of Chadyr-Lungskiy fault, and definition of Besarabsko-Chronomorska plate perspectives (especially its upper tectonic level – sedimentary cover) in term of oil and gas prospecting in view of defined regularities in tectonics of the given area.

A number of problems also concern unification of the geological terminology being used in tectonic studies in the area between Prut and Dnister rivers, as well as unequivocal understanding of the terms like Moldovska monocline, Moldovska plate, Fore-Dobruja and Side-Dibruja troughs, Gorikhivska “straight arch”. This also concerns general terminology: litho-tectonic complexes, tectonic floors, levels, etc., which are being treated by various authors unequivocally. This situation requires development of the tectonic glossary of Ukraine.

Some problems can be solved in the course of extended geological studies in the scale 1:200 000 (EGSF-200) in the territories adjacent from the east.

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ANNEXES

Annex 1. List of deposits and occurrences indicated in the "Geological map and map of mineral resources of pre-Quaternary units" of map sheet M-35-XXIII (Izmail)

Cell index, number in map	Mineral type, object name and its location	Deposit exploitation state or brief description of occurrence	Geological-economic type and age of productive pile	Notes (references cited)
1	2	3	4	5
Combustible mineral resources **Solid** Brown coal Deposit				
III-3-4	Vladychenske; Vladychen village, Bolgradskiy area	Out of production	Sheeted, N_1tg	38
Occurrence				
III-3-2	Bolgradskiy; Vladychen-Vynogradivka villages, Bolgradskiy area	Bed, thickness 0.02-0.7 m	Sheeted, N_1tg	37
III-3-3	Krynychanskiy-I; Krynychne, Zhovtneve villages, Bolgradskiy area	Bed, thickness 0.1-0.7 m	Sheeted, N_1tg	37
III-3-5	Krynychanskiy-II; Krynychne village, Bolgradskiy area	Batches, thickness 0.58 m, 0.72 m	Sheeted, N_1tg	37
III-4-6	Vasylivskiy; Vasylivka village, Bolgradskiy area	Alternating beds, total average bed thickness 1.1 m	Sheeted, N_1tg	37
III-4-7	Karakutskiy; Krynychne village, Bolgradskiy area	Beds, thickness 0.8 m	Sheeted, N_1tg	37
IV-2-8	Reniyskiy; Lymanske village, Reniyskiy area	Alternating beds, thickness 0.01-2.65 m	Sheeted, N_1dl	37
Non-metallic mineral resources **Construction raw materials** **Aggregate raw materials** Limestone Deposit				
II-3-1	Vynogradivske; Vynogradivka village, Bolgradskiy area	In production	Sheeted, N_1tg	24

Annex 2. List of deposits and occurrences indicated in the "Geological map and map of mineral resources of Quaternary sediments" of map sheet M-35-XXIII (Izmail)

Cell index, number in map	Mineral type, object name and its location	Deposit exploitation state or brief description of occurrence	Geological-economic type and age of productive pile	Notes (references cited)
1	2	3	4	5
		Non-metallic mineral resources **Construction raw materials** **Sand-gravel raw materials** Construction sand Deposit		
IV-2-16	Dolynske; Dolynske village, Reniyskiy area	Out of production	Sheeted	24
		Brick-tile raw materials Loam Deposit		
I-4-9	Ogorodnynske; Ogorodne village, Bolgradskiy area	Out of production	Sheeted	24
II-3-10	Bolgradske-2; Bolgrad town	In production	Sheeted	24
II-4-11	Kalchivske; Kalchevo village; Bolgradskiy area	Out of production	Sheeted	24
III-3-12	Bolgradske-1; Bolgrad town	In production	Sheeted	24
III-3-13	Minzulske; Bolgrad town	In production	Sheeted	24
III-4-14	Suvorovske; Suvorove village, Izmailskiy area	In production	Sheeted	24
III-4-15	Kamyanske; Kamyanka village, Izmailskiy area	Out of production	Sheeted	24
IV-2-17	Reniyske; Reni town	Out of production	Sheeted	24
IV-2-19	Orlovske; Orlovka village, Reniyskiy area	Out of production	Sheeted	24
IV-4-20	Izmailske-3; Izmail town	Out of production	Sheeted	24
IV-4-21	Izmailske-4; Staro-Nekrasivka village	In conservation	Sheeted	24
		Waters **Groundwaters** Drinking waters Deposit		
IV-2-18	Reniyske; Reni town	In exploitation	Sheeted	19
IV-4-22	Izmailske; Izmail town	In exploitation	Sheeted	56

Annex 3. List of deposits and occurrences indicated in the "Geological map and map of mineral resources of pre-Cenozoic units" of map sheet M-35-XXIII (Izmail)

Cell index, number in map	Mineral type, object name and its location	Deposit exploitation state or brief description of occurrence	Geological-economic type and age of productive pile	Notes (references cited)
1	2	3	4	5
Metallic mineral resources **Non-ferrous and base metals** Zinc Occurrence				
IV-2-23	Lymanskiy; Lymanske village	Dolomitized limestone with veinlets filled with calcite, sericite and sulphides, and zinc content – 3%	Veined, $D_{2-3}c$	20

Annex 4. List of deposits and occurrences indicated in the “Geological map and map of mineral resources of Quaternary sediments” of map sheet L-35-XXIX (Tulcha)

Cell index, number in map	Mineral type, object name and its location	Deposit exploitation state or brief description of occurrence	Geological-economic type and age of productive pile	Notes (references cited)
1	2	3	4	5
Non-metallic mineral resources **Construction raw materials** **Brick-tile raw materials** Loam Deposit				
IV-4-1	Izmailske-5; Izmail town	In production	Sheeted	24

Annex 5. List of deposits and occurrences indicated in the "Geological map and map of mineral resources of pre-Cenozoic units" of map sheet L-35-XXIX (Tulcha)

Cell index, number in map	Mineral type, object name and its location	Deposit exploitation state or brief description of occurrence	Geological-economic type and age of productive pile	Notes (references cited)
1	2	3	4	5
Non-metallic mineral resources **Ore-chemical raw materials** **Chemical raw materials** Barite Occurrence				
V-2-3	Orlovskiy; Orlovka village	Kersantites with numerous thin (1-2 cm) veinlets composed of quartz and barite. Barite content – 40%	Veined, $k\chi C_{1-2}$	42
Construction raw materials **Aggregate raw materials** Schists Deposit				
V-2-2	Orlovske; Orlovka village	Exhausted	Sheeted, C_1	22

Annex 6. List of nature landmarks shown in the "Scheme of geological landmark location"

No. (in the map)	Landmark name	Object location	Landmark type	Brief description
1	Sandy sediments N_1*tg* outcrop	Ogorodne village, Bolgradskiy area, Odeska Oblast	Stratigraphic	Outcrop of Novorosiyskiy sub-regio-stage terrigenous-clayey sequence
2	Outcrop of Quaternary sediments ("Babelskiy horizon")	Southern outskirt of Ozerne village, Izmaiskiy area, Odeska Oblast	Stratigraphic	Column of Late Evksinski sediments nearby Ozerne village ("Babelskiy horizon")
3	Gypsum occurrence	Eastern outskirt of Kalchevo village, Bolgradskiy area, Odeska Oblast	Mineralogical	Outcrop of Eo-Pleistocene oink-grey and red-brown clays with gypsum druses and large crystals
4	Neogene brown coal occurrence	South-eastern outskirt of Bolgrad town	Petrologic	Outcrop of brown coal interbed 0.3-0.4 m thick in Novorosiyskiy sub-regio-stage sediments
5	Surface exposure of Triassic sediments	In 4.5 km from south-eastern outskirt of Novoselske village, Reniyskiy area, Odeska Oblast	Petrologic	Outcrop of Triassic Novosilska Suite marbled limestones
6	Outcrop of Orlovska sequence (D_3*or*)	South-western outskirt of Orlavka village, Reniyskiy area, Odeska Oblast	Petrologic	Outcrop of Devonian Orlovska sequence schists with kersantite dyke
7	High flood-land and first over-flood terraces	Southern outskirt of Dolynske village, Reniyskiy area, Odeska Oblast	Geomorpho-logic	Contact of high flood-land of Kagul lake with first over-flood terrace

STATE GEOLOGICAL MAP OF UKRAINE

Scale 1:200 000

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