MINISTRY OF ECOLOGY AND NATURAL RESOURCES OF UKRAINE
STATE GEOLOGICAL SURVEY

TREASURE ENTERPRISE "PIVDENEKOGEOTSENTR"
UKRAINIAN STATE GEOLOGICAL RESEARCH INSTITUTE
"UkrSGRI"

STATE GEOLOGICAL MAP OF UKRAINE

Scale 1:200 000

Crimean Series
Map Sheet Group
L-36-XXI (Chornomorske), L-36-XXII (Krasnoperekopsk),
and L-36-XXVII (Morske)

EXPLANATORY NOTES

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In the work, the geological data are summarized based on results of extended geological studies in the western part of Plain Crimea in the scale 1:200 000 conducted over 1982-1985. The Explanatory Notes contain description of geological map and map of mineral resources of pre-Quaternary units, geological map and map of mineral resources of Quaternary sediments in the scale 1:200 000, geomorphologic, tectonic, and geological-ecological schemes in the scale 1:500 000. Description is given for entire stratigraphic column of the area from Ryphean to Holocene sediments, tectonics, geomorphologic and hydrogeological features, and ecological-geological situation. The list of mineral deposits and occurrences and list of geological landmarks are provided.

CONTENTS

Abbreviations used in the text

BCI – bulk contamination indicator
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
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
GEE – Geological Exploration Expedition
GM-50 – Geological Mapping in the scale 1:50 000
IP – Induced Polarization
MCDP – Method of Common Deep Point
MPS – Method of Polarized Sounding
MRW – Method of Reflected Waves
MTS – Magnetic Telluric Sounding
OGA – Oil-Gas-Bearing Area
SGA – structure-geomorphologic area
SSU – the State Standard of Ukraine
TAC – top admissible concentration
TAL – top admissible level
UISC – Ukrainian Inter-Ministry Stratigraphic Committee
UNAS - National Academy of Sciences of Ukraine
VES – Vertical Electric Sounding
VSS – Vertical Side Sounding

INTRODUCTION

The territory of map sheet group L-36-XXI (Chornomorske), L-36-XXII (Krasnoperekopsk), L-36-XXVII (Morske) is defined by geographic coordinates 45°19'-46°00' N latitude and 32°29'-34°00' E longitude. In the administrative respect it comprises counterpart of Crimean Autonomic Republic (CAR) and encompasses Rozdolnenskiy, Chornomorskiy and partly Krasnoperekopskiy, Krasnogvardiyskiy, Pervomayskiy, and Sakskiy areas. The total square of the territory is 8617 km^2.

In the studied area two physico-geographic regions are distinguished: Pivnichnokrymska lowland and Tarkhankutska height. Latitudes over the map sheets vary from +178 m in the west (Tarkhankut peninsula) to +3 m in the north (Sovkhozne village). Major water line is Chatyrlyk river flowing from Susanine village to Ishyn village. Also valuable are Pivnichnokrymskiy channel and its branches – Zyednuvalniy, Rozdolnenskiy, Chornomorskiy channels and their satellites. The north-western part of map sheets is occupied by Karkinitskiy Bay of Black Sea. The shoreline in some coast areas is pretty curvilinear and does form the harbors (Yarylgatska, Vuzka, Karadzhynska) and salt lakes separated from the sea by sand banks (Panske, Dzharylgach, Yarylgach, Bakalske, Donuzlav). Besides that, in the northern part of the area there are known salt lakes (Stare, Krasne, Kiyatske) which are the relicts of Pra-Syvash. At some shoreline places considerable capes are developed – Tarkhankut, Pryboyniy, Pishchaniy.

The climate over territory is moderate continental, in the western areas it is coastal-continental, moderate hot, dry. Minimum month-average air temperature in January is -3°C, and the maximum one in July is +25°C. Average annual precipitation amount is 300-600 mm. In the north of territory salty black soils, meadow soils, and salty soils with holophyte-type vegetables are developed. In Tarkhankutska height, grussy black soils and steppe vegetables are more characteristic, and somewhere artificial settings of acacia, fruit-tree and shrubs occur.

The biggest inhabited localities include Krasnoperekopsk, Pervomayske, Chornomorske, Rozdolne, Novoselivske. Agriculture is well developed. There is also located major industrial centre in the south of Ukraine – Krasnoperekopska group of chemical plants. Communication network is dense and includes motor way Simferopol-Armyanske and railroad Dzhankoy-Kherson. Major electric energy sources include Simferopolska heat-power station and Kakhovska hydro-power station. Exposure degree varies from bad in the north to appropriate in the south. Complexity of geological structure is moderate, and accessibility of territory is appropriate.

The map sheet territory is confined to the junction zone of major geological structures of Eastern-European Platform and Scythian Plate.

The major information sources in compilation of Derzhgeolkarta-200 set of maps include results of EGSF-200 and EGSF-50 works over the map sheets L-36-XXI, L-36-XXII, and L-36-XXVII.

The preparation to publication of the given map sheet group is performed after 15 years upon completion of EGSF-200 works. This is why in the preparation of Derzhgeolkarta-200 new geological data were taken into account obtained during studies of Pliocene and Quaternary sediments at the exploration sites for construction raw material deposits. Some adjusting-edition field trips were also conducted which allowed changes and amendments stated in the new stratigraphic schemes of Pliocene and Miocene sediments for the Crimean region. Geological structure of the older horizons is described on the ground of data received from deep drilling for oil and gas over last fifty years.

The set of maps includes geological map and map of mineral resources in pre-Quaternary units and geological map and map of mineral resources in Quaternary sediments over the map sheets L-36-XXI, L-36-XXII, and L-36-XXVII, as well as supplementing explanatory notes.

In the map design S.V.Biletskiy and B.P.Chaykovskiy participated. The text of explanatory notes is prepared by B.P.Chaykovskiy, S.V.Biletskiy, O.S.Demyan, S.I.Krasnorudska, V.D.Deev. Technical arrangement of maps and supplementary materials is performed by O.O.Bilokrys, N.I.Udovychenko, T.N.Goloshchapova, L.M.Dyachenko, G.S.Tarashylova, G.P.Samusenko, G.M.Kildey.

1. GEOLOGICAL STUDY DEGREE

The information on geology over map sheet group L-36-XXI (Chornomorske), L-36-XXII (Krasnoperekopsk), L-36-XXVII (Morske) has been summarized by M.V.Muratov in 1973 during preparation to publication of Crimean Series of the State Geological Map of USSR in the scale 1:200 000. The geological maps designed through compilation were based on the numerous data obtained in various years under conduction of geological mapping in the scales 1:100 000 – 1:50 000, geological exploration for oil and gas, groundwaters, construction raw materials. These data reflect main features of geology in the region according to ideas of geologists Z.A.Khramchenko, A.P.Oslopovskiy, V.D.Frolov, V.D.Ivanova, G.P.Kurylo, L.N.Kukhtina, A.A.Andreeva, Yu.V.Kravtsov, P.K.Markov, P.D.Levytskiy, as well as known researchers P.S.Palas, K.K.Fokht, M.A.Sokolov, M.A.Golovkinskiy, A.D.Arkhangelskiy, P.A.Dvoychenko, V.V.Menner, K.I.Markov, G.A.Lychagin.

The geological maps, designed under leadership of M.V.Muratov, by the time of their publishing had provided substantial fundamental work which pretty completely elaborated main issues of stratigraphy, tectonics, history of geological development in the area. In these works, the spatial margins of regional structures and higher order ones were adjusted, stratigraphic subdivision of sediments up to the stage rank has been provided, and Neogene rocks – up to the horizon. General assessment of mineral resources was conducted, major water-bearing horizons were defined, and tectonic scheme for the area has been designed. However, Pliocene-Quaternary sediments and neo-tectonics were shown briefly. Mentioned cartographic materials were non-conditional and provided the ground for further studies.

In view of permanent hydro-resources deficit, one of the important directions in geological studies of the area have included hydrogeological study of potential water-bearing horizons aiming water supplying for inhabited localities, industrial and agriculture enterprises. In 1970, it was published the VIIth volume of "Hydrogeology of USSR. Crimea" edited by A.V.Fedorenko, where main information was summarized on hydrogeology of the area obtained in the studies of V.I.Snegiryova, O.A.Rishes, E.Ya.Martakova, B.M.Ivanov, F.P.Samsonov. The issues of hydrogeological zonation, regional setting, formation and chemistry of groundwaters were highlighted and opportunities for their exploitation were assessed. At the same time, I.V.Kostryk had compiled materials on mineral waters and performed assessment to their use in curative purposes.

In 1973 the works were completed on groundwater studies for deep water-bearing horizons in Prysivashshya and Tarkhankutskiy peninsula (I.M.Morozova), hydrogeological features of Sarmatian and Middle Miocene water-bearing horizons were studied in view of potable water supplying (V.I.Morozov), and conditions for artificial groundwater resources upgrading in Crimea were elaborated (I.A.Borisova).

Since the beginning of 70th in the studied area the system works were commenced on the complex geological, hydrogeological and engineering-geological mapping of Quaternary sediments in the irrigation purposes in the scale 1:50 000. These works covered map sheets L-36-79-C,D; L-36-80-C; L-36-81-A,B (O.M.Lapshyn, 1973); L-36-92-D (A.V.Luparenko, 1973); L-36-91-A,B,C,D; L-36-92-A,B,C (A.I.Buldovych, 1974); L-36-80-B,D (V.I.Morozov, 1975); L-36-90-B,D (A.I.Buldovych, 1980). As a result, the sets of non-conditional geological maps were designed in the scale 1:50 000. In the same period, some fundamental works on geology of Crimea were published, specifically, on the map sheet territory (Yu.G.Ermakov, A.V.Chekunov, V.A.Grygoryev, E.V.Lvova, Yu.V.Kazantseva, L.G.Plakhotniy); in these works main aspects of Crimean geology were elaborated from different tectonic positions. In 1980 by Institute of Geological Sciences of Academy of Sciences of UkSSR, and in 1981 by Institute of Geography of Academy of Sciences of UkSSR were designed and then approved by UISC respective regional stratigraphic schemes of Phanerozoic for the South-Ukrainian oil-gas-bearing province and Pliocene and Quaternary sediments of Ukraine. Approved schemes had provided the stratigraphic base to further geological exploration works.

In 1982-1985 the western part of Plain Crimea has been encompassed by EGSF-200. The studies were extended to the footwall of Middle Miocene sediments (90-300 m) while below the column has been studied through data compilation from deep drilling for oil and gas, thermal and mineral waters. It was designed the set of non-conditional maps with geological background in the scale 1:200 000. Stratigraphic subdivision of Mesozoic, Paleogene and Neogene sediments were performed up to the stage, sub-stage and horizon ranks, and in Quaternary sediments – for climato-horizon or stagelith. As a result of prospecting works, the 43 sites were identified prospective for construction raw materials.

In view of Plain Crimea perspectives for oil and gas, geophysical studies in the map sheets also were of high priority. As a result of works by A.I.Kotlyar and Zh.G.Melmet, the area has been covered by gravity and

magnetic surveys in the scale 1:50 000. A number of pre-Cretaceous basement uplifts and fault network were identified. Based on these data, S.V.Popovych had designed tectonic maps in the scale 1:100 000 by the footwall of Jurassic sediments. In 1976 A.I.Kotlyar, using magnetic survey data from diverse sources, has designed the map of iso-dynams Za in the scale 1:200 000.

Seismic studies in the map sheet area have commenced from the late 40th: by MRW – A.I.Adamovych, I.S.Kyselyov, S.V.Alyokhin; by MCDP – C.I.Didenko, V.V.Cherkashyn. Some sites were studied by CMRW – B.S.Nykyforuk, M.A.Borodulin. Through the complex seismic studies a number of local structures in Paleogene and Lower Cretaceous sediments were identified and recommended for oil and gas prospecting. Results of regional seismic studies by MCDP and DSS were summarized by M.A.Borodulin.

Electric surveys have been being performed by VES, and since 1965, coupling with MPS, MTS and CMTS, entire map sheet area was covered by electric and magneto-telluric surveys. The latter were performed in the scale 1:100 000 – 1:200 000 under leadership of I.L.Svyrydenko. Summary and re-interpretation of VES surveys up to 24 km has been performed by V.I.Lytvynov in 1966. This had allowed amendment of stratigraphic position for the high-Ohm electric horizon and design schematic tectonic map in the scale 1:200 000 for its hanging-wall.

In 1966, under leadership of Z.A.Boyko, the VSS works were performed with ranges up to 3 km in the scale 1:25 000 and 1:50 000 in three sites, almost 1100 km^2 in size, and laying conditions of Neogene water-bearing limestones have been defined. In 1977, in the southern part of map sheet L-36-XXI (Chornomorsk), by VES with ranges up to 0.3 km and seismic survey by MRW, V.I.Lytvynov has preformed the territory zonation by composition and karst degree of Sarmatian limestones, and the sites were recommended to be the raw materials for sugar industry. Since 1972 to 1983 under irrigation mapping by VES and seismic survey by MRW the groundwater mineralization has been assessed and lithological subdivision was performed for the upper column part up to the regional water-proof.

Over subsequent years in the studied area prospecting and exploration works have been carried out for construction materials, as well as prospecting drilling for oil and gas and groundwaters. Obtained results had allowed adjustment in distribution boundaries, facial composition and hydrogeological features of water-bearing horizons.

Since the late 80th in Plain Crimea the complex geological-ecological study of the area had been commenced to assess impact of human economic activities over geological environment (V.V.Ermolenko, N.M.Kapinos, K.O.Tsurykov, F.M.Yabluchniy), and EGSF-50 with the complex of geological-ecological study of Krasnoperekopskiy industrial hub (Yu.D.Stepanyak). That time, a range of important works were published on the area stratigraphy (V.M.semenenko, I.M.Barg). In 1993 UISC has published the “Stratigraphic scheme of Ukraine” for the maps of new generation. This scheme includes zonation of Plain Crimea territory in general, and studied map sheets in particular, for specific slices of stratified Phanerozoic units. Pliocene and Quaternary sediments are grouped and subdivided under climate-stratigraphic principle. Among marine Pkliocene sediments, some subdivisions only of regional scale were defined (horizons, sub-horizons) while their Miocene part has been not considered.

Within the period of preparation and publishing of Derzhgeolkarta-200, it was designed and approved by UISC the “Regional stratigraphic scheme for Neogene sediments in Plain Crimea (S.V.Biletskiy, 1996), where, based on EGSF-200 results and previous studies, stratification is given for Neogene sub-aerial, sub-aqueous and marine sediments with their subdivision into suites, sub-suites and sequences.

Thus, the history of geological studies reflects increasing interest of researchers to the territory. One can find both continuity in the tasks have to be solved, and evolution in scientific insights on the history of geological structure formation in the region.

2. STRATIFIED UNITS

In the geological structure of map sheet group L-36-XXI (Chornomorske), L-36-XXII (Krasnoperekopsk), L-36-XXVII (Morske) Upper Proterozoic, Paleozoic, Mesosoic and Cenozoic rocks participate. Specifically, they include Upper Riphean, Carboniferous, Triassic, Jurassic, Cretaceous, Paleogene, Neogene and Quaternary systems. Stratigraphic subdivision of sedimentary rocks is conducted in compliance with the "Stratigraphic Code of Ukraine" (1977), "Stratigraphic scheme of Ukraine for the new-generation maps", "Correlation stratigraphic scheme of Ryphean-Paleozoic rocks in Crimea", "Regional stratigraphic scheme of Neogene sediments in Plain Crimea", and the serial legend for Crimean Series of Derzhgeolkarta-200 approved by Scientific-Editorial Council (1995). In comparison to the latter, some differences should be noted:

- Skadovskiy Complex is removed from the legend, because after deeper studies of data on magmatism in the area is was established that magmatism is only confined to the structures of Precambrian basement of Ukrainian Shield which are almost not extended into the studied area;
- the name of "tele-orogenic" granite Complex is changed from "Averyanivskiy" to "Syvashskiy", because in more detailed studies it was found that this Complex is confined to major Syvashskiy gravity maximum, so new name highlights this feature;
- the ranks of "Novoselivska" and "Zuyska" series are changed to the same-named suites according to new "Stratigraphic scheme of Paleozoic sediments in Plain Crimea" (UISC protocol No. 4 of 17.07.2000);
- Burulchynska sequence is removed from integrated stratigraphic column, because the deeper data study has shown that it is not developed in the studied area being mainly known in adjacent territory;
- the sequence of grey-green argillites is removed since on deeper data studies the age of this sequence is adjusted and these sediments are ascribed to the sequence of argillites with sandstone and aleurolite interbeds;
- Batysyfonova Suite is removed and its facial analogue is introduced – sequence of clays; based on deeper data studies it is shown that Indolo-Kubanskiy trough is not extended into the studied map sheets where, respectively, the rocks of another sedimentation basin are developed;
- the name of layers with globigerina is changed to the "sequence of marls and clays with globigerina", in compliance with recommendations of "Stratigraphic Code" and index unification for stratigraphic subdivisions.

INTEGRATED STRATIGRAPHIC COLUMN
OF PRECAMBRIAN AND PHANEROZOIC ROCKS IN THE AREA

PHANEROZOIC ACROTHEME
C e n o z o i c e r a t h e m e
Quaternary System
Holocene division (H)

tH – technogenic sediments
eH – modern soils
lm,mHčm – Chornomosrskiy horizon. Estuary and marine sediments
lH – lake sediments
apH – alluvial-proluvial sediments

Neo-Pleistocene – Holocene (P_{III}-H)

Upper branch, Prychornomorskiy climatolith and Holocene undivided
cP_{III}pč-H – coluvial sediments
dpP_{III}pč-H – deluvial-proluvial sediments
a,ap$^{1}P_{III}$pč-H – alluvial and alluvial-proluvial sediments of the first over-flood terrace and high flood-land

Pleistocene Division
Neo-Pleistocene
Upper branch

vd,edP$_{III}$pl+pč – Prylutskiy, Udayskiy, Vytachivskiy, Dofinivskiy and Prychornomorskiy climatoliths combined. Aeolian-deluvial and eluvial-deluvial sediments
ed,vdP$_{III}$df+pč – Dofinivskiy and Prychornomorskiy climatoliths combined.. Eluvial-deluvial and aeolian-deluvial sediments
lm,mP$_{III}$sr – Surozkiy horizon. Estuary and marine sediments
ed,vdP$_{III}$pl+vt – Prylutskiy, Udayskiy and Vytachivskiy climatoliths combined. Eluvial-deluvial and aeolian-deluvial sediments
dpP$_{III}$ud-vt – Udayskiy and Vytachivskiy climatoliths undivided. Deluvial-proluvial sediments
apP$_{III}$ud-vt – Udayskiy and Vytachivskiy climatoliths undivided. Alluvial-proluvial sediments
mP$_{III}$vl – Vylkivskiy horizon. Marine sediments

Middle branch

vd,edP$_{II}$zv+ts – Zavadivskiy, Dniprovskiy, Kaydatskiy and Tyasminskiy climatoliths combined. Aeolian-deluvial and eluvial-deluvial sediments
pdP$_{II}$dn+ts – Dniprovskiy, Kaydatskiy and Tyasminskiy climatoliths undivided. Proluvial-deluvial sediments
a,ap^{5+4}P$_{II}$dn-ts – Dniprovskiy, Kaydatskiy and Tyasminskiy climatoliths undivided. Alluvial, alluvial-proluvial sediments of V and IV buried terraces
ed,vdP$_{II}$zv+kd – Zavadivskiy, Dniprovskiy and Kaydatskiy climatoliths combined. Eluvial-deluvial and aeolian-deluvial sediments

Lower branch

dpP$_{I}$sl-tl – Sulskiy, Lubenskiy and Tyligulskiy climatoliths undivided. Deluvial-proluvial sediments
a,ap^{7+6}P$_{I}$sl-tl – Sulskiy, Lubenskiy and Tyligulskiy climatoliths undivided. Alluvial and alluvial-proluvial sediments of VII and VI buried terraces
ed,vdP$_{I}$mr+lb – Martonoskiy, Sulskiy and Lubenskiy climatoliths combined. Eluvial-deluvial and aeolian-deluvial sediments
vd,edP$_{I}$sh+sl – Shyrokynskiy, Pryazovskiy, Martonoskiy and Sulskiy climatoliths combined. Eluvial-deluvial and aeolian-deluvial sediments
dpP$_{I}$sh-pr – Shyrokynskiy and Pryazovskiy climatoliths undivided. Deluvial-proluvial sediments
ed,vdP$_{I}$sh+pr – Shyrokynskiy and Pryazovskiy climatoliths combined. Eluvial-deluvial and aeolian-deluvial sediments
a,ap^{9+8}P$_{I}$sh+pr – Shyrokynskiy and Pryazovskiy climatoliths undivided. Alluvial and alluvial-proluvial sediments of IX and VIII buried terraces

Eo-Pleistocene
Upper branch

lE$_{II}$ps – Prysyvaska sequence. Lake sediments
edE$_{II}$kr – Kryzhanivskiy climatolith. Eluvial-deluvial sediments

Upper and Lower branches undivided

a,ap^{10+9}Ebr-il – Berezanskiy, Kryzhanivskiy and Illichivskiy climatoliths undivided. Alluvial and alluvial-proluvial sediments of X and IX buried terraces
vd,edEbr+il – Berezanskiy, Kryzhanivskiy and Illichivskiy climatoliths combined. Aeolian-deluvial and eluvial-deluvial sediments

Neogene and Quaternary systems
Pliocene and Lower Eo-Pleistocene undivided
Syvaska LTZ

N_2-E_1td – Tyup-Dzhankoyski layers

Neogene System
Upper Pliocene
Akchagylian regio-stage

N_2*kl* – Kuyalnytski layers

Tsentralna LTZ
Upper-Lower Pliocene (undivided)

N_2*ng* – Nogayska Suite

Lower Pliocene
Kimmerian regio-stage (upper sub-stage)
Syvaska LTZ

N_2*pn* – Pantykapeyska Suite

Middle sub-stage

Tsentralna LTZ
N_2*br* – Bagrationivska sequence

Syvaska LTZ
N_2*kb* – Kamysh-Burunska Suite

Lower sub-stage

N_2*čt* – Chatyrlytska sequence

Miocene (N_1)
Upper Miocene
Meotychniy regio-stage (upper sub-stage) – Pontychniy regio-stage

N_1*kz* – Kazankivska sequence

Pontychniy regio-stage
Novorosiyskiy horizon

N_1*od* – Odeski layers
N_1*ev* – Evpatoriyski layers

Meotychniy regio-stage

N_1*bg-ak* – Bagerivska and Akmanayska suites undivided
N_1*ak* –Akmanayska Suite
N_1*bg* – Bagerivska Suite

Sarmatskiy regio-stage

N_1*hr* – Khersonska Suite
N_1*bs* – Besarabska Suite
N_1*kp* – Krasnoperekopska Suite
N_1*vl* – Volynska Suite

Middle Miocene
Konkskiy regio-stage

N_1*vs* – Veselyanski layers
N_1*ef* – Ervilievo-Foladovi layers

Karaganskiy regio-stage

N_1*p* – sandstone sequence

Chokrakskiy regio-stage

N_1*br* – Brykivski layers

Lower Miocene
Tarkhanskiy regio-stage

N_1*jr* – Yurakivski layers
N_1*mč* – Mayachkynska Suite

Maykopska Series (~~P~~$_3$-N_1*mk*)
Batysyfonoviy regio-stage

N_1*g* – clay sequence

Paleogene System
Oligocene (~~P~~$_3$)
Gornostaivskiy regio-stage

Tarkhankutska LTZ
~~P~~$_3$*kr*$_2$ – Kerleutska Suite. Upper sub-suite

Syvaska LTZ
~~P~~$_3$*gr* – Gornostaivska Suite

Askaniyskiy regio-stage

Tarkhankutska LTZ
~~P~~$_3$*kr*$_1$ – Kerleutska Suite. Lower sub-suite

Syvaska LTZ
~~P~~$_3$*as* – Askaniyska Suite

Sirogozkiy regio-stage
~~P~~$_3$*sr* – Sirogozka Suite

Molochanskiy regio-stage

~~P~~$_3$*ml* – Molochanska Suite

Planorbeloviy regio-stage

~~P~~$_3$*pl* – Planorbelova Suite
~~P~~$_3$*pl*$_2$ – Upper sub-suite
~~P~~$_3$*pl*$_1$ – Lower sub-suite

Eocene (~~P~~$_2$)
Upper Eocene
Alminskiy regio-stage

~~P~~$_2$*al* – Alminska Suite

Middle Eocene
Kumskiy regio-stage

Tarkhankutska LTZ
P₂*ma* – sequence of marls and aleurolites

Syvaska LTZ
P₂*mg* – sequence of marls and clays

Simferopolskiy and Novopavlivskiy regio-stages combined
P₂*rd* – Rodnikovska sequence

Novopavlivskiy regio-stage
P₂*np* – Novopavlivska Suite

Lutetian stage
Simferopolskiy regio-stage

P₂*sm* – Simferopolska Suite

Lower Eocene
Ypresian stage
Bakhchysarayskiy regio-stage

Tarkhankutska LTZ
P₂*ok* – Okunivska Suite

Syvaska LTZ
P₂*g* – sequence of clays

Paleocene (P₁)
Upper Paleocene
Thanetian stage
Kachynskiy regio-stage

P₁*lz* – Lazurnenska Suite

P₁*mv* – sequence of marls and limestones

Lower Paleocene
Danian and Montian stages
Bilokamyanskiy regio-stage

P₁*gm* – Gromivska Suite
P₁*gm*₂ – Upper sub-suite
P₁*gm*₁ – Lower sub-suite

P₁*bg* – Bogachivska Suite

M e s o z o i c e r a t h e m e
Cretaceous System
Upper division (K₂)
Campanian stage – Maastrichtian stage

Prykarkinitska LTZ
K₂*st* – Stroganivska sequence

Pivnichnokrymska and Tsentralnokrymska LTZs
K₂*dž* – Dzhankoyska Suite
K₂*dž*₂ – Upper sub-suite
K₂*dž*₁ – Lower sub-suite

Santonian stage (upper sub-stage) and Campanian stage (lower sub-stage)

Prykarkinitska LTZ
K₂*nm* – Novomayachkynska sequence

Pivnichnokrymska and Tsentralnokrymska LTZs
K₂*pl* – Pavlivska sequence

Santonian stage (lower sub-stage) – Coniacian and Turonian stages

Prykarkinitska LTZ
K_2kr – Karkinitska sequence

Tsentralnokrymska LTZ
K_2kc – Koltsovska sequence

Santonian stage (lower sub-stage)

Pivnichnokrymska LTZ
K_2vr – Voronkivska sequence

Turonian and Coniacian stages

Tsentralnokrymska LTZ
K_2nt – Natashynska Suite

Pivnichnokrymska LTZs
K_2zn – Znamyanska Suite

Cenomanian stage
Prykarkinitska LTZ

K_2gn – Genicheska sequence

Upper and lower divisions
Cenomanian stage – Albian stage (upper sub-stage)
Cenomanian stage (upper and middle sub-stages)
Pivnichnokrymska and Tsentralnokrymska LTZs

$K_{1\text{-}2}kp_3$ – Krasnopolyanska Suite. Upper sub-suite

Lower sub-stage

Pivnichnokrymska and Tsentralnokrymska LTZs
$K_{1\text{-}2}kp$ – Krasnopolyanska Suite.
$K_{1\text{-}2}kp_2$ – Middle sub-suite

Serebryansko-Dzhankoyska sub-zone
$K_{1\text{-}2}pv$ – Pryvolnenska Suite.
$K_{1\text{-}2}pv_2$ – Upper sub-suite

Lower division (K_1)
Albian stage (upper sub-stage)

Pivnichnokrymska and Tsentralnokrymska LTZs
$K_{1\text{-}2}kp$ – Krasnopolyanska Suite.
$K_{1\text{-}2}kp_1$ – Lower sub-suite

Serebryansko-Dzhankoyska sub-zone
$K_{1\text{-}2}pv$ – Pryvolnenska Suite.
$K_{1\text{-}2}pv_1$ – Lower sub-suite

Kovylnenskiy horizon

$K_{1\text{-}2}kv$ – Kovylnenska Suite.
$K_{1\text{-}2}kv_2$ – Upper sub-suite

Tsentralnokrymska LTZs
K_1ev – Evpatoriyska sequence

Pivnichnokrymska LTZ
$K_{1\text{-}2}kv$ – Kovylnenska Suite.
$K_{1\text{-}2}kv_1$ – Lower sub-suite

Upper and middle sub-stages

Prykarkinitska LTZ
K_1av – Averyanivska sequence

Tsentralna LTZs
K_1el – Elyzavetynska sequence

Middle sub-stage

Pivnichnokrymska LTZ
K_1tr – Tarkhankutska Suite

Lower sub-stage

Prykarkinitska LTZ	*Tarkhankutska LTZ*	*Serebryansko-Dzhankoyska sub-zone*
K_1*hr* – Khersonska sequence	**K_1*rl*** – Ryleivska Suite	**K_1*tt*** – Tetyanivska Suite

Aptian stage (upper sub-stage)

K_1*kš* – Kashtanivska Suite

Upper and Middle sub-stages

K_1*no* – Novooleksiivska Suite

Middle and Lower sub-stages

K_1*dn* – Donuzlavska Suite

Barremian stage – Hauterivian stage (upper sub-stage)

K_1*kl* – Kalininska Suite

Jurassic System
Middle division (J_2)
Bathonian stage
Upper and Middle sub-stages

J_2*iš* – Ishunska Suite

Bathonian stage (lower sub-stage) – Bajocian stage (upper sub-stage)

J_2*čč* – Chaychynska sequence

Middle and Lower divisions (J_{1-2})
Bajocian stage (lower sub-stage), Aalenian and Toarcian stages

J_{1-2}*at* – Ateyska Suite

Triassic System
Upper division (T_3)
Norian stage

T_3*p* – sequence of sandstones

Carnian stage

T_3*a* – sequence of argillites

P a l e o z o i c e r a t h e m e
Carboniferous System
Middle division

C_2*ns* – Novoselivska Suite

Lower division

C_1*zj* – Zuyska Suite

PRECAMBRIAN
PROTEROZOIC ACROTHEME
Upper Proterozoic eonotheme
Ryphean eratheme (R_3)

R_3*bk* – Bakalska Series

Description of stratified units from older to younger ones is given below.

PRECAMBRIAN

Proterozoic Acrotheme

Upper Proterozoic eonotheme

The rocks of Upper Proterozoic eonotheme are encountered in Borysivska field where they are intersected by two drill-holes in Bakalska spit. The complex of Upper Ryphean metamorphic rocks is developed over there.

Upper Riphean

The rocks are defined in Bakalska LTZ in the volume of Bakalska Series.

Bakalska Series (R_3*bk*)

The rocks of Bakalska Series in the studied map sheets comprise the oldest complex of those defined in the lower tectonic floor of Scythian Plate. They are intersected by deep drill-holes for oil and gas in Borysivska field. The Series stratotype is distinguished in DH Borysivska-2 drilled on Bakalska spit. In the depth run 4727-4772 m are intersected quartz-muscovite, chlorite-muscovite and garnet-mica shists. The Series lower contact is not identified; the rocks are overlain by Cretaceous sandstones. By seismic data, thickness of the Series attains 3-5 km. The rocks of Bakalska Series are correlated to meso-zonal shists of Dobrudja (Chamurlia Series), they also are similar to the rocks developed in the area of north-western plunging of Dobrudja, and are correlated by radiologic data with the age of Vendian "tele-orogenic" granites and meta-diorites (600-620 Ma) and exotic greenshist rocks from Triassic sediments of Tavriyska Series (820-900 Ma) [17, 18].

PHANEROZOIC

It includes geological records of Paleozoic, Mesozoic and Cenozoic erathemes. Their accessibility and study degrees increase from the older to younger ones.

Paleozoic eratheme

It is locally developed being only comprised of Carboniferous rocks well studied in Novoselivske uplift and composed of slightly-metamorphosed rocks of Novoselivska and Zuyska suites.

Carboniferous System

The rocks are identified in Novoselivska LTZ and include lower and middle divisions.

Lower Division

Zuyska Suite (C_1*zj*). The Suite rocks are intersected by deep drill-holes in the southern part of map sheets in Novoselivske uplift. The typical column is encountered in DH Krasnovska-1 (depth 1920-3020 m). The Suite is composed of black-shale (aspide) formation comprising intercalation of dark-grey to black schistose flysch-like argillites, carbonaceous-mica-carbonate and graphite-mica-carbonate schists. Suite thickness attains

1100 m. Underlaying rocks are not identified. The Suite is conformably overlain by Novoselivska Suite rocks or unconformably – by Mesozoic sediments.

In the depth run 2348-2464 m of DH Novoselivska-3 M.M.Zharkova and A.A.Sergeeva has determined spores *Trilobozonotriletes trivialis* (Waltz) Isch., *Leiotriletes sp., Euryzonotriletes sulcatus* (Waltz) Isch., *Trematozonotriletes cf. variabilis* (Waltz) Isch., *Densosporites sp. Diatomozonotriletes sp., Calamospora sp.,* allowing the host rocks ascription to Carboniferous [14].

The rock composition and low metamorphic degree allows comparison of the Suite rocks with Lower Carboniferous Karapelitova Suite in Dobrudja.

Middle Division

Novoselivska Suite (C_2ns). This unit is also developed in Novoselivska LTZ and its typical column is taken from DH Krasnovska-1 (depth 1170-1920 m). The Suite is composed of 750 m thick thin rhythmic intercalation of quartz-mica-carbonaceous schists and grey limestones. The Suite rocks conformably lie over black-shale rocks of Zuyska Suite and are unconformably overlain by Mesozoic sandstone-clayey sediments.

In the depth run 741-746 m in DH Krasnovska-3 the spore-pollen complex includes *Zonotriletes* group. In view of E.M.Andreeva, this complex is similar to that contained in Lower-Middle Carboniferous rocks of Kuznetskiy basin in Kazakhstan [14].

Mesozoic eratheme

It includes the rocks of Triassic, Jurassic and Cretaceous systems comprised of thick diverse-facies complex of sedimentary and extrusive-pyroclastic rocks.

Triassic System

The rocks of Triassic System are encountered in Pivnichnokrymska LTZ where they include sediments of upper division.

Upper division

Carnian stage

Sequence of argillites (T_3a) is developed in Pivnichnokrymska LTZ where it is intersected by drill-holes in Bakalska, Tetyanivska, Mizhvodnenska and other fields. The Sequence lies at the bottom of Mesozoic column. The contact with underlaying rocks is not intersected by any drill-hole. Most complete columns are encountered in DH Tetyanivska-1 (depth 4756-4831 m), Bakalska-15 (4406-4493 m) and Bakalska-17 (4240-4458 m). Sequence is composed of dark-grey argillites with sandstone and argillite interbeds. Its intersected thickness is 200 m. Sequence of argillites is conformably overlain by Norian sequence of sandstones or unconformably – by Upper Hauterivian – Barremian Kalininska Suite rocks. By findings of two-shell molluscs *Halobia cf. ɞittneri* Moiss*., H. septentrianalis* Smith the rocks are ascribed to Carnian stage [7].

Norian stage

Sequence of sandstones (T_3p) is developed in Pivnichnokrymska LTZ and is intersected by a number of drill-holes in Bakalska, Tetyanivska, Avrorivska, Berezivska and Krasnoyarska fields (Fig. 2.1). Over complete thickness it is only studied in DH Tetyanivska-1 (depth 4720-4756 m). Maximum thickness (276 m) of the Sequence is attained in DH Tetyanivska-3 where it is intersected at the depth 4580-4856 m. It is composed of parti-coloured sandstones with interbeds of dark-grey argillites, aleurolites, gravelites and fine-pebble conglomerates. In DH Tetyanivska-1 the Sequence includes grey sandstones with interbeds of light-grey diverse-grained sandstones, aleurolites and argillites. It conformably lies over Carnian argillite sequence and throughout is unconformably overlain by Upper Hauterivian – Barremian Kalininska Suite rocks. Fauna remnants are not identified but in view of its setting in the geological column above Carnian sediments, the age of this sequence is conventionally set to be Norian.

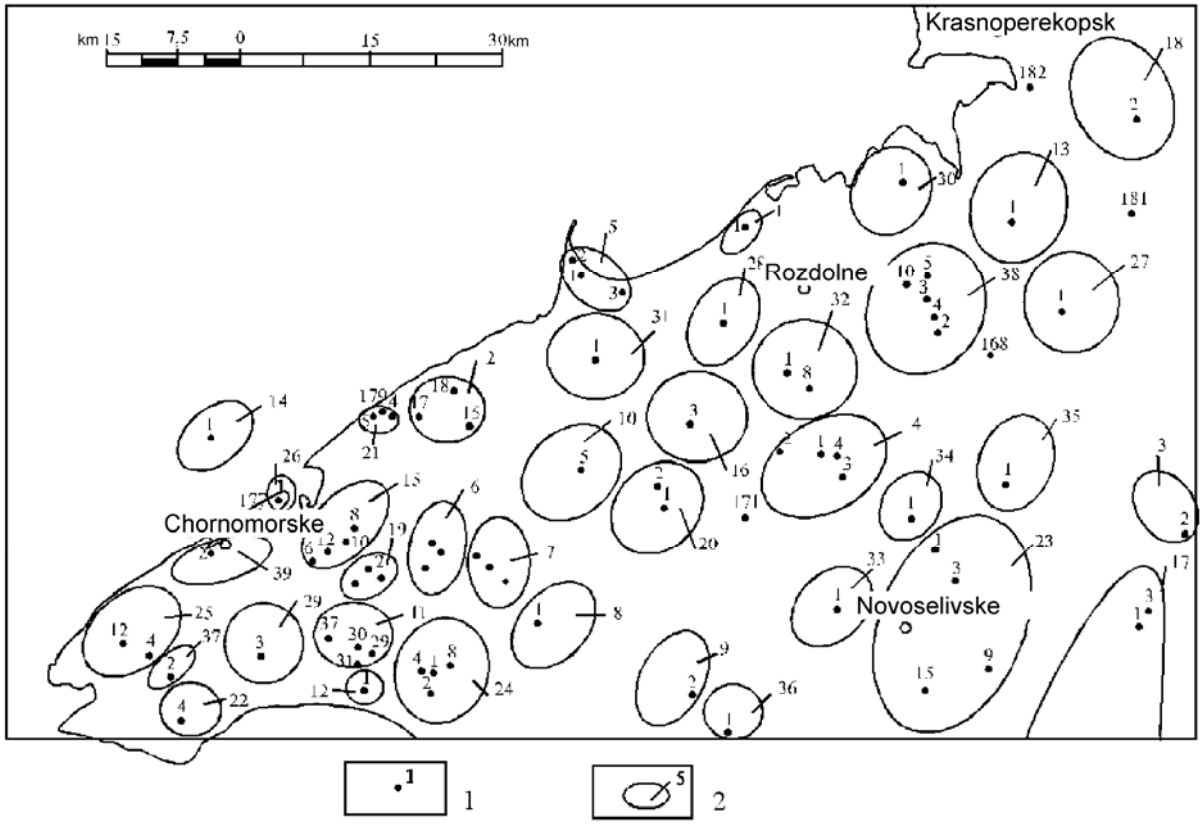

Fig. 2.1. Location scheme of prospecting fields for oil and gas with basic drill-holes.

1 – drill-holes and their numbers; 2 – prospecting fields for oil and gas with their numbers: 1 – Avrorivska-AV (DH 1), 2 – Bakalska-BK (DH 15, 17, 18), 3 – Baranivska-BR (DH 2), 4 – Berezivska-BZ, 5 – Borysivska-B (DH 1, 2, 3), 6 – Glibivska-GB, 7 – Dozornenska-DZ, 8 – Donuzlavska-DN (DH 1), 9 – Elyzavetynska-EL (DH 2), 10 – Zadornenska-ZD (DH 5), 11 – Zakhidno-Oktyabrska-ZO (DH 29, 30, 31, 37), 12 – Znamyanska-ZN (DH 1), 13 – Illinska-IL (DH 1), 14 – Karkynitska-KK (DH 1), 15 – Karlivska-KR (DH 6, 8, 10, 12), 16 – Kashtanivska-KSH (DH 1, 3), 17 – Krasnivska-KS (DH 1, 3), 18 – Krasnoperekopska-KP (DH 2), 19 – Krasnopolyanska-K (DH 1), 20 – Krasnoyarska-KYA (DH 1, 2), 21 – Mizhvodnenska-MV (DH 4, 5), 22 – Melova-ML (DH 4), 23 – Novoselivska-N (DH 1, 3, 9, 15), 24 – Oktyabrska-O (DH 1, 2, 4, 8), 25 – Olenyovska-OL (DH 4, 12), 26 – Panska-PN (DH 1), 27 – Pervomayska-PR (DH 1), 28 – Pivnichno-Serebryanska-PS (DH 1), 29 – Rodnikovska-R (DH 3), 30 – Rozdolnenska-RZ (DH 1), 31 – Ryleivska-RL (DH 1), 32 – Serebryanska-S (DH 1, 8), 33 – Severska-SR (DH 1), 34 – Susanivska-SU (DH 1), 35 – Skhidno-Voronkovska-SV (DH 1), 36 – Tarasivska-T (DH 1), 37 – Tarkhankutska-TR (DH 2), 38 – Tetyanivska-TT (DH 1, 2, 3, 5, 10), 39 – Chornomorska-CH (DH 2).

Jurassic System

The rocks of Jurassic System are found in Pivnichnokrymska LTZ and include lower and middle division sediments.

Lower and Middle divisions

Toarcian stage (upper sub-stage) – Bajocian stage (lower sub-stage)

Ateyska Suite ($J_{1-2}at$) is developed in Pivnichnokrymska LTZ at Novoselivska, Susanivska and Krasnovska fields in the south-eastern part of map sheet L-36-XXII. The typical column is studied DH Novooleksiivska-1 (depth 1818-1712 m). The Suite is composed of alternating grey and greenish-grey limestones, often marble-like and pyritized, with grey, quartzite-like, diverse-grained sandstones under carbonate cement, pyritized and calcitized. It unconformably lies over Novoselivska Suite sediments and is unconformably

overlain by Chaychynska sequence or younger sediments. Thickness of the Suite in the studied map sheets attains 100 m, and in the stratotype area (Prychornomorska depression) – 500 m. In sediments of stratotype I.M.Yamnychenko has determined Late Toarcian fauna, and O.K.Kaptarenko-Chrnousova and D.M.Pyatkova had mentioned findings of Bajocian fauna. On this ground in "Stratigraphic scheme" (1993) the age of Ateyska Suite is taken to be Toarcian – Early Bajocian.

Middle division

Bajocian stage (upper sub-stage) – Bathonian stage (lower sub-stage)

Chaychynska sequence (J_2*čč*) is developed in Pivnichnokrymska LTZ. The typical column is studied in DH Novoselivska-1 (depth 1712-1418 m). The Sequence is composed of alternating clays and schistose clays with lava flows of diabases, plagioclase porphyries and their tuffs, 1.5-4.0 m thick. Besides that, in the lower column part the marble-like pyritized limestones are characteristic. Thickness of the Sequence in the studied map sheets is up to 250 m. The sequence unconformably lies over sediments of Ateyska Suite and is conformably overlain by Ishunska Suite. From the depth 1500 m of mentioned drill-hole I.M.Yamnychenko has determined molluscs *Terebratula aff. voghti* M o i s s. [7]. By lithology, the Sequence is similar to sediments of Karadazka Suite in Mountain Crimea. Taking into account its stratigraphic position in the column, occurrence of sodium basalt-liparite formation lava flows (similar to Karadazka Suite), the Sequence age is thought to correspond to Late Bajocian – Early Bathonian.

Bathonian stage (middle and upper sub-stages)

Ishunska Suite (J_2*iš*). The Suite sediments are developed in Pivnichnokrymska LTZ. Its most complete columns are intersected by drill-holes in Novoselivska and Krasnoperekopska fields. The typical column is studied in DH Novoselivska-1 (depth 1418-1260 m). The Suite is composed of dark-grey, calcareous, low-mica clays with interbeds of aleurolites and light-grey, quartz-feldspar, diverse-grained sandstones with mica-clay cement. In the northern direction psammite varieties in the Suite are being replaced by pelitic ones. In DH Krasnoperekopska-2 (depth 3837-3496 m) argillites and schistose clays are intersected. Maximum Suite thickness attains 400 m. The Sequence does conformably lie over Chaychynska sequence sediments and is unconformably overlain by Upper Hauterivian – Barremian Kalininska Suite rocks. The Suite is characterized by Bajocian-Bathonian brachyopoda and two-shell molluscs *Nucula ventricosa* P č e l., *Lucina bellona* (O r b.), *Terebratula aff. voghti* M o i s s. [7].

Cretaceous System

The rocks of Cretaceous System include both divisions. Three LTZs are distinguished – Prykarkinitska, Tsentralnokrymska and Pivnichnokrymska, with two sub-zones – Tarkhankutska and Serebryansko-Dzhankoyska.

The columns of various LTZs differ one from another both in petrographic respect and in thickness of some stratons. In Pivnichnokrymska LTZ extrusive and sedimentary-volcanogenic rocks are developed accompanied by Tarkhankutskiy sub-volcanic complex, which are not characteristic for two other zones.

Lower division

Hauterivian stage (upper sub-stage) – Barremian stage

Kalininska Suite (K_1kl) is developed in Pivnichnokrymska and Tsentralnokrymska LTZs. The basic column is studied in DH Tetyanivska-5 (depth 4605-4518 m). The Suite is composed of continental sediments including grey, brownish-brown, oligomictic, diverse-grained sandstones with silica-hydromica cement, and aleurolite and argillite interbeds with gravelites at the bottom. The Suite transgressively lies over older sediments and is unconformably overlain by Donuzlavska Suite rocks. Thickness of the Suite is not consistent and varies from 20 to 250 m. The highets thickness is encountered in Bakalska, Mizhvodnenska and Chornomorska fields (map sheet L-36-XXI) (see Fig. 2.1), as well as Berezivska, Tetyanivska and Kashtanivska fields (map sheet L-36-XXII) where it varies from 120 to 250 m. The footwall depth of Neocomian sediments increases from the south to north from 1000 m to 4500 m (Fig. 2.2). The Hauterivian-Barremian age of the sequence is substantiated by palinological data: in the lower part E.R.Guzova has determined pollen *Classopolis* (62 %), while among Filicinae spores of schizean (13%), cyathean, dyxonian, and selaginelean are determined. In the

upper Suite part spores of schizean (more than 23%) varieties *Cicatricosisporites, Pilosisporites, Appendicisporites, Anemia, Pelletieria* are determined [7].

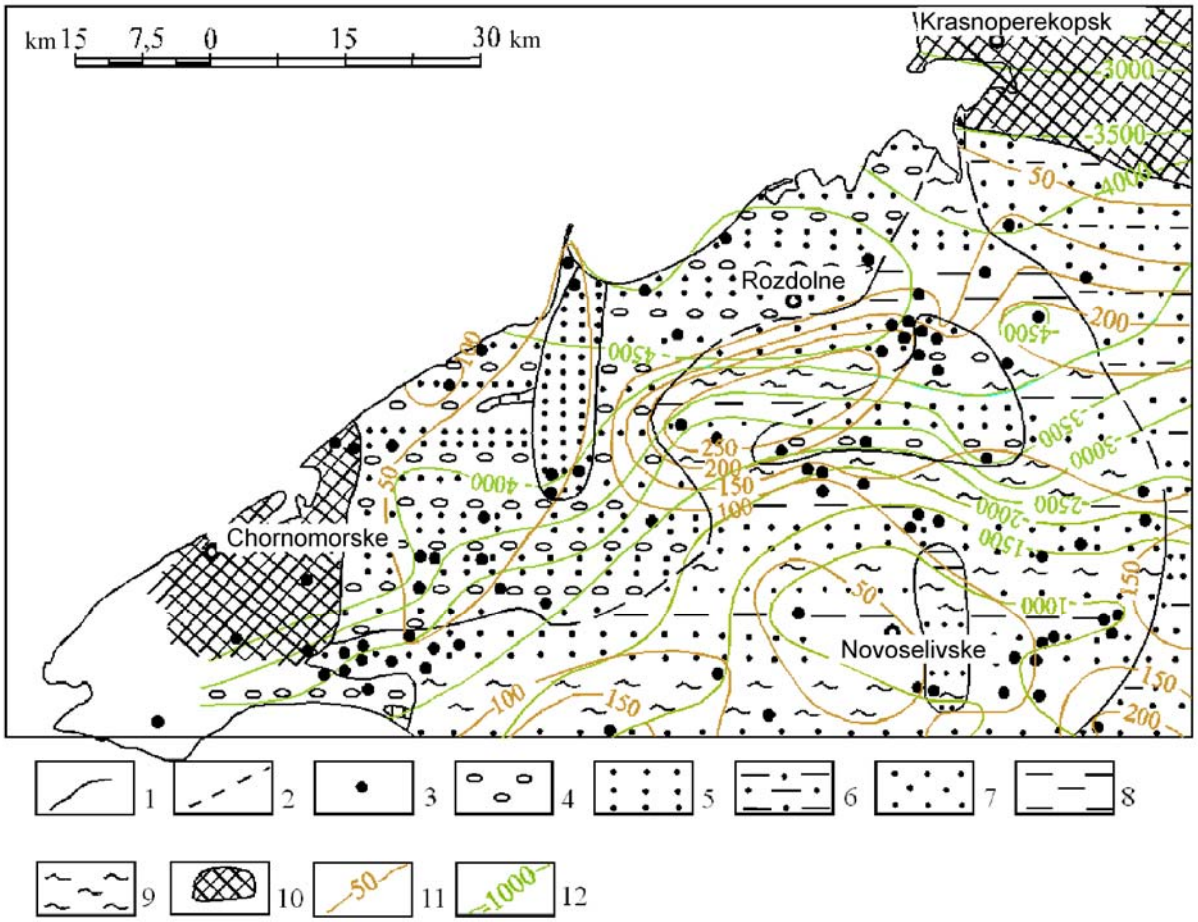

Fig. 2.2. Lithological scheme of Hauterivian – Barremian sediments.

1 – geological boundaries proven; 2 – geological boundaries possible; 3 – drill-holes; 4 – conglomerates; 5 – sandstones; 6 – aleurolites; 7 – sands; 8 – argillites; 9 – clays; 10 – areas of complete erosion of Hauterivian – Barremian sediments; 11 – thickness contour lines; 12 – depth contour lines of Hauterivian – Barremian sediments footwall.

Barremian stage (upper sub-stage) – Aptian stage (lower and middle sub-stages)

Donuzlavska Suite (K_1*dn*) is developed throughout in the area except the northern part of map sheets where it is facially replaced by the lower part of Novooleksiivska Suite. The column in DH Zakhidnooktyabrska-31 (depth 3191-3167 m) is taken to be the stratotype. The Suite is composed of marine, coastal-marine and shallow-water sediments – dark-grey, diverse-grained to gravelous sandstones, coarse-grained aleurolites with argillite, clay and limestone interbeds. In the south of the Suite distribution area amount of coarse-terrigenous rocks is decreased while they are being substituted by clayey sediments. The Suite unconformably lies over Kalininska Suite or older sediments and is conformably overlain by Kashtanivska Suite rocks. Thickness of the Suite sediments in the central part of studied area is 200 m dropping down to 100 m in the southern and northern directions. The Suite is well-characterized in paleontological respect; from calcareous sandstones foraminifera are determined typical for Urgonian facies of Barremian-Aptian sediments in Mediterranean: *Choffatella decipiens* S c h u m b., *Palorbitolina lenticularis* (B l u m.). In argillites and aleurolites of middle and upper Suite parts *Gavelinella ex gr. suturalis* (M j a t l.), *Hedbergella aptica* (A g a l) are found suggesting for the Aptian age [7].

Aptian stage (middle and upper sub-stages)

Novooleksiivska Suite (K_1no) is developed in Prykarkinitska LTZ in the north of maop sheet group. The typical column is studied in DH Borysivska-2 in the depth range 4689-4535 m. The Suite is composed of alternating sandstones, aleurolites and argillites, in places limestone interbeds occur. At the boundary with Pivnichnokrymska LTZ the sediments of lower Suite part are being facially replaced by the rocks of Donuzlavska Suite. The Suite does unconformably lie over odd-aged rocks – from Ryphean to Jurassic, and is conformably overlain by Khersonska Suite. Thickness of sediments varies from 100 to 200 m. In the typical column foraminifera *Hedbergella aptica* A q a l. and spore-pollen *Gleichenia sp.* are found.

Kashtanivska Suite ($K_1kš$) is developed in Pivnichnokrymska and Tsentralnokrymska LTZs. The stratotype is studied in DH Kashtanivska-3 (depth 3130-2830 m). The Suite is composed of dark-grey argillites with interbeds and lenses of sandstones, aleurolites and clayey siderites. In the northern direction amount of coarse-terrigenous rocks increases in the Aptian column, and in Prykarkinitska LTZ Kashtanivska Suite is facially replaced by sandstones and aleurolites of Novooleksiivska Suite. In Tsentralnokrymska LTZ it does conformably, and in Pivnichnokrymska – unconformably lie over the rocks of Donuzlavska Suite, and is conformably overlain by sediments of Ryleivska and Tetyanivska suites. Maximum thickness of Kashtanivska Suite is 200 m while it decreases up to 40 m in the northern and southern directions. In lithological respect aleurolites comprise polymictic and oligomictic rocks. Sandstones are oligomictic quartz-glauconite rocks with abundant iron sulphides as well as pyritized and coalified fossil remnants. The age of Kashtanivska Suite is supported by fauna of molluscs *Hypacanthoplites nolaniformis* (N a t z k.) G l a s., *H. jacobi* C o l l and others, numerous foraminifera, as well as spore-pollen complex with prevailing *Gleichenia.*

Albian stage (lower sub-stage)

Khersonska sequence (K_1hr) is developed in Prykarkinitska LYZ in the north of map sheet group. The stratotype is defined outside the map sheet boundary. Typical columns are intersected by DH Krasnoperekopska-2 (depth 3346-3202 m) and Avrorivska-1 (4600-4448 m). The Sequence sediments include dark-grey mica aleurolites with interbeds of dark-grey to black aleuritic argillites and grey quartz-mica diverse-grained sandstones. In the southern and north-eastern directions amount of sandstones increases in the column. In the south-eastern direction the rocks of Khersonska sequence are being facially replaced by sediments of Tetyanivska, and in the south-western direction – by the rocks of Ryleivska Suite. Without visible evidences for disconformity the Sequence sediments lie over the rocks of Novooleksiivska Suite and are conformably overlain by Averyanivska sequence argillites. Thickness of Khersonska sequence is 120-160 m. Early Albian age is supported by foraminifera complex: *Haplophragmoides aff. nonioninoides* R e s*., Gavelinella suturalis* (M j a t l .) and others.

Ryleivska Suite (K_1rl) is developed in Pivnichnokrymska LTZ (Tarkhankutska sub-zone) and in Tsentralnokrymska LTZ where it facially replaces Tetyanivska Suite. The stratotype is defined in DH Ryleivska-1 (depth 4200-4077 m). The Suite is composed of dark-grey aleurolites and grey to black argillites with grey sandstone interbeds. It does unconformably lie over the rocks of Kashtanivska Suite and without visible interruption is overlain by Elyzavetynska sequence and Tarkhankutska Suite; thickness is 170 m. Coarse-aleuritic, massive and layered aleurolites with glauconite and pyritized fossil remnants predominate in the column. Argillites are aleuritic, slightly-clayey, with fine-disseminated pyrite. Sandstones are more typical for the northern part of the Suite's distribution area. These are oligomictic, fine- and medium-grained rocks with clayey cement of porous type. Early Albian age is supported by foraminifera complex: *Haplophragmoides rosaceus* S u b b., H. *nonioninoides* R e s., *Hedbergella trocoidea* G a n d., ammonites *Hamites attenuatus* S o w ., and two-shell molluscs *Grammatodon carinatus* S o w*., Inoceramus sp.*

Tetyanivska Suite (K_1tt) is developed in Pivnichnokrymska LTZ (Serebryansko-Dzhankoyska sub-zone) and in Tsentralnokrymska LTZ where it facially replaces sediments of Ryleivska Suite. The stratotype is defined in DH Tetyanivska-1 (depth 4369-4222 m). The Suite is composed of dark-grey to black, slightly-calcareous and aleritic argillites with interbeds of polymictic aleurolites enriched in glauconite; thickness is up to 150 m. The Suite conformably lies over Kashtanivska Suite and is overlain by Tarkhankutska Suite. Early Albian age is supported by ammonites *Hamites attenuatus* S o w., two-shell molluscs *Grammotodon carinatus* S o w ., and foraminifera *Haplophragmoides rosaceus* S u b b*., Trochogaudryina filiformis* (B e r t h .).

Middle sub-stage

Tarkhankutska Suite (K_1tr) is developed in Pivnichnokrymska LTZ and its most complete columns are characteristic for Tarkhankutska sub-zone. The typical column is intersected in DH Melova-4 (depth 3769-3335 m). The Suite is composed of alternating black clastic tuffs of andesitic composition and dark-grey spotty coarse-grained litho-crystalo-clastic tuffs with dark-grey to black argillites and dark-grey thin-aleuritic mica aleurolites; in places thin (2-3 m) beds of andesitic tuff-lava and tuffites are observed.

In Serebryansko-Dzhankoyska LTZ amount of tuff material decreases in the Suite column while the fraction of extrusive rocks – andesite and andesite-dacite porphyries increases. In most extent extrusive rocks are developed in Tetyanivska (DH 1, 2), Krasnoyarska (DH 1) and Rozdolnenska (DH 1) fields. Most likely it is related to activity of volcanic centers. Distribution areas of Middle and Upper Albian diverse-facies rocks and location of volcanic units are shown in Fig. 2.3. Towards Prykarkinitska and Tsentralnokrymska LTZs the Suite rocks are facially replaced by the fine-terrigenous sediments of Averyanivska and Elyzavetynska sequences lower parts respectively.

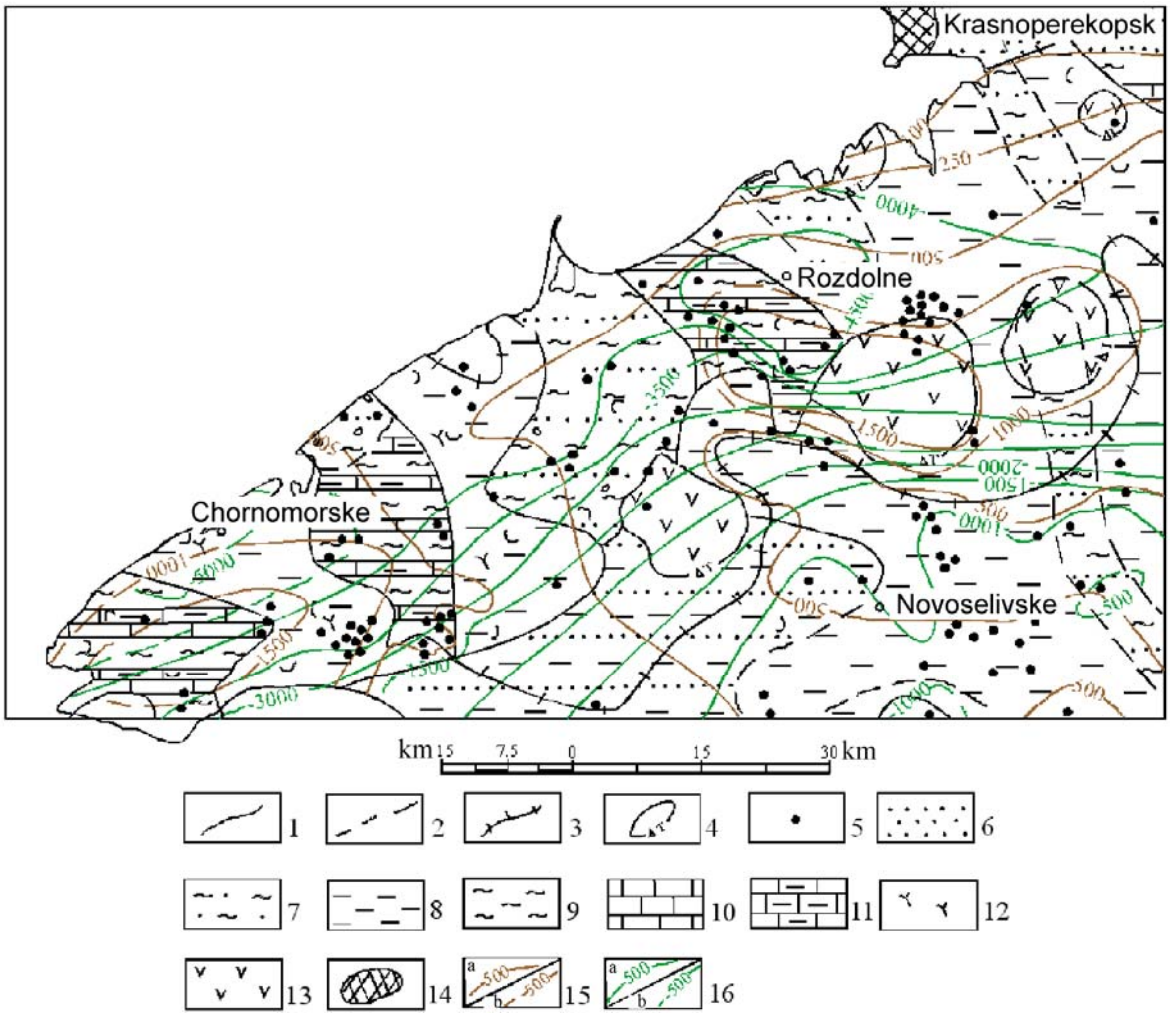

Fig. 2.3. Lithological scheme of Upper-Middle Albian rocks.

1 – geological boundaries proven; 2 – geological boundaries possible; 3 – distribution boundaries of volcanogenic-sedimentary rocks; 4 – contours of volcanic bodies by magnetic survey data; 5 – drill-holes; 6 – sands; 7 – aleurites; 8 – argillites; 9 – clays; 10 – limestones; 11 – marls; 12 – tuffs; 13 – andesites; 14 – areas of complete erosion of Upper-Middle Albian rocks (Tarkhankutska and Kovylnenska suites); 15 – thickness contour lines: a – proven, b – possible; 16 – contour lines of Upper-Middle Albian rocks footwall (Tarkhankutska and Kovylnenska suites, Averyanivska, Evpatoriyska and Elyzavetynska sequences): a – proven, b – possible.

Middle and upper sub-stages

Averyanivska sequence (K_1*av*) is developed in Prykarkinitska LTZ. The stratotype is defined out side the studied area. The typical column is intersected by DH Borysivska-1 (depth 4760-4482 m). The Sequence is composed of dark-grey calcareous and siliceous argillites with cocolithoforides and interbeds of clays, aleurolites and grey sandstones. In the southern direction amount of volcanogenic material increases in the column and the Sequence is being facially replaced by Evpatoriyska and Elyzavetynska sequences. In the north-eastern direction amount of siliceous rocks increases in the Sequence. Thickness of the Sequence varies from 170 to 280 m. Middle-Lte Albian age of the Sequence is supported by the complex of foraminifera *Gavelinella slavutichi* (K a p t.), *Lingulogavelinella zoratensis* (D j a f f. e t A g a l.).

Elyzavetynska sequence (K_1*el*) is developed in Tsentralnokrymska LTZ. The stratotype is intersected in DH Elyzavetynska-2 (depth 950-735 m). The sequence is composed of calcareous argillites with aleurolite interbeds. In the northern and north-eastern part of the area siliceous rocks appear in the column and the Sequence is facially replaced by sediments of lower sub-suite of Kovylnenska Suite. In the south of map sheet group the Sequence is replaced by Evpatoriyska sequence. In the north-western direction the lower part of the Sequence is facially replaced by Tarkhankutska Suite with considerable amount of volcanogenic rocks.

The rocks of the Sequence do conformably lie over the sediments of Tetyanivska and Ryleivska suites and is also conformably overlain by Upper Kovylnenska Suite rocks. In the west of map sheet group the Sequence rocks are unconformably overlain by sediments of Krasnopolyanska Suite. Thickness of Elyzavetynska sequence attains 500 m. Middle-Late Albian age of the Sequence is supported by ammonites *Hoplites dentatus* S o w., and foraminifera *Hedbergella aff. infracretacea* (G l a e s s n), *Pseudolamarckina cf. woodi* K h a n.

Upper sub-stage

Evpatoriyska sequence (K_1*ev*) is developed in Tsentralnokrymska LTZ. It does facially replace the upper part of Elyzavetynska sequence and the lower sub-suite of Kovylnenska Suite. The Sequence stratotype is located outside the map sheet group boundaries. The typical column is intersected by DH Tarasivska-1 at the depth 695-580 m. The Sequence is composed of grey, quartz, medium-grained sandstones with interbeds of aleurolites, argillites and siliceous rocks. The Sequence sediments unconformably lie over the rocks of lower part of Elyzavetynska sequence and are conformably overlain by the rocks of upper sub-suite of Kovylnenska Suite. Thickness of the Sequence varises from 120 to 280 m. Late Albian age (its beginning and middle part) is supported by foraminifera *Ticinella (?) aff.breggiensis* (G a n d.) findings.

Kovylnenska Suite (K_1*kv*) is developed in Pivnichno-Tsentralnokrymska LTZ. The stratotype is defined in DH Serebryanska-8 (depth 4184-3200 m). The Suite is composed of terrigenous-volcanomictic rocks and is divided in two sub-suites.

The lower sub-suite (K_1kv_1) is developed in Pivnichnokrymska LTZ, in the central part of map sheet L-36-XXII. Sub-suite is composed of argillites, volcanomictic and polymictic sandstones, volcanogenic gravelites and siliceous rocks. Maximum thickness is 1600 m.

The upper sub-suite (K_1kv_2) is developed in Pivnichnokrymska and Tsentralnokrymska LTZs. It is composed of alternating argillites, marls, and volcanomictic rocks. In Serebryansko-Dzhankoyska sub-zone the interbeds of extrusive rocks are known. Thickness of sub-suite attains 300 m. Relationships with underlaying and overlaying sediments are conformable. Late Albian age (beginning and middle part) of lower sub-suite is supported by the findings of ammonites *Hamites cf. attenuatus* S o w. and foraminifera *Pervinquieria subinflata* (P i c t.). Late Albian age of upper sub-suite (Vrakonskiy horizon) is supported by the findings of foraminifera *Planomalina buxtorfi* (G a n d.), *Praeglobotruncana delrioensis* (P l u m m.).

Lower and Upper divisions

Albian stage (upper sub-stage) and Cenomanian stage (undivided)

Krasnopolyanska Suite (K_{1-2}*kp*) is developed in Pivnichnokrymska LTZ (Tarkhankutska sub-zone) and Tsentralnokrymska LTZ. The stratotype is defined in DH Karlavska-10 (depth 3977-3452 m). The Suite is divided into three sub-suites.

The lower sub-suite ($K_{1-2}kp_1$) is composed of alternating dark-grey, dense, cracked marls and limestones. Thickness of sub-suite attains 600 m. Late Albian age is supported by the findings of foraminifera *Rotalipora ticinensis* (G a n d.).

The middle sub-suite ($K_{1-2}kp_2$) is composed of dark-grey cracked marls with interbeds of dark-grey to black spotty limestones. Thickness of sub-suite attains 300 m. Early Cenomanian age is supported by the findings of foraminifera *Rotalipora appeninnica* (R e n z.).

The upper sub-suite ($K_{1-2}kp_3$) is composed of dark-grey to black, spotty, clayey, dense limestones with pyrite inclusions. Thickness of sub-suite attains 300 m. Middle-Late Cenomanian age is supported by the findings of foraminifera *Rotalipora cushmani* M o r n*., R. deeckei* (F r a n k e).

Krasnopolyanska Suite does conformably (and in the south of map sheets partly with unconformity) lie over Kovylnyanska Suite or Evpatoriyska sequence and is conformably overlain by limestones of Natashynska Suite. In the east of map sheet group the lower and middle sub-suites of Krasnopolyanska Suite are facially replaced by synchronous in age sediments of Pryvolnenska Suite.

Pryvolnenska Suite ($K_{1-2}pr$) is developed in Tsentralnokrymska LTZ (Serebryansko-Dzhankoyska sub-zone). The stratotype is defined outside the studied map sheet group in DH Dzhankoyska-3 (depth 3176-2971 m). Two sub-suites are distinguished in the Suite.

The lower sub-suite ($K_{1-2}pv_1$) is composed of clayey marls, aleurolites, volcanomictic and siliceous sandstones, up to 60 m thick. Late Albian age (its final part) is supported by the findings of foraminifera *Rotalipora ticinensis* (G a n d.).

The upper sub-suite ($K_{1-2}pv_2$) is composed of extrusive and pyroclastic rocks, siliceous sandstones, aleurolites and clayey marls, up to 300 m thick. Early Cenomanian age is supported by the findings of two-shell molluscs *Inoceramus crippsi* M a n t. and foraminifera *Rotalipora appeninnica* (R e n z.).

In the columns of Albian-Cenomanian rocks in the map sheet L-36-XXII the similar rock complex is encountered in Tetyanivska, Srebryanska and Pervomayska fields. Over there, in the upper sub-suite volcanogenic-sedimentary and carbonate rocks predominate while the lower sub-suite increases to 150 m. Pryvolnenska Suite does conformably lie over Kovylnenska Suite and is also conformably overlain by the upper sub-suite of Krasnopolyanska Suite.

Upper division

Cenomanian stage

Genicheska sequence (K_2gn) is developed over entire Prychornomorya and in the north-western Black Sea offshore. The typical column is studied outside the given map sheet group in DH Genicheska-5 (depth 2167-2047 m). The Sequence is composed, in the lower part, of quartz-glauconite sandstones, sands, aleurolites and clays, and in the upper part – of marls, limestones and siliceous rocks. Similar columns of Cenomanian sediments are only known from Karkinitska Bay (DH Karkinitska-1) and in Pivnichnokrymska LTZ (DH Borysivska-2 on Bakalska spit). Over most part of this area the Cenomanian sediments are similar to Upper Albian ones in term of lithology. They are also mapped in Krasnopolyanska and Pryvolnenska suites and do have somewhat different lithology in pomparison to Genicheska sequence (Fig. 2.4). In Serebryanska, Tetyanivska, Pervomayska and Ryleivska fields the columns of mentioned stratons contain abundant volcanogenic-sedimentary and pyroclastic rocks, while in Novoselivska, Krasnovska, Krasnopolyanska and Elyzavetynska fields the Cenomanian sediments are lacking at all. Genicheska sequence does unconformably lie over sediments of Averyanivska sequence and also unconformably is overlain by Karkinitska sequence. The Cenomanian age is supported by the findings of foraminifera: at the bottom – *Gavelinella cenomanica* B r o t z., *Lingulogavelinella globosa* (B r o t z.), at the top – *Rotalipora cushmani* M o r n.

Turonian and Coniacian stages

Natashynska Suite (K_2nt) is developed in Tsentralnokrymska LTZ. The typical column in the map sheet group is studied in DH Elyzavetynska-2 (depth 1053-995 m). The Suite is composed of limestones with marl, clay and sandstone interbeds. Limestones are white, greyish-white, organogenic-detritus, clayey, with sutures and stilolite bands. Thickness of the Suite is 200 m. In the north of the area the Suite is facially replaced by sediments of Znamyanska Suite. The Suite does conformably lie over Krasnopolyanska Suite and is unconformably overlain by the sediments of Koltsovska sequence. Turonian-Coniacian age of the Suite is supported by the findings of foraminifera: in the lower part – *Gavelinella ammonoides* (R e s.), in the upper part – *Stensioeina emscherica* B a r y s h n.

Znamyanska Suite (K_2zn) is developed in Pivnichnokrymska LTZ. The stratotype is defined in DH Tarkhankutska-2 (depth 2273-1525 m). The Suite is composed of limestones with thin dark-grey clay interbeds and flint inclusions. Limestones are light-grey, white, organogenic (pitonellic), clayey, with sutures and stilolite bands. Thickness of the Suite attains 1200 m. In the east of the territory it is facially replaced by Natashynska

Suite. The Suite does most commonly lie over Krasnopolyanska Suite and is unconformably overlain by Voronkivska sequence. Turonian-Coniacian age of the Suite is supported by the findings of foraminifera: in the lower part – *Gavelinella ammonoides* (R e s.), *Globotruncana lapparenti* B r o t z., in the upper part – *Stensioeina emscherica* B a r y s h n., and others.

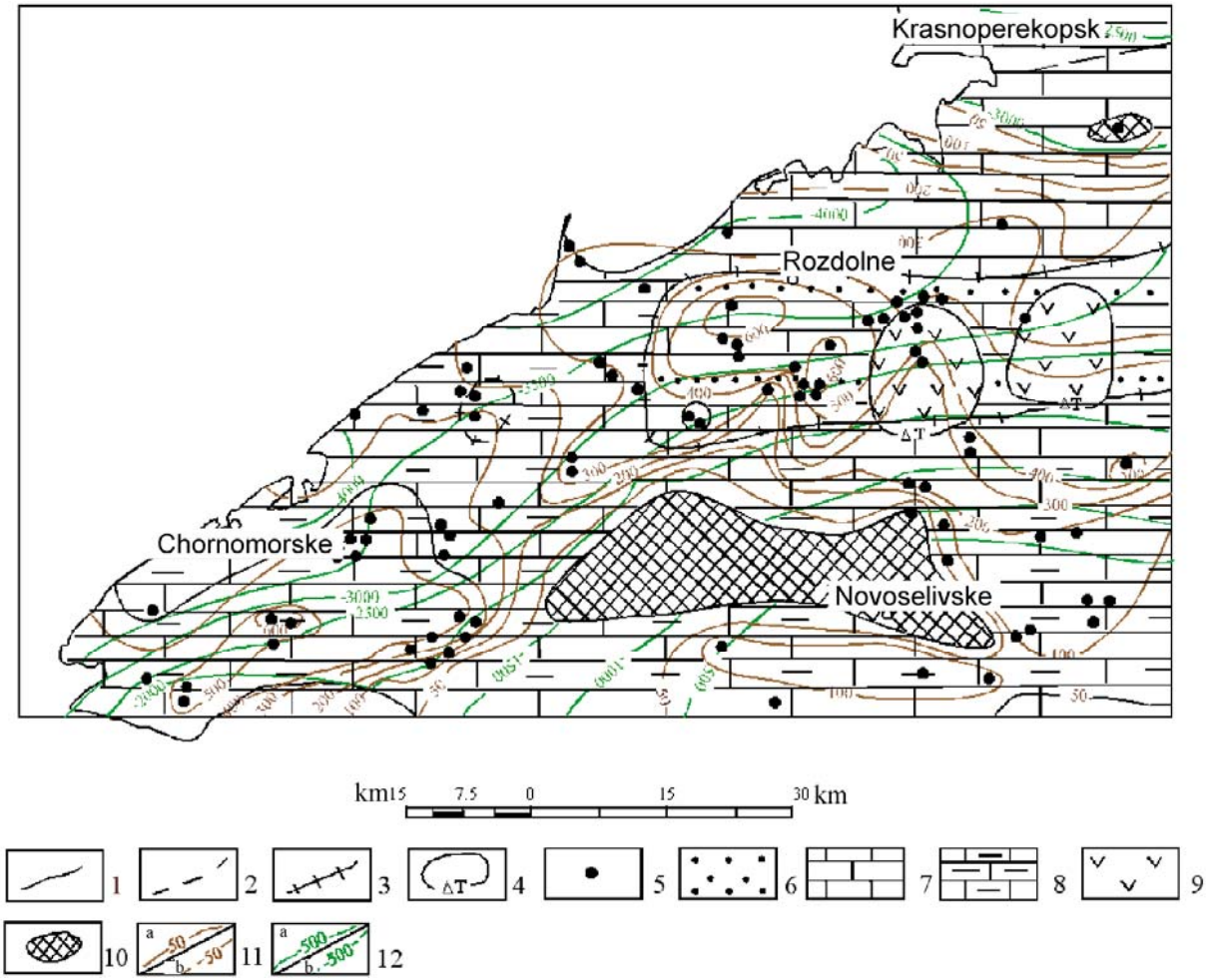

Fig. 2.4. Lithological scheme of Cenomanian rocks.

1 – geological boundaries proven; 2 – geological boundaries possible; 3 – distribution boundaries of volcanogenic-sedimentary rocks; 4 – contours of volcanic bodies by magnetic survey data; 5 – drill-holes; 6 – sands; 7 – limestones; 8 – marls; 9 – andesites; 10 – areas of complete erosion of Cenomanian rocks; 11 – thickness contour lines: a – proven, b – possible; 12 – contour lines of Cenomanian rocks footwall: a – proven, b – possible.

Turonian, Coniacian stages and Santonian stage (upper sub-stage)

Karkinitska sequence (K_2*kr*) is developed in Prykarkinitska LTZ and in Karkinitska Bay. The typical column is defined outside the studied map sheet group in DH Khersonska-17 (depth 1169-1052 m). The Sequence is composed of light-grey and white clayey limestones with sandstones at the bottom. Most completely the Sequence is intersected in DH Borysivska-1 on Bakalska spit (depth 4154-3215 m). Over there, the Sequence thickness attains 839 m. In the north-west of map sheet L-36-XXI the Sequence is more sandy. The Sequence does unconformably lie over Genicheska sequence sediments and is conformably overlain by Novomayachkynska sequence. Turonian – Early Santonian age is supported by the findings of foraminifera: at the bottom – *Hedbergella cf. agalarovae* V a s s., *Globigerinelloides escheri* (K a u f f.), at the top – *Globotruncana concavata* B r o t z., *G. coronata* B o l l i.

Santonian stage (lower sub-stage)

Koltsovska sequence (K_2kc) is developed in Tsentralnokrymska LTZ, in the southern part of map sheet L-36-XXII. The typical column is defined outside the studied map sheet group. The Sequence is composed of grey marls and clayey limestones. In Novoselivske uplift the column contains white calcareous clay interbeds. In the northern direction the Sequence is facially replaced by sediments of Voronkivska sequence. Thickness of the Sequence is 120 m. It lies unconformably over Natashynska Suite and is conformably overlain by Pavlivska sequence. Early Santonian age is supported by the findings of foraminifera *Pseudovalvulineria infrasantonica* (B a l a k h m).

Voronkivska sequence (K_2vr) is developed in Pivnichnokrymska LTZ. The typical column is defined in DH Pivnichnoserebryanska-1 (depth 2188-1996 m). The Sequence is composed of grey and light-grey porcelain-like limestones, at the top – of grey marls and clayey limestones. In the western part of the territory amount of marls increases in limestones and flints appear. Thickness of sediments attains 200 m. The Sequence unconformably lies over sediments of Znamyanska Suite and is conformably overlain by the rocks of Pavlivska sequence. Early Santonian age is supported by the findings of foraminifera *Pseudovalvulineria infrasantonica* (B a l a k h m), *Stensioeina gracilie* (B r o t z.).

Santonian stage (upper sub-stage) – Campanian stage (lower sub-stage)

Novomayachkynska sequence (K_2nm) is developed in Prykarkinitska LTZ. The typical column is defined outside the studied map sheet group in DH Novomayachkynska-17 (depth 1020-1265 m). The Sequence is also intersected by numerous drill-holes in Krasnoperekopska, Rozdolnenska and Borysivska fields. It is composed of grey, light-grey, white limestones with greenish-grey and grey clay interbeds at the top. In the south of territory the Sequence is facially replaced by sediments of Pavlivska sequence. Thickness of the Sequence in DH Krasnoperekopska-1 attains 300 m. Late Santonian – Early Campanian age is supported by the findings of foraminifera: at the bottom – *Gavelinella stelligera* (M a r i e), *Globotruncana fornicata* (P l u m m.), at the top – *Pseudovalvulineria clementiana pseudoexcolata* (R a l i n.), *Cibicidoides temirensis* (V a s s.).

Pavlivska sequence (K_2pl) is developed thoughout the studied map sheets. The typical column is defined in DH Dzhankoyska-3 (depth 2106-2299 m). The Sequence is composed of light-grey, whote, clayey limestones with marl and clay interbeds. In the south of the territory amount of limestones decreases in the column. Most complete columns of the Sequence are intersected in Serebryanska, Tetyanivska and Ryleivska fields and in Tarkhankutskiy peninsula. Thickness of the Sequence attains 250 m. The Sequence does conformably lie over underlaying sediments and is also conformably overlain by Dzhankoyska Suite. Late Santonian – Early Campanian age is supported by the findings of foraminifera *Cavelinella stelligera* (M a r i e), *Cibicidoides temirensis* (V a s s.).

Campanian stage (upper sub-stage) – Maastrichtian stage

Stroganivska sequence (K_2st) is developed in Prykarkinitska LTZ. The typical column is defined outside the studied area. Most complete column over the given map sheet group is intersected in DH Borysivska-1 (depth 3215-2640 m). The Sequence is composed of limestones with greenish-grey marl interbeds. Limestones are light-grey, clayey, in places flinted. Thickness of the Sequence attains 700 m. The Sequence does conformably lie over Novomayachkynska sequence and is unconformably overlain by Gromivska Suite. Late Campanian – Maastrichtian age is supported by the findings of foraminifera: at the bottom – *Bolivina kalinini* V a s s . , at the top – *Neoflabellina reticulata* R o s s.

Dzhankoyska Suite ($K_2dž$) is developed in Pivnichnokrymska and Tsentralnokrymska LTZs. The stratotype is defined outside the studied area in DH Dzhankoyska-3 (depth 2106-1810 m). Two sub-suites are distinguished.

The lower sub-suite ($K_2dž_1$) is composed of grey clayey limestones with greenish marl interbeds. Most complete column is intersected by drill-holes in Oktyabrska and Melova fields where thickness of these sediments attains 450 m.

The upper sub-suite ($K_2dž_2$) is exposed at the surface in Tarkhankutskiy peninsula. It is composed of light-grey, dense, flinted marls. Thickness of sub-suite in the eastern part of the area attains 900 m.

The rocks of Dzhankoyska Suite in the west does conformably lie over Pavlivska sequence and over most part of the territory are conformably overlain by Gromivska or Bogachivska suites; it is only the south of Tarkhankutskiy peninsula, Melova field, where these rocks are unconformably overlain by Miocene sediments. In the northern direction Dzhankoyska Suite is facially replaced by Stroganivska sequence. Late Campanian age

of the lower sub-suite is supported by the findings of foraminifera *Globotruncana coactava* (B o l l i), while Maastrichtian age of upper sub-suite is evidenced by the findings of foraminifera *Bolivina incrassata* (R e s.).

Cenozoic eratheme

Cenozoic sediments in the studied map sheet group constitute the upper sedimentary cover. These include the rocks of Paleogene, Neogene and Quaternary systems. Throughout the area at the pre-Quaternary surface are only exposed Neogene sediments while Paleogene rocks – just in the map sheet L-36-XXI.

Paleogene System

Paleogene sediments are developed over most territory of map sheet group and are only lacking in Novoselivske uplift, in the south of L-36-XXII map sheet.

Two LTZs are distinguished – Tarkhankutska and Syvaska, which differ both in lithology and reduced thickness in Syvaska LTZ caused by erosions and interruptions.

Paleocene

Lower Paleocene. Danian and Montian stages
Bilokamyanskiy regio-stage

Gromivska Suite (P_1gm) is developed in Tsentralna LTZ where its columns are intersected by a number of drill-holes. The stratotype is defined in DH Zakhidnooktyabrska-30 (depth 577-237 m). The Suite is composed of carbonate rocks. In the western part of its distribution area thickness of the Suite is decreased and it is facially replaced by Bogachivska Suite, and in Elyzavetynska field Paleogene sediments are completely pinched out. Over most part of the distribution area Gromivska Suite does conformably lie over sediments of Dzhankoyska Suite and Stroganivska sequence and in Tarkhankutskiy peninsula only it unconformably overlies Dzhankoyska Suite. Throughout the Suite without visible evidences for interruption is overlain by Lazurnenska Suite. Two sub-suites are distinguished in the Suite.

The lower sub-suite (P_1gm_1) is composed of grey and greenish-grey marls with limestone interbeds; thickness is up to 200 m. Early Paleocene age of sub-suite is supported by the findings of foraminifera *Stensioina caucasica* (S u b b.), *Anomalinoides danicus* (B r o t z.), *Globigerinamicrocellulosa* M o r., *G. taurika* M o r. and others.

The upper sub-suite (P_1gm_2) is composed of organogenic-detritus and foraminifera limestones with marl interbeds; thickness is up to 240 m. Early Paleocene (its secind half) age of sub-suite is supported by the findings of foraminifera *Heterostomella gigantica* S u b b., *Eponides saginaris* N. B y k., *Brotzenella praeacuta* (V a s s .), *Anomalinoides danicus* (B r o t z .), *Globorotalia angulata* W h i t e, *Reussella paleocenica* B r o t z.

Bogachivska Suite (P_1bg) is developed in Syvaska LTZ. The stratotype is defined in DH Balashivska-6 in Prysyvashshya (depth 1700-1587 m). The Suite is composed of organogenic re-crystallined sandy limestones, in places with clay interbeds.

In the west of territory the Suite is facially replaced by the rocks of Gromivska Suite, and in the south its thickness drops down sharply up to complete pinching out in Novoselivske uplift. Thickness of the Suite increases in the northern direction from the first meters in the south to 120 m in the north. The Suite normally does unconformably lie over sediments of Dzhankoyska Suite conformably – over Stroganivska sequence. Throughtout Bogachivska Suite is unconformably overlain by the sequence of marls and limestones. Early Paleocene age of the Suite is supported by the findings of foraminifera *Arenobulimina dubia* W o l o s c h., *Ataxophragmium frankei* (B r o t z . *), Elphidiella prima* D a m*., Anomalinoides danicus* (B r o t z.), *Karreria fallax* R z e h a k . , *Pulsiphonina cf. prima* B r o t z., *Globoconusa daubjergensis* (B r o n n.), which allow correlation of these sediments with Bilokamyanskiy regio-stage.

Upper Paleocene. Thanetian stage
Kachynskiy regio-stage

Lazurnenska Suite (P_1lz) is developed in Tsentralna LTZ. The stratotype is defined in DH Zakhidnooktyabrska-30 (depth 237-112 m). The Suite is composed of light-grey, greenish-grey marls with clayey limestone and clay interbeds. In the eastern and north-eastern parts of the territory it is facially replaced by terrigenous-carbonate sequence of marls and limestones with sandstone and aleurolite interbeds; the Suite

thickness is reduced at the same time. In general, the Suite thickness varies from 25 to 260 m. It conformably lies over Gromivska Suite and is also overlain, with prominent contact, by Okunivska Suite clays. Late Paleocene age of the Suite is supported by abundant foraminifera complex – *Heterostomella gigantica* S u b b., *Anomalinoides fera* (S c h u t z.), *A. danicus* (B r o t z.), *Cibicidoides proprius* B r o t z., *Stensioina caucasica* (S u b b .), *Acarinina acarinata* S u b b., *A. subsphaerica* (S u b b.), *A. tadjikistanensis djanensis* S c h u t z, allowing correlation of these sediments with Kachynskiy regio-stage.

Sequence of marls and limestones (₽$_1$*mv*) is developed in Syvaska LTZ, and only in Serebryanska, Elyzavetynska, Kashtanivska, Tetyanivska and Novoselivska fields it is partly or completely eroded. Most complete columns are characteristic for Borysivska field. The Sequence is composed of grey and dark-grey marls and light-grey and grey clayey limestones. In the north-west of the map sheet group it is facially replaced by sandstones and aleurolites. Maximum thickness of the Suite is encountered in DH Borysivska-1, -2, where it attains up to 125 m. With erosion contact the Sequence lies over older sediments and is commonly unconformably but in the north-east – conformably overlain by Lower Eocene clay sequence. Late Paleocene age of the Sequence is supported by foraminifera complex – *Stensioina caucasica* (S u b b.), *Globigerina nana* C h a l *., Acarinina subsphaerica* S u b b., *A. tadjikistanensis djanensis* S c h u t z *., Reussella paleocenica* (B r o t z .), *Bulimina pseudopuschi* S u b b*., Angulogerinawilcoxensis* (C u s h m. e t P o n t.).

Eocene

Eocene sediments are almost throughout developed and are only eroded at the cores of some structures (Zakhidnooktyabrska, Melova, Oktyabrska in Tsentralna LTZ) and in Novoselivska, Berezivska and Baranivska fields of Syvaska LTZ.

Lower Eocene
Ypresian stage
Bakhchysarayskiy regio-stage

Okunivska Suite (₽$_2$*ok*) is only developed in Tsentralna LTZ. The stratotype is defined in DH Zakhidnooktyabrska-30 (depth 113-43 m). The Suite is composed of light-grey and dark-grey calcareous clays, in places dark-grey clayey marls. In the north-east of the map sheet group it is facially replaced by sequence of clays. Thickness of the Suite sediments varies from 25 m to 120 m. The Suite normally does conformably lie over Lazurnenska Suite and is also conformably overlain by Rodnikovska sequence. Early Eocene age of the Suite is supported by the complex of ostracoda, radiolaria, sea urchins and foraminifera – *Marginulina eofragaria* B a l a k h m., *Pseudoparrella culter* (P a r k. e t J o n.), *Globorotalia aequa* C u s h m. e t R e n z., *G. subbotinae* M o r., *G. velascoensis acuta* T o u l m., *G. wilcoxensis* C u s h m. e t P o n t., *G. nartanensis* S c h u t z . , *G. marginodentata* S u b b.

Sequence of clays (₽$_2$*g*) is locally developed in Syvaska LTZ in Krasnoperekopska, Serebryanska, Rozdolnenska, Baranivska and other fields in the northern part of map sheet L-36-XXII. The typical column is encountered in DH Krasnoperekopska-4 (depth 1760-1710 m). The Sequence is composed of grey calcareous aleuritic clays with thin marl interbeds. Maximum thickness (100-110 m) is intersected in Bakalska and Rozdolnenska fields while in the southern part of its distribution area the thickness is reduced up to complete pinching out. This straton lies over the sequence of marls and limestones with erosion in the south of the territory, and conformably, with gradual transition, elsewhere. Throughout it is conformably overlain by Simferopolska Suite. Early Eocene age of the Sequence is supported by the findings of foraminifera *Acarinina subbotinae* M o r., *A. camerata* C h a l.

Middle Eocene
Lutetian stage
Simferopolskiy regio-stage

Simferopolska Suite (₽$_2$*sm*) is developed in Syvaska LTZ. The stratotype is defined outside the studied territory in Bakhchysarayskiy area of Crimean fore-mountain land. In the map sheet group area the Suite columns are intersected by a number of drill-holes especially in the east of the territory. It is composed of light-grey nummulite limestones, in places clayey, and in the north marls predominate in the columns. In Berezivska, Elyzavetynska and part of Novoselivska fields the Suite is completely eroded. Thickness of the Suite attains 140 m. Normally the Suite confrmably lies over the clay sequence of Bakhchysarayskiy regio-stage, and with gradual lithological transition it is overlain by Novopavlivska Suite. Early-Middle Eocene age of the Sequence is

supported by the findings of bivalve and brachyopoda molluscs, sea urchins and numerous foraminifera, specifically *Acarinina bullbrooki* (B o l l i.), *Truncorotalia aragonensis* (N u t t.).

Simferopolskiy and Novopavlivskiy regio-stages

Rodnikovska sequence (P$_2$*rd*) is developed in Tsentralna LTZ. The typical column is encountered in DH Rodnikovska-3 (depth 370-90 m) in Tarkhankutskiy peninsula, and besides that, it is exposed at the surface to the west from Rodnikove village in the isolated outcrop 1.2 by 0.8 km in size. The Sequence is composed of marls with interbeds of greenish-grey, light-grey clayey limestones and thin greenish-grey clay interbeds. Most complete columns are intersected in the north-western part of map sheet L-36-XXI where the Sequence does conformably lie over Okunivska Suite and is also conformably overlain by the sequence of marls and aleurolites. In the eastern and north-eastern parts of Tsentralna LTZ the lower and upper layers are pinched out from the column. In the area of Rodnikove village the Sequence rocks with angular and stratigraphic unconformity are overlain by Miocene rocks. Maximum thickness of the Sequence is defined by drill-holes in the area of Chornomorske town where it is set to 360 m. In the south-western part of Tarkhankutskiy peninsula the Sequence thickness is reduced to 280 m. Early-Middle Eocene age of the Sequence is supported by abundant foraminifera complex – *Valvulineria intenta* N. B y k., *Anomalina affinis* H a n t k., *A. granosa* G ű m b., *Kolesnikovella elongata* (H a l k.), *Globorotalia lensiformis* S u b b., *Truncorotalia aragonensis* (N u t t.), *T. aragonensis caucasica* (G l a e s s n.), *Acarinina bullbrooki* (B o l l i.), *Globigerapsis subconglobatus* C h a l.

Novopavlivskiy regio-stage

Novopavlivska Suite (P$_2$*np*) is developed in Syvaska LTZ and in the north-western Black Sea offshore. The stratotype is defined in Bakhchysarayskiy area of Crimean fore-mountain land. The Suite is composed of limestones and dense white and light-grey marls. In the north of the distribution area, marls predominate in the column and clay interbeds appear. The Suite conformably lies over Simferopolska Suite limestones or with erosion over older sediments, and is conformably overlain by the sequence of marls and clays of Kumskiy regio-stage. In the map sheet group most complete columns are intersected by drill-holes in Bakalska, Borysivska and Krasnoperekopska fields. In the north of Syvaska LTZ thickness of the Suite is 150 m (DH Bakalska-15) while in the south its thickness is reduced up to 20 m. In Novoselivske uplift the Suite is completely eroded. In the stratotype the Suite is supported by abundant fauna complex: bivalvia molluscs, pearlworts, crustaceans and foraminifera. In the area, Midde Eocene age of Novopavlivska Suite is supported by the findings of foraminifera – *Operculina alpina* H. D o u v., *O. thracensis* A r c h., and crustaceans – *Argilloecia aduncta* M a n d., *A. karakemirensis* M a n d e l.

Kumskiy regio-stage

Sequence of marls and aleurolites (P$_2$*ma*) is developed in Tsentralna LTZ and in the north-western Black Sea offshore. The typical column is defined in offshore Golitsynske uplift. It is composed of greenish-grey marls with interbeds of grey clays and brown aleurolites and grey-brown marl batch at the bottom. In Tarkhankutskiy peninsula (Bakalska field) limestone interbeds are observed in the upper column half. Thickness of the Sequence attains 260 m. The Sequence conformably lies over seddiments of Novopavlivska Suite and is also conformably overlain by Alminska Suite. Midde Eocene age of the Sequence and its ascription to Kumskiy regio-stage is supported by the findings of foraminifera – *Globigerina turkmenica* C h a l., *G. subtriloculinoides* C h a l., *G inflata* O r b., *Hyperammina sp., Spiroplectammina spectabilis* G r z y b .

Sequence of marls and clays (P$_2$*mg*) is developed over entire studied territory. Formerly it has been distinguished as the layers with in the sequenceof marls and clays (P$_2$*mg*). It is composed of alternating marls and clays, at the bottom – brown-grey, at the top – greenish-grey. It conformably lies over Novopavlivska Suite and is conformably overlain by Alminska Suite. In the north of Syvaska LTZ (Bakalska and Krasnoperekopska fields) thickness of the Sequence is 40-50 m, and in the east it attains 150 m. The Sequence contains poor complex of organic remnants. Besides the zone variety, foraminifera are identified: *Globigerina azerbaidjanica* C h a l . , *G. bulloides bulloides* O r b., *G. instabilis* K o r o v., *Globanomalina micra* (C o l e), *Baggina valvulineriaformis* (N.B y k)., *Brotzenella acuta taurica* (S a m l.), *Turborotalia centralis* (C u s h m . e t B e r m .). This complex is characteristic for the lower part of Kumskiy regio-stage of Crimean-Caucasus region.

Alminskiy regio-stage

Alminska Suite (P$_2$*al*) in Plain Crimea is developed in all LTZs. In the map sheet area these sediments are only lacking at the uplift cores in Novoselivska, Elyzavetynska, Oktyabrska, Zakhidnooktyabrska, Melova and other fields. The typical column is defined outside the map sheet group in Bakhchysarayskiy area. Most complete columns in the area are intersected in Tetyanivska, Illinska and Pervomayska fields. It is composed of light-grey, greenish-grey, tripoli-like marls with iron-enrichment spots; in the upper part calcareous clays occur. Lithology of the Suite and systematic fauna composition are well consistent over entire distribution area. The Suite does conformably overlie marl-clayey and marl-alerolite sequences and with prominent contact is overlain by the Planorbelova Suite clays of Maykopska Series. Thickness of the Suite in the most complete columns attains 280 m. The rich complex of plankton and bentos foraminifera includes *Globigerapsis tropicalis* (B l o w. et B a n n e r.), *G. index* F i n l., *Globorotalia permicra* B a n n. et B l o w*, Bolivina antegressa* S u b b., *Margnulina infracompressa* T h a l m. and others, allowing Suite ascription to Late Eocene.

Paleogene and Neogene systems

Oligocene – Lower Miocene undivided

Maykopska Series (P$_3$-N$_1$*mk*). Maykopski sediments are widely developed over studied map sheets and are involved in two LTZs. In the northern one – Syvaska LTZ, the sediments are developed which are typical for entire Black Sea region, while in the southern domain, Tsentralna LTZ, those rocks are developed which are most typical for Maykopskiy trough of Eastern Para-Thetys (Fig. 2.5). Each of distinguished LTZs contains distinct stratons with characteristic rock lithology. Reduced columns, and somewhere their complete pinching out, are observed in the axial zone of Tarkhankutskiy arch and in Novoselivske uplift. Normally the columns are being reduced at the expense of the upper regio-stages. In Tsentralna LTZ Maykopska Series includes Oligocene Planorbelova, Molochanska and Kerleutska suites and clay sequence of Batysyfonoviy regio-stage. In Syvaska LTZ, Planorbelova, Molochanska, Sirogozka, Askaniyska and Gornostaivska suites are distinguished in Maykopska Series.

Oligocene

Planorbeloviy regio-stage

Planorbelova Suite (P$_3$*pl*) in full extent corresponds to the even-named regio-stage. It is distinguished by L.M.Golubnycha after gastropoda family *Planorbella* widespread in Plain Crimea. The Suite is divided in two sub-suites.

The lower sub-suite (P$_3$*pl*$_1$) is composed of grey and dark-grey, aleuritic, often calcareous clays, up to 150 m thick. In the southern direction thickness decreases to 50 m. It contains foraminifera complex: *Haplophragmoides fidelis* T e r-G r i g., *H. deformabilis* S u b b., *Ammomarginulina foliaceus* (B r a d y), *Gaudryina gracilis* C u s h m., *Lenticulina herrmanni* (A n d r.), *Heterolepa almaensis* (S a m l.), *H. oligocenica* (S a m l.), characteristic for the lower sub-regio-stage of Early Oligocene Planorbeloviy regio-stage. In Tarkhankuyskiy peninsula these sediments contain plankton varieties *Globigerina khadumica* N. B y k., *G. officinalis* S u b b . , *Globigerinella liwerovskayae* N.B y k., *Acarinina tetrarugosa* J e n n. and ohters.

The upper sub-suite (P$_3$*pl*$_2$) is composed of grey, dark-grey and brown-grey clays. In the upper part clays are sandy, thickness is from 100 to 250 m. In clays foraminifera *Textularia carinata oligocenica* (J. N l k.), *Cyclammina constrictimargo* S t e w. e t S t e w., *Neogyroidina memoranda* S u b b., *Uvigerinella majcopica* K r a j e v a , and plankton forms *Globigerina trefa* N. B y k., *G. parva* B o l l i*, G. brevispira* S u b b. and others are determined. This complex is characteristic for the upper part of Planorbeloviy regio-stage. The Suite does unconformably lie over Alminska Suite rocks and is conformably overlain by the clays of Molochanska Suite.

Molochanskiy regio-stage

Molochanska Suite (P$_3$*ml*) in full extent is synchronous to the same-named regio-stage. In the studied map sheet group it is developed in all LTZs. The stratotype is studied in Eastern Prychornomorya. It is composed of light-grey calcareous clays and aleurolites. In Syvaska LTZ amount of aleuritic fraction increases in the column. The lower Suite boundary is set by appearance of calcareous clays, and the upper one – by their disappearance . The Suite thickness in the stratotype srea does not exceed 40 m. In the studied area thickness

increases in the north-eastern direction and attains 100 m. Organic remnants of the Suite include molluscs *Lentidium vinogrodskii* M e r k l., *L. garetzkii* M e r k l., *Cardium serogosicum cimlanicum* Z h i z h., *Rzehakia cimlanica* (Z h i z h.); остракодами: *Cytherella beyrichi* (R e u s s), *Candona candidula* L n k l., *Pterygocythereis fimbriata fimbriata* (M u n s t.),*Disopontocypris oligocaenica* (Z a l.), and coccolites – *Sphenolitus predistentus* (B r a m l. e t W i l c o x.), *Sph. distentus* (M a r t i n i), characteristic for the upper part of Early Oligocene.

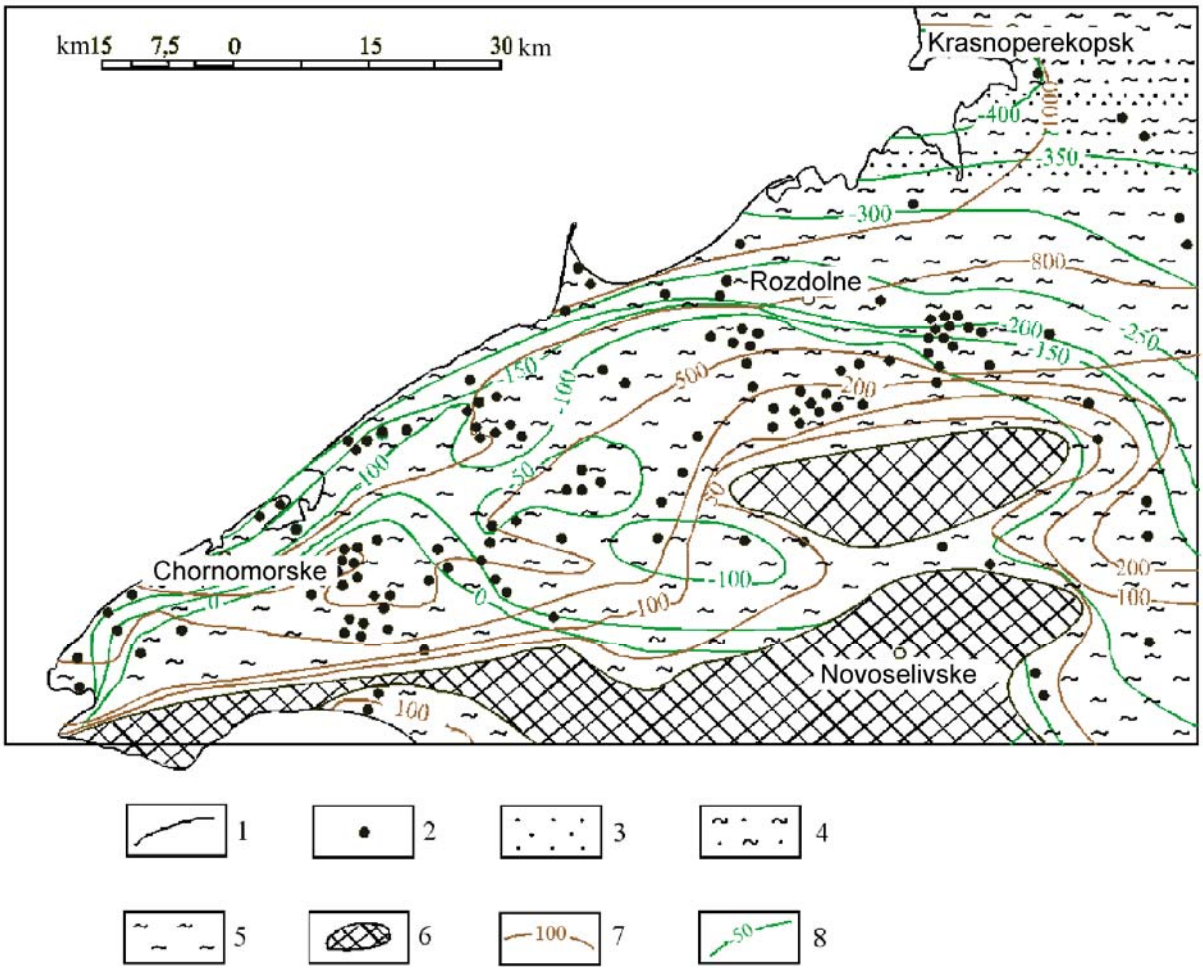

Fig. 2.5. Lithological scheme of Maykopski sediments.

1 – geological boundaries; 2 – drill-holes; 3 – sands; 4 – aleurites; 5 – clays; 6 – areas of complete erosion of Maykopski sediments; 7 – thickness contour lines; 8 – contour lines of Maykopski sediments footwall.

Sirogozkiy regio-stage

Sirogozka Suite (P$_3$*sr*) is developed in Syvaska LTZ. The stratotype is defined in Khersonska Oblast to the north from the studied map sheet group. It is composed of sandy-aleurite sediments up to 200 m thick. The Suite conformably lies over calcareous clays of Molochanska Suite anb with prominent contact is overlain by clays of Askaniyska Suite. Organic remnants include molluscs *Cardium serogosicum* N o s s o v., *Corbula sokolovi* (K a r l.), *Lentidium vinogrodskii* M e r k l. and ostracoda *Cytherella beyrichi* (R e u s s.), *Pontocypris oligocenica* Z a l. The Suite is in full extent synchronous in age to Sirogozkiy regio-stage.

Askaniyskiy regio-stage

Askaniyska Suite (P$_3$*as*) is developed in Syvaska LTZ. The stratotype is defined in Khersonska Oblast to the north from the studied map sheet group. It is composed of greenish-grey aleuritic, in places sandy clays up to 600 m thick. It conformably lies over Sirogozka Suite and is also conformably overlain by Gornostaivska Suite rocks. Organic remnants include molluscs *Chlamys hofmanni* (M u n s t.), *Ch. bifida* (M u n s t.), *Cardium abundans* L i v., *Similipecten hauchecornei* (K o e n.), foraminifera *Textularia (Spiroplectammina) carinata follis* K r a j e v a, *Cibicidoides nefastus* (J. N i k), *Uvigerinella californica* C u s h m., *Sphaeroidina variabilis* R e u s s . , and ostracoda *Cytherella beyrichi* (R e u s s.), *C. gracilis* L n k l., *Pontocypris oligocenica* Z a l. By position in the column and complex of organic remnants this Suite is correlated with the lower part of upper sub-regio-stage of Kerleutskiy regio-stage.

Gornostaivskiy regio-stage

Gornostaivska Suite (P$_3$*gr*) is developed in Syvaska LTZ. The stratotype, formerly defined in Khersonska Oblast, is recently re-studied and now it partly includes the sediments of Askaniyska Suite. The Suite is composed of greenish-grey aleuritic clays, clayey aleurolites and sandstones. In the map sheet area the sediments of Gornostaivska Suite conformably lie over Askaniyska Suite and is also conformably overlain by the rocks of Batysyfonoviy regio-stage. Thickness of the Suite attains 400 m. Organic remnants include molluscs *Chlamys cornea* S o w . , *Cardium abundans* L i v., *Dentalium kickxi* N y s t., foraminifera *Porosononion dendridicus* (C h a l.), *Elphidium onerosum* B o g d., *Cibicidoides ornatus* (B o g d.), *C. ex gr. ornatus* (B o g d.), *Nonion granosus* (O r b.), and ostracoda *Pontocypris brevis* L n k l., *Pterygocytheries jonesii* (B a i r d.), *P. fimbriatafimbriata* (M u n s t.).

Sirogozkiy, Askaniyskiy and Gornostaivskiy regio-stages

Kerleutska Suite (P$_3$*kr*) in the map sheet group is pretty widely developed. These sediments are only lacking in Novoselytska, Elyzavetynska, Oktyabrska, Zakhidnooktyabrska, Rodnikovska and Melova fields. The Suite is divided in two sub-suites.

The lower sub-suite (P$_3$*kr*$_1$) is composed of greenish- and brownish-grey clays, from 50 to 100 m thick. Organic remnants include single findings of foraminifera *Haplophragmoides periferoexcavatus* S u b b. and *Neobulimina elongata* (O r b.).

The upper sub-suite (P$_3$*kr*$_2$) is composed of grey, brownish-grey and dark-grey clays with sandstone, aleurite and siderite interbeds and lenses. Over most part of the area the rocks of this sub-suite are partly or completely eroded. Maximum thickness attains 250-300 m. Organic remnants include foraminifera *Haplophragmoides kjurendagensis kerleuticus* K o z., *Ammodiscus tenuiculus* S u b b. In general, Kerleutska Suite conformably lies over Molochanska Suite. In the core portion of most uplifts it is overlain, with erosion, by Miocene sediments while elsewhere it is conformably overlain by Lower Miocene clays.

Lower Miocene

The Miocene part of Maykopska Series in the map sheet group is comprised of Batysyfonoviy regio-stage. Its hanging-wall, as well as part of underlaying Neogene column, had been the objects for EGSF-200 in the area.

Batysyfonoviy regio-stage

Sequence of clays (N$_1$*g*). It is developed in all LTZs and constitutes upper part of Maykopska Series. The typical column is intersected in DH Mizhvodnenska-4 (depth 542-172 m). It is composed of dark-grey, in places sandy clays with rare aleurite interbeds. In the studied map sheets the Sequence sediments are only preserved in Syvaska LTZ where they conformably lie over Gornostaivska Suite. In Tsentralna LTZ clays are completely eroded at the uplifts while in the dimples they overlie upper Kerleutski sediments without visible break. Throughout the Sequence, with erosion, is overlain by Mayachkynska Suite or younger sediments. In the most complete columns thickness of the Sequence attains 200 m. Organic remnants are rare in the Sequence and include single bits of weakly-preserved radiolaria and fish fragments. By its position in the column, the Sequence is correlated with Batysyfonova Suite of Kerchenskiy peninsula and corresponds to Early Miocene.

Neogene System

The rocks of Neogene System comprise both divisions and two LTZs are distinguished – Syvaska and Tsentralna. Neogene columns in various facial zones well differ one from another in lithology, thickness and relationships between marine and continental facies.

Miocene

Tarkhanskiy regio-stage

Mayachkynska Suite ($N_1mč$) is mainly developed in Syvaska LTZ while in Tsentralna LTZ these sediments are preserved from erosion in depressions only. The Suite columns are intersected by the mapping drill-holes. The stratotype is defined outside the map sheet group in Khersonska Oblast. In Syvaska LTZ most complete column is encountered in DH 182 (depth 328.3-342.0 m). The Suite is composed at the bottom of brownish-green to black sandy clays with numerous orange-brown spots of iron-enrichment and powder-like carbonate inclusions 2-3 cm across; thickness of the Suite is 4.6 m. In Tsentralna LTZ thin column of the Suite clays is intersected in DH 177 at the depth 181.9-179.9 m. The Suite transgressively lies over underlaying rocks and is conformably overlain by Yurakivski layers, or unconformably – by Brykivski layers. Thickness of the Suite in the northern direction increases from 5 to 15 m. Fauna complexes of the Suite are very poor and include foraminifera, ostracoda and chara algae. L.A.Digas in DH 182 has determined *Elphidium macellum* (F.et M.) *E. rugosum atschiensis* S u z i n . , *E. rugosum* (O r b.), *Nonion granosus* (O r b.), *Globulina cf. gibba* O r b., *Globigerina pseudoedita* S u b b., *Eponides vialovi* V e n g l. By age this Suite is correlated with lower part of Tarkhanskiy regio-stage.

Yurakivski layers (N_1jr) are locally developed. They are only preserved from erosion in Syvaska LTZ and in some sites of Tsentralna LTZ. In the stratotype on Kerchenskiy peninsula these layers are composed of spirialis clays. In the studied area, these sediments are conventionally distinguished. In DH 183 (depth 327.5-313.5 m), located somewhat to the north from the map sheet boundary, the brown-grey to dark-grey, calcareous, thin-layerd clays are intersected, with fine dust of quartz-glauconite sand at the jointing planes. Thickness of Yurakivski layers is 5-6 m. They conformably lie over sandy-clayey sediments of Mayachkynska Suite and are unconformably overlain by iron-enriched clays with organogenic limestone fragments with fauna of Chokrakskiy regio-stage. By position in the column, Yurakivski layers are conventionally ascribed to the upper part of Tarkhanskiy regio-stage.

Lower and Middle Miocene clayey rocks macroscopically are pretty uniform but differ in chemical and mineralogical composition. In Syvaska LTZ kaolinite-hydromica-montmorillonite clays predominate while in Tsentralna LTZ the clays are hydromica, in places hydromica- montmorillonite in composition.

Most pure clay varieties constitute clayey sequence of Middle Miocene Batysyfonoviy horizon and Yurakivski layers with >0.6 mm fraction content from 6.12 to 11.3%; in Mayachkynska Suite clays content of this fraction increases to 38%.

Chokrakskiy regio-stage

In the studied area, only upper part of Chokrakskiy regio-stage is developed. At the boundary with underlaying sediments the stratigraphic break is observed with erosion signs and formation of red-coloured rocks. Hanging-wall altitudes of Chokrakski sediments vary from -350 m in the north and -320 m in Donuzlaskiy graben in the south-west to -20 m in Novoselivske uplift and +80 m in the uplift cores of Tarkhankutskiy peninsula.

Upper sub-regio-stage

Brykivski layers (N_1br) are developed in the post-Maykopski depressions of Tsentralna LTZ and stratigraphically higher of Tarkhanski sediments in Syvaska LTZ. The stratotypic column is studied in Kerchenskiy peninsula. In Syvaska LTZ these layers are two-folded. In DH 185 (Stroganivka village), located somewhat to the north from the map sheet group, at the depth 254.0-246.5 m in the lower column part the clays occur, from emerald-green at the bottom to bluish-grey at the top. The middle column part is composed of iron-enriched clays, and the upper part, in the depth range 246.5-243.0 m – of light-grey, greenish-grey, re-crystallized limestones. Brykivski layers, with interruption, lie over Yurakivski layers and, normally with erosion, are overlain by sandstone sequence of Karaganskiy regio-stage. In the clays of Brykivski layers

L.A.Digas [7] has determined *Elphidium macellum* (F. et M.), *Nonion ex gr. subgranosus* (E g g .), *Quinqueloculina akneriana* O r b., and in limestones V.G.Kulichenko [7] has found *Spaniodontella intermedia* A n d r u s., *Gibbula pictiformis* A n d r u s. Thickness of the layers varies from 10 to 20 m.

In Tsentralna LTZ the column of Brykivski layers exhibits similar features but is inconsistent in thickness. Most complete column is studied in DH 171 (depth 159.5-143.0 m), where thickness of clays is 12.5 m and limestones – 3.5 m. In clays *Nonion punctatus* (O r b.), *Elphidium macellum* (F.et M.), *Quinqueloculina akneriana media* G e r k e. are determined. In general, thickness of Brykivski layers in Tsentralna LTZ varies from 0 to 20.0 m. Reduced thickness up to complete erosion is typical for uplift cores. By complex of organic remnants and position in the column, Brykivski layers are correlated with upper part of Chokrakskiy regio-stage. In Syvaska LTZ the clays are montmorillonite in composition while in Tsentralna LTZ these rocks are mainly hydromica with minor montmorillonite admixture. From Yurakivski clays the given rocks differ in higher CaO content (7-16%), and in term of grain size – higher 0.6 mm fraction; the latter contains quartz (80-85%), feldspars, iron hydroxide aggregates, calcite grains and mica flakes, accessories include zircon, rutile and apatite.

Karaganskiy regio-stage

Sandstone sequence (N_1p) in the studied map sheet group is thoughout developed. It is mainly composed of alternating sandstones and sands with thin limestone and clay interbeds. The patterns of rock alternation are variable in lateral direction. The Sequence altitudes vary from +150 m in Novoselytske uplift to -150 m in the south of Tsentralna LTZ and -300 m in Syvaska LTZ. The Sequence, with erosion, lies over clays of Chokrakskiy regio-stage or older rocks and is conformably, with gradual transition, overlain by the clays of Ervilievo-Foladovi layers. In the northern direction increasing of both the total thickness and the number and thickness of limestone interbeds. Most typical column in Syvaska LTZ is intersected in DH 182 at depth 317.3-284.8 m. The lower part, 5.3 m thick, is composed of dark-grey and greenish clays with sandy dust at the layering planes. The upper part, 27.0 m thick, is composed of ligth-grey and greenish quartz-feldspar fine-grained sands with thin (0.2 m) interbeds of dolomitized limestones and sandstones.

In the clays V.G.Kulichenko [7] has determined *Spaniodontella pulchella* B a i l y, *Mohrensternia grandis* A n d r u s., Yu.B.Lyulyeva [7] has found ostracoda *Cyprideis littoralis* (B r a d y), and A.A.Digas [7] – foraminifera *Quinqueloculina akneriana* (O r b.), *Q.akneriana rotunda* G e r k e., *Q. ovula* K a r r e r., *Nonion semiinvolute* K r a s h., *Elphidium cf. crispum* (L i n n e .).

In Tsentralna LTZ most trypical column is encountered in DH 161 (depth 167.0-151.0 m). Over there, the lower Sequence part is also composed of 1.5 m thick clays, 0.8 m thick greenish-grey organogenic-detritus limestones with *Spaniodontella sp*. and the lens of grey, greenish-grey quarzt-carbonate fine-grained clayey sands with thin (0.05 m) sandstone interbeds; intersected thickness is 12.3 m. In the sands L.A.Digas [7] has found *Ammonia of. beccarii* (L i n n e .), *Nonion cf. punctatus* (O r b.), *Elphidium cf. listeri* (O r b.), *Quinqueloculina ex gr. ersaconica* (K r). Among molluscs V.G.Kulichenko [7] has determined *Spaniodontella opistodon* A n d r u s . , *Mohrensternia sp.* The upper Sequence part, up to 1.5 m thick, is composed of limestone breccia with clayey cement. The total Sequence thickness in Syvaska LTZ attains 35 m and in Tsentralna LTZ – 15 m. By the complex of organic remnants the Sequence is ascribed to Karaganskiy regio-stage. By mineralogical composition the sands in Syvaska LTZ are mainly quartz, and in the southern direction they become quartz-detritus and quartz-carbonate.

Konkskiy regio-stage
Lower sub-regio-stage

Ervilievo-Foladievi layers (N_1ef) are locally developed in the dimples over Karaganska surface and in the junction zone of Syvaska and Tsentralna LTZ. The typical column of the layers is defined in Kerchenskiy peninsula where in the three-fold column of Konkskiy regio-stage the given layers comprise the lower part.

The layers include greenish-grey, dark-grey to black clays with characteristic complex of molluscs *Ervilia trigonula* S o k., *Barnea pseudoustjurtensis* (B o g.). They unconformably lie over the sandstone sequence of Karaganskiy regio-stage and are unconformably overlain by the sediments of upper sub-regio-stage of Konskskiy regio-stage. Thickness of the layers attains 19 m.

Upper sub-regio-stage

Veselyanski layers (N_1vs) in the studied map shett group are developed throughout. The typical column is defined in Kerchenskiy peninsula where the rocks are positioned at the top of Konkskiy regio-stage and include light-grey, greenish-grey, organogenic-detritus, in places pelitomorphic and dolomitized limestones. In

the area of local uplifts they unconformably lie over Ervilievo-Foladovi layers and everywhere are conformably overlain by Sarmatian sediments. Limestone hanging-wall plunges down in the northern direction from altitudes +60 m in Tsentralna LTZ to -260 m in Syvaska LTZ. Their thickness increases from 2 to 20 m in the same direction. In limestones *Ervilia trigonula* S o k., *Cerastoderma cf. andrussovi* S o k., *Donax sp., Gibbula sp.* are determined.

Limestones are mainly composed of calcite, and dolomitized varieties – of calcite and dolomite. Besides that, quartz (1-20%), feldspar and hydromica-montmorillonite admixtures are determined in limestones. Chemical composition of limestones is fairly variable.

Sarmatian regio-stage
Lower sub-regio-stage

Volynska Suite (N_1*vl*) is developed in Syvaska LTZ and in the northern part of Tsentralna LTZ. It is composed of grey organogenic and detritus, in places organogenic-clastic limestones. It conformably lies over Veselyanski layers and is also conformably overlain by Krasnoperekopska Suite. The Suite hanging-wall gradually plunges down from the south to north from altitudes -200 m to -300 m while its thickness increases from 2 to 13 m. In the studied area organogenic limestones are almost composed of the shells *Ervilia dissita* E i c h w . , and in the areas adjacent from the north I.M.Barg has determined *Donax dentiger* E i c h w . , *Modiola sarmatica* G a t., *Cerastoderma ustjurtense* A n d r u s., *C. praeplicatum* (H i l b.), *Trochus ex gr. marginatus* E i c h w . , *Paphia vitaliana* (O r b.) in addition. By position in the column and organic remnants Volynska Suite does correspond to the lower part of Sarmatian regio-stage.

Lower and Middle sub-regio-stages

Krasnoperekopska Suite (N_1*kp*) is throughout developed in Plain Crimea except Melova and Rodnikovksa structures in Tarkhankutskiy peninsula. The stratotype is defined in Syvaska LTZ, in DH 182 (depth 265.8-219.4 m) nearby Ishun village. It is composed of clayey sediments which provide the regional water-proof. In the most part of map sheet group the Suite lies below erosion basis. The Suite hanging-wall altitudes vary from +80 m at the most elevated sites (Novoselivska field) to -241 m in the north of territory. In the stratotype the rocks include dark-grey thin-layered clays with fine-grained quartz sand and detritus dust at the layering planes.

In the upper column part (depth 219.4-220.0 m) L.A.Digas has described foraminifera *Elphidium reginum* (O r b.), *Nonion granosus* (O r b.), *Quinqueloculina consobrina* O r b*., Flintina cf. tutkowskii* B o g d*., Articulina cf sarmatica* K a r r e r., *Spirolina sp., Porosononion subgranosus* (E g g e r*),P. martkobi* (B o g d*.),* Yu.B.Lyulyeva [7] has determined radiolaria *(Spongiomma sp.)* and ostracoda *(Trachyleberis sp.).* From the lower part V.G.Kulichenko [7] has determined molluscs *Cerastoderma ex gr. vindobonense (*P a r t s c h*), Ervilia dissita* E i c h w *.,* and, besides that, L.A.Digas [7] has determined foraminifera *Quinqueloculina reussi* (B o g d *.), Articulina problema* B o g d*., A. voloshinovae* B o g d.

The Suite unconformably lies over Middle Miocene sediments and is conformably overlain or facially replaced at the top by clayey-carbonate sediments of Besarabska Suite. Maximum thickness of the Suite attains 56 m and in the northern and southern directions it decreases to 30 m. In Tsentralna LTZ, besides column reduction, content of sandy-aleuritic fraction increases. Most typical column is studied in DH 171 (depth 126.0-110.0 m). Below Middle Sarmatian limestones the dark-grey layered clays are intersected with interbeds of dark-grey aleurites and fine-grained quartz-mica sand dust at the layering planes. Among organic remnants, L.A.Digas [7] has determined *Elphidium macellum* (F. et M), *Nonion granosus* (O r b .), *Porosononion ex gr. martkobi* B o g d. Thickness of the Suite varies from 0.2 m in the central part of Tarkhankutskiy peninsula to 35-40 m in the eastern part of the studied area.

The clays of Krasnoperekopska Suite are pretty persistent in granulometric and chemical composition. The clay fraction includes montmorillonite and hydromica, the coarse fraction – quartz, feldspars, calcite, mica flakes. The Suite age is defined after rich complex of organic remnants suggesting for Early Sarmatian age at the uplift cores. In depressions of Tsentralna LTZ and in Syvaska LTZ the Suite hanging-wall becomes younger and involves lower part of Middle Sarmatian.

Middle sub-regio-stage

Besarabska Suite (N_1*bs*) in the studied map sheet group is throughout developed. At the surface it is exposed in the western part of territory at uplift cores in Tarkhankutskiy peninsula, and over remaining territory it is intersected by numerous drill-holes. The Suite hanging-wall plunges down to -200 m and -60 m respectively.

The Suite is composed of limestones with clay, sandstone and sand interbeds. Limestones are organogenic, organogenic-detritus, sandy, dolomitized, oolitic and nubecular.

The most complete columns are encountered in Karkinitska Bay. In Syvaska LTZ, especially in its northern part, the columns contain clay interbeds, and on the slopes of Karkinitskiy trough – sand lenses.

Most typical column is studied in DH 182 (depth 219.4-160.6 m). Over there, above the clays of Krasnoperekopska Suite, from bottom to top, brownish-grey, nubecular-shelly, detritus-nubecular, re-crystallized limestones are observed with 0.1-0.3 m thick interbeds of dark-grey calcareous horizontally-layered clays. In Limestones V.G.Kulichenko [7] has determined *Mactra fabreana* O r b*., M. vitaliana* E i c h w*., Cerastoderma sp., Gibbula sp.* In clays L.A.Digas has found *Elphidium rugosum* (O r b.), *E. crispum* (L in n e), *E. ex. gr. fichtellianum* (O r b*.). Flintina tutkowskii* B o g d., *Articulina cf. lucoviensis* V e n g l*., A.cf. sarvatica* (K a r r e r), *Nubecularia novorossica nodulus* K a r r e r. et S i n-Z o m*., Nubecularia sp*. Thickness of the batch is 13 m.

Higher in the column lie dark-grey and greenish-grey clays with up to 0.1 m thick detritus limestone interbeds. Besides aforementioned molluscs, *Arteocina lajonkairena* (B a s t.) and foraminifera *Nonion granosus* (O r b.), *Porosononion cf subgranosus* E g g e r*., Quinqueloculina consobrina* O r b*., Triloculina cf. ukrainica sarmatica* D i d k*., Articulina cf. problema* B o g d. are also found. Thickness of the unit is up to 3.2 m. The Suite upper column part is composed of organogenic and detritus, nubecular-detritus, pelitomorphic, dolomitized limestones. At the bottom V.G.Kulichenko [7] has determined molluscs *Cerastoderma ex. gr. uiratamense* (K o l e s .), *Mactra sp., Paphia sp. Gibbula sp*. In the middle part of layers the lens is intersected composed of up to 2.2 m thick brownish, calcareous, diverse-grained sands. Thickness of the unit attains 42.6 m, and total thickness is 58.8 m. The maximum thickness of the Suite in Syvaska LTZ is intersected in DH 176 and is 94 m.

In Tarkhankutskiy peninsula, in the cores of Melova and Rodnikovska structures, Besarabska Suite is eroded, and in the structure limbs it is composed of organogenic and nubecular limestones with dipping azimuth 135º, angle 2-5º, and 335º, angle 3-5º.

In Tsentralna LTZ the most complete Suite column is intersected in DH 174 (Shtormove village) at the depth 148.2-57.2 m. Over there, the Suite is composed of cream and light-grey, shelly-detritus, organogenic-detritus, pelitomorphic and clayey limestones. At the bottom and top the batch is observed consisting of alternating clays and sandy, clayey limestones, 19-20 m thick. In limestones V.G.Kulichenko [7] has determined *Gibbula picta* (E i c h w.), *Paphia sp., Modiolus sp., Mactra vitaliana* (E i c h w.), *M. fabreana* O r b*., Cerastoderma fittoni* (O r b.), *C. ingratum (*K o l e s*.), Solen subfragilis* E i c h w. In DH 169 and 179 from the upper column part L.A.Digas [7] has determined *Elphidium crispum* (L i n n e), *E. macellum* (F.e t M.), *E. reginum* (O r b.), *Porosononion subgranosus umboelata* G e r k e*., P. subgranosus* E g g e r*, Nonion granosus* (O r b.), *Quinqueloculina consobrina* O r b*., Articulina sp.* Thickness of Besarabska Suite varies in the wide range from 0-6 m in the structure cores of Tarkhankutskiy peninsula to 90 m in the south of the territory. By the complex of organic remnants Besarabska Suite encompasses same-named sub-stage of Sarmatian regio-stage.

Upper sub-regio-stage

Khersonska Suite (N_1hr) in the studied map sheet group is almost throughout developed except the cores of positive structues in Tarkhankutskiy peninsula. In Syvaska LTZ the Suite lies below erosion basis with hanging-wall altitudes from -34 m in the south to -120 m in the north. It is composed of limestones, which conformably lie over Besarabska Suite sediments, and is overlain by Meotic Bagerivska Suite.

Most typical column is intersected in DH 182 at the depth 160.4-107.0 m. The lower column part is composed of grey and greenish-grey, marleous and pelitomorphic limestones with single fossilized cores of foraminifera *Elphidium macellum* (F. et M.) [7]. The upper column part is composed of light-grey to dark-grey shelly, detritus-shelly limestones with up to 0.2 m thick interbeds of fine-oolitic and dark-grey clays. V.G.Kulichenko [7] has determined molluscs *Mactra caspia* E i c h w . , and L.A.Digas has mentioned numerous findings of foraminifera, specifically, *Spirolina cf. ustjurtensis* B o g d*, Sp. cf. krokosii* B o g d*., Miliolina ungeriana* (O r b .), *Elphidium macellum* (F. e t M.), *Quinqueloculina sp.* and ostracoda *Cypriideis littoralis* (B r .), *Xestoleberis sp.* Thickness of Khersonska Suite in DH 182 is 53.6 m and its maximum thickness in Syvaska LTZ attains 65 m. In the north-western direction, outside the studied area, carbonate column of the Suite lower half is facially replaced by sandstones and sands.

In Tsentralna LTZ the Suite is exposed at the surface in Sarybaske, Novoselivske, Glibovske and other uplifts, at the coast of Tarkhankutskiy peninsula and in the river and gully valleys. From the north to south thickness of the Suite decreases and in the column frequently clay, sand, sandstone and marl lenses up to 8 m thick lenses occur. The sudden thickness change from 0.1 m in the structure cores to 47.3 m (DH 177) in their limbs on Tarkhankutskiy peninsula, as well as occurrence of red-colour clay interbeds, resembling weathering crust, in the columns (DH 247, 294, 308 and others) suggest for varibale environments in sedimentation basin

caused by latitudinal dislocations. Among organic remnants, besides those noted above, in Tsentralna LTZ V.M.Semenenko [7] has mentioned the findings of *Mactra bulgarica* T o u l a, and L.A.Digas [7] – *Ammonia cf. beccarii* (L.). The complex of described organic remnants and position in the column indicate that Khersonska Suite encompasses upper sub-stage of Sarmatian regio-stage.

Meotic regio-stage
Lower sub-regio-stage

Bagerivska Suite (N_1*bg*) is throughout developed. From the north to south the hanging-wall altitudes vary from -100 m to -50 m. It is composed of grey, detritus-oolitic, detritus limestones, in the southern limb of Karkinitskiy trough – with grey calcareous clay interbeds. The typical column in Syvaska LTZ is intersected in DH 182 where at the bottom (depth 107.0-82.2 m) light-grey, brownish-grey to dark-grey, detritus, sandy, in places oolitic-detritus limestones occur with *Ervilia minuta* S i n z*., Pirenella disjuncta disjunctoides* (S i n z.).

The middle column part (depth 82.1-80.4 m) is composed of brownish-grey to dark-grey, calcareous, dense clays with abundant detritus. V.G.Kulichenko [7] and L.A.Digas [7] has mentioned chara algae, gastropoda and re-deposited foraminifera *Pirenella disjuncta disjunctoides* (S i n z), *Ammonia cf. beccarii* (L.), *Porosononion martkobi* (B o g d).

The column is capped (depth 80.4-68.3 m) with grey to dark-grey, detritus-oolitic, re-crystallized limestones with *Dosinia maeotica* A n d r u s., *Pirenella disjuncta disjunctoides* (S i n z), *Cerastoderma sp.,* determined by V.G.Kulichenko [7].

Thickness of Bagerivska Suite in Syvaska LTZ attains 42 m. In Tsentralna LTZ the rocks are exposed at pre-Quaternary surface in the limbs of positive structures or are disclosed by the river erosion cut beneath the younger sediments. Transition from Syvaska to Tsentralna LTZ is expressed in the sudden Suite thickness drop up to its complete erosion in Donuzlavska structure. The Suite dipping in the northern and north-western limbs of most structures is from azimuth 0-30º, angle 36º, to azimuth 330º, angle 3-5º, and in the southern and south-eastern limbs – from azimuth 100-120º, angle 5-8º, to azimuth 160-190º, angle 4-10º. Most typical Suite column in Tsentralna LTZ is intersected by DH 172 (nearby Kamenolomnya village) located to the south from the given map sheet group. Over there, below fauna-supported limestones of Akmanayska Suite lie yellowish-grey, grey, shelly-detritus and marleous limestones with calcareous clay interbeds. According to V.M.Semenenko [7], in the upper column part *Musculus minor* (H u d r u s), *Valvata aff. piscinalus* (M i i l l.) are found, and in the lower part – *Loripes pseudoniveus* (A n d r u s.), *Cerastoderma arcella mithridatis* (A n d r u s.), *Pirenella disjuncta disjunctoides* (S i n z.). The Suite conformably lies over Mactra limestones of Khersonska Suite and is also conformably overlain by limestones of Akmanayska Suite. Thickness of the Suite in DH 172 is 7.1 m while the total thickness varies from 0.3 to 30 m. By the complex of organic remnants noted above, the Suite is synchronous to the lower sub-stage of Meotic regio-stage.

Upper sub-regio-stage

Akmanayska Suite (N_1*ak*) in the studied map sheet group is thoughtout developed. In Syvaska LTZ its hanging-wall altitudes from the south to north vary from -20 to -70 m. The typical column is intersected in DH 181. In the depth range 55.3-47.0 the Suite is composed of clayey, light-grey limestones with interbeds of shelly-detritus, re-crystallized and breccia-like varieties with *Congeria panticapaea* A n d r u s. In the southern and south-western directions the interbeds of coarse-terrigenous rocks appear in the column. Total thickness of the Suite attains 13 m.

In Tsentralna LTZ Akmanayska Suite rocks are exposed at pre-Quaternary surface or are disclosed by river erosion on the slopes of positive structures. The typical column is intersected in DH 165 in the depth range 7.5-0.1 m where the Suite is composed of oolitic and oolitic-detritus limestones with brownish clay lenses with *Congeria panticapaea* A n d r u s, determined by V.M.Semenenko [7]. The maximum intersected thickness is 11 m. The Suite regressively lies over Bagerivska Suite or, with tectonic contact, over the older sediments. By position in the column and organic remnants Bagerivska Suite is synchronous to the upper sub-stage of Meotic regio-stage.

Lower and Upper sub-regio-stages

Bagerivska and Akmanayska suites undivided (N_1*bg-ak*) are mainly developed in the west of studied map sheet group, in Tarkhankutskiy peninsula. It is composed of limestones with clay interbeds and organic remnants of Meotic regio-stage, with numerous erosions and very variable thickness from 0.2 to 10 m.

Meotic and Pontychniy regio-stages

Kazankivska sequence (N_1kz) is locally developed in Tsentralna LTZ. The basic column of Kazankivska sequence is located outside the studied area, in Alminska depression. Over there, the Sequence includes pebble-stones, gravel-stones, with interbeds of sandstones, sands, clays, in places organogenic limestones. The clastic material from 0.5 to 10 cm in size is composed of limestones, sandstones, igneous rocks, flints. The filler is aleuritic, sandy-clayey, brownish-yellow, greenish-yellow. In the studied area the Sequence is composed of red-coloured clayey-sandy facies which facially replace by strike the upper part of Akmanayska Suite and Evpatoriyski layers from the lower part of Pontychniy regio-stage. Thickness of the Sequence is up to 6 m. By position in the column and age it is ascribed to Late Meotis – Pont of Early Miocene.

Pontychniy regio-stage
Novorosiyskiy horizon

Evpatoriyski layers (N_1ev) in the studied map sheet group are throughout developed. In Syvaska LTZ they are composed of up to 4-5 m thick grey-brown and light-grey oolitic and detritus-oolitic limestones where V.M.Semenenko in DH 182 has determined *Congeria novorossica* S i n z*, Prosodacna littoralis* E i c h w. [7]. In Tsentralna LTZ Evpatoriyski layers are exposed at the surface where they constitute the negative forms of Upper Miocene surface or are disclosed by the river and gully erosion in the limbs of positive structures. Over there, the layers are composed of oolitic limestones, while in the limbs of positive structures the interbeds of red-brown clays and somewhere sandstones appear in the columns. Maximum thickness of the layers attains 6 m.

In limestones bivalve molluscs *Dreissensia rostriformis* D e s h*, Dr. simplex* B o r b*., Congeria novorossica* S i n z*., Prosodacna littoralis* E i c h w. are determined. The layers conformably, or with slight erosion, do lie over Akmanayska Suite and are conformably overlain by Odeski layers of Novorosiyskiy horizon of Pontychniy regio-stage. By the complex of above organic remnants the layers are synchronous to the lower part of Novorosiyskiy horizon.

Odeski layers (N_1od) are throughout developed: in Tsentralna LTZ they constitute significant portions of pre-Quaternary surface, and in Syvaska LTZ they are overlain by Pliocene sediments. The layers are composed of shelly limestones, but in the southern direction, towards Alminska depression, they are facially replaced by sub-aerial clays.

In the archs of positive structures Odeski layers are commonly eroded. In Syvaska LTZ they are from 6.0 to 7.4 m thick and are composed of shelly limestones, grey and brownish-grey shell-detritus re-crystallized limestones with *Prosodacna cf. littoralis* (E i c h w), *Monodacna novorossica* S i n z [7]. In Tsentralna LTZ most complete column is intersected in DH 170 at the depth 16.5-5.1 m. The lower column part (depth 16.5-14.5 m) is composed of dark-grey, organogenic, re-crystallized limestones, with *Prosodacna sp.,Monodacna sp.* cores, and yellow-brown, detritus, partly re-crystallized limestones; the middle column part (depth 14.5-6.2 m) is composed oflight-yellow shelly limestones with interbeds of detritus-oolitic limestones and leaching hollows; the upper column part (depth 6.2-5.1 m) is composed of detritus-shelly light-yellow cavernous limestones with *Prosodacnalittoralis* E i c h w., *Monodacna pseudocatillus* B a r b .

Odeski layers conformably lie over Evpatoriyski layers and are unconformably overlain by the sub-aqueous rocks of Chatyrlytska sequence or by sub-aerial soils of Bagrationivska sequence. By position in the column and according to the complex of organic remnants Odeski layers are synchronous to the lower part of Novorosiyskiy horizon of Pontychniy regio-stage.

Pliocene

Pliocene sediments are widely developed in the northern part of the area. In Syvaska LTZ they include open sea sediments as well as coastal and lagoon rock types of Kimmerian and Akchagylskiy regio-stages.

In Tsentralna LTZ Pliocene sediments are locally developed. They include terrigenous continental rocks of Middle Kimmerian – Akchagyl or shallow-water sediments of Lower Kimmerian Chatyrlytska sequence.

Lower Pliocene
Kimmerian regio-stage
Lower sub-regio-stage

Chatyrlytska sequence ($N_2čt$) is only developed in Tsentralna LTZ where it is preserved in pre-Quaternary surface in the “caps” above Upper Miocene Odeski limestones. In the lower part it is composed of

grey-pink (to red) re-crystallized pelitomorphic limestones with evidences for the desert "tan" – so called "stone cap", and in the upper part – of alternating limestones, marls and chocolate clays. At the contact with Odeski limestones the interbed (0.1-0.2 m thick) of dark-grey to black, fine-detritus-oolitic, re-crystallized, manganese-enriched limestone is often observed. Most complete columns of the Sequence are preserved in the north-eastern part of the area, in the right bank of Chatyrlyk river. Maximum thickness of the Sequence attains 25 m over there. It is unconformably, with stratigraphic interruption, lies over Odeski layers, and with erosion is overlain by Middle Kimmerian Bagrationivska sequence. The Sequence is poorly supported by organic remnants of which *Dreissensia angusta* R o u s s*, Dr. rostriformis* D e s h*., Didacna sp.* are determined [7]. By the mentioned complex of organic remnants the Sequence is correlated with Lower Kimmerian Azovskiy horizon.

Middle sub-regio-stage

Bagrationivska sequence (N_2*br*) is developed in Tsentralna LTZ where it constitutes some residual fragments of pre-Quaternary surface. By the dipping conditions and composition the Sequence in genetic respect is similar to the lateritic weathering crust. It is composed of cherry-red, ocher, fine-disperse, ductile clays, often gypsumized, in places calcareous. The basic column is defined in DH 273 (depth 21.6-6.0 m) in the central part of Tarkhankutskiy peninsula. The Sequence substratum is normally comprised of the karsted, corroded limestones in the zones of tectonic breaks. At the bottom of clays substratum fragments are observed, and further up in the column – numerous slicing surfaces under the angle 45º. From the typical laterites these clays differ in high (50%) content of SiO_2, while the fraction >0.01 mm includes quartz (60-70%), gypsum (10-20%), calcite (10-15%), feldspar, ilmenite, garnet and mica grains. The clayey fraction is composed of montmorillonite with hydromica and kaolinite admixtures. Maximum thickness of the Sequence attains 20 m. It lies, with erosion, over Chatyrlytska sequence, or, with stratigraphic interruption, over Upper Miocene sediments, and is unconformably overlain by Quaternary sediments. Of organic remnants, single fossilized foraminifera *Quinqueloculina sp.* cores are observed.

In stratigraphic respect, Bagrationivska sequence does correspond to Sevastopolskiy and Aydarskiy climatoliths of the continental range in stratigraphic scheme of Pliocene sediments. In Syvaska LTZ and in the eastern direction the Sequence is replaced by marine sediments of Middle Kimmerian Kamyshburunska Suite.

Kamyshburunska Suite (N_2*kb*) is developed in Syvaska LTZ where it constitutes lower part of Pliocene column. It is not exposed at the pre-Quaternary surface. From the south ot north the hanging-wall altitudes vary from -35 m to -40 m. It is composed of greenish-grey, dark-grey, calcareous clays with sandstone, marl and limestone interbeds. The Suite stratotype is studied in Kerchenskiy peninsula. In the studied map sheet group its representative columns are intersected in DH 180, 181, 320. In the southern direction the Suite is facially replaced by sub-aerial sediments of Bagrationivska sequence. In this respect, the column is characteristic in DH 341 (depth 24.2-17.7 m) where in the sequence of greenish-grey and dark-green calcareous clays with iron-enrichment spots the red-brown clays are observed with evidences for embrionic soils. The Sequence is poor in organic remnants, the single findings of bivalve molluscs *Dreissensa theodori* A n d r u s*., Dr. polymorpha* (P a l l.) and ostracoda *Cyprideis littoralis* (B r a d y), *C. heterostigma* (R e u s s) are known.

Granulometric and chemical composition of the clays is pretty consistent. The clay fraction (47%) is composed of montmorillonite, hydromica and kaolinite in the ratio 3:2:1. The Suite, with stratigraphic interruption, lies over the sediments of Pontychniy regio-stage, and is conformably overlain by Upper Kimmerian Pantykapeyska Suite. Maximum thickness of the Suite attains 16 m. By the complex of data and position in the column the Suite is correlated with the same-named horizon of the middle sub-stage of Kimmerian regio-stage.

Upper sub-regio-stage

Pantykapeyska Suite (N_2*pn*) is locally developed in Syvaska LTZ. It is composed of light-grey, greenish, non-calcareous clays with quartz sand and sandstone interbeds. From the south to north the Suite hanging-wall plunges down from altitudes -14 m to -21 m. The stratotype is defined in Kerchenskiy peninsula. In Syvaska LTZ most complete columns are studied to the north from the map sheet group in DH 375 (depth 83.0-70.0 m). Over there, the Suite at the bottom is composed of light-grey clays, and at the top – of grey-brownish with greenish shade, sandy clays with lenslets of light-grey fine-grained quartz sands. In the same sediments in DH 12-p (depth 76.0-70.8 m) G.V.Pasichniy has determined *Dreissensia theodori* A n d r u s*., Dr. theodori kubanica* K r e s t*., Didacna crassatelata* (D e s h), *Prosodacna macrodon* D e s h [34]. Granulometric and chemical composition of the Suite rocks is pretty consistent. The clay fraction (33-47%) mainly consists of montmorillonite and hydromica. Quartz sands contain feldspar admixture and somewhere ilmenite, epidote, rutile, leucoxene, zircon and other grains. The Suite conformably lies over Kamyshburunska Suite and, with

erosion, over Bagrationivska sequence, and is gradually overlain by marine sediments of Akchagylskiy regio-stage. At the border with Tsentralna LTZ Pantykapeyska Suite is facially replaced by the continental rocks of the lower part of Nogayska Suite. By position in the column and leading fauna findings the Suite is synchronous to Upper Kimmerian.

Lower and Upper Pliocene
Kimmerian regio-stage (upper sub-stage) – Akchagylskiy regio-stage

Nogayska Suite (N_2*ng*) is mainly developed in the eastern part of Plain Crimea. In the studied map sheet group it is encountered at pre-Quaternary surface in the local "caps' over Odeski layers and the border of Syvaska and Tsentralna LTZs. It is composed of continental rocks – brown clays and aleurites. In ther stratotype, defined outside the map sheet group, the Suite is divided in two sub-suites and encompasses five Pliocene climatoliths. In the studied area the Suite is mapped as the single body. In the northern direction it is facially replaced by Upper Kimmerian – Akchagylian marine sediments. It conformably lies over Odeski layers and is unconformably overlain by Quaternary sediments. The maximum thickness attains 8 m. The age of Suite formation is set by its position in the column and lateral relationships with synchronous fauna-supported sediments.

Upper Pliocene
Akchagylskiy regio-stage

Kuyalnytski layers (N_2*kl*) are widely developed in Syvaska LTZ where they constitute pre-Quaternary surface over significant areas of Northern Prychornomorya and Karkinitskiy trough. The layers are not exposed by the modern erosion basis. From the south to north the hanging-wall altitudes decrease from -7.0 to -27.0 m. Most typical column is intersected in DH 182 at the depth 35.2-17.3 m, where above Upper Kimmerian sediments of Pantykapeyska Suite lies greenish-grey, brownish-grey, sandy, calcareous clay (depth 35.2-29.5 m); the middle column part (depth 29.5-19.5 m) is composed of brownish and grey, quartz, fine-grained, clayey sand, and the upper part (depth 19.5-17.3 m) is composed of greenish-grey, spotty, calcareous clays.

Thickness of the layers is 17.9 m and they are unconformably overlain by Eo-Pleistocene sediments. In the eastern direction the upper part of Kuyalnytski layers is partly facially replaced by wax-like clays of Tyup-Dzhankoyski layers while thickness of sands increases to 20-22 m. The layers are poor in organic remnants. In DH 381, located to the north from the studied area, at the depth 61.0-61.1 m V.M.Semenenko has determined *Limnocardium ex gr. limanicum* K r e s t . , *Valvata naticina* M e n k e., and in DH 13-p [34] V.V.Synyogub from the depth run 27.0-23.6 m has determined ostracoda *Lerpetocyprella gigantica* S u g b., *Cyprideis ex,. gr. littoralis* B r a d y, and in the depth run 44.0-36.0 – foraminifera *Streblus beccarii* (L.).

Kuyalnytski layers conformably lie over Upper Kimmerian sediments and with interruption are overlain by the odd-aged Quaternary sediments. By position in the column and single findings of organic remnants Kuyalnytski layers apparently are synchronous to the sediments of Kuyalnytskiy regio-stage distinguished by I.F.Syntsov [7] nearby Odesa city and do correspond to Akchagylian.

By granulometric composition the clays are consistent enough: the fraction <0.001 mm (40-48%) is composed of montmorillonite, hydromica and kaolinite in ratio 3:2:1, and the fraction >0.6 mm does not exceed 9% of the bulk rock mass. The sands are almost mono-quartz (quartz content 84-86%) with feldspar, ilmenite, zircon, rutile admixture.

Neogene and Quaternary systems

Akchagylskiy regio-stage – Lower Eo-Pleistocene undivided

Tyup-Dzhankoyski layers (N_2-E_1*td*) are developed widely enough in the eastern part of Plain Crimea and this is the area where their basic column is defined. In the studied map sheet group these layers are locally developed and are intersected by DH 318 in the east with the facies of residual lagoon or lakes. They are composed of olive-brown, spotty, wax-like clays. Northward they are facially replaced by the upper (clayey) part of Kuyalnytski layers and sub-aqueous Eo-Pleistocene rocks. In the stratotype area *Coretus corneus* (L.)., *Planorbis sp., Unio sp*. are determined [7].

The layers unconformably lie over Kuyalnytski layers and are unconformably overlain by the odd-aged Quaternary sediments. Thickness of the layers attains 8-10 m. By position in the column Tyup-Dzhankoyski layers are synchronous with Beregivskiy and Berezanskiy climatoliths.

Quaternary System

In the studied msp sheet group Quaternary sediments are widely developed. In the northern part of map sheet L-36-XXII are throughout developed sub-aqueous and sub-aerial facies which exhibit most complete columns and thickness up to 30 m. To the south, in the area of neo-tectonic uplifts, Quaternary sediments mainly inlcude up to 15 m thick sub-aerial facies and are completely lacking somewhere. By geological structure of Quaternary cover, its thickness, column completeness and genetic type sets, Quaternary sediments are grouped in two structure-geomorphologic areas (SGA): Pivdennosyvaskiy and Tarkhankut-Novoselivskiy. Pivdennosyvaskiy SGA encompasses the northern half of map sheet L-36-XXII, and Tarkhankut-Novoselivskiy SGA – the land in map sheets L-36-XXI, L-36-XXVII and southern half of map sheet L-36-XXII. The boundary between the two is extended in latitudinal direction and follows the line Kamyaniy Cape – Semenivka village – Krestyanivka village.

Eo-Pleistocene

Eo-Pleistocene sediments are widely developed in Pivdennosyvaskiy SGA where include alluvial, alluvial-proluvial sediments of Pra-Salgyr (modern valley of Chatyrlyk river) and lake sediments of Upper Eo-Pleistocene Prysyvaska sequence. In Tarkhankut-Novoselivskiy SGA these sediments are only preserved in its northern and south-eastern parts where they include sub-aerial loess-like loams and soils.

Upper Eo-Pleistocene

Kryzhanivskiy climatolith. Eluvial-deluvial sediments /edE$_{II}$kr/. The sediments are preserved in the limbs of neo-tectonic uplifts where they are exposed at the surface in the south-eastern part of Tarkhankut-Novoselivskiy SGA nearby Izvestkove village. They include 2.5-3.0 m thick orange-red paleo-soils with limestone fragments. The rocks are overlain by Lower Neo-Pleistocene deluvial-proluvial sediments.

Prysyvaska sequence. Lake sediments /lE$_{II}$ps/. In the map sheet area these sediments are only found in Pivdennosyvaskiy SGA where their complete thickness is intersected in DH 317 (depth 24.5-19.3 m). The rocks conformably lie over sub-aqueous Eo-Pleistocene sediments and are overlain by Lower Neo-Pleistocene sub-aerial sediments. The intersected thickness is 5.2 m. The Sequence age in the map sheet L-36-XXII is defined by correlation in the southern direction with Illichivskiy climatolith and does correspond to the upper part of Upper Eo-Pleistocene.

Berezanskiy, Kryzhanivskiy and Illichivskiy climatoliths undivided. Alluvial, alluvial-proluvial sediments of tenth-ninth buried terraces /a,ap^{10+9}Ebr-il/. The rocks are developed in Pivdennosyvaskiy SGA where they fill up the bottom of Salgyr river pra-valley at the site of inherited modern Chatyrlyk river valley. Terrace is embeded into Kuyalnytski layers and is from 10 km (in the east) to 20 km (in the west) wide. Most complete column is intersected in DH 317 (depth 34.9-24.5 m) and includes 7.0 m thick light-brown polymictic fine-grained sands with 3.4 m thick bed of grey-green, yellowish-green, dense clays.

Terrace sediments are overlain by Neo-Pleistocene sub-aerial clays. At the terrace margins thickness of sands decreases. Maximum thickness of terrace sediments is 10.4 m.

Berezanskiy, Kryzhanivskiy and Illichivskiy climatoliths combined. Aeolian-deluvial and eluvial-deluvial sediments /vd,edEbr+il/. Climatolith sediments are locally developed in Tarkhankut-Novoselivskiy SGA. With interruption they lie over Miocene-Pliocene sediments and are unconformably overlain by Neo-Pleistocene sub-aerial rocks. Most complete column is studied in DH 346 (depth 28.0-23.5 m) where it includes: Berezansko-Kryzhanivski pink-pale, aleuritic, fine-lumpy loams with inclusions of fine iron-manganese concretions (thickness – 2.3 m) and Illichivski light-brown, yellowish, loess-like loams with disseminated manganese hydroxides (thickness – 2.2 m). Thickness of the complex of climatoliths attains 4.5 m.

Neo-Pleistocene

Neo-Pleistocene sediments in the studied map sheet group are widespread enough. In Pivdennosyvaskiy SGA they throughout include sub-aqueous and sub-aerial facies. In Tarkhankut-Novoselivskiy SGA Neo-Pleistocene is composed of sub-aerial sediments and in Chatyrlyk river valley only alluvial-proluvial sediments of the upper branch appear. They are preserved at the residual Pliocene surfaces and at the sites subsided on the neo-tectonic stage.

Lower branch
Shyrokynskiy and Pryazovskiy climatoliths undivided

Alluvial, alluvial-proluvial sediments of the ninth and eighth terraces /a,ap^{9+8}P$_1$sh-pr/. Climatolith sediments are developed in Pivdennosyvaskiy SGA where they constitute the buried terrace of Pra-Salgyr. They conformably lie over Eo-Pleistocene terrace and are overlain by Middle Quaternary sediments. Terrace is locally developed in the pra-valley and is intersected by some drill-holes. In DH 318 (depth 21.1-20.2 m) the rocks include light-yellow quartz-feldspar fine-grained sands with up to 20% clay admixture. Thickness of terrace sediments is 2.0 m.

Shyrokynskiy and Pryazovskiy climatoliths combined. Eluvial-deluvial and aeolian-deluvial sediments /ed,vdP$_1$sh+pr/. Climatolith sediments are locally developed in Tarkhankut-Novoselivskiy SGA where they are preserved in transitional zone to Pivdennosyvaskiy SGA or constitute the lower part of Neo-Pleistocene sub-aerial cover at the most elevated sites of positive structures in the map sheet L-36-XXI. The rocks include brownish-red and dark-brown paleo-soil clays with interbeds of loess-like loams and aleurites. At the surface this complex is not exposed. It conformably lies over Eo-Pleistocene sub-aerial sediments or the older rocks and is conformably overlain by the younger rocks. Most complete columns are intersected in the northern part of Tarkhankut-Novoselivskiy SGA (DH 357) where sediment thickness attains 10 m. To the south thickness of sediments decreases to 6.5 m (DH 297) and most part of thickness is attributed to Shyrokynski paleo-soils. Pryazovskiy climatolith, composed of loess-like light-pale loams or yellow-brown aleurites and clays, is of subordinate value.

Shyrokynskiy and Pryazovskiy climatoliths undivided. Deluvial-proluvial sediments /dpP$_1$sh-pr/. Climatolith sediments are developed in Pivdennosyvaskiy SGA where they constitute the slope facies inthe southern coast of Karkinitska Bay. The rocks are not disclosed by the modern erosion basis. In DH 175 (depth 15.1-13.5 m) they include brown clays with inclusions of Pontychniy regio-stage limestone fragmnets, and in DH 346 (depth 23.5-16.0 m) – dark-brown aleurites at the top, and light-brown, yellowish-orange loams with manganese hydroxides at the bottom. Maximum thickness of sediments is 7.5 m. They unconformably lie over Eo-Pleistocene sub-aqueous facies and without interruption are overlain by sub-aerial rocks of the upper part of Lower Neo-Pleistocene.

In Tarkhankut-Novoselivskiy SGA deluvial-proluvial sediments comprise the blanket-like and separated bodies on the uplift slopes. They are most widespread in Sary-Bashske, Novoselivske, Oktyabrske and Melove uplifts (Fig. 2.6). Over there, the rocks include reddish-brown and brown clays, in places loams with limestone gruss and fragments (up to 30%). At the surface they are exposed on the northern slope of Chatyrlyk river valley where they unconformably lie over Miocene limestones and are overlain in the upper slope part by Upper Neo-Pleistocene sub-aerial, and in the lower part – sub-aqueous sediments. Thickness of sediments in DH 132 attains 2.2 m. In the western direction this complex of sediments is pinched out or is overlain by the younger sediments of various genesis and age.

Shyrokynskiy, Pryazovskiy, Martonoskiy and Sulskiy climatoliths combined. Aeolian-deluvial and eluvial-deluvial sediments /vd,edP$_1$sh+sl/. These sediments are developed in Pivdennosyvaskiy SGA (except Pra-Salgyr valley) and in the north part of Tarkhankut-Novoselivskiy SGA.

In Pivdennosyvaskiy SGA most complete columns are confined to the slopes of Karkinitskiy trough and from the east to west their thickness decreases because of lower climatoliths pinching out. In Pra-Salhyr valley (modern Chatyrlyk river valley) sub-aerial facies are replaced by alluvial sediments of the ninth and eighth undivided buried terraces. Most complete column is studied in DH 366 (nearby Vogni village) where below paleo-soils of Middle Neo-Pleistocene Zavadivskiy climatolith the following sediments occur downward:

8.8-11.0 m – Sulskiy climatolith. Pale-brown and yellowish-brown ductile clay with manganese hydroxide pods.

11.0-12.1 m – Martonoskiy climatolith. Brown-red dense clay with manganese hydroxide pods and fine carbonate concretions.

12.1-15.7 m – Pryazovskiy and Shyrokynskiy climatoliths. Light-brown, pink clay, often manganese-enriched, with up to 10% admixture of fine limestone gravel fragments.

Below the Upper Miocene limestones occur. In the eastern direction (DH 335) the column of the lower (Shyrokynskiy) horizon is upgraded with brown clay with pink shade which conformably lies over Eo-Pleistocene sediments. Thickness of the complex of climatoliths attains 5-7 m.

In Tarkhankut-Novoselivskiy SGA the sediments under consideration are preserved at watersheds, somewhere on the slope sites of Early Neo-Peistocene relief. At the surface these sediments are not exposed. The

column is variable in thickness and set of climatoliths and exhibits more coarse-terrigenous rock composition, for example, in DH 346 (depth 16.0-25.7 m):

16.0-23.5 m – Pryazovskiy climatolith. Brown, brownish-pink aleurite with carbonate films and manganese hydroxide pods.

23.5-25.7 m – Shyrokynskiy clitamolith. Light-brown with yellowish-pink shade aleuritic loam, at the bottom replaced by clay with manganese hydroxides.

Higher in the column aleurites of Pryazovskiy horizon are changed by Eo-Pleistocene deluvial-proluvial sediments. Thickness of sediments varies from 0.1 to 10 m.

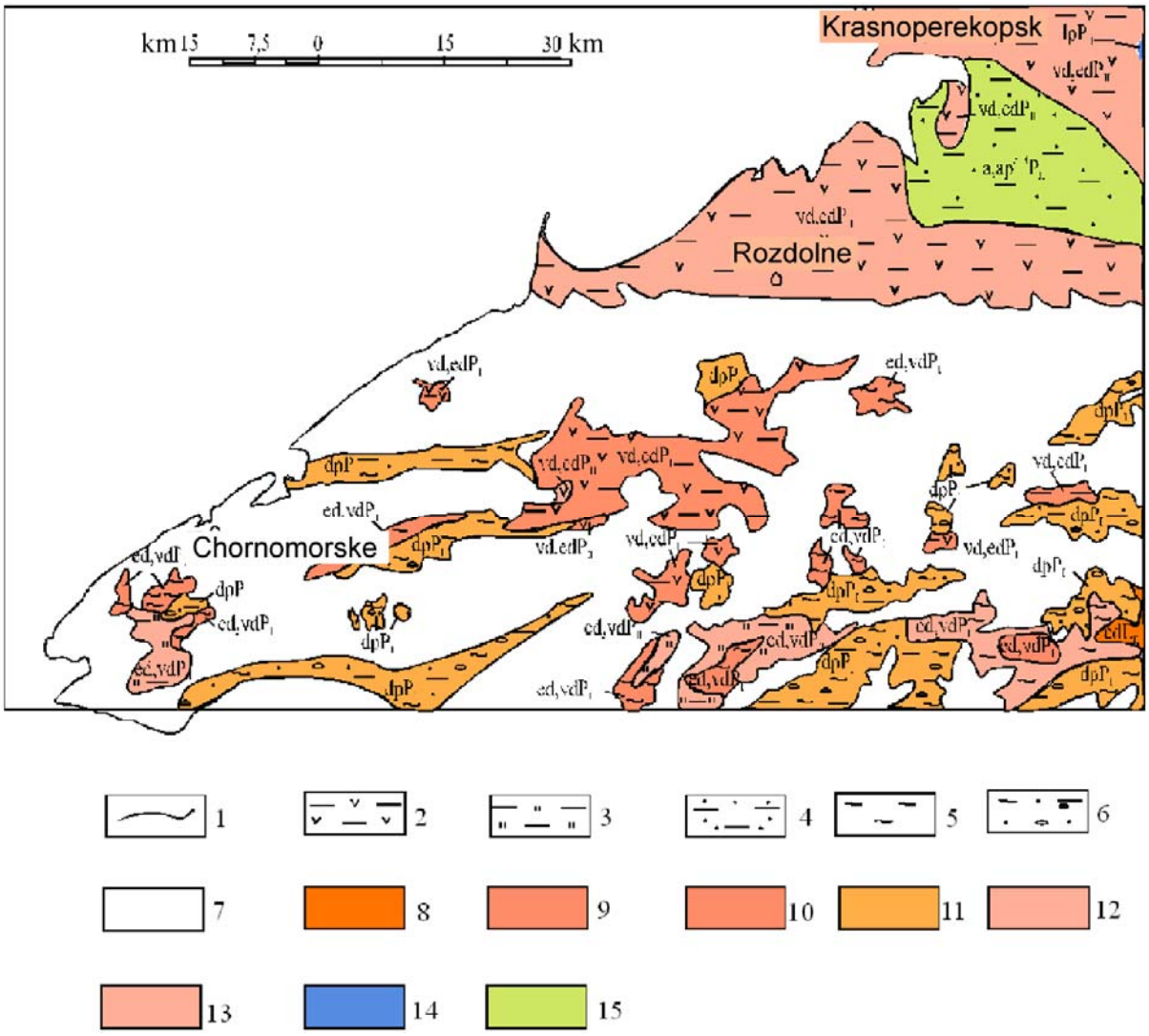

Fig. 2.6. Geological scheme of pre-Quaternary level.

1 – geological boundaries; 2 – loess loams; 3 – medium loams; 4 – loams, sands; 5 – clays; 6 – clays, loams with limestone gravel and gruss; 7 – fields of lacking pre-Quaternary sediments; 8 – Eo-Pleistocene (edE_{II}) eluvial-deluvial sediments; 9 – Lower Pleistocene (vd,edP_I) aeolian-deluvial and eluvial-deluvial sediments; 10 – Lower Pleistocene eluvial-deluvial and aeolian-deluvial sediments (ed,vdP_I); 11 – Lower Pleistocene deluvial sediments (dP_I); 12 – Middle Pleistocene (vd,edP_{II}) aeolian-deluvial and eluvial-deluvial sediments; 13 – Middle Pleistocene eluvial-deluvial and aeolian-deluvial sediments (ed,vdP_{II}); 14 – Middle Pleistocene (lpP_{II}) estuary-proluvial sediments; 15 – Middle Pleistocene ($a,ap^{5+4}P_{II}$) alluvial, alluvial-proluvial sediments.

Martonoskiy, Sulskiy and Lubenskiy climatoliths combined. Eluvial-deluvial and aeolian-deluvial sediments /ed,vdP$_I$mr+lb/. These sediments are developed at watershed surfaces of Lower Pleistocene paleo-relief. In the column are well expressed the rocks of warm stages and almost lacking sediments of Sulskiy cold stage. At the surface these sediments are only exposed in the western part of Tarkhankutskiy peninsula where they lie on residual surface composed of Miocene limestones in Olenyovska structure. Relationships with underlaying and overlaying sediments in Pivdennosyvaskiy SGA are conformable while in Tarkhankut-Novoselivskiy SGA some climatoliths are missed from the column. In Pivdennosyvaskiy SGA the sediments of Martonoskiy climatolith are intersected in the lower part of alluvial complex of the buried seventh and sixth buried terraces (DH 7-p). On the slopes of Karkinitskiy trough the rocks of Lubenskiy climatolith are developed (DH 362, 317).

Martonoskiy climatolith is composed of reddish-brown ductile clays with manganese hydroxide spots. Lubenskiy climatolith is composed of brown, brownish with pink shade clays (rarely loams) with carbonate inclusions and manganese hydroxide spots. Total thickness of the climatolith complex varies from 1 to 6 m. In Tarkhankut-Novoselivskiy SGA most complete column is intersected in DH 290. In the depth range 12.0-8.4 m orange-brown heavy loams occur with manganese hydroxide films. Further to the east, in DH 00 (depth 16.5-13.0 m) the column is composed of brown-red hard-ductile clays with manganese hydroxide dendrites, and single limestone gravel at the bottom. Maximum thickness of these sediments in Tarkhankut-Novoselivskiy SGA attains 4 m.

Sulskiy and Tyligulskiy climatoliths undivided

Alluvial, alluvial-proluvial sediments of the seventh and sixth buried terraces /a,ap^{7+6}P$_I$sl-tl/ are only developed in Pivdennosyvaskiy SGA. They mark second major phase of regional erosion basis descend in Early Neo-Pleistocene. The rocks are cut into sub-aerial sediments of Martonosko-Lubenskiy climatoliths. Altitudes of most subsided bottom parts are -10 m and elevated (southern) suture -0.1 m. Terrace width is less than Eo_pleistocene one and varies from 7 km in the east to 25 km close to Karkinitska Bay. Most complete terrace column is intersected in DH 7-p. In the lower part (depth 16.2-11.0 m) lie 0.5 m thick greenish-grey, medium-grained, polymictic sands. Higher in the column, 3.2 m thick grey-green, sandy, iron-enriched clays occur with fine-crystalline gypsum inclusions. The upper part of aqueous column is composed of 2 m thick clays with interbeds and lenses of greenish-grey, quartz-feldspar, fine-grained sands.

Deluvial-proluvial sediments /dpP$_I$sl-tl/ are only developed in Tarkhankut-Novoselivskiy SGA where they constitute the foothills of positive structures which had been being eroded in Sulskiy time. The rocks lie with erosion over pre-Quaternary sediments and are unconformably overlain by the younger sub-aerial sediments. At the surface they are only exposed in Novoselivske uplift in the east and Olenyovske uplift in the west. They are composed of yellow-brown clays at the top and bewlo – pale-brown heavy loams with up to 10% admixture of limestone gruss. Maximum thickness attains 3.0 m.

Middle branch

Zavadivskiy, Dniprovskiy and Kaydatskiy climatoliths combined. Eluvial-deluvial, aeolian-deluvial sediments /ed,vdP$_{II}$zv+kd/ are only developed in Tarkhankut-Novoselivskiy SGA. They are confined to the elevated watershed parts in post-Lower Neo-Pleistocene relief. At the surface they are exposed in the western part of map sheet group. They unconformably lie over genetically similar Lower Neo-Pleistocene rocks. Zavadivski paleo-soils in Plain Crimea comrpise the typical marker horizon of Pleistocene stratigraphy which is characterized by distinct paleo-pedologic, paleo-climatic and physyomonic features. Dniprovskiy climatolith, which in Prychornomorya is composed of loess formation, and in Alminska depression – alluvial facies, in the studied map sheet group is weakly presented and is only known between the soil break or in thin interbed of loess-like loams.

This stratigraphic-genetic complex conformably lies over Lower Neo-Pleistocene sub-aerial rocks or with erosion over older rocks and with slight stratigraphic discontinuity is overlain by Upper Pleistocene rocks.

Zavadivskiy climatolith is composed of reddish-orange clays and heavy and medium loams with manganese hydroxide spots, powder-like carbonate inclusions and numerous bunches of crystalline gypsum.

Kaydatskiy climatolith is composed of brown medium loams, in places brown and light-yellow clays with manganese hydroxide dendrites and spotty inclusions of powder-like carbonates.

Total thickness of the climatolith complex does not exceed 4 m.

Dniprovskiy, Kaydatskiy and Tyasmynskiy climatoliths undivided. Alluvial, alluvial-proluvial sediments of fifth and fourth buried terraces /a,ap^{5+4}P$_{II}$dn-ts/ are developed in pra-valley of Salgyr river (modern Chatyrlyk river valley), in Pivdennosyvaskiy SGA. with erosion they are cut into Middle Pleistocene sub-aerial sediments. Altitudes of most descended terrace bottom part are -5 m, the back sutures - +12 m. Terrace width at the mouth attains 20 km. In DH 7-p (depth 9.0-4.5 m) terrace is composed of greenish-grey clays with up to 0.5 m thick interbeds of light-grey, greenish, quartz, fine-grained, clayey sands. The sand lenses up to 0.2 m thick are known. On the northern slope (DH 186), yellowish-grey, medium-pebble pebble-stones are observed at the terrace bottom composed of medium-rounded limestones (90%) and milk-white quartz (10%). The filler occupies 30-40% and is composed of loamy-sandy material. Thickness of fifth and fourth terrace sediments attains 5 m. Terrace sediments are extended to the west beneath sea level in Karkinitska Bay where they are intersected by drill-holes above Uzunlarski sediments. The time of fifth and fourth terrace sediments formation is defined by their position in the column between Middle Pleistocene Zavadivskiy climatolith and Upper Pleistocene Prylutskiy climatolith.

Proluvial-deluvial sediments /pdP$_{II}$dn-ts/ are developed in Pivdennosyvaskiy SGA. They are not exposed at the surface and by strike (in ancient Pra-Salgyr gully network) they replace sub-aerial facies. In the studied map sheet group, the sediments are intersected in the southern part of the area in the narrow longitudinal bands along Vorontsivka, Samarchyk and other rivers. They are composed of pale-brown and brown loams and sandy loams with oblique banding (DH 351, depth 10.8-7.8 m) with carbonate concretions and limestone gruss. Maximum thickness attains 3 m. The time of formation is defined by position in the column between the marker Zavadivskiy climatolith (below) and overlaying complex of Upper Pleistocene sub-aerial sediments.

Zavadivskiy, Dniprovskiy, Kaydatskiy and Tyasmynskiy climatoliths combined. Aeolian-deluvial, eluvial-deluvial sediments /vd,edP$_{II}$zv+ts/ are developed over entire map sheet group. In the column aeolian-deluvial rock types predominate. In Pivdennosyvaskiy SGA this complex conformably lies over Lower Neo-Pleistocene sub-aerial sediments and is overlain by genetically similar Upper Neo-Pleistocene rocks. Most complete column is intersected in DH 362 (depth 24.5-14.0 m) where at the bottom light-brown, pale, loess-like loams with manganese hydroxide are developed, and at the top – pink-brown, brown, medium loam with powder carbonates and manganese hydroxide dendrites.

The lower part by age corresponds to Zavadivskiy and Dniprovskiy climatoliths, and upper one – Kaydatskiy and Tyasminskiy.

In Tarkhankut-Novoselivskiy SGA the complex sediments are developed in positive structures where they conformably lie over sub-aerial sediments of Lower Neo-Pleistocene deluvial-proluvial varieties. Most complete column is studied at the depth 14.3-7.0 m where it is composed of brown-pale, loess-like loam with paleo-soil interbeds up to 0.3 m thick. Thickness of the complex attains 7.5 m. The age is defined by position in the column and characteristic paleo-pedologic features.

Upper branch

Vylkivskiy horizon. Marine sediments /mP$_{III}$vl/. They are encountered in the northern coast of Tarkhankutskiy peninsula in the mouth part of Bila gully, where in 5 m above sea level grey-brown, feldspar, medium-coarse-grained, coarse-layered, platy, from 0.8 to 1.2 m thick sands are exposed. The rocks are cut into Upper Miocene limestones. The age of marine terrace is defined by direct observation and correlation with synchronous and fauna-supported terraces in the northern coast of Karkinitska Bay (Tendrivska spit). Over there, sea molluscs *Cerithium vulgatum* B r u g*, Gibbula albida* G m*., Cyclope neritea* (Z.) and others are determined. From estuary sediments *Dreissena polymorpha* P a l l*., Dr. rostriformis* (D e s h.), *Monodacna sp., Didacna sp.* are determined.

Udayskiy and Vytachivskiy climatoliths undivided. Alluvial-proluvial sediments /apP$_{III}$ud-vt/ are developed in Tarkhankut-Novoselivskiy SGA where they are exposed at the surface in the northern bank of Chatyrlyk river. In morphologic respect, alluvial-proluvial sediments do form gently dipping to the south terrace up to 400 m wide and up to 5 km long in the map sheet L-36-XXII. The rocks include light-brown, pale-brown, lumpy loamd with admixture of limestone gruss (up to 10%), crushed stone (up to 3%) and gravel (up to 1%). Maximum thickness attains 2.5 m. These rocks are underlain by Lower Neo-Pleistocene deluvial-proluvial sediments and are overlain by the modern soils.

Deluvial-proluvial sediments /dpP$_{III}$ud-vt/ are developed in Tarkhankut-Novoselivskiy SGA where they are confined to the uplift slopes, in the cross-profile replacing facially the even-aged sub-aerial eluvial-deluvial facies. The rocks include light-brown loams with limestone gruss admixture up ro 30%. The rocks lie over odd-aged sediments from Miocene to Pleistocene. The sediments are overlain by Upper Neo-Pleistocene soil-loess rocks.

Prylutskiy, Udayskiy and Vytachivskiy climatoliths combined. Eluvial-deluvial, aeolian-deluvial sediments /ed,vdP$_{III}$pl+vt/ are developed in Tarkhankut-Novoselivskiy SGA at the elevated sites of Pleistocene relief. They exhibit paleo-soil column of warm climatoliths (Prylutskiy and Vytachivskiy) and less prominent cold Udayskiy climatolith. By dipping conditions the rocks lie over Middle Pleistocene surface composed of sediments from Upper Miocene to Middle Neo-Pleistocene. In the northern direction eluvial-deluvial facies are replaced by aeolian-deluvial sediments of combined Upper Pleistocene complex, and in Tarkhankutskiy peninsula, in the area of modern motions, they are lacking at all. Most complete column is studied in cape Tash-Burun to the north from Severne village (Fig. 2.7). Downward in the column below Buzki loess-like loams the following units are observed.

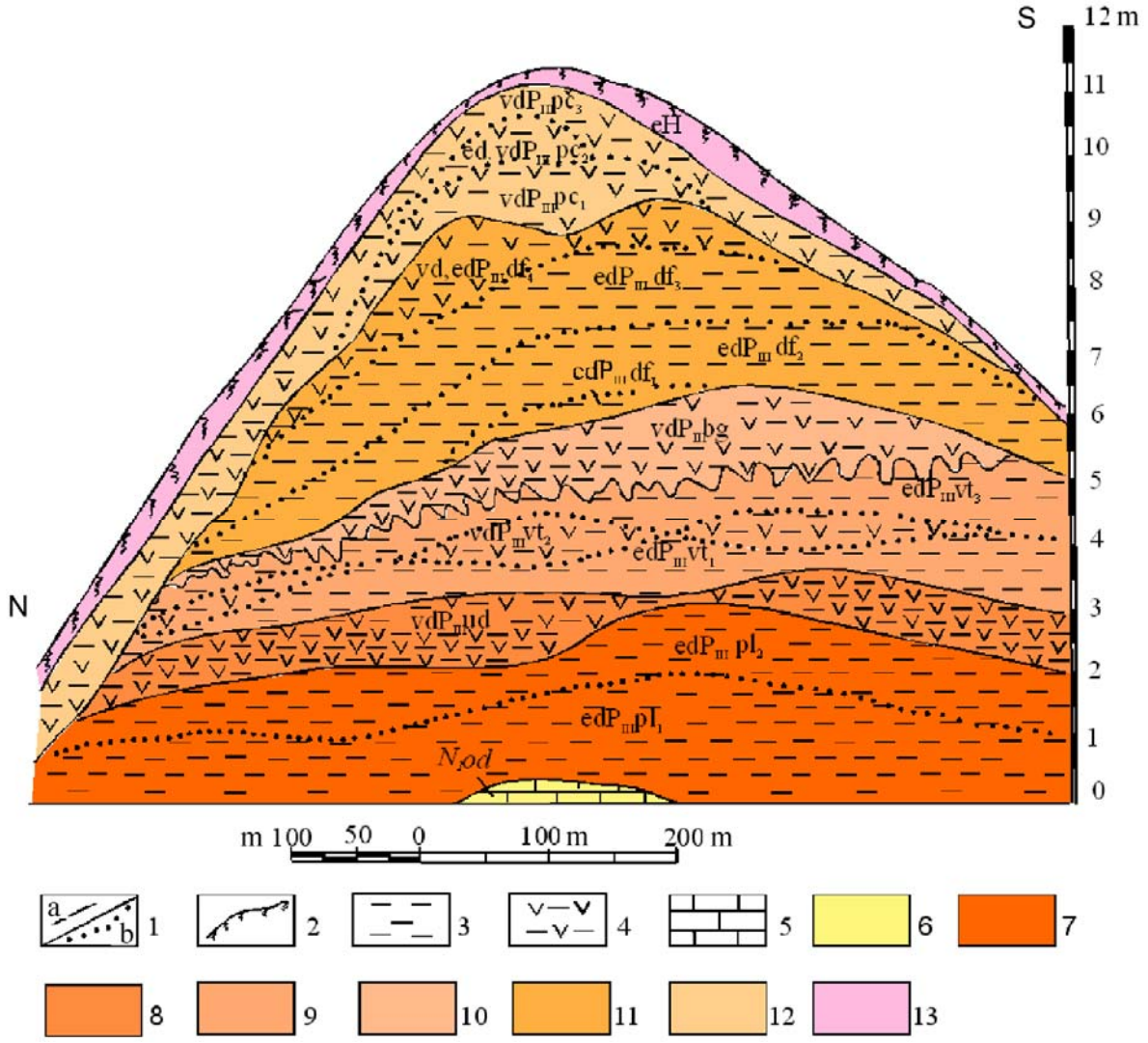

Fig. 2.7. Basic column of Upper Pleistocene sediments in cape Tash-Burun.

1 – geological boundaries between: a – climatoliths, b – units in climatoliths; 2 – modern soils; 3 – loams; 4 – loess loams; 5 – limestones; 6 – Odeski layers (N_1od), Upper Pleistocene; 7 – eluvial-deluvial sediments of 1st and 2nd units of Prylutskiy climatolith (edP$_{III}$pl$_1$, edP$_{III}$pl$_2$); 8 – aeolian-deluvial sediments of Udayskiy climatolith (vdP$_{III}$ud); 9 – eluvial-deluvial and aeolian-deluvial sediments of 1st, 2nd and 3rd units of Vytachivskiy climatolith (edP$_{III}$vt$_1$, edP$_{III}$vt$_2$, edP$_{III}$vt$_3$); 10 – aeolian-deluvial sediments of Buzkiy climatolith (vdP$_{III}$bg); 11 – aeolian-deluvial and eluvial-deluvial sediments of 1st, 2nd, 3rd and 4th units of Dofinivskiy climatolith (edP$_{III}$df$_1$, edP$_{III}$df$_2$, edP$_{III}$df$_3$, edP$_{III}$df$_4$); 12 – eluvial-deluvial and aeolian-deluvial sediments of 1st, 2nd and 3rd units of Prychornomorskiy climatolith (vdP$_{III}$pč$_1$, vdP$_{III}$pč$_2$, vdP$_{III}$pč$_3$); 13 – Holocene soil climatolith (eH).

Vytachivskiy climatolith includes three sub-units. The upper 1.0 m thick sub-unit ($edP_{III}vt_3$) is composed of brown with pink shade loams with fine-crystalline gypsum bunches. Middle 0.1-0.7 m thick sub-unit ($edP_{III}vt_2$) is composed of spindle-like interbed of bright-brown light loams with fine-crystalline gypsum bunches and small (up to 0.8 cm across) carbonate aggregates. The lower, up to 1.3 m thick sub-unit ($edP_{III}vt_1$) is composed of brown-red and pink-brown heavy glued loams with inclusions of carbonate aggregate and fine-crystalline gypsum bunches (from 7 to 15 cm in size). Thickness of entire climatolith varies from 1 to 3 m. Contact with underlaying sediments is gradual.

Udayskiy climatolith, up to 0.7 m thick, is composed of grey-pale loess-like fine-porous loams with inclusions of small gypsum crystals up to 5%. Rounded mole paths are observed filled with loamy material from overlaying climatoliths. The contact with underlaying layers is sharp, wedge-shaped.

Prylutskiy climatolith includes two soil sub-units. The upper one, up to 1.3 m thick, is composed of grey-brown heavy glued loam with inclusions of fine disseminated gypsum crystals. The contact with lower paleo-soil is sharp, by the rock colour switch. The lower sub-unit, 0.5 m thick, is composed of dark-brown heavy glued loam with film-disseminated manganese hydrozides, at the bottom – gruss of Chatyrlytski limestones. Total thickness of climatolith attains 1.8 m, and entire complex – 4.8 m.

Complex of Upper Neo-Pleistocene sediments unconformably lies over eroded surface of Odeski layers. In the rocks, by spore-pollen analysis in Institute of Geological Sciences of National Academy of Sciences of Ukraine, in /$edP_{III}vt_3$/ and in /$edP_{III}pl_2$/ pollen grains *Pinus sylvestris* are determined and minor amount of *Quercus, Ulmus, Alnus* pollen, and with herbage – *Chenopodiaceae, Poaceae, Coryophyllaceae* (determinations of S.I.Turlo). This spore-pollen complex as well as position in the column allow dating to entire complex of sub-aerial sediments by the early phase of Upper Neo-Pleistocene stage in geological development of the area.

Surozkiy horizon. Estuary and marine sediments /lm,mP_{III}sr/. These sediments are identified in some drill-holes in the northen coast of Tarkhankutskiy peninsula and in Karkinitska Bay. The typical column is intersected in DH 9 in the southern coast of Dzharylgach Lake. Over there, beneath estuary sandy sediments of Holocene Chornomorskiy horizon, the following rocks are observed (downward):

1. depth 3.5-6.0 m – dark-grey to black, pelite, greasy mud, at the bottom – blue-grey mud with limestone gruss up to 5%; thickness 2.5 m;

2. depth 6.0-6.6 m – grey with greenish shade, viscous clay with carbonate concretions (up to 3%); thickness 0.6 m.

Mentioned sediments are underlain by Miocene limestones. In the same rocks at Dzharylgach Lake and Karkinitska Bay, at the top, besides *Cerastoderma edule* Z, comprising up to 50% of organic remnants, are also determined *Paphia senescens* (C o c.), *Ostrea lamellose* B r o c e h i, *Hydrobia sp., Valvata sp*. and others. From the lower column part *Monodacna cf. subcolorata* (A n d r u s), *Dreissena polymorpha* (P a l.) and others are determined. Absolute age by radio-carbon analysis varies from 34.7 to 41 thousand years providing sediments ascription to the middle part of Upper Neo-Pleistocene.

Dofinivskiy and Prychornomorskiy climatoliths combined. Eluvial-deluvial, aeolian-deluvial sediments /ed,vdP_{III}df+pč/ are developed in Tarkhankut-Novoselivskiy SGA where they constitute pre-Holocene surface of watershed areas. The columns everywhere are two-folded: from 0.8 to 2.2 m thick soils of Dofinivskiy climatolith at the bottom, composed of brown, dark-brown, lumpy loams with inclusions of fine-crystalline gypsum, and then 0.2-0.8 m thick loess-like loams of Prychornomorskiy climatolith with numerous inclusions of powder-like carbonates ("bilozirka"). The total thickness of the complex is 2.8 m. The rocks lie mainly unconformably over older Late Cenozoic sediments or over relicts of Buzkiy climatolith.

Prylutskiy, Udayskiy, Vytachivskiy, Dofinivskiy climatoliths combined. Aeolian-deluvial, eluvial-deluvial sediments /vd,edP_{III}pl+pč/. This complex of sediments is developed in Pivdennosyvaskiy SGA. In outcrops, aeolian-deluvial rock varieties predominate by thickness. The complex sediments conformably lie over genetically similar Middle Neo-Pleistocene rocks and constitute pre-Holocene surface. Most complete column is intersected in DH 362 at the depth 11.2-0.3 m, where from bottom to top the following rocks are observed:

1. depth 11.2-4.4 m – light-brown medium loam with inclusions of powder-like carbonates and manganese hydroxide;

2. depth 4.4-0.3 m – light-brown loess-like loam with inclusions of powdery carbonates.

The first layer by age does correspond to Prylutsko-Dofinivskiy climatoliths, and seond one – to Dofinivsko-Prychornomorskiy climatoliths. Thickness of the complex attains 11 m.

Neo-Pleistocene, upper branch, Prychornomorskiy climatolith and Holocene

Alluvial, alluvial-proluvial sediments of first over-flood terrace /a^1,ap^1P_{III}pč-H/. Terrace is only expressed in Pivdennosyvaskiy SGA, in the valley of Chatyrlyk river. From the east to west terrace surface altitudes decrease from 12 to 5 m and its width increases from 180 to 240 m. The sediments contain fine gravel (up to 0.5 cm) and limestone gruss up to 10% of rock volume. Maximum thickness of alluvium in the first over-flood terrace does not exceed 1.5 m. Terrace age is determined by geomorphologic data.

Deluvial-proluvial sediments /dpP_{III}pč-H/ are widely developed on the uplift slopes in Tarkhankut-Novoselivskiy SGA. They include brown, pale-brown medium loams with limestone gruss and single fragments. Thickness of sediments increases from 0 to 1.2 m towards the slope foothills. In places up to 0.6-0.7 m high bench is observed. The rocks do conformably lie over the older Upper Cenozoic sediments.

Coluvial sediments /cP_{III}pč-H/ are only defined in Tarkhankut-Novoselivskiy SGA along the northern and western coasts of Tarkhankutskiy peninsula and in the northern coast of Donuzlav Lake. In the map scale they are lamost not mapped because of negligible size of individual bodies – limestone boulder, cobble and gravel accumulations, as well as land-slides. Dimensions of individual bodies do not exceed 3 m by height and 10 m by width. The time of their formation is set by the position in the column.

Holocene

Alluvial-proluvial sediments /apH/. These sediments are throughout developed constituting the river and gully flood-land. By the dipping features, two categories of sediments are distinguished: those cut into the older rocks, and those lean against the older rocks. The flood-land width varies from 10 to 180 m. The rocks include brown and dark-brown heavy loams and sandy loams with up to 40% admixture of clastic material – gruss, gravel, pebble, sand. Maximum thickness of alluvial-proluvial sediments attains 1.2 m.

Lake sediments /lH/ in Pivdennosyvaskiy SGA are tightly related to Syvaska group of lakes: Krasne, Kyatske, Stare, Kerleutske, and Bakalske lake in the southern coast of Karkinitska Bay. In Tarkhankut-Novoselivskiy SGA lake sediments are studied in Dzharylgach Lake. In geomorphologic respect, the modern lake sediments constitute first lake terrace with 0.8 m height above water line. Terrace width attains 250 m. The typical column of these sediments is intersected in DH 9 on the coast of Dzharylgach Lake (downward):

0.0-0.2 m – dark-grey, greenish, pelite, viscous mud with detritus of modern molluscs;

0.2-3.5 m – grey, bluish-grey, greenish-grey, feldspar-quartz, coarse-grained sand with detritus of modern molluscs.

The fauna complex, suggesting for Holocene age of lake sediments, in the lower part includes marine euri-haline, and in the upper part – salty-water and mixed forms: *Dreissena rostriformis* (D e s h.), *Dr. polymorpha* (P a l l .), *Hypanis angusticostata angusticostata* (B o c e a), *Theodoxus milastewitchi* (G o l e t S t .), *Teriricaspia variabilis* (E i c h w.), *Cerastoderma sp., Abra ovata* (P h i l), *Hydrobia sp.*

Chornomorskiy horizon. Estuary-marine sediments /lm,mHcm/. They are widely developed along the coast of Karkinitska Bay in partly or completely separated bays and lakes, as well as in Donuzlav Lake. The sediments are composed of muds and muddy sands, 3.5-5 m thick, in Donuzlav Lake – up to 8 m.

The rocks contain mixed fauna complex of euri-haline salty-water molluscs *Cerastoderma lamarcki lamarcki* (R e e v e), *Abra ovata* (P h i l), *Hydrobia acuta* (D r a p.), *Hypanis colorata* (E i c h w.), *Dreissena polymorpha* (P a l l a s), *Theodoxus fluviatilis* (Z.), suggesting for Holocene Chornomorskiy horizon.

Chemical and granulometric composition of friable Quaternary rocks is consistent enough within genetic types. The rocks of marine and continental types are clearly disinguished.

Modern soils /eH/. Sub-aerial soils are developed widely enough. They include soil horizon composed of black-soil-like, dark-grey and brownish-grey madium and haevy loams, in places sandy loams. Thickness of sediments varies from 0.2 to 1.0 m.

Formation time of these sediments is defined by their position in the upper column part with the lower boundary by hanging-wall of Late Pleistocene sediments.

Technogenic sediments /tH/ are developed widely enough especially in the southern part of map sheet group. They constitute dumps in quarries for construction materials, the heaps along Pivnichnokrymskiy channel, and dam units. They include the rocks of broken structure, density and lithology – sand-clay, sand-gruss, gruss-cobble, and sand. Thickness of sediments varies from 0.1 to 15.0 m.

3. INTRUSIVE AND SUBVOLCANIC UNITS

Intrusive and volcanic rocks in the map sheet group L-36-XXI, L-36-XXII, L-36-XXVII are developed in Pivnichnokrymskiy riftogenic trough and in Novoselivske uplift. They cut through dislocated Upper Paleozoic and Lower-Middle Mesozoic sediments in the folded basement. These rocks are overlain by Meso-Cenozoic sedimentary complexes and are not exposed at the surface being only intersected by drill-holes for oil and gas. Four complexes of non-stratified rocks are distinguished: Syvaskiy of "tele-orogenic" granitoids, Novoselivskiy subvolcanic, Pivnichnokrymskiy of small intrusions and dykes, and Tarkhankutskiy subvolcanic.

Late Proterozoic (Vendian)
Syvaskiy complex of "tele-orogenic" granitoids – εγV*sv*

It is established by L.G.Plakhotniy [17] and includes subalkaline and alkaline granites. Information on this Complex is given after the data obtained from prospecting works for oil and gas in Averyanivska and Balashivska fields located to the north from the map sheet group and confined to the northern limb of Pivnichnokrymskiy Mesozoic rift.

In DH Averyanivska-9, in the core of fault-side fold, at the depth range 2507-2509 m, below Lower Cretaceous rocks, medium-grained pink granites and migmatites are intersected. The Complex is related to the local gravity minimum which comprises the northern apophysis of major Syvaskiy gravity minimum.

In Balashivska field, DH 5 (depth 2960-2962 m) are intersected alaskite granites, alkaline micro-aplites, micro-pegmatites, alaskites and greisenized granodiorites, overlain by Triassic rocks. Rock textures include micro-pegmatite, micro-aplite, granite, grano-blastic. Rock-forming minerals include quartz, plagioclase, potassium feldspar, muscovite. Accessories: chlorite, calcite, magnetite, zircon, tourmaline.

Geophysical data allow assumption that Syvaskiy complex comprises a part of large (35×70 km) Syvaskiy Vendian igneous pluton within Archean basement, which belongs to the extended regional Byrladsko-Pivnichnoazovska band of gravity minimums, related to the sub-latitudinal zone of Vendian granitoid plutons in the southern marginal band of Eastern-European Platform. Formation of this pluton, according to L.G.Plakhotniy [17], was two-phase. Absolute rock age in DH Averyanivska-9 (depth 2508-2509 m), determined by K-Ar method, is 600-620 Ma suggesting for Early Vendian [17, 18].

Paleozoic - Triassic
Novoselivskiy subvolcanic complex – ν-δ(Pz-T)*ns*

It is established by L.G.Plakhotniy and V.G.Bondarenko [17] and includes gabbro-diabases, diabase porphyries, gabbro-diorites, quartz gabbro-diorites, diorites, granodiorites, granodiorite-porphyries.

Information on the earliest phases of Novoselivskiy subvolcanic complex concerns adjacent territory located to the north from the map sheet group. Over there, in Balashivska field, in the column of DH 4 and 5, thin bodies of volcanic rocks are encountered composed of trachy-diabase, diabase, quartz and felsite rhyolites and porphyries. Like the host rocks, the igneous ones are notably hornfelsitized. Radiometric are of hornfelsites (after biotite) is 350 Ma [14, 19].

In DH Balashivska-4 (depth ranges 2496-2497, 2508-2511 m) subalkaline diabase porphyries are intersected. The rocks are grey and dark-grey, almost black. Structure is massive, breccia-like, texture is porphyry. Inclusions are fine and single, composed of plagioclase crystals. Mafic mineral is pseudo-morphically replaced by actinolite. Quartz is of mosaic texture. Rock groundmass is completely re-crystallized and is composed of secondary minerals: biotite, chlorite, actinolite and quartz. And DH Balashivska-5 has only intersected trachy-diabase porphyries.

Main occurrences of Novoselivskiy subvolcanic complex are confined to the same-named uplift where whey are intersected by DH Novoselivska-1, 3, 9; Krasnoperekopska-1; Severska-1. This complex includes quartz gabbro-diabases, quartz gabbro-diorites, quartz diabase porphyries, diorites, granodiorite-porphyries. These rocks are observed in the dykes, vein bodies, which cut through Carboniferous aspide schists, Triassic and Jurassic clayey shales and sandstones, which occur at the depth 900-2100 m.

In Severska field the igneous stock is composed of quartz gabbro-diabases and quartz gabbro-diorites and is expressed by negative gravity anomaly – 4.0 mGal, 2.0-4.0 km^2 in size. In magnetic field this body is expressed in positive 50-170 nTl anomaly of ΔTa. By seismic data, intrusion is isometric in shape, 3.5×5 km in

size, elevated by 1000 m above the surface of folded basement. In drill-hole the depth run over igneous rocks exceeds 500 m (depth 910-1560 m) and did not leave them. Rock age by K-Ar radiometric data is 210 Ma and corresponds to Triassic [17].

Macroscopically, the rocks of Severskiy stock are grey, dark-grey, greenish-grey, fine-medium-grained, mainly of massive, in places banded structure. Rock texture is diabasic, gabbroic, in places porphyry-like. Mineral composition: plagioclase (labrador 60%), pyroxene (diopside 0-5%), amphibole (cummingtonite 5-10%), quartz (5%). Plagioclase arrangement degree is 0.0-0.3. Accessory: apatite, secondary minerals include chlorite, sericite, biotite, epidote, calcite, quartz, leucoxene, albite. Chemical composition of mafic rocks in DH Severska-1 is similar to the average diabase of Daly and only differs in lower MgO content.

Quartz diabases and diabase porphyries in drill-holes of Novoselivska group – DH 1 (depth ranges 1504-1507, 1665-1667, 2353-2359 m), DH 3 (2353-2359 m), DH 9 (1083-1086, 1092-1094 m) cut through Carboniferous shale-limestone sequence. Thickness of the bodies by core sections does not exceed 10 m. Rock-forming minerals: plagioclase (60%), pyroxene (20%), olivine (2-3%). Secondary minerals: chlorite, calcite, albite, quartz. Quartz diabases and diabase porphyries in DH Novoselivska-1 exhibit increased contents of CaO, MgO, Al_2O_3, and decreased alkali and SiO_2 content.

Diorites and granodiorite-porphyries are intersected by DH Krasnovska-1 (depth 2373-2377 m), Novoselivska-1 (1929-1933 m). These rocks do form the dykes which cut through Carboniferous shale sequence.

In gravity field the zone of diorite and granodiorite-porphyry rocks in Krasnovska field (1-5 km^2) is expressed by the local 0.8 mGal gravity maximum. The rocks are grey, dark-grey, fine-grained, of massive structure. Texture is micro-diorite, hypidiomorphic, porphyry-like, poikilitic. Mineral composition of diorites: plagioclase (60%), quartz (15%), biotite (20%). Granodiorite-porphyries differ from diorites in higher quartz content and porphyry texture. Accessory minerals: apatite, zircon. Secondary: chlorite, calcite, epidote. In chemical composition of granodiorite-porphyries of DH Krasnovska-1 increased MgO content is noted. Average rock density of Novoselivskiy complex is 2.68 g/cm^3.

Chemical composition of mafic and intermediate rocks of Novoselivskiy complex is given in Table 3.1 and rocks indicators after A.M.Zavaritskiy – in Table 3.2.

Late Triassic – Middle Jurassic

Pivnichnokrymskiy complex of small intrusions and dykes - γ-$\nu(T_3$-$J_2)$*pk*

It is established by V.G.Bondarenko [17]. The complex is intersected by drill-holes in the northern and southern limbs of Pivnichnokrymskiy rift. In the northern limb these are DH Mizhvodnenska-4, 5; Bakalska-17; Borysivska-3; Illinska-1; Avrorivska-1; in the southern limb – Oktyabrska-1, 2, 4, 8. The rocks are intersected in the upper part of Triassic-Jurassic folded basement at the depth 4000-4700 m. In the gravity and magnetic fields Pivnichnokrymskiy complex is weakly expressed. Intersected thickness of intrusions is 30-70 m. They form vein bodies and dykes.

The complex is composed of diorites, gabbro-porphyrites, diabases, granodiorite-porphyries, granites.

In Mizhvodnenska and Bakalska fields granites are grey, greenish-grey, pink, coarse-medium-grained. Rock texture is porphyry-like, hypidiomorphic. The rocks are composed of plagioclase (50%), potassium feldspar (10%), quartz (30%), and biotite (10%). Accessory minerals: apatite, zircon; secondary – chlorite, sericite, muscovite, iron hydroxides, calcite. Absolute rock age of granites in Mizhvodnenska field is 185 Ma which corresponds to Early Jurassic [17].

Diorites in Borysivska field are grey, dense, fine-crystalline, texture porphyry-like. The rocks are composed of plagioclase (50-70%), biotite (10-120%), pyroxene (up to 10%), and magnetite (up to 3%) crystals; secondary minerals: chlorite, calcite, sericite.

Aplite in Illinska field is grey, light-grey, dense, with aplite texture. Mineral composition: plagioclase (55-60%), quartz (30%), biotite (10%); secondary minerals – chlorite, calcite, albite.

Gabbro-porphyries and diabase porphyries in Borysivska, Avrorivska and Illinska fields are dark-grey with greenish shade, dense. Texture is diabasic, ophitic. Rock-forming minerals: plagioclase (50%), pyroxene (30%), hornblende (10%), other amphiboles (10%). Accessory mineral is apatite. The rock is altered by secondary processes: chloritization, sericitization, carbonatization, zeolitization.

In the southern trough limb intrusions of Pivnichnokrymskiy complex are intersected in DH Oktyabrska-1, 2, 4, 8. Jurassic host rock depths in this area are 2600-3800 m. In gravity field intrusions of Oktyabrska field are set within narrow positive Δga anomaly (2.6-5.0 mGal) extended in sub-latitudinal direction.

Table 3.1. Chemical composition of the rocks from Novoselivskiy subvolcanic complex

		Content, %													
		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	P_2O_5	SO_3	H_2O	Σ
1	Quartz diabase porphyrite, DH Novoselivska-1, depth 1504–1507 m	53.22	1.43	15.07	4.64	6.16	0.10	4.10	2.58	3.43	0.78	0.29	0.50	3.01	100.5
2	DH Novoselivska-9, depth 1083–1086	45.84	1.06	6.25	15.01	6.80	0.19	9.25	8.50	1.19	0.64	0.12	-	14.34	100.6
3	Quartz gabbro-diorite, DH Severska-1, depth 1030 m	59.04	0.71	16.66	1.49	4.74	0.10	4.80	2.84	2.86	2.14	0.28	-	0.40	99.96
4	Quartz gabbro-diabase, DH Severska-1, depth 1429–1432 m	54.72	1.08	16.17	3.94	5.35	0.17	6.68	4.55	3.37	1.60	-	-	0.98	100.4
5	Granodiorite-porphyry, DH Krasnovska-1, depth 2373–2377 m	67.35	0.24	17.23	0.63	1.92	0.05	3.36	0.70	2.19	2.61	0.14	-	0.38	100.48
6	Diorite, DH Novoselivska-1, depth 1929–1933 m	58.51	0.49	15.09	2.25	4.81	0.09	4.96	6.01	2.47	1.69	0.13	0.13	3.60	100.3

Table 3.2. Numeric indicators after A.M.Zavaritskiy

	a	**c**	**b**	**s**	**a^1**	**f^1**	**m^1**	**c^1**	**n**	**Q**
1	9.6	5.5	17.0	67.9	10	62	28	–	87.0	+21.0
2	3.3	2.5	42.1	52.1	–	45	34	21	66.0	+4.9
3	9.6	6.2	12.6	71.6	12	48	40	–	68.0	+17.9
4	10.0	6.0	19.0	65.0	–	46	41	13	78.0	+4.0
5	10.1	4.2	7.3	78.4	51.3	32	16	-	62	+32.4
6	7.1	6.1	18.0	67.8	6.0	37	57	-	68	+16.3

Granodiorite-porphyries and quartz diabases in Oktyabrska field do form thin vein bodies (3-5 m) which cut through Jurassic sequence of hornfelsites and spotty shales. Granodiorite-porphyries are grey, fine-grained, with massive structure. Texture is porphyry, hypidiomorphic, micro-granite. Mineral composition: albite (60%), potassium feldspar (10%), quartz (30%). The groundmass is composed of quartz and albite grains in proportion 40 to 60%. Accessory minerals: zircon, apatite; secondary minerals – quartz, seiricte, zeolite, chlorite, leucoxene. By chemical composition granodiorite-porphyries in Oktyabrska field are enriched in Na_2O and depleted in K_2O (Table 3.3).

Diabases in Oktyabrska field are light-grey, dense, fine-grained, of massive structure. Rock texture is micro-diabase. Mineral composition: plagioclase (50%), pyroxene (3%), amphibole (20%). The rocks are highly altered by secondary processes: kaolinitization, sericitization, chloritization. By chemical analysis, diabases are somewhat depleted in SiO_2, Al_2O_3, MgO, CaO and slightly enriched in K_2O (see Table 3.3). Average rock density of Pivnichnokrymskiy complex is 2.64 g/cm^3. Absolute age of quartz diabases determined by radio-carbon method is 158 Ma and corresponds to Middle Jurassic [17].

By geochemical and radiometric studies, intrusive rocks of Pivnichnokrymskiy complex have been formed in Triassic – Middle Jurassic; they are co-magmatic to Karadazka and Chaychynska suites and are similar to intrusions of gabbro-plagiogranite formation in Mountain Crimea.

Cretaceous

Tarkhankutskiy subvolcanic complex – γ-$\delta K_1 tr$

It is established by V.G.Bondarenko [17] and is developed in Pivnichnokrymskiy rift where is confined to Lower Cretaceous volcanic rocks. The body shape includes dykes, stocks, veins. Intrusive rocks of the complex are intersected by drill-holes in Melova field (map sheet L-36-XXI), Tetyanivska and Serebryanska fields (map sheet L-36-XXII). It is concluded they are related to sub-latitudinal fault zones along which extended positive gravity field Δga anomalies (2.5-5.0 nTl) are traced.

Complex is composed of quartz porphyries and diorite porphyries, micro-diabases.

DH Melova-4 (depth 3895-4003 m) has intersected granodiorite stock which cut through Lower Cretaceous tuffs. Granodiorites are grey, dark-grey, mainly of massive, in places breccia structure. Mineral composition: plagioclase (78%), quartz (10%), microcline (10%), amphibole (1-2%). Accessories: apatite, zircon; secondary minerals: quartz, chlorite, calcite, sericite, leucoxene. The rocks are altered under influence of potassium metasomatism and in places they are milonitized. By chemical analysis, granodiorites are slightly enriched in K_2O (Table 3.5). In the lower part of intersected column (depth 4000-4003 m) quartz rhyolites are encountered with porphyry and micro-felsite texture and spotty structure. The rocks are composed of corroded quartz, tabular crystals of sericitized feldspar, and single grains of quartz granite-porphyry.

In Tetyanivska field (DH 1, depth 3786-3799 m) light-grey and grey, fine-grained, strong micro-diabases are encountered. Mineral composition: plagioclase (90%), amphibole (10%), single biotite crystals. The rock is slightly altered by secondary processes: chloritization, clayeyzation, albitization and zeolitization. Apparently, these rocks do form dykes in Upper Cretaceous volcanic rocks.

DH Serebryanska-5 (depth 3892-4053 m) has intersected quartz diorite porphyrite – greenish-grey and grey rock with granophyre texture and massive structure. Its mineral composition: plagioclases, in places amphiboles, biotite plates and quartz grains; groundmass is of quartz-feldspar composition. Secondary processes: albitization and sericitization.

Absolute age of quartz porphyries in Melova field, determined by K-Ar method, is 120 Ma which corresponds to Early Cretaceous [16, 17].

Table 3.3. Chemical composition of intrusive rocks from Pivnichnokrymskiy complex

		Content, %												
		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	P_2O_5	SO_3	H_2O	Σ
1	Granodiorite-porphyry. DH Okyabrska-1, depth 2724–2727 m	65.71	0.59	16.39	0.28	3.81	0.06	1.65	1.75	5.62	1.18	0.26	–	–	100.6
2	Diabase, DH Okyabrska-5, depth 3342–3347 m	48.05	2.93	14.95	2.61	8.78	0.27	7.41	4.81	3.06	1.66	-	–	0.37	100.0

Table 3.4. Numeric indicators after A.M.Zavaritskiy

	a	c	b	s	a^1	f^1	m^1	c^1	n	Q
1	14.2	2.0	8.8	75.0	21	45	34	-	87	+20.4
2	9.6	5.8	23.9	60.7	-	37	28	25	74	-3.6

Table 3.5. Chemical composition of granodiorites from Melova field

		Content, %													
		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	P_2O_5	SO_3	H_2O	Σ
1	Granodiorite, DH 11, depth 3895–3899 m	65.77	–	17.34	–	4.65	-	2.32	1.30	4.75	2.05	0.11	–	0.10	100.62

Table 3.6. Numeric indicators after A.M.Zavaritskiy

	a	c	b	s	a^1	f^1	m^1	c^1	n	Q
1	13.2	2.9	10.4	73.5	37	42	21	–	77	+17.4

4. TECTONICS

In geotectonic respect, the map sheet group includes fragments of two major structures: Eastern-European Platform with geosyncline cycle completed by the end of Middle Proterozoic, and Scythian Plate where in the basement diverse folded-metamorphic complexes are developed. The first domain includes southern slope of Ukrainian Shield, and the second one – the elevated portion of Tsentralnokrymske uplift. The boundary between these domains by the basement coincides with the axial part of superimposed Prychornomorska depression. In the structure of Eastern-European Platform the internal and external parts of Ukrainian Shield slope are distinguished. In the studied map sheets only external part of Ukrainian Shield slope is developed.

In the geological structure of the territory, by composition, metamorphic degree and laying conditions two tectonic levels are distinguished: the lower one – the basement of pre-Alpine consolidation, and the upper one – Alpine platform cover.

Lower (pre-Alpine) tectonic level

In the lower tectonic level pre-Baikalian, Baikalian, pre-Ryphean, Herzinian and Lower Kimmerian tectonic floors are distinguished that formed at different stages of development.

Pre-Baikalian tectonic floor AR-PR$_1$ includes the oldest geological units in the region. In the studied map sheets the information on structure, zonation and composition is limited enough and mainly based on geophysical data. The floor is composed of Archean – Lower Proterozoic rock complex. At the northern border of map sheet L-36-XXII the complex depth is 2 km, and to the south its gentle (1-2^o) plunging is observed, and then sharp subsidence with formation of tectonic benches. The external part of Ukrainian Shield slope in the north of the area is only comprised of Perekopskiy ledge. At the latitude of Perekopskiy neck pre-Ryphean basement is buried to the depths 10-12 km. Archean part of the complex exhibits highest values of magnetic susceptibility which differs this complex from Ryphean-Paleozoic units.

In mosaic magnetic field the complex is expressed in extensive highly differentiated anomalies. The linear magnetic field with consistent sub-longitudinal extension of magnetic anomalies is characteristic for Lower Proterozoic units. In the area of Archean rocks the gravity field is extensive enough, with numerous gravity anomalies, and it is gentler (with reduced gravity values and simple patterns) in the area of Lower Proterozoic units.

Fault tectonics. Suture zone at the junction of Eastern-European Platform and Scythian Plate comprises major element of pre-Ryphean tectonic floor. It is identified through a range of evidences and comprises latitudinal zone buried beneath the thick sedimentary cover of Prychornomorska depression.

In the Moho surface relief this suture zone is expressed in the changes of tectonic patterns and in the gravity field it coincides with Karkinitskiy and Syvaskiy gravity minimums.

By DSS data, suture zone axis coincides with the axis of Karkinitska Bay and further crosses Perekopskiy neck. Along this line, the strike of linear structures is being changed from sub-longitudinal (characteristic for the folded structures in pre-Ryphean basement of Ukrainian Shield) to diagonal with smoothed-linear outlines in Scythian Plate.

Baikalian tectonic floor R$_3$. Information on structure of Ryphean tectonic floor is limited. In the north of studied area, in the junction zone of Ukrainian Shield and Scythian Plate, this floor comprises Late Ryphean rift where horst blocks and peri-cratonic depressions are distinguished. Golitsynsko-Bakalskiy crystalline ledge, as the part of Karkinitske paleo-uplift, provides the good example. Ryphean rocks are encountered in the course of oil well drilling in Borysivska field (DH 3, 4) at the depths from 4500 to 6000 m.

Tectonic floor is mainly composed of diverse mafic gneisses, gneisses and amphibolites of Upper Ryphean Bakalska Series which marks Baikalian cycle of tectogenesis.

Baikalian basement of Scythian Plate in the map sheet area is defined in Krymske arch and is expressed in sharp drop of magnetic intensity. Gravity field provides enhanced regional background values and a range of positive sub-latitudinal local anomalies; this suggests for the changes in the Earth's crust deep structure and general sub-latitudinal extension of structures.

Tectonic patterns of the floor are caused by the massifs, faults and tectonic blocks. Ryphean tectonic floor is associated with igneous activity: in the north of the area the massifs are distinguished of Syvaskiy complex of "tele-orogenic" granitoids composed of sub-alkaline and alkaline granites. Their relationships with the host Archean-Proterozoic units in the studied area are not investigated.

In the geophysical fields the given complex is expressed in Syvaskiy gravity minimum. Depth of intrusions is estimated to 3500 m from geophysical data and deep drilling data in Averyanivska and Balashivska fields. Gravity data analysis allows ascription of these massifs to Byrladsko-Pivnichnoazovska zone of gravity minimums with sub-latitudinal zone of Rhyphean granitoid massifs development inside. The massifs have been intruded under compression conditions at Late Ryphean rift closure in the course of Baikalian tectogenesis.

Fault tectonics. Evpatoriysko-Skadovskiy, Bratsko-Perekopskiy and Salgyro-Oktyabrskiy deep-seated faults are distinguished. The breaks inside these zones comprise the intricate system of higher-order sub-parallel faults. The dipping angles and displacement amplitudes are weakly studied yet.

Herzinian tectonic floor C_{1-2} constitutes lower part of structures in Tsentralnokrymske uplift; the latter in the studied map sheet group is comprised of Novoselivske uplift with sub-latitudinal zones of Herzinian folded basement. The floor elements have been identified in the course of oil well drilling in some fields of Novoselivske uplift at the depths 1100-1500 m.

Tectonic floor is composed of Zuyska Suite of black carbonaceous flysch-like quartz-carbonate, graphite-quartz-carbonate schists and Novoselivska Suite of quartz-chlorite, epidote-quartz-mica, actinolite-epidote-chlorite schists. Thickness of tectonic floor exceeds 3000 m.

It is characteristic for the floor that magnetic field intensity decreases along sub-latitudinal zones while gravity field exhibits increased regional background gravity field; this suggests for the changes in the Earth's crust deep structure and general sub-latitudinal extension of structures. Isometric anomalies of magnetic field are also characteristic which probably can be attributed to the igneous rocks.

Herzinian tectonic floor is associated with Novoselivskiy subvolcanic complex expressed in diabase porphyry, gabbro-diorite and granodiorite sills and dykes.

Fault tectonics. It is weakly studied so far. Formation of Herzinian litho-tectonic complex has been accompanied by development of deep-seated zones along sub-latitudinal tectonic breaks with amplitude of some kilometers.

Lower Kimmerian tectonic floor $T\text{-}J_2$ includes diverse-order structures in Prychornomorska depression and Tsentralnokrymske uplift.

In Prychornomorska depression, in the junction zone of Ukrainian Shield and Scythian Plate, Early Kimmerian complex of sediments fills up primary Pivnichnokrymskiy (Syvaskiy) riftogen, which is included in Prydobrudja-Azovska band of pre-Alpine rift depressions formed along the southern margin of Eastern-European Platform [20]. The northern border of this trough does therefore follow the junction zone of Eastern-European Platform with Ryphean block, while its southern margin coincides with the northern boundary of Novoselivske uplift of Herzinian basement. To date, this structure is weakly studied. This rift trough is extended across entire northern part of Plain Crimea. DSS data suggest for the link of this rift with the mantle astenolith evidenced by the identified layer of crust-mantle mixture in the upper crustal part with finite speed 7.5 km/s. According to V.V.Sollogub and N.V.Sollogub, this layer has been resulted from low-density astenosphere uplift at the crustal extension stage (rifting) in Early Kimmerian epoch.

The rift is filled with Triassic – Middle Jurassic litho-tectonic rock complex which lower part is encountered in the course of oil well drilling in Balashivska field. Over there, in DH Balashivska-4, 5, 6, beneath Aptian sediments, the hornfelsites and nodose schists (metamorphic clayey shales) as well as tuff-sandstones and lava of diabse composition are intersected.

Similar association of primary-sedimentary rocks is established in Tarkhankutskiy peninsula. This includes alternating clayey shales, aleurolites, in places limestones and dolomites with interbedding porphyry bodies. Rock dislocation degree is variable, dipping angles vary from 10-30 to 50-80^o.

Tsentralnokrymske uplift is the studied map sheet group includes Novoselivske uplift where sub-latitudinal anticline zones have been formed.

The complex of Early Kimmerian rocks, defined in Novoselivska and Krasnovska fields, is quite similar to the complex intersected by drill-holes in Balashivska field of Pivnichnokrymskiy riftogen.

Among the local structure elements of this floor the massifs and faults are distinguished.

Lower Kimmerian tectonic floor is associated with Pivnichnokrymskiy subvolcanic complex. These rocks are indentified both in Balashivska field, where granite dykes with absolute age 160 Ma cut through volcanogenic-sedimentary sequences, and in Tarkhankutskiy peninsula, where cutting granite bodies are Triassic – Middle Jurassic in age. Their formation corresponds to two compression phase (Late Triassic and Middle Jurassic) occurred in the Early Kimmerian rift zone upon its closure.

Fault tectonics. Formation of primary Pivnichnokrymskiy (Syvaskiy) Early Kimmerian rift has been accompanied by tectonic breaks development along the rift margins with amplitude 2-2.5 km identified in the area of Bakal spit and Donuzlav Lake (Pivnichnotarkhankutskiy, Donuzlavskiy). Sulynsko-Krymskiy and Evpatoriysko-Krasnogvardiyskiy faults, established by gravity survey data, are also traced with a range of magnetic anomalies and decreased value of apparent resistance in VES.

Upper (Alpine) tectonic level K-Q

Alpine tectonic level overlies pre-Alpine fold structures with prominent angular and stratigraphic discontinuity. Two tectonic floors are distinguished: Lower Alpine (K_1-N_1^1) and Upper Alpine (N_1^2-Q).

Lower Alpine tectonic floor K_1-N_1^1 lies with angular and stratigraphic discontinuity and is involved in the 1st-order structures of Scythian Plate – superimposed Prychornomorska depression and Tsentralnokrymske uplift. In both above domains 2nd-order structures are distinguished: Pivnichnokrymskiy Cretaceous riftogen, Novoselivske uplift and Kalynivskiy trough, as well as massifs, faults, tectonic blocks, and numerous structures of 3rd and 4th orders. Tectonic floor is composed of Cretaceous – Eocene terrigenous and volcanogenic sediments and Oligocene – Lower Miocene terrigenous-carbonate sediments of Maykopska Series.

Most extensive uplifts and folding processes had occurred in pre-Chokrakskiy time when Paleogene and Cretaceous sediments were deformed into narrow anticline folds. Folding has been accompanied by disjunctive dislocations. In such zones of tectonic breaks the limbs of anticline folds had been being thrusted over their cores, and in this manner Melova, Rodnikovska and other pseudo-anticlines with Paleogene sediments in the cores have been formed. In the south of the area one of these tectonic breaking zones is expressed at the surface in depression of Donuzlav Lake.

Pivnichnokrymskiy Cretaceous graben-like (riftogenic) trough is included into the chain of age-different trough formed at the junction zone of ancient Eastern-European and young Scythian platforms. It comprises separated portion of Prychornomorska depression composed of Alpine litho-tectonic complex and superimposed over Prydobrudja-Azovska band of pre-Alpine graben-like depressions.

The trough is extended in sub-latitudinal direction over entire central part of map sheet group in the rift 20-35 km wide and is further continued both to the west, towards Black Sea offshore, and to the east. The southern rift border is set by contour lines 2000-2500 m of pre-Cretaceous surface [17], and the northern one coincides with suture zone of pre-Ryphean basement of Ukrainian Shield and Scythian Plate. From the south the trough is separated from Novoselivske uplift by Sulynsko-Krymskiy and Donuzlavskiy deep-seated faults. In the trough basement Carboniferous-Jurassic rocks are developed. Most buried part of the rift is located to the west from Tarkhankutskiy peninsula where Cretaceous sediments footwall is at the depths 7.5-8 km; in the eastern direction it goes up to the depths 2.5-4 km.

Pre-Alpine rock complex in the trough is well enough studied by deep drilling for oil and gas, and by these results inside the trough are established both 3rd-order structures including anticline and syncline structures in Mesozoic-Cenozoic sediments, and a number of local 4th-order structures composed of terrigenous rocks in the lower part, and terrigenous-carbonate sediments in the upper part. The complex contains some intra-formation interruptions.

It is characteristic for Prychornomorskiy trough that it is most expressed in Cretaceous and Paleogene sediments and it is associated with a number of buried Cretaceous volcanoes of mainly Albian – Early Cenomanian time. In the Neogene-Quaternary complex of sediments the trough is less prominent.

According to the seismic surveys and drilling works, a range of local anticline structures are distinguished in Upper Cretaceous sediments: Karlavska, Krasnoyarska, Zadornenska, Mizhvodnensko-Berezivska, Avrorivsko-Pervomayska, and others.

Syncline zones comprise odd-oriented narrow (4-7 km) units extended over 25-30 km and well expressed at the pre-Upper Alpine surface.

The biggest and high-amplitude 4th-order folds are located in Tarkhankutskiy peninsula and folding intensity increases in the southern direction, towards the junction zone of the trough and Novoselivske uplift. The folding is continued inside the latter without changes in tectonic patterns suggesting for its superimposed nature.

The fold structure is very similar. One of the biggest anticline folds, Karlavska, comprises north-east-trending brachy-anticline 9 km long, 3 km wide and 120 m high. In the core, below Miocene limestones drill-holes have intersected Maykopska Series clays. The fold is asymmetric; rock dipping in the northern limb is 10^o, and in the southern one – 13-16^o. With depth the dipping angles increase. Relationships of Karlavska brachy-anticline with other folds are of en echelon type.

Novoselivske uplift comprises 80×30 km in size ledge (elevated block) of Scythian Plate basement extended in sub-latitudinal direction. In the Lower Cretaceous hanging-wall it is expressed in the broad irregularly-shaped dome-like uplift complicated by small dimple in the central and eastern parts. In the north this uplift by Sulynsko-Krymskiy deep-seated fault adjoins Pivnichnokrymskiy rift, and in the south, by Evpatoriysko-Krasnogvardiyskiy deep-seated fault, it adjoins Kalynivskiy trough.

Paleozoic basement in uplift is intersected at the depth 1100-1500 m and is well expressed in the gravity field. Uplift is asymmetric: its northern limb is steeper, with Upper Cretaceous dipping angles 5-6^o, Jurassic – 8-

12°, Paleozoic – 20°; and the southern limb is more flat. Lower Alpine tectonic floor in the uplift is composed of Lower Cretaceous parti-coloured terrigenous rocks and Upper Cretaceous terrigenous-carbonate sediments; the latter are lacking in the highest uplift parts. Complex of sedimentary rocks is cut by subvolcanic bodies.

The rocks of Lower Alpine tectonic floor are deformed into the linear folds. Using marker horizons of Cretaceous sediments in seismic surveys, sub-latitudinal anticline zones are defined in Novoselivske uplift – Pivnichnonovoselivska, Novoselivska, as well as Vynogradivska syncline zone located to the south. In the younger Paleogene sediments the group of en echelon local brachy-anticlines is defined; the uplift axes in Paleogene sediments are somewhat shifted to the north and east. Structure of the local uplifts is similar. The length of individual folds is 10 km, width – 2-3 km, rock dipping in the limbs is under angles from 3-4 to 15°, and often their southern limbs are steeper.

For instance, Oktyabrske uplift comprises latitudinal asymmetric brachy-anticline, 12 km long in Upper Cretaceous sediments, 4 km wide, and 320 m high. Rock dipping in the northern limb is 10-13o, in the southern one – 20-35o; besides that, the southern limb is complicated by two vertical normal faults expressed in Late Paleogene. Fault amplitude is from 100 m in the west to 500 m in the eastern part of the fold. In the core, beneath Miocene limestones drill-holes have intersected sediments of Danian Bilokamyanskiy horizon, and in the limbs – Paleocene and Eocene. From the north and south Oktyabrska anticline is separated from other uplifts by the shallow syncline depressions. Tectonic patterns in all Upper Cretaceous units coincide; with depth the anticline gets narrower and steeper. In Lower Cretaceous sediments the fold is north-east-trending and its northern limb is steeper than southern one. Most active Oktyabrske uplift was in the end of Oligocene and in the beginning of Miocene. Late Alpine phase did not affect development of this structure.

Among the local tectonic elements of the floor under consideration the faults and subvolcanic bodies are distinguished. Specifically, Tarkhankutskiy subvolcanic complex is developed n Pivnichnokrymskiy rift and Novoselivske uplift. Subvolcanic bodies are confined to sub-latitudinal reverse fault-thrust zones with Late Albian activation of Donuzlavskiy and Sulynsko-Krymskiy breaks. The bodies are expressed in a range of positive gravity anomalies and are intersected by drill-holes. The complex includes dykes and vein bodies of granodiorites, andesite porphyries and plagiogranites.

Kalynivskiy trough in the map sheet group is presented by the fragment in the north-east of the territory; it comprises continuation of deep trench extended in the north-eastern direction from Evpatoriya town and is followed by Gvardiyskiy trough (outside the eastern border of studied map sheets).

Kalynivskiy trough bounds from the south Novoselivske uplift with basement altitudes from 1000 to 1500 m. In comparison to adjacent uplifts, Albian sediments are thicker in the trough and Upper Cretaceous – Lower Miocene column is more complete.

Fault tectonics. Alike plicative tectonics, it is important in structures of Lower Alpine tectonic floor. The breaks are defined by geophysical data and supported by drilling works. The faults include sub-latitudinal reverse-thrusts, thrusts, in lesser extent – diagonal normal faults and fault-shears along deep-seated fault zones.

The 3rd-order structures, mentioned above and shown in "Tectonic scheme in the scal1 1:500 000, can be considered as the frontal zones of sub-latitudinal tectonic thrusts. In Pivnichnokrymskiy rift fault planes are commonly inclined to the north. In the lower part of Early Alpine complex dipping angles are 15-20° while higher in the column they increase to 30-70°. Horizontal displacement amplitudes by Cretaceous footwall attain 1.5 km, by Upper Cretaceous – Paleogene sediments – 500 m, and Neogene ones – 50 m. In Novoselivske uplift reverse fault-thrust planes dip to the south under angles 10-15o and displacement amplitude by Lower Cretaceous footwall is 0.5-1.0 km.

Diagonal north-west-trending breaks are accompanied by the fault-shear deformations. Displacement counterpart amplitude attains 2.5 km, and normal fault amplitude – 40-50 m, dipping angles – 70-90°. The breaks have been activated late in Oligocene – Miocene. The folding processes were also affected by the system of north-eastern basement faults activated in Miocene. The cross-wise faults are also distinguished apparently linked with the longitudinal Evpatoriysko-Skadovskiy fault. Some are expressed in Cretaceous sediments while others were developing up to Miocene.

Upper Alpine tectonic floor (N_1^2-Q) lies over Lower Alpine floor with prominent angular and stratigraphic unconformity. The floor constitutes 1st-order structures – Prychornomorska depression and Pivnichnokrymske uplift with the border between the two extended in latitudinal direction through Bakal peninsula.

Prychornomorska depression in the map sheet group is represented by the 2nd-order structure – Pivnichnokrymskiy trough retained upon closure of the same-named Cretaceous riftogen. Tsentralnokrymske uplift includes Tarkhankut-Novoselivske uplift, developed under inherited mode from Novoselivske uplift and the zone of inversion uplifts and Late Alpine folding in the southern part of Cretaceous riftogen (Gamburtsivsko-Tarkhankutska zone or Tarkhankutskiy arch), and Kalynivskiy trough which bounds Tarkhankut-Novoselivske uplift from the south-east.

The floor is composed of up to 500 m thick Upper Cenozoic sediments which overlie Lower Alpine floor with irregular blanket filling up depression resulted from insufficient motions during formation of 3rd and 4th order structures. Upper Cenozoic sediments exhibit relatively simple structure and flat dipping.

Most structures in sedimentary cover are directly linked with the basement motions and do have long-term and inherited nature. In general, sediments of this floor constitute monocline limb of Prychornomorska depression with flat uplift in the north. The monocline is complicated by higher-order structure forms of various morphology and genesis, of which most developed are local folds and flexures tightly related to the Lower Alpine anticline and syncline zones of Scythian Plate. These structures are oval-shaped up to 3-5 km across. Besides that, the monocline is also complicated by the local dimples. The monocline dipping angles are 1-3°, increasing to 5-10° in the local forms. Thickness of sediments increases towards the central part of Prychornomorska depression.

In the south-east, in Kalynivskiy trough, thick enough Pliocene-Quaternary sediments are preserved from erosion because of neo-tectonic and modern subsiding processes.

Fault tectonics. The breaks are also important in structure of Upper Alpine tectonic floor. Their majority is inherited and related to Late Miocene – Anthropogenic activation and rejuvenation of previously developed deep-seated regional faults. Tectonic breaks include thrust-shears, thrusts and normal faults. Their vertical amplitude is low (up to first tens of meters) and horizontal displacement is up to 1.5 m. Faults are well expressed in geological cross-sections because of basic horizon depth and thickness switches, as well as in sudden sediment lithology and facies changes. The breaks are often observed in outcrops of Neogene sediments.

The line Slavne-Orlivka villages is followed by Serebryanskiy north-west-trending normal fault which reflects neo-tectonic activation of Alushtynsko-Bakalskiy fault. This break is defined by vertical displacement of Pontychni and Sarmatian sediments (northern limb is pulled down by 30 m). By latitude Susanine-Zymine villages are defined sub-latitudinal breaks of Pivnichnonovoselivskiy thrust which complicate the southern limb of Pivnichnonovoselivska anticline; in Sarmatian sediments this is reverse fault with vertical displacement amplitude up to 60 m and horizontal – up to 1.5 m. The north-west-trending normal fault crosses Rodnikovska anticline. Vertical displacement amplitude for Pontychni limestones is estimated up to 30 m.

Studies of neo-tectonic motions in the territory suggests for modern vertical movements of some blocks in the basement of Scythian Plate (Fig. 4.1). Analysis of geomorphologic levels indicates that most extensive upward motions are observed in the north-west of Novoselivske uplift (Tarkhankutskiy peninsula) while in the north of the area, in Pivnichnokrymskiy trough and partly in Kalynivskiy trough, the downward motions predominate.

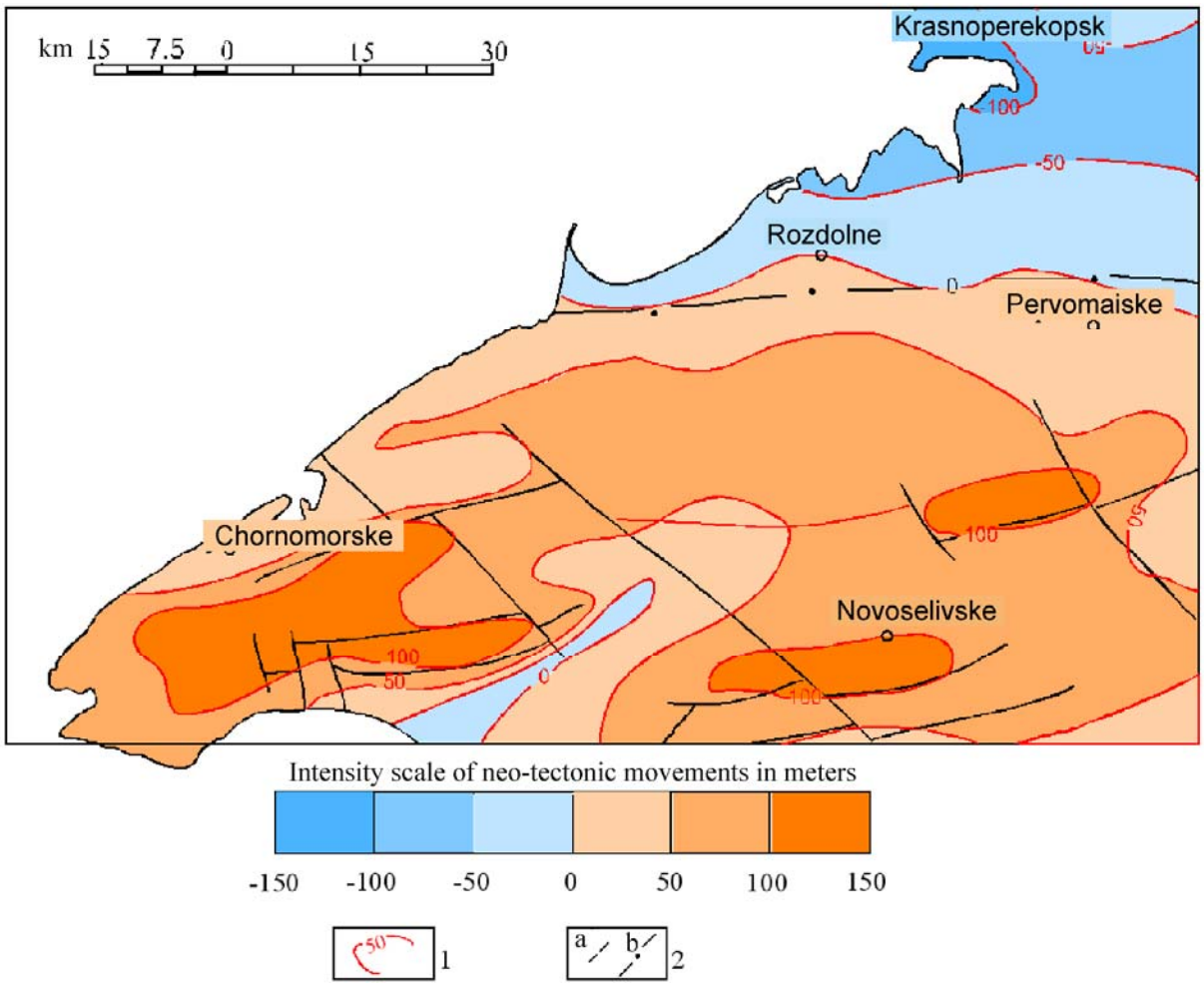

Fig. 4.1. Scheme of neo-tectonic and modern motions, after M.M.Novyk with application of morpho-structure analysis.

1 – depth contour lines of modern (Pliocene-Quaternary) tectonic motions; 2 – faults expressed in a) Neo-Pleistocene time, b) Pliocene time.

5. HISTORY OF GEOLOGICAL DEVELOPMENT

In the history of geological development of the studied territory five major epochs are distinguished: pre-Baikalian, Baikalian, Herzinian, Kimmerian and Alpine, which differ in the types of geodynamic regimes and related geological processes. First three epochs have been completed with formation of intrusive complexes: Ryphean – with Syvaskiy, Paleozoic – with Novoselivskiy, and Kimmerian – with Pivnichnokrymskiy complexes. Alpine magmatism in the map sheet area is expressed in Tarkhankutskiy complex of small intrusions and dykes.

The data available are obviously insufficient for reconstruction of the area geological development in pre-Ryphean and Ryphean epochs. Formation of Syvaskiy complex, involved in extended Prychornomorsko-Azovskiy belt of granitoid plutons, is related to the closure of Dobrudja-Krymska rift zone [14, 18]. The latter has been formed within young Scythian Plate due to destruction of continental crust and epi-Karelian craton breakdown in two blocks – northern (Ukrainian Shield) and southern (Chornomorskiy) separated by Dobrudja-Krymska rift zone.

Ryphean complex (Bakalska Series), composed of metamorphic rocks, is extensively deformed and enriched in diverse-order fold and fault dislocations making complicated deciphering of structure. As a result of Late Ryphean tectogenesis (Chornomorskiy, to be analogue of Dalslandian in Scandinavia), the sequences were consolidated and have formed the crystalline basement of young Scythian platform. Up to Late Paleozoic the territory has been under sub-platform regime.

In Late Paleozoic (Carboniferous time), in the southern part of the region, on the Ryphean basement of young Scythian platform sub-latitudinal Novoselivsko-Simferopolskiy trough emerged, where thick Zuyska and Novoselivska suites were depositing including phillite-like quartz-carbonate-mica and quartz-chlorite, actinolite-epidote-chlorite schists. As a result of Herzinian tectogenesis, accompanied by greenschist-facies metamorphism and subvolcanic Novoselivskiy complex emplacement, the mountain system has been formed in place of trough late in Paleozoic (Novoselivske uplift). Later on with time, it was peneplainized and pulled down beneath sea level while its remnants existed as the islands.

Kimmerian period in the region development in Late Triassic, in front of Herzinides in Syvaskiy trough, is marked with formation of superimposed Early Kimmerian rift zone extended through the northern part of modern Plain Crimea. It is included in the broad Prydobrudja-Azovska band of pre-Alpine graben-like troughs in the junction zone of ancient Eastern-European Platform and young Scythian Plate. Formation of rift is caused by the Earth's crust extension (rifting).

Early Kimmerian litho-tectonic complex of Syvaskiy trough is composed of hornfelsites and nodose schists (metamorphosed clayey shales), argillites, tuff-sandstones, and diabase porphyries. It is intersected by drill-holes in Tarkhankutskiy peninsula and Balashivska field. This complex is cut by granitoid intrusions of Pivnichnochornomorskiy complex (160 Ma, DH Balashivska-4, 5, 6). Emplacement of the latter is related to two tectonic phases of compression and inversion in rift zone, first in Late Triassic, and then in Middle Jurassic, resulted in Early Kimmerian rift zone closure late in Middle Jurassic. Over subsequent long-term continental regime most part of the region comprised coastal plain with branched tectonic relief.

Thus, over Kimmerian period of region development the bases of 1^{st}-order structures in Scythian platform have been created – superimposed Prychornomorska depression and Tsentralnokrymske uplift. And in these structures the 2^{nd}-order units have commenced to form – Pivnichnokrymskiy and Kalynivskiy troughs and Novoselivske uplift.

Alpine period is divided in two major phases of geological history – Early Alpine (K_1-N_1) and Late Alpine (N_2-Q), where, in turn, some stages are distinguished: Early Cretaceous – Cenomanian, Turonian – Early Paleocene, Late Paleocene – Eocene, Oligocene – Early Miocene, Middle – Late Miocene, and Pliocene – Quaternary.

In Cretaceous stage of Early Alpine phase, in the junction zone of Eastern-European and Scythian platforms Early Cretaceous Pivnichnokrymskiy graben-like (riftogenic) trough was forming which is the part of Prychornomorska depression. It is characteristic that this trough is only expressed in sediments and it is associated with numerous buried Cretaceous, mainly Albian – Early Cenomanian volcanoes. Emplacement of Tarkhankutskiy subvolcanic complex is also related with Late Albian time.

Formation of Kalynivskiy and Pivnichnokrymskiy troughs continued over Late Cretaceous and the axis of the latter was gradually switching northward. Most extensive elevation had occurred in pre-Chokrakskiy time. Paleogene and Cretaceous sediments were deformed into narrow anticline folds complicated by thrust-type breaks and resulted in formation of pseudo-anticlines like Melova, Rodnikovska, etc.

Late Alpine phase (its Pliocene-Pleistocene stage) is neo-tectonic and it is characterized by mainly vertical motions. It is accompanied by faults most of which are inherited and related to rejuvenation of early formed regional basement breaks. Most notably this activation was expressed in Berezanskiy time, at the border of Pliocene and Holocene. The sea is only preserved in the most subsided part of Pivnichnokrymskiy trough. Novoselivske uplift and Tarkhankutskiy peninsula were developing as a common structure and laterite-like cherry-red clays were depositing over there with maximum thickness confined to sub-latitudinal tectonic zones (DH 273). On the slope of Prychornomorska depression extensive erosion of Pontychna surface also suggests for continental regime. And only in Late Kimmerian time the territory is pulled down beneath the shallow sea level, and with repeating interruptions thick sandy-clayey sequences were depositing over there (DH 182).

In Eo-Pleistocene the IX and X denudation levels were forming in Tarkhankut-Novoselivskiy area, deposition of red-coloured sediments had continued (aeolian-deluvial and eluvial-deluvial), and to the north, in the relief dimples, lake clayey sediments of Prysyvaska sequences occurred.

Next phase in erosion level switch does correspond to Early Neo-Pleistocene. The VIII and VII denudation levels have been formed. Uplifts in Tarkhankut-Novoselivskiy area have caused river valley moving to the south, the side erosion and pebble material accumulation at Bulganatskiy and Novovasylivskiy terrace levels commenced, as well as deposition of aeolian-deluvial and eluvial-deluvial sediments continued.

Tectonic motions in Middle Neo-Pleistocene are expressed in the changes of erosion level and formation of VI and V terrace levels. Uplifting in Tarkhankut-Novoselivskiy area and subsidence in Pivdennosyvaskiy area continued over that time. At the watersheds aeolian-deluvial loams, and in gullies and rivers – alluvial and alluvial-proluvial sands and pebble-stones of Novopavlivskiy and Sudatskiy terrace levels were forming which overlie the older rocks.

Next phase in erosion level changing fell to Late Neo-Pleistocene when IV, III and II terrace levels were formed. In Late Neo-Pleistocene time main features of previous stage were preserved while tectonic activity increased a bit and significant erosion cuts have been formed. Deposition of Quaternary loams has been completed at the watersheds. In Karkinitska Bay marine sediments of Vylkivskiy horizon were deposited first, and then later on sea lagoon emerged over there where marine and estuary sediments of Surozkiy horizon were depositing.

Over Holocene the relief formation was continuing under influence of tectonic and denudation processes. Analysis of geomorphologic data suggests for the axes movement of novice uplifts to the north, relatively to the older layout. Holocene sedimentation includes coluvial, deluvial-proluvial, aeolian-deluvial, eluvial-deluvial, alluvial-proluvial, alluvial, as well as marine, estuary, lake, and technogenic types.

Over Pleistocene time multiply periodic changes in climate conditions had occurred. Each warm stage has been accompanied by formation of soil horizons, and the cold one – deposition of loess-like sediments. All Quaternary sediments were formed in the back-glacier zone.

Modern vertical movements – uplifting in Tarkhankutske plateau and subsidence in Prychornomorska depression – will cause in the future, from the one hand, Syvash escaping to the north, and from another hand – sea strait formation and Crimea separation from the continent.

Perhaps, from the point of view of the modern lithosphere plate geotectonic concept the history of structure formation in the region may be presented in another way. It can be considered as the sequential addition of terrains with different age of basement consolidation to the ancient Eastern-European Platform. First time, in Early Paleozoic, a terrain of Baikalian consolidation (Ukrainia) has been added through collision to the ancient platform, then in Late Paleozoic next collision had resulted addition of the terrain with Herzinian consolidation (Scythia) to the southern margin of Baikalian craton. Finally, in this direction of geological history, Mesozoic, to the south of studied area the Mountain Crimean terrain (Crimia) was added to the margin of Herzinian craton.

6. GEOMORPHOLOGY AND RELIEF-FORMING PROCESSES

According to geomorphologic zonation, the territory of map sheet group is ascribed to the province of Plain Crimea which comprises the counterpart of Prychornomorska lowland. Combination of exogenic and endogenous relief-forming processes has caused formation of diverse relief types which are tightly related to the geological structure and modern tectonic motions. Structure-denudation, erosion-denudation and accumulative relief types are widely developed.

Geomorphologic zonation has been performed by previous authors [5] using historic-morphogenetic principle [34] which implies the modern relief comprises a range of age-different surfaces of smoothing. Their links in the space, combination of similar morphogenetic features and similarity in the history of relief development had provided the ground to distinguish two sub-provinces in the province of Plain Crimea (in the map sheet group) – Prysyvaska erosion-accumulation plain and Tarkhankutsko-Novoselivska structure-denudation height.

Prysyvaska erosion-accumulation plain

It encompasses the northern part of the area and in the south adjoins Tarkhankutsko-Novoselivska structure-denudation height; from the north it is bounded by Syvash Lake whose coasts comprise the intricate labyrinth of straits, bays and lakes which are periodically get dried in the river and gully tongues (so called "droughts"). Two relief types are developed in this plain: erosion-accumulative and accumulative. Over there, the major factors for the modern relief formation include processes of aeolian and alluvial accumulation with minor value of estuary accumulation and erosion processes.

Prysyvaska plain comprises accumulative loess plain elevated above sea level from 0.1 m (in the north) to 20 m (in the south). Its primary surface is of Late Pliocene – Early Eo-Pleistocene age (N_2-E_1) and is slightly cut by shallow broad river valleys and gullies with gentle slopes, over most territory without signs of modern erosion cut suggesting for the land pulling down. In some places only river erosion is notable and causes some relief cut – vertical (up to 10 m) and horizontal (erosion network length – 0.02 km per 1 km^2). Erosion network includes plain-type rivers – Chatyrlyk, Vorontsivka, Samarchyk, whose valleys are from 200 m to 2 km wide at the mouth, as well as the system of sub-longitudinal gullies originated from Tarkhankutsko-Novoselivska height. In the northern part of the plain the valley-type dimples are developed confined to the buried river valleys. The watershed surfaces are slightly-wavy with some hills (relative height up to 8 m) and hollows comprising the sites for season accumulation of atmospheric precipitates or irrigation water drops providing over-wetting and soil swamping. In the river valleys the flood-land and first over-flood terrace are well expressed.

The first over-flood terrace is observed in the narrow band (up to 0.5 km along Chatyrlyk river) along the flood-land. Terrace height does not exceed 2 m, back sutures are unclear, smoothed and are gradually changed by watershed discharges. Terrace benches are overgrown with grass; slope dips are from 10 to 70°. In the valley tongues marine and estuary-marine accumulation is developed in association with formation of modern coastal-marine terraces.

The group of Prysyvaski lakes – Krasne, Stare, Kiyatske – comprises the distinct geomorphologic elements. Their high (up to 14 m) abrasive shores are composed of aeolian-deluvial sediments and are gradually changed by the lowered sites. These lakes are thought to be the relicts of estuary bays separated from the Syvash water area due to sea regression and territory uplifting. Abrasion processes are also developed along the coast of Karkinitska Bay where they do form up to 8 m high abrasion cliff.

Tarkhankutsko-Novoselivska structure-denudation height

It encompasses most part of the territory and in the north adjoins Prysyvaska erosion-accumulation plain. The border between the two is well expressed in the relief bend – smoothed bench between sub-horizontal flattening surface of erosion-accumulation plain and denudation slope of watersheds in Tarkhankutsko-Novoselivska height.

The most important feature of this area comprises direct elements reflecting of positive neo-tectonic structure – Novoselivske uplift – in the relief. Anticline uplifts elongated in sub-latitudinal direction are expressed in the relief by the heights with plateau-like surfaces while the lowered relief sites with developed river valleys and big gullies are confined to the syncline troughs.

General relief features in Tarkhankutsko-Novoselivska height include: 1) significant horizontal and vertical cutting in the areas adjoining to the river valleys; 2) spit development in the coast which separate a range of salt lakes (former marine bays and harbours) in the under-flooded mouths of river valleys and gullies (Donuzlav, Dzharylgach, Panske, Yarylgach lakes); 3) karst occurrences at the sites of erosion cut approaching sequences of carbonate rocks.

By morpho-structure features in the given sub-province two geomorphologic regions are distinguished: structure-denudation-erosion plain and actually structure-denudation surface of Tarkhankutska height.

The structure-denudation-erosion plain encompasses the central, northern and eastern parts of sub-province. This is considerable plateau-like surface which is irregularly eroded by valleys and gullies. The central part of the plain exhibits significant horizontal (0.5-2.0 m) and vertical (up to 10 m) relief cutting; here direct link of modern relief with anticline and syncline structures is quite well observed. The northern part (Bakalsko-Chatyrlytska) looks like slightly-wavy steppe plain with relatively mild relief outlines. Flat plateaus in the central watershed parts and highly flattened watershed slopes separated by broad gullies are characteristic for this area. The link between tectonic structures and modern relief is almost not observed over there.

The following relief forms are developed in the mentioned area: structure-denudation, erosion-denudation, erosion-accumulative, and somewhere accumulative. Structure-denudation relief is developed in the gently inclined to the north smoothing surface in the area of Susanine-Tanyne villages with altitudes up to 137 m. It is composed of limestones of Pontychniy, Meotychniy and Sarmatian regio-stages and thin eluvium; the surface is of Late Miocene – Holocene age (N_1-H). Its formation is caused by recent uplifting tectonic motions. From the south it is bounded by neo-tectonic break expressed in Neogene and Anthropogene sediments. This fault zone has caused development of sub-latitudinal gully and depression filled with Quaternary sediments (in the area of Voykove, Susanine villages).

The same relief type is also attributed to the smoothing surface extended in sub-latitudinal direction in the area of Kirovske-Oktyabrske towns and Natashyno-Stakhanivka villages, with altitudes 65-100 m. It is composed of aeolian-deluvial and deluvial-proluvial sediments and is of Late Miocene – Early Pliocene age (N_1-N_2). The relief of this surface is slightly hilly. Single low ridges and individual heights in watershed sites are oriented in sub-latitudinal direction and are up to 1 km long and 0.2-1 km wide; hill slopes are gentle (0.5-1.5^o) and overgrown with grass.

These smoothing surfaces are separated one from another by Miocene – Early Pleistocene erosion-denudation slopes. The surfaces are cut by dense sub-latitudinal and sub-longitudinal erosion network and gently pull down to the north towards Prysyvaska erosion-accumulative plain and Black Sea coast. The slopes are composed of Lower Neo-Pleistocene deluvial-proluvial and aeolian-deluvial sediments. The border of watersheds and their slopes is clearly observed only in the area of Vynogradne-Vogneve villages where relief bend is confined to Donuzlavskiy fault. Erosion-accumulative relief type is resulted from processes of prevailing alluvial and aeolian-deluvial accumulation and partly erosion. Erosion network in the plain includes upper courses of Samarchyk, Vorontsivka and Chatyrlyk rivers, as well as branched gully system providing the transport channels for surface water drops.

Intensity and direction of neo-tectonic motions significantly affect morphology of river and gully valleys being expressed in the courses and thalwegs straightening, canyon-like valleys development with up to 12 m bench height (Samarchyk river) and up to some hundreds of meters long. The banks of these gullies are steep (30-60^o), complicated by grooves, their cross-section is V-like, bottom width attains up to 100 m, length – up to 500 m, and modern course depth not exceeds 1.5 m. In the upper course of Chatyrlyk river the flood-land and I and III over-flood terraces are well expressed. Terrace height is 2 m, back sutures are smoothed and gradually move into watershed surfaces. In some coast sites of Karkinitska Bay the active processes of marine and estuary-marine accumulation are observed providing modern coastal-marine sand terraces up to 1 km wide and up to 3 m high (Bakalska spit). Besides terraces, the sand beaches and spits are also developing. In the area Dmytrivka-Voykove villages, at the border of neo-tectonic blocks, in the trough zone at altitudes 40-60 m the fragment is observed of smoothing surface gently-dipping towards Chatyrlyk river course and composed of Middle Neo-Pleistocene – Holocene alluvial-proluvial and deluvial-proluvial sediments.

The distinct types of exogenic relief-forming processes in this plain include karst and karst-erosion relief forms – niches, grottos, funnels and other hollows. Karst is imposed on 50-160 m thick Pontychni, Meotyhcni and Sarmatian limestones. The karst relief forms are most typical for the sites of open karst confined to the gully bottoms and banks and related to the zones of tectonic breaks. Some karst hollows attain 10 m across.

Structure-denudation surface of Tarkhankutska height encompasses the western part of Tarkhankutsko-Novoselivska structure-denudation height. Structure-denudation and in lesser extent erosion-denudation and erosion-accumulative relief types are developed over there. The modern relief of Tarkhankutske plateau is

contrasted enough and consists of the odd-age smoothing surfaces which are correlated with the similar surfaces in structure-denudation-erosion plain but located at higher altitudes.

Late Miocene – Holocene smoothing surface comprises the highest geomorphologic level about 120-170 m high above sea line. In its flat-convex watersheds the hard, mainly carbonate rocks (and their eluvium) are exposed, in places providing 0.3-0.5 m high benches. Width of some heights is 2-2.5 km and their length – up to 10-12 km.

The next geomorphologic level includes Late Miocene – Early Pliocene smoothing surface which surrounds previous, higher surfaces. The watersheds and slopes of this level are inclined towards periphery parts of Tarkhankutske plateau and are complicated by ravine-gully network. The surface altitudes are from 80 to 120 m. The boundary with older geomorphologic level is not clear and gradual [34]. Erosion network exhibits radial-concentric patterns, where gully valleys are fan-arranged outward, suggesting for long-term uplift of some structures in the area. Longitudinal gullies are mainly straight, short, deep-cut. Their banks are high (10-15 m) and steep (up to 40^{o}). Sub-latitudinal gullies are flattened, trough-like. They are associated with Neo-Pleistocene – Holocene erosion-accumulative relief forms composed of alluvial-proluvial and deluvial-proluvial sediments.

At the sites adjacent to the plateau slopes, Miocene – Late Neo-Pleistocene fan plain is distinguished and formed by contiguous fans composed of proluvial and deluvial-proluvial sediments.

The smoothing surfaces noted above are separated by the flat Miocene – Early Neo-Pleistocene erosion-denudation slopes composed of aeolian-deluvial sediments. The southern plateau slopes are short and steep (inclination – 0.02), complicated by cobble and gravel heaps over hard rocks. The western part of Tarkhankutske plateau exhibits most extensively cut relief. Narrow anticline cores are inherited and cause over there formation of narrow, elevated to 150-170 m above sea level flat-convex watersheds and their eroded slopes.

Important relief-forming and dynamic processes in the coast of Tarkhankutskiy peninsula include gravitation and abrasion. Significant development of land-slide forms over there had caused formation of so called “Dzhangulske land-slide coast” (2508×100 m in size) with chimera exotic relief micro-forms. In the interval from Donuzlav Lake to Maryine village, the height of active abrasion coast, composed of Late Neo-Pleistocene aeolian-deluvial and deluvial-proluvial sediments, is 5-20 m. In the far west of Tarkhankutskiy peninsula the abrasion cliff, developed in Sarmatian limestones, attains 40 m in height (Atlesh). Sea coast is highly cut by numerous small harbours, the coast benches are penetrated by grottos and abrasion hollows in association with the cliff-remnants.

In the mouths of big gullies abrasion bench is replaced by low flat accumulative shore – beach, and some sea bays and harbours, separated from the sea by spits, do form the lakes. The biggest one (Donuzlavske), 30 km long and 0.6-1.0 km wide, is located in the south-eastern part of Tarkhankutska structure-denudation height. It is confined to the north-east-trending deep-seated fault zone and has been formed in Late Pleistocene – Holocene time be means of ancient sea bay separation into the lake of estuary type. In the spit and sea coast areas estuary-marine sediments are developed [4]. The north-east coast of Donuzlav Lake is cliffy (to the east from Myrne village bench height attains 10-12 m) and is often complicated by the slides. The lake depth attains 15-25 m [9].

Important role in the relief-forming process is played by karst. The open karst hollows are developed in Donuzlavska valley, Kelsheykhska harbour, and coastal niches in the west of Tarkhankutskiy peninsula. The karst and karst-erosion relief forms and elements including hollows, niches, funnels, etc. are widely developed on the plateau surface providing additional impressive features to the landscape. Karst funnels in places are 2-10 m in size.

7. HYDROGEOLOGY

According to zonation, the north-western part of steppe Crimea encompasses hydrogeological areas of Plain Crimea artesian basin (G) and partly Prychornomorskiy artesian basin (H) (Fig. 7.1).

In the cover sediments of the Crimean platform part some consistent regional water-proofs are distinguished, specifically, mainly water-proof Aptian-Albian and partly Upper Cretaceous sediments (marls, clays), Paleogene clays; Lower Sarmatian clays and clays of Pliocene Kuyalnytski layers are also consistent over the area. On the ground of previous works the authors have distinguished the following water-bearing horizons and complexes:

- water-bearing horizon in Holocene estuary and marine sediments (m,lmH);
- water-bearing horizon in Upper Neo-Pleistocene – Holocene alluvial and alluvial-proluvial sediments (a,apP_{III}-H);
- water-bearing horizon in Neo-Pleistocene eluvial-deluvial, aeolian-deluvial and proluvial-deluvial sediments (ed,vd,pdP_{I-III});
- water-bearing horizon in Eo-Pleistocene alluvial, alluvial-proluvial sediments (a,apE);
- water-bearing horizon in Pliocene Kuyalnytski and Kimmerian sediments (N_2kl-k);
- water-bearing horizon in Sarmatian-Meotychni-Pontychni sediments (N_1s-p);
- water-bearing horizon in Middle-Upper Sarmatian and Meotychni sediments (N_1s_{2-3}-m);
- water-bearing horizon in Middle-Upper Sarmatian sediments (N_1s_{2-3});
- water-bearing complex in Middle Miocene and Middle-Upper Sarmatian sediments (N_1^2-N_1s_{2-3});
- water-bearing complex in Middle Miocene and Lower Sarmatian sediments (N_1^2-N_1s_1);
- water-bearing complex in Middle Miocene sediments (N_1^2);
- water-bearing complex in undivided Paleocene-Eocene sediments (P_{1-2});
- water-bearing complex in Upper Cretaceous sediments (K_2);
- water-bearing complex in Lower Cretaceous sediments (K_1);
- water-bearing horizon in Lower-Middle Carboniferous sediments (C_{1-2}).

Quaternary sediments

Water-bearing horizon in Holocene estuary and marine sediments (m,lmH) is developed in separate narrow bands along the sea coast and is the first from the surface. Thickness is 0.6-0.8 m. Water-bearing rocks include sands and sandy loams with mud interbeds. From below they are underlain by dense loams and clays of various genesis, but often water-proof rocks are lacking providing hydraulic link with underlaying water-bearing horizons. The horizon is ground-seated with depth 0.1-1.0 m, and in the site away from the coast – up to 3 m.

Specific borehole yields are 0.086-86.4 m^3/d. Waters are salty to brines, chloride sodium. Horizon is fed through atmospheric precipitates and water inflow from underlaying horizons, as well as through sea water "pushing" by the winds.

Water-bearing horizon in Upper Neo-Pleistocene – Holocene alluvial and alluvial-proluvial sediments (a,apP_{III}-H) is locally developed in the flood-lands and first over-flood terraces of Samarchyk, Vorontsivka, Chatyrlyk rivers. Water-bearing rocks include sands with pebble and gravel, sandy loams and loams with clay interbeds. Waters are ground-seated and underlain by denser rocks of various age and genesis, in some places they have hydraulic link with underlaying water-bearing horizons. Specific borehole yields are 0.864-129.6 m^3/d. Filtration coefficients are variable, depending on rock lithology, and vary from 5 to 60 m/d.

Water mineralization is 0.5-0.7 g/dm^3, in upper courses – up to 7.9-22.4 g/dm^3. Chemical composition varies from sulphate-hydrocarbonate to chloride.

Water-bearing horizon is fed through atmospheric precipitates and irrigation water infiltration; discharge is being done to Black Sea and underlaying water-bearing horizons. Water-bearing horizon is out of practical value.

Water-bearing horizon in Neo-Pleistocene eluvial-deluvial, aeolian-deluvial and proluvial-deluvial sediments (ed,vd,pdP_{I-III}) is developed in Prysyvaska plain, over remaining area these rocks are water-permeable but dry. It is first below the surface and confined to Neo-Pleistocene loams, sandy loams and clays from 5 to 20 m thick. It is underlain by Lower Neo-Pleistocene aeolian-deluvial clays and Pliocene clays. Natural groundwater regime is broken due to irrigation and water infiltration from the channels. Specific borehole yields are 0.26-2.12 m^3/d, loams filtration coefficients are 0.3-2.2 m/d, clays – 0.1-0.008 m/d.

Chemical composition is variable, from sulphate-hydrocarbonate magnesium-sodium to chloride sodium. Water mineralization is from 0.8 to 135 g/dm^3, the lowest mineralization exhibit groundwaters in the irrigation channel zones, the highest – at the coast of Karkinitska Bay and Syvash.

Water-bearing horizon is fed through irrigation waters, infiltration from the transporting and irrigation channels, as well as atmospheric precipitates. Discharge is being done via low-yield springs in the coast, into underlaying water-bearing horizons, partly through evaporation.

Water-bearing horizon in Eo-Pleistocene alluvial, alluvial-proluvial sediments (a,apE) is confined to the tenth and ninth buried terraces developed in the mouth parts of Samarchyk and Chatyrlyk rivers. Eo-Pleistocene alluvial and alluvial-proluvial sandy loams, sands with pebble and gravel are overlain by Neo-Pleistocene aeolian-deluvial and eluvial-deluvial loams. With the latter the waters are in hydraulic connection and they do have common level of 1.0-10 m. Total thickness of water-bearing rocks varies from 2.4 to 15.6 m being increased towards Karkinitska Bay. Groundwaters move in the same direction. Specific yields are 0.43-106.27 m^3/d, filtration coefficients do not exceed 10 m/d.

Water mineralization is 0.5-4.5 g/dm^3. Feeding is being done through water inflow from overlying water-bearing horizon of aeolian-deluvial and eluvial-deluvial sediments, as well as through discharge of overlying Pliocene water-bearing horizons. Own water discharging is being done to Karkinitska Bay. Waters of this horizon are out of practical value.

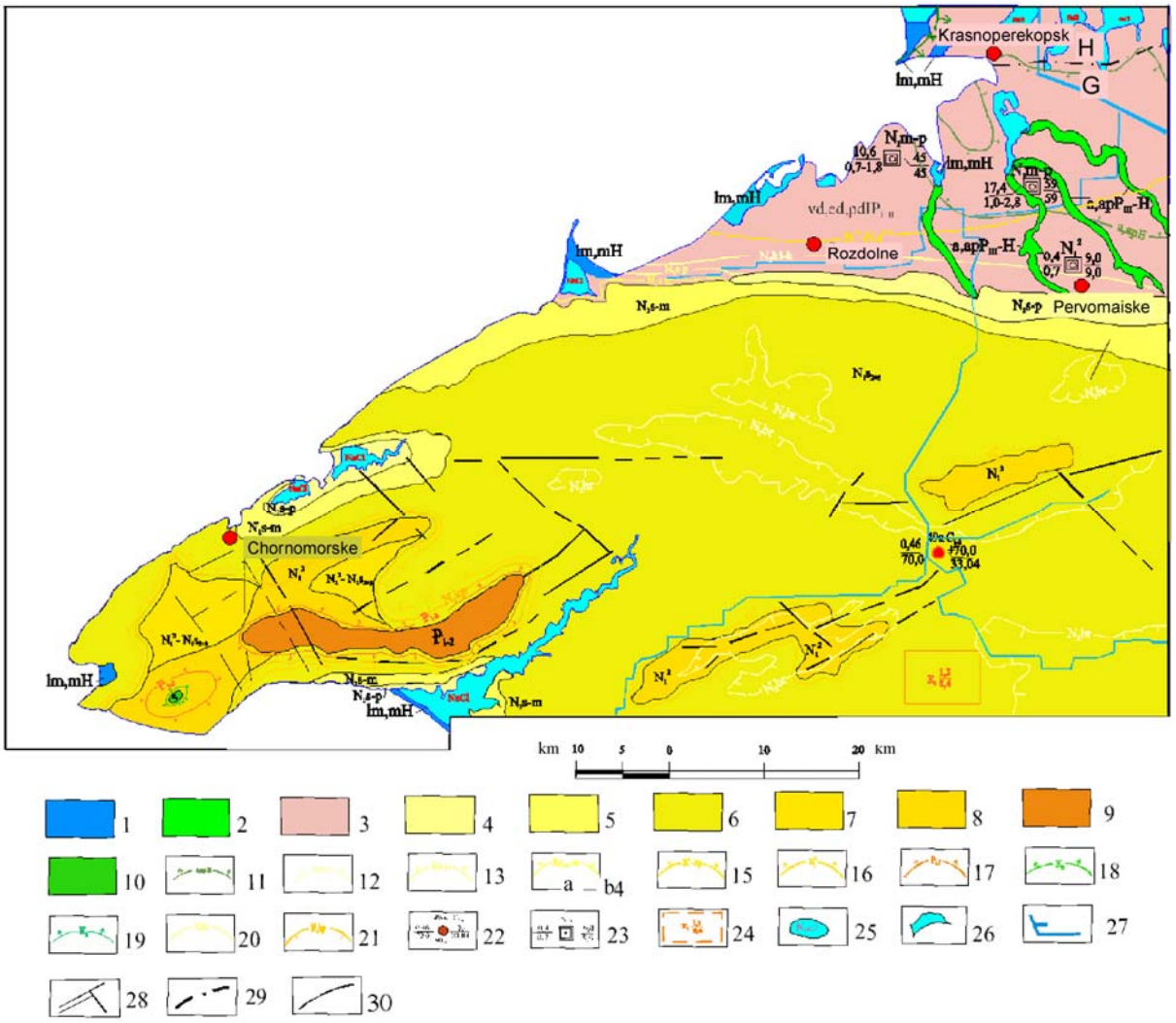

Fig. 7.1. Distribution scheme of water-bearing horizons and complexes.
See next page for the legend.

Fig. 7.1. Continued. Legend.

Distribution areas of the first from the surface water-bearing horizons and complexes: 1- water-bearing horizon in Holocene estuary and marine sediments; 2 - water-bearing horizon in Upper Neo-Pleistocene – Holocene alluvial and alluvial-proluvial sediments; 3 - water-bearing horizon in Neo-Pleistocene eluvial-deluvial, aeolian-deluvial and proluvial-deluvial sediments; 4 - water-bearing horizon in Sarmatian-Meotychni-Pontychni sediments; 5 - water-bearing horizon in Middle-Upper Sarmatian and Meotychni sediments; 6 - water-bearing horizon in Middle-Upper Sarmatian sediments; 7 - water-bearing complex in Middle Miocene and Middle-Upper Sarmatian sediments; 8 - water-bearing complex in Middle Miocene sediments; 9 - water-bearing complex in undivided Paleocene-Eocene sediments; 10 - water-bearing complex in Upper Cretaceous sediments;

Distribution boundaries of water-bearing horizons and complexes below the first from the surface ones: 11 - water-bearing horizon in Eo-Pleistocene alluvial, alluvial-proluvial sediments; 12 - water-bearing horizon in Pliocene Kuyalnytski and Kimmerian sediments; 13 - water-bearing horizon in Sarmatian-Meotychni-Pontychni sediments; 14 - water-bearing horizon in Middle-Upper Sarmatian and Meotychni sediments; 15 - water-bearing complex in Middle Miocene and Lower Sarmatian sediments; 16 - water-bearing complex in Middle Miocene sediments; 17 - water-bearing complex in undivided Paleocene-Eocene sediments; 18 - water-bearing complex in Upper Cretaceous sediments; 19 - water-bearing complex in Lower Cretaceous sediments;

Distribution boundaries of water-proof rocks: 20 – clays of Pliocene Bagrationivska sequence; 21 – clays of Lower Sarmatian Krasnoperekopska Suite;

Water-scoop units and sites with estimated groundwater reserves: 22 – drill-hole: top – number in the map and geological index of water-bearing horizon; bottom – drill-hole altitude, m; to the left: numerator – yield, m^3/d; denominator – depression; to the right: numerator – static level depth, m; denominator – water mineralization, g/dm^3; (static level defined above the surface is indicated with "+" symbol; drill-hole symbol in yellow indicates thermal waters, red colour of symbol filling – chloride water type); 23 – water-scoop units operating under exploitation groundwater reserves approved by State Commission of Ukraine on Mineral Reserves or its territorial bodies: top – geological index of water-bearing horizon, to the left: numerator – bulk yield, $th.m^3/d$; denominator – mineralization, g/dm^3; to the right: numerator – reserves, sum of A+B+C categories, $th.m^3/d$; denominator – reserves of A+B categories, $th.m^3/d$; 24 – undeveloped site with exploitation groundwater reserves approved by Scientific-Technical Council of SE "Krymgeologia": to the left – index of geological age of water-bearing complex; numerator – reserves, category B, m^3/d; denominator – reserves, categories B+C, m^3/d; yellow symbol indicates thermal waters;

Other symbols: 25 – salt lakes; 26 – water reservoirs; 27 – Pivnichnokrymskiy channel; 28 – tectonic breaks of undefined hydrogeological charge; 29 – boundaries of the first-order hydrogeological regions: G – Plain Crimean artesian basin; H – Prychornomorskiy artesian basin; 30 – boundaries of water-bearing horizons and complexes.

Cenozoic sediments

Water-bearing horizon in Pliocene Kuyalnytski and Kimmerian sediments (N_2kl-k) is developed in Pivdennosyvaskiy area where it is observed at the second and more positions from the surface. Horizon is confined to fine-grained sands in the lower part of Kuyalnytski layers and Kimmerian regio-stage sediments. Thickness of horizon is from 0.5 to 22 m. The lower water-proof is provided by 0.5-22 m thick Kimmerian clays. In some places water-proof clays are lacking providing direct hydraulic link with underlaying Sarmatian-Meotychni-Pontychniy water-bearing horizon. It is overlain by 0-23.1 m thick clays in the upper part of Kuyalnytski layers. In case of lacking these sediments, the direct hydraulic link with groundwater in Quaternary sediments is established. Horizon depth is from 15 to 35 m. Horizon is pressurized, pressure value is 7-30 m. Specific borehole yields are 0.52-86.4 m^3/d. Filtration coefficient is 0.1-15.3 m/d.

Water mineralization is 0.4-2.3 g/dm^3 and is increased towards Syvash and Karkinitska Bay; in the same direction hydrocarbonate magnesium-calcium waters are gradually substituted by hydrocarbonate-chloride, chloride-hydrocarbonate and chloride magnesium-sodium and sodium.

Feeding is being done through water inflow from "hydraulic windows" in Quaternary sediments. Discharge is being conducted to the sea and underlaying horizons.

Water-bearing horizon in Sarmatian-Meotychni-Pontychni sediments (N_1s-p) is the first from the surface and is developed in the narrow bands along the sea coast in the south of Tarkhankutskiy peninsula, close to Donuzlav, Dzharylgach, Panske lakes, in the south of Prysyvaska plain, to the east from Bakal lake to

Pervomayske town. To the north of above line it is observed to be second and third from the surface. Water-bearing rocks include porous, cavernous, fractured, karsted limestones, at the bottom – sands and sandstones. Total thickness of the sequence is 112-173 m being increased from the south to north. The lower water-proofs include Middle-Lower Sarmatian and Konkski clays (regional water-proof), 10-30 m thick. Water depth in Prysyvaska plain is 18-25 m. When going down beneath younger sediments, this water-bearing horizon becomes pressurized. The upper water-proof includes clays of Kimmerian regio-stage, 0.5-22.0 m thick. In some places water-proof clays are lacking and horizon is in hydraulic connection with overlaying water-bearing horizon of Pliocene marine sediments. Pressure is increased towards Karkinitska Bay and Syvash where its value is 68-86 m. Water content in horizon is irregular, it varies in lateral and vertical directions and depends on composition and type of water-bearing rocks. Borehole yields are 1296.0-3628.8 m^3/d at the depression up to 3 m. Specific borehole yields from Meotychni sediments vary from 172.8 to 6503 m^3/d, Sarmatian – 146.88-570.24 m^3/d. Filtration coefficients for limestones of Pontychniy stage are 5-915 m/d, Sarmatian – 3-8 m/d.

Water mineralization in general does not exceed 1 g/dm^3. Towards Syvash in the lower layers mineralization increases to 4 g/dm^3, in places 17-22 g/dm^3. Chemical type of waters varies in lateral and vertical directions: hydrocarbonate, hydrocarbonate-sulphate, chloride-hydrocarbonate with diverse cationic composition. With mineralization increasing the water type becomes chloride sodium.

Feeding of horizon is being done through atmospheric precipitates, irrigation waters, and in the buried portion – by water inflow from overlaying Pliocene marine sediments. Horizon is being discharged to Black Sea and via exploitation water-scoop. This water-bearing horizon is the major exploitation object in the north of studied area. The centralized water-scoops with approved reserves are concentrated over there.

Water-bearing horizon in Middle-Upper Sarmatian and Meotychni sediments (N_1s_{2-3}-m) is developed in the narrow band along the shores of Donuzlav, Panske and Dzharylgach lakes where it is first from the surface. Meotychni and Sarmatian groundwaters are linked hydraulically and provide the common water-bearing horizon with no water-proof in between. Water-bearing rocks include fractured, porous and cavernous limestones, at the bottom of Sarmatian sediments – sands and sandstones. The lower water-proof is comprised of 10-20 m thick Lower Sarmatian clays which also provide the regional water-proof. Water content in horizon is irregular in lateral and vertical directions being related to various degrees of rock porosity, cavernosity and variable lithology. Specific borehole yields vary from 86.4 to 7603.2 m3/d. filtration coefficients – from 1 to 266 m/d. Under influence of irrigation and extensive exploitation the natural regime is broken.

By chemical composition the waters are mainly chloride sodium, salty and saline up to brines. Feeding is being done through infiltration of atmospheric precipitates and irrigation waters as well as water discharging from Sarmatian water-bearing horizon laying higher in Tarkhankutske uplift. Water discharge is being done to the underlaying water-bearing horizons, as well as to Donuzlav Lake and Black Sea, partly through evaporation and by exploitation water-scoop.

Water-bearing horizon in Middle-Upper Sarmatian sediments (N_1s_{2-3}) comprises major exploitation horizon, developed over almost entire territory except the cores of anticline structures: Melova, Oktyabrska, Rodnikovska and Sary-Bashska. It is the first horizon from the surface in the most part of Tarkhankutske uplift, and is located between other horizons elsewhere. Water-bearing rocks include organogenic limestones with clay interbeds and oolite-organogenic, cavernous, fractured, karsted limestones of Besarabska and Khersonska suites. The lower water-proof includes clays of Lower Sarmatian Krasnoperekopska Suite. In some places Middle-Upper Sarmatian sediments are overlain by water-proof Pliocene clays. Groundwater aeration zone for this horizon is related to limestones of Pontychniy and Meotyhcniy regio-stages.

Groundwater level for this horizon lies at the depth from 0 to 60 m, in anticline uplifts – up to 100 m. Thickness of water-contained rocks is from 10-15 to 130 m. Filtration coefficients vary from 0.29 to 288 m/d, borehole specific yields – from 864 to 10368 m^3/d. Water mineralization over most part of the area is about 1 g/dm^3, along the coast it increases to 3-10 g/dm^3. The waters are mainly sulphate-hydrocarbonate, magnesium-sodium, hydrocarbonate-chloride calcium-magnesium.

Groundwater flow is directed from uplifts towards depressions and sea. Natural groundwater flow is broken by depression "funnels" emerged under influence of extensive water output. The water-bearing horizon is being drained at the sea coast and lake shores in Tarkhankutskiy peninsula, as well as through sub-marine springs along entire coast of the latter. Water mineralization less than 1 g/dm^3 is retained in some limited areas while over most part of the territory, under influence of extensive water extraction, hydrochemical regime of this horizon is broken and mineralization is 1-3 g/dm^3 and more [82]. The horizon is being used for water supplying of inhabited localities by individual boreholes.

Water-bearing complex in Middle Miocene and Middle-Upper Sarmatian sediments (N_1^2-N_1s_{2-3}) is positioned first from the surface in the northern slopes of Rodnikovska anticline in Tarkhankutskiy peninsula, in the fields where the regional water-proof, the clays of Lower Sarmatian Krasnoperekopska Suite, are lacking. Thickness of the complex is 20-40 m; water-bearing rocks include limestones (in places with clay interbeds).

The complex is ground-seated, water level depth is 50-67 m; it is overlain by Neogene limestones, in places by the upper water-proof which includes Pleistocene loams and clays as well as clays of Pliocene Bagrationivska sequence.

Borehole yields are from 34.6 to 129.9 m^3/d, water permeability – 56-155 m^2/d. The natural regime is broken by water extraction from individual wells.

Mineralization is 0.7-1.23 g/dm^3, water composition – hydrocarbonate-sulphate-chloride, sulphate-hydrocarbonate-chloride, sulphate-chloride calcium-magnesium.

The feeding is being done through atmospheric precipitates and inflow from overlaying Middle Miocene and Paleogene water-bearing horizons. Discharge is related to underlaying Upper-Middle Sarmatian and Middle Miocene water-bearing horizons.

Water-bearing complex in Middle Miocene and Lower Sarmatian sediments (N_1^2-N_1s_1) is developed in Pivnichnosyvaskiy artesian basin, where Lower Sarmatian column includes limestones, and constitutes the common water-bearing complex with water-bearing horizon in Middle Miocene sediments. This complex is the third and more from the surface. Water-bearing sediments include limestones, sands, conglomerates, 10-55 m of total thickness, which increases from the south to north towards Karkinitska Bay and Syvash. Depth of the complex is 230-300 m and increases in the same direction as the thickness does.

The lower water-proof includes clays of Maykopska Series, and the upper one – Middle-Lower Sarmatian clays.

The waters of this complex are pressurized (+200-285 m). Groundwater flow direction is from the south to north towards Karkinitska Bay. Water content of the complex is low, specific yields are from 8.6 to 432 m^3/d, limestone filtration coefficient – 7-23.5 m^3/d.

Regime is natural, stagnant. It is being broken since to the south the Middle Miocene horizon is under exploitation while both horizons are in hydraulic connection.

The waters are chloride sodium, mineralization exceeds 1 g/dm^3 (normally in the range 5-19 g/dm^3), sulfur hydrogen content is up to 6.5 mg/dm^3; mineralization increasing is observed towards Karkinitska Bay.

The feeding in the southern part is related to Middle Miocene water-bearing horizon discharge, and in the north, outside studied area where horizon is first from the surface, it is being done through infiltration of atmospheric precipitates. Discharge from horizons is released to Black Sea. According to conclusion of Odesa Research Institute of Resorts, the waters of this complex are suitable for curative use.

Water-bearing complex in Middle Miocene sediments (N_1^2) is developed over entire territory, except anticline arcs in Tarkhankutskiy peninsula, and is confined to limestones, sands and sandstones. The lower water-proof is related to the clays of Mayachkynska Suite and Yurakivski layers, and the upper water-proof – the clays of Krasnoperekopska Suite.

Water mineralization is 1-3 g/dm^3, water composition is hydrocarbonate calcium or sodium-calcium. In the area of Tarkhankutski folds, in the southern limb of Pivnichnosyvaskiy basin, in the south-western part of Novoselivske uplift, mineralization is from 1 to 10 g/dm^3. Water composition is hydrocarbonate-chloride, magnesium-sodium and sodium-calcium, or chloride calcium-sodium.

Feeding of the horizon is being provided from atmospheric precipitates in places of this horizon exposure at the surface in Novoselivske uplift. In Pervomayska site groundwater reserves are estimated and approved by Middle Miocene horizon. The waters of this horizon are being used by inhabited localities in Sakskiy, Pervomayskiy and Chornomorskiy areas through individual boreholes.

Water-bearing complex in undivided Paleocene-Eocene sediments (P_{1-2}) is developed in the north-western part of the studied area and is the first from the surface at the arcs of Rodnikovska and Oktyabrska anticlines. The complex is confined to Paleocene fractured organogenic and detritus limestones and Eocene nummulite limestones separated by the even-aged clays and marls.

The waters of the complex in the southern direction become pressurized and high-pressurized. The complex hanging-wall depth in Pivnichnosyvaskiy basin is 1400-1700 m, pressure value – from -63.0 to +3.7 m.

Water mineralization is 1-1.45 g/dm^3; by chemical composition the waters are hydrocarbonate-magnesium, hydrocarbonate-chloride, with depth chemical composition becomes chloride sodium, and mineralization rises to 11.4-49.9 g/dm^3 with iodine content up to 40 mg/dm^3. Further down the waters become thermal (collar outflow temperature is 50-60^{o}C). Borehole yields are 0.95-19.0 m^3/d.

Feeding is being provided by infiltration of atmospheric precipitates in the area, where the complex is first from the surface, and also with waters upwelling by tectonic breaks. Practical use of this water-bearing complex is limited.

Mesozoic sediments

Water-bearing complex in Upper Cretaceous sediments (K_2) is first from the surface over small area in the western part of Tarkhankutske uplift, in the arc of Melova anticline, while elsewhere it is positioned second and more beneath younger sediments and is confined to Cenomanian and Turonian limestones.

Water content of the complex is low. Mineralization is 10-40 g/dm^3, by chemical composition waters are methane, chloride sodium. Feeding is related to water inflow from overlaying horizons and complexes.

Water-bearing complex in Lower Cretaceous sediments (K_1) is developed throughout in the area. In Novoselivske uplift the depth of this complex is from 600 to 1200-1300 m, and to the north and west the depth increases to 3800 m and more. The complex is confined to Albian fractured sandstones, conglomerates, gravelites, and Hauterivian-Barremian fractured sandstones and sands. Thickness of the latter is from 36.5 to 192 m, and Albian sediments – from hundreds to 1500 m. Groundwaters of these horizons are linked. Water pressures attain 100-200 m at collars.

Water mineralization is from 6.4 to 37.8 g/dm^3, and it increases with depth from south to north. Be chemical composition the waters are chloride sodium. Water temperature is 30-80^{o}C and it increases with depth in the northern direction. Over there, thermal water reserves are explored and recommended for approval in amount of 8412 m^3/d with temperature from 47-60 to 69-78^{o}C [68].

Paleozoic sediments

Water-bearing horizon in Lower-Middle Carboniferous sediments (C_{1-2}) is weakly studied and intersected by some drill-holes at the depth from 900 to 2700 m; it is confined to the tectonic crushing zones in quartzites, schists, sandstones, limestones of Zuyska and Novoselivska suite, or to 20-60 m thick weathering crust after Lower-Middle Carboniferous rocks. The waters are thermal, chloride calcium-sodium, pressurized, with mineralization up to 39 g/dm^3 [68].

8. MINERAL RESOURCES AND REGULARITIES IN THEIR DISTRIBUTION

By the complex of mineragenic features the studied territory is included in Rivnynnokrymskiy structure-mineragenic area [27]. In turn, Alminsko-Tarkhankutska, Tsentralnorivnynna mineragenic zones and Pivnichnokrymskiy trough are distinguished. Over there, most developed are construction minerals and raw materials for their manufacturing. Combustible minerals are comprised of small oil, gas and gas-condensate deposits.

Combustible minerals

With regard to petroleum evidences, the studied territory belongs to Chornomorsko-Pivnichnokrymskiy area, included into Prychornomorsko-Krymska region of Prychornomorsko-Pivnichnokavkazko-Mangyshlatska oil-gas-bearing province. The oil-gas-bearing area is located in Pivnichnokrymskiy trough. The stratigraphic interval of oil-gas-bearing rocks is extended from Lower Cretaceous to Miocene. Majority of deposits are related to Paleocene sediments where Paleocene organogenic-detritus limestones comprise hydrocarbon containers and Lower Eocene clays are the proofs. A range of deposits is also related to Maykopski sandstone-aleurolite sediments, Upper Cretaceous clayey-carbonate sediments, and Lower Cretaceous terrigenous sediments. Considerable facial variability of Lower Cretaceous sediments and abundant tectonic breaks facilitate wide development of lithologically bounded and tectonically limited traps.

In the map sheet group two oil, one oil-gas, seven gas and three gas-condensate deposits are known. Of oil deposits, the biggest one is Serebryanske (III-4-32), of gas – Zadornenske (III-3-30), and of gas-condensate – Tetyanivske (II-5-10). Zadornenske gas deposit only is in production. Glibivske gas-condensate deposit (IV-3-57) is almost exhausted. Exploration works continue in other deposits.

Iodine, boron and bromine contents in bed waters of oil, gas and gas-condensate deposits often attain economic values. Specifically, iodine content in Zakhidnooktyabrske deposit (IV-2-53) is 46.8 mg/l; boron concentrations (in mg/l): in Krasnopolyanske deposit (IV-2-52) – 392.1; Olenivske (IV-1-50) – 383; Glibivske (IV-3-57) – 409.5; Zadornenske (III-3-30) – up to 452.7. Bromine content in excess of 50 mg/l is typical for Olenivske (IV-1-50), Chornomorske (IV-1-48), Krasnopolyanske (IV-2-52), Karlavske (III-2-25), Yarylgatske (III-2-18) and Serebryanske (III-4-32) deposits.

Mentioned oil and gas deposits are confined to tectonically and lithologically limited traps within Maykopski, Paleocene, Upper and Lower Cretaceous terrigenous and carbonate rocks, in lesser extent – pre-Cretaceous sediments. They exhibit pretty appropriate filtration properties and are being well identified by seismic surveys. However, small size of anticline folds and facial inhomogeneity of productive sediments impose constraints on perspectives to discover more significant economic hydrocarbon accumulations in the continental part of Karkinitsko-Pivnichnokrymskiy trough.

Gaseous

Gas

In the studied area seven gas deposits are known: Zadornenske (III-3-30), Olenivske (IV-1-50), Krasnopolyanske (IV-2-52), Chornomorske (IV-1-48), Kirovske (III-3-31, Mizhvodnenske (III-2-21), Yarylgatske (III-2-18).

These deposits are mainly confined to fracture-porous-type carbonate containers including fractured organogenic-detritus limestones with marl and clayey limestone interbeds. Gas traps in Yarylgatske and Mizhvodnenske deposits are confined to Middle-Maykopski sandstones and sandy-aleurolite sediments while five other deposits are located in Paleocene carbonate sequences. Productive horizon depth varies in the wide range: from 211 to 268 n in Yarylgatske and Mizhvodnenske deposits, to 560 m in Zadornenske deposit, and to 2172 m in Chornomorske deposit.

Besides that, gas traps are encountered in Lower Paleocene and Cenomanian limestones in Karlavske oil-gas deposit (III-2-25).

In the gas composition methane predominates, its content varies from 81.8% (Karlavske deposit) to 95.2% (Yarylgatske deposit). Gas is mainly dry.

Zadornenske deposit only is in production, Yarylgatske deposit is prepared for development, and Olenivske, Krasnopolyanske, Chornomorske and Mizhvodnenske deposits are under exploration.

The greatest reserves are estimated in Zadornenske deposit (III-3-30) located in 36 km to the east from Chornomorske town and in 2 km to the south from Zadorne village. It is confined to the same-named structure in Pivnichnokrymska zone of Karkinitsko-Pivnichnokrymskiy trough. Zadornenska structure comprises brachy-anticline of western, north-western extension, with dimensions 4.5×1.5 km by the closed contour line -560 m and height 100 m. Economic gas inflow has been obtained in 1960 testing the interval composed of Lower Paleocene organogenic-fine-detritus limestones. Gas yield through 7 mm aperture was 52 th.m^3/d. Gas traps are massive-bedded, arched; containers are of fracture-porous type; depth – 550-614 m. Gas in deposit is methane, its content is up to 94.8%. Economic exploitation has been conducted since 1968 to 1983. Over this period 925 mln.3 of gas extracted which comprised 90.4% of reserves. Deposit has been turned again into production in 2000.

Liquid

These include gas-condensate and oil deposits.

Gas-condensate

These include three deposits: Zakhidnooktyabrske (IV-2-53), Tetyanivske (II-5-10) and Glibivske (IV-3-57).

Productive horizon in Zakhidnooktyabrske deposit is composed of Middle Albian tuffogenic rocks of dacite-andesite composition (alternating tuffs, tuffites, tuff-aleurolites with argillite batches); in Glibivske deposit – Upper and Lower Paleocene carbonate sediments; in Tetyanivske deposit – Lower Aptian and Upper Albian sandstones with conglomerate, aleurolites and argillite interbeds. The trap depth is from 918 m in Glibivske deposit to 4420 m in Tetyanivske deposit.

In all mentioned deposits containers are of the fracture-porous type, porosity coefficient is 0.04-0.10; gas saturation coefficient – 0.49-0.78; methane content of gas – 52-89%. Condensate is light with low content of sulfur, tar and paraffin; it belongs to methane-naphthene type.

In Tetyanivske and Zakhidnooktyabrske deposits geological exploration is continued. Glibivske deposit has been in production since 1966 to 1983 and then it was transformed into the underground gas storage.

Description of gas-condensate deposits is given on the example of Tetyanivske deposit (II-5-10) located in 60 km to the north from Evpatoriya town.

Deposit has been discovered in 1974-1976 by the trust “Krymnaftogazrozvidka” and explored in 1989. It is confined to the same-named anticline fold in Serebryansko-Pervomayska zone of anticline uplifts on the southern slope of Pivnichnokrymskiy trough. The fold (by hanging-wall of productive horizon) comprises flat anticline of the north-western extension with dipping angles 4-5^o in the limbs.

Productive horizon is composed of Lower Aptian sandstones with fine-pebble conglomerate, aleurolites and argillite interbeds (horizon A-21) and Upper Albian sandstones (horizon A-18). The depth of horizon is from 3774 to 4420 m. Containers are of porous and fracture-porous types.

The traps are bedded, arched. Bed pressure is 41.5-43.0 MPa. Gas yield is 71 th.m^3/d and condensate – 78 m^3/d. Porosity coefficient is 0.07-0.1; gas saturation coefficient – 0.1-0.78; permeability – up to 32.6×10^{-15} m^2. Gas composition (%): methane – 65.9-82.7; ethane – 2.7-15.5; propane – 0.76-7.21; nitrogen – 2.14-10.68; carbon dioxide – 1.2-3.1. Condensate comprises yellow and light-brown transparent liquid ; density – 729-734 kg/m^3 ; viscosity – 80×10^{-6} m^2/s; boiling temperature – 32^{o}C. Actual condensate content in gas is 637-1105 cm^3/m^3. Contents of sulfur, tars and paraffin is low, gas-condensate belongs to methane and methane-naphthene type.

The out-contour waters are hydrocarbonate-sodium with mineralization 12.9 g/l and admixtures of iodine (2.1 mg/l), bromine (10.6 mg/l) and boron (59.5 mg/l).

Oil

Two oil deposits are located in the studied map sheet group – Serebryanske (III-4-32) and Oktyabrske (IV-2-54), as well as one deposit of oil with accompanied gas – Karlavske (III-2-25).

Oil traps are confined: in Serebryanske deposit – to Coniacian-Santonian limestones with containers of porous-fracture and porous-fracture-cavernous types; in Oktyabrske – to three productive horizons: upper – in Cenomanian carbonate rocks, middle – in Barremian – Lower Aptian fractured sandstones, aleurolites and

conglomerates, lower – in pre-Cretaceous terrigenous sediments; in Karlavske deposit – to Turonian fractured limestones.

The oil contains great amount of benzine and light oil products, specific gravity – 0.76-0.83 t/m^3.

In all three deposits exploration works are continued; the trial-industrial exploitation has been undertaken in various years (in Serebryanske deposit 4 th.t of oil are extracted, in Oktyabrske – 3 th.t).

Serebryanske deposit (III-4-32) is the biggest one in term of reserves and typical in geology. It is located in Rozdolnenskiy area in 51 km to the north from Evpatoriya town. It is confined to Serebryanska depression within Karkinitsko-Pivnichnokrymskiy trough. Structure of the productive horizon hanging-wall comprises flat tectonic nose of the north-western extension, 3×3 km in size and about 50 m high. Deposit is discovered in 1971 in the course of testing over Upper Cretaceous sediments. In the test, oil inflow received in amount of 58.9 m^3/d as well as 2.9 th.m^3/d of gas (through 7 mm aperture).

Oil traps are confined to Upper Cretaceous (Coniacian-Turonian and Lower Santonian) limestones; the traps are bedded, lithologically and tectonically bounded; containers are of mixed porous-fracture and porous-fracture-cavernous types. Oil specific gravity is 0.76-0.78 g/cm^3, gas saturation – 125.4 m^3/t. Dissolved gas is of mixed composition: methane – 43%, ethane – 13%, propane – 22%.

Nowadays exploration works continue in the deposit.

Non-metallic minerals

These include flux limestones and dolomites, limestones for soda industry, dimension limestones, limestones for aggregates, and sands.

Non-ore raw materials and non-metallic ore minerals

Flux and chemical raw materials

Flux limestones and dolomites and limestones for soda industry

In the studied map sheet group are known three deposits of carbonate raw materials suitable for complex use as fluxes and for soda manufacturing – Pervomayske (III-6-46), Donuzlavske (IV-3-62), Dalne (III-3-28). Ore bodies are confined to Pontychni-Meotychni-Sarmatian sediments of Tarkhankutske and Novoselivske uplifts; deposits are discovered by Krymska GE of trust "Dniprogeologiya" in 1962-1966 [49].

Pervomayske deposit (III-6-46) is explored in details in 1968-1971 [71]; it is located in 11 km to the south-west from Pervomayske town. Thickness of productive horizon is 60 m; thickness of Quaternary stripping loams – 0.05-3.2 m.

The column of carbonate sequence in Pervomayske deposit is as follows (downward):

1. Yellowish-grey, cavernous, calcitized shell limestones (Evpatoriyski and Odeski layers of Pontychniy regio-stage) and yellowish, yellowish-grey oolite limestones of Meotychna Akmanayska Suite (I bed of "soda" limestones). Thickness is from 5.0 to 14.8 m, average – 6.6 m.

2. Yellow and yellowish-grey pelitomorphic limestones of Bagerivska Suite, lower part of Meotychniy regio-stage, and light-grey pelitomorphic limestones of Khersonska Suite, upper part of Sarmatian regio-stage. Thickness is from 4.0 to 20.9 m, average – 12.8 m.

3. White Mactra shell limestones of Khersonska Suite, middle part of Upper Sarmatian (II bed of "soda" limestones). Thickness is from 9 to 10 m, average – 9.5 m.

All three mentioned layers constitute low-magnesium complex of limestones with average thickness 29.0 m.

4. Grey, detritus, nubecular, dolomitized limestones of Khersonska Suite and upper part of Besarabska Suite. With dolomite bed the rocks are separated in two layers. The first layer of dolomitized limestones is from 4.4 to 23.8 m thick (11.1 m in average). Dolomite bed, confined to the middle part of Upper Sarmatian, is from 0.1 to 11.6 m thick (6.4 m in average). The second, up to 21.1 m thick layer of dolomized limestones includes lower part of Upper Sarmatian (Khersonska Suite) and upper part of Middle Sarmatian (Besarabska Suite); it is composed of light-grey, pelitomorphic and detritus limestones and yellowish-grey nubecular limestones.

Ponctychni, Meothychni and Upper Sarmatian limestones in this deposit are suitable for soda and cement manufacturing, limestones and dolomites of Middle and Upper Sarmatian – in flux purposes for iron-ore concentrates and magnesium oxide production. Strength of low-magnesium limestones is from 1.28 to 17.65 MPa (6.3 MPa in average), magnesium ones – from 2.4 to 29.7 MPa (8.7 MPA in average). Average volume weight is 1.8 t/m^3. Lower part of dolomitized limestones is wetted below 6.5-7.0 m.

Because of low profitability deposit and its reserves are estimated to be off-balance.

Similar limestones are explored in Dalne (III-3-28) and Donuzlavske (IV-3-62) deposits. Limestones in these deposits comply with requirements to the raw materials for cement industry, for lime manufacturing, for iron-ore agglomerate fluxing, as well as for construction aggregates, sands and road quarry-stone manufacturing.

Construction raw materials

Deposits of construction raw materials are related to carbonate sequences of Pontychniy, Meothychniy and Sarmatian age and include deposits of dimension limestones (55 deposits) and construction stones suitable for road construction and aggregates (four deposits). They differ both in physical-mechanical properties and chemical composition, and in practical use. Most valuable are Pontychni limestones of Evpatoriyski and Odeski layers. They are easily sawed coupled with low heat conductivity and high frost resistance; by these reasons they are being used for standard wall stone manufacturing which is widely used in the urban and rural construction. The wastes are being used for construction liquids, lime and lime powder manufacturing.

Raw materials for dimension wall stones

Limestones

Dimension (sawed) limestones are significant in wall stone supplying for housing and social-resort constructions, especially in rural areas and in the localities of compact living of Crimean Tatars.

In Plain Crimea wall stones are being produced mainly from shell limestones of Pontychniy and Meotychniy age (Odeski and Evpatoriyski layers, Akmanayska and Bagerivska suites), as well as from Upper Sarmatian Mactra and oolite limestones (Khersonska Suite). All these limestones are ascribed to the formation of dimension limestones of organogenic origin.

Odeski and Evpatoriyski layers of Pontychniy regio-stage are developed in the watersheds and almost horizontal bedding. Thickness of the layers is from 1.5 to 4.5 m, in places 6 m. Thickness of the stripping rocks (Quaternary loams, Pliocene clays or non-dimensional varieties of limestones) is mainly 1.2-4.0 m. At the top of dimension-stone horizon the bed of strong re-crystallized limestone, up to 1.8 m thick, is often observed.

Dimension limestones of Meothychni Akmanayska and Bagerivska suites, from 0.7 to 2.8 m thick, are composed of fine-oolite varieties and lie below Pontychni dark-brown cavernous limestones, 0.3-2.5 m thick, which constitute interim stripping rocks. Most complete columns of Pontychna and Meothychna dimension limestone sequences are known from Illinske (IV-6-83), Stovpove (IV-5-76), Pivnichnobaranivske (IV-5-74) and Zhuravlivske (IV-6-82) deposits.

Description of this group of deposits is given on the example of Illinske deposit (IV-6-83). Stripping rocks, up to 5.5 m thick, include Quaternary loams, Upper Pliocene clays and re-crystallized limestones. Productive horizon is composed of detritus-oolitic and fine-detritus limestones of Odeski layers, Pontychniy regio-stage (first dimension limestone layer, 3.6 m thick in average), and shell limestones of Evpatoriyski layers (second dimension limestone layer, 3.2 m thick in average). In between these layers re-crystallized, platy limestones are developed (interim stripping rocks, 1.4 m thick in average). The third dimension limestone layer, 2 m thick, is composed of Meotychni fine-oolitic limestones of Akmanayska Suite. Underlaying rocks include alternating limestones and clays. Productive horizon is dehydrated. Stone grades in the upper and middle dimension limestone layers are “4”-”10”, and from Meotychni fine-oolitic limestones – “15”-”50”. The output of saleable wall stone is 49% (upper layer), 47.8% (middle layer) and 47.5% (lower layer). Non-dimension limestone varieties and wastes from sawing are suitable for road construction, lime powder and construction lime manufacturing, and as mineral addition in cattle and poultry feeding.

Upper Sarmatian shell-detritus and oolite limestones (Khersonska Suite), prospective as raw materials for dimension wall stone, are exposed in the western part of Tarkhankutskiy peninsula. Typical Olenivske deposit (IV-1-51) is composed of Upper Sarmatian limestones of Khersonska Suite. Dimension limestones are developed in the second and third layers of total average thickness 7.5 m. Stripping rocks are composed of Quaternary loams of 2.4 m average thickness. Productive horizon is dehydrated. Limestones comply with requirements for wall stones of “75”-“100” grades. The stone volume mass is 1580-2390 kg/m^3. Output of saleable wall stone is 39.3%. It is possible the complex use of limestones for wall stones, aggregates, carbonate sand, lime, and in cement manufacturing. Deposit has never been mined.

The major deposits – Zhuravlivske (IV-6-82), Olenivske (IV-1-51), Novoselivske (IV-5-66), Pervomayske-Nove (IV-5-60), Novooleksiivske (III-5-41), Pivnichnobaranivske (IV-5-74), Illinske (IV-6-83) and Naumivske-II (IV-5-78) are confined to Novoselivske uplift.

Raw materials for aggregates

Shell limestone

In Plain Crimea shell limestones of Sarmatian, Meotychniy and Pontychniy age comprise the raw materials for aggregates and quarry-stones. They are of low strength (up to 10 MPa) and are being used mainly in purposes of road construction. In the studied map sheet group Chekhivske (II-4-35), Stepove (II-6-17), and Kovylnenske (II-5-14) deposits, and two blocks of Krasnoyarske deposit: Lenska (III-4-37) and Dozornenska (IV-3-56), are explored.

Description of deposits is given on the example of Chekhivske deposit (II-4-35), where 46.2 m thick productive horizon is made of three layers, specifically, limestones of Pontychniy, Meotychniy and Sarmatian age, respectively. This horizon is dehydrated. By their properties, limestones are assigned to II-III groups by strength, with clay minerals content less than 5%.

Resource base of construction stones is being upgraded through their by-product mining in dimension limestone deposits (stripping rocks, sawing waste).

Sand-gravel raw materials

Construction sand

In the studied map sheet group Donuzlavske construction sand deposit is explored (IV-3-90); it is located in the southern coast of Tarkhankutskiy peninsula, at the mouth part of Donuzlav Lake. Productive horizon includes grey and dark-grey, fine-grained, weakly-sorted, carbonate sands composed of semi-rounded limestone grains and shells, with lenses and interbeds (up to 2.5 m) of sand enriched in limestone gravel and pebble (up to 20% by volume).

The sheeted body is traced across Donuzlavska depression over 9 km being from 0.4 to 2 km wide; its maximum thickness attains 18.9 m. Stripping rocks include muds up to 2 m thick. Productive horizon is located at the depth 1.9-2.6 m In general, the sands comply with requirements GOST 8736-77 except the fraction +10 mm which is contained in amount of 1.9% (admissible – 0.5%). Average specific weight of sand is 2.73 g/dm^3, natural moisture – 10%.

In the course of refilling with barges beneficiation of sands occur because of fine grains and clay removal as well as fraction +10 mm. In mineral composition of sands calcium carbonate predominates (up to 94%) with low quartz content. Heavy fraction content is 3% and includes iron hydroxides (hematite, goethite, hydrotroilite), sulphides, in places rutile, zircon and ilmenite grains are noted. Unwanted ion contents: sulphates – 0.05%, sulphides – 0.08%, chlorides – 0.03%. Organic admixtures are insufficient. The sands are suitable in filling the grade “200” heavy concrete, grades “100” and “200” light clayey-concrete, for construction liquids and road construction. Deposit is being mined by Evpatoriyskiy sea port.

Because of specific geology of the area and effective restrictions for sand mining in the coastal zone of Black and Azov seas, there is no perspective for construction sand resource base upgrading. The region and overall Crimean demands in construction sands are being covered through their supplying from Zaporizka and Khersonska Oblasts of Ukraine.

Waters

Groundwaters

Groundwaters in the area include fresh and thermal ones.

Fresh waters

The complex of Pontychni-Meotychni and Upper-Middle Sarmatian sediments (N_1ps_{2-3}) comprises major fresh water unit, which contains Pivnichnosyvaske fresh groundwater deposit. Reserves are approved for five sites: Perekopska-1 (I-6-1), Vorontsivska (I-6-2), Rozdolnenska (II-4-5), Perekopska-3 (II-6-15), Pervomayska (II-6-16). The waters are chloride-hydrocarbonate calcium-sodium with mineralization 0.1-1.4 g/dm^3 (in Rozdolnenska site – up to 3 g/dm^3). Depth of water-bearing horizon is 31.5-98.7 m (in Pervomayska site – 173 m). Deposit is in production.

Thermal waters

Novoselivske thermal groundwater deposit (IV-6-84) is known in the territory. In 1960-1968 trust "Krymnaftogazrozvidka" had drilled some boreholes which intersected thermal waters in Hauterivian-Barremian water-bearing horizon. The waters are high-temperature at collars (50-70^{o}C), with essential mineralization and content of biologically-active compounds. Economic-category reserves of thermal waters are established on the ground of detailed exploration [68].

Water-bearing horizon is associated with Hauterivian-Barremian sediments (Kalyninska Suite sandstones with gravelite and conglomerate interbeds. Depth is from 699 to 1308 m, Self-outflow yield is 337-484 m^3/d. Mineralization of waters is 5.7-17.3 g/dm^3, content of biologically-active compounds: iodine – 11.5 mg/dm^3, bromine – 10-81 mg/dm^3, boron – 68-117.6 mg/dm^3. Collar outflow water temperature is 49-65^{o}C. By composition the waters are chloride sodium, chloride-hydrocarbonate sodium. Water-bearing horizon is high-pressurized, pressure height attains 811-1290 m. The trial devices (geo-cycling systems) with thermal waters are being used for heat supply to hothouses, administrative and housing premises in Illinka village.

Iodine, bromine and boron contents allow considering the system also to be thermal mineral iodine-bromine with potentially high curative properties. However, significant distance from the sea and resorts, uniform and non-attractive landscape, relatively hard climate and lack of opportunities to drop the used high-mineralized waters preclude establishment of curative complex over there for the time being.

Mineral sludge and mud

In the studied area Tarkhankutska group of sludge lakes is distinguished, which includes deposits – Dzharylgach Lake (III-2-86), Panske Lake (III-2-88), and occurrences – Karlavskiy (Yarylgach Lake, III-2-87), Karadzha (Lyman Lake, VI-1-89), Bakalskiy (II-3-85). All lakes are of estuary-marine type, from 1.6 to 23.4 km^2 in size, shallow-water (2.0 m) with salt or saline water, and belong to halogenic formation. Bottom sediments are composed of black mud with physical-chemical properties characteristic for curative sludge.

Geological exploration is only conducted in Dzharylgach Lake. It is 8.9 km^2 in size, thickness of sludge layers is 0.45 m. Main parameters: moisture – 50%, volume mass – 1.5 g/cm^3, salinity – 0.9%, organic matter content – 0.7%, pH – 7.0. According to classification developed by Odeskiy Research Institute of Resorts, the type of sludge is sulphide, chloride-magnesium-sodium.

To date, in medical-curative purposes the lakes are actually not being used, and Krasne Lake occurrence, located in the industrial zone of Krasnoperekopska chemical plant group, is out of curative value.

From the positions of litho-tectonic analysis, the studied territory is included in the Plain Crimea tectonic-mineragenic area, where Alminsko-Tarkhankutska zone, zone of Novoselivske uplift, and Tesntralnorivnynna mineragenic zone are distinguished. All these units belong to Scythian Plate. In the mentioned zones, within different tectonic stages, the rock complexes have been formed which differ in genesis and correspond to certain sedimentation phases.

The study depth over these complexes depended on the direction of geological prospecting and exploration rocks. The greatest study depth (3-5 km) achieved in the prospecting works for oil and gas.

Regularities in formation and distribution as well as perspective assessment of oil and gas deposits are tightly related to the problem of genesis of hydrocarbon traps. From the point of view of inorganic concept – planetary hydrocarbon upward migration from upper mantle and planetary concentration of their accumulations at the disjunctive continent and plate margins – main perspectives are only related with heterogeneous basement and deep-seated fault zones, especially junction site of latitudinal and sub-longitudinal dislocations [8]. From the point of view of sedimentary-migration theory, where primary hydrocarbon matter is being formed together with sediments in the ancient sea basins under reducing conditions from the remnants of phyto- and zoo-plankton, location of deposits and their perspectives are thought to be related to the most buried portions of Pivnichnokrymskiy trough.

In the regional prospecting and exploration works within mentioned portions of mineragenic areas of Scythian Plate and Prychornomorska depression the study depth has been mainly limited by the footwall of Lower Miocene sediments, thus, the objects of analysis include rock formation types emerged over the platform stage of development.

In the region of Scythian Plate and Prychornomorska depression the carbonate formation of Upper Sarmatian, Pontychniy, and in places Meotychniy-Pontychniy stages has been formed. The rocks of this formation are relatively pure in term of carbonate mineral composition, and because of high crystallization capacity of calcite under lithogenesis conditions these rocks had acquired physical-mechanical properties

allowing their use in wall dimension stone purposes (by this reasons this formation is called “formation of dimension limestones”). The rocks of this formation are developed over considerable parts of Novoselivske uplift and Tarkhankutskiy arc, where they are confined to the watersheds above negative tectonic structures in the basement or to the small flat dimples in the relief. “Formation of dimension limestones” is lacking in the modern river valleys and watersheds above positive tectonic structures in the basement.

“Formation of dimension limestones” has been delineated in the course of EGSF-200 [34] providing real ground to assess perspective of its development. In lithological respect, it is consistent enough in lateral and vertical directions. Productive horizon comprises shell limestones which did not undergo exogenic alteration. Amount of these limestones in the column does increase in depressions and decreases at the watersheds. In general, thickness of formation sediments varies from 0.3 to 10.0 m. Besides that, distribution of the formation in some places is controlled by tectonic breaks. Of these, most important one is Sulynsko-Krymskiy latitudinal fault which bounds Novoselivske uplift from the north (in the northern elevated limb of the fault formation rocks are partly eroded).

By results of EGSF-200 some prospective sites for dimension limestones are defined (Krylovska, Avrorivska, Slavna, Bagrationivska and others), and in some of these ones in 1989-1998 prospecting-exploration works have been conducted and reserves were confirmed.

Almost all lithological varieties in these sites are suitable to be used as raw materials for cement industry and can be involved into development on request. Besides that, these rocks can be used in construction lime, silicate brick and glass manufacturing.

Upper Miocene (Middle-Upper Sarmatian) carbonate rocks include limestones and dolomites which are also widely developed in Novoselivske uplift and Tarkhankutskiy arc. Among limestones, often pure Mactra and oolitic limestones (composed of calcite by 95-98%) are observed and formed under conditions of relatively calm marine sedimentation. By their parameters, these limestones comply with requirements to raw material for metallurgy and cement industry.

At the same time, significant part of the column is composed of the clastic limestones formed under oscillating tectonic motions in unstable sedimentation basin and considerable input of terrigenous material. The rocks are of high volume weight and cannot be used for dimension stone although they are suitable for aggregates production. By these reasons, aforementioned limestones are distinguished in the “formation of metallurgy and cement limestones”, dolomites and raw materials for road construction. The rocks of this formation are confined to Middle and Upper Sarmatian sediments and widely developed in Novoselivske and Tarkhankutske uplifts where they constitute the cores of positive structures and often are exposed at the surface. Likewise the overlaying “formation of dimension limestones”, by strike the rocks are often controlled by tectonic breaks. Rock dipping in formation varies from sub-horizontal (0-2^{o}) to monoclinal in the limbs of positive structures (4-12^{o}).

Thus, the leading minerals in the area include hydrocarbon deposits and non-ore raw materials (limestones for metallurgy and soda industry, dimension limestones).

Most important mineragenic factors in the distribution regularities of hydrocarbon deposits include tectonic (association with Pivnichnokrymskiy trough), stratigraphic (Paleocene, Maykopska Series, Lower and Upper Cretaceous), and lithological-facial (containers include organogenic-detritus limestones, sandstone-aleuritic piles, clayey-carbonate and terrigenous sediments; coupled with tectonic breaks they form lithologically bounded and tectonically limited traps).

For non-ore minerals the leading role in distribution regularities is played by tectonic factor (deposit location in Novoselivske uplift), as well as stratigraphic (Pontychni-Meotychni-Sarmatian sediments) and lithological-facial (shell and oolite limestones) factors.

Distribution of other common minerals (construction raw materials) is mainly controlled by lithological-facial factor.

9. ASSESSMENT OF THE AREA PERSPECTIVES

Perspectives of the studied map sheet group in term of mineral-resource base upgrading are limited enough. In stratigraphic respect, perspectives in discovery of new oil and gas deposits are mainly related to Lower Cretaceous and, probably, Jurassic and Paleozoic sediments at the depth 4.0-4.5 km. This conclusion is supported by discovery of economic hydrocarbon accumulations in Oktyabrske oil deposit (IV-2-54), Tetyanivske (II-5-10) and Zakhidnooktyabrske (IV-2-53) gas-condensate deposits confined to Lower Cretaceous and pre-Cretaceous sediments. To date, the north-western offshore and deep-water depression of Black Sea both remain most perspective in term of hydrocarbons. These works, however, are restrained by the difficulties in developments over deep-water areas and lack of exploration and exploitation technical tools.

In view of energy resources deficit in Ukraine and Crimea, the local thermal waters use in heat supplying for inhabited localities and agriculture complexes is of particular value. Discovered Novoselivske deposit (IV-6-84) is the first in the range prepared to further study and development of such objects in Crimea, in the band between Novoselivske and Chornomorske towns.

Prospecting-exploration works, and therefore perspectives for new discovery of non-energy mineral deposits, strongly depend on the structure of land use. In the studied map sheet group most lands are in agricultural use, and in the coastal band the lands are included into the State reserves and protected areas (Dzharylgach Lake, Lebyazhi islands). Thus, land use for mineral exploration and mining is fairly limited. Of 55 explored dimension limestone deposits significant part (34 deposits) is out of production since they are located on the lands of extensive irrigated farming or on the shared lands. And there are no perspectives to discover new considerable deposit of dimension and construction limestones on low-productive lands. Some reserve upgrade is possible to the depth (in Meotychni and Sarmatian carbonate sediments), as well as in some sites in the central part of Tarkhankutske uplift, where to the west from Donuzlavske deposit Tarkhankutska field is encountered with perspective resources of “cement” limestones [75]. Over there, productive horizon hanging-wall lies at the depth from 0.05 to 48 m (mainly from 2 to 5 m). It is composed of five batches of Middle-Upper Sarmatian carbonate rocks: nubecularian, fine-shell, clastic, oolitic and Mactra limestones with thickness 40-120 m. By all parameters they are suitable for manufacturing of cement, class “A” lime, and partly for iron-ore agglomerate fluxing. Processing waste can be sued for aggregate and lime powder manufacturing.

10. ECOLOGICAL-GEOLOGICAL SITUATION

Ecological state of the studied area has undergone strong negative changes over last decade, first of all, related to the industrial producing methods implementation in agriculture and chemical industry development in Prysyvashshya.

In this works unpublished materials of SE "Pivdenecogeotsentr" are used, as well as data of Ministry of Agriculture and Food of Crimea, the Plant Protection Station, and Sanitary Epidemiologic Station of Crimea.

Collected data had provided the ground to design schematic map for ecological state of geological environment in the scale 1:500 000 (Fig. 10.1).

Landscape zonation. In the landscape respect, the map sheet group L-36-XXI, L-36-XXII and L-36-XXVII is located in the north-western part of Plain Crimea (A), which, in turn, comprises counterpart of the bed-accumulative lowland of Prychornomorska plain with fescue and feather-grass vegetation on light-brown soils coupled with saline lands and alkali soils. Taking into account the landscape families and types two landscape provinces are distinguished.

A-I (Ca^{+}, Na - Cl^{-} - SO_4^{2-}) – calcium and salt-bearing landscapes of Prysyvasko-Pryazovska lowland (in its western part), including absinth-cereals steppe coupled with absinth-alkali soil in saline lands, light-brown saline soils formed over loess-like loams and clays. In the province two landscape families are distinguished: lowland accumulative plains with groundwater level below 3 m, with migration of technogenic elements during infiltration and their accumulation in salt deposition horizons; and bed-accumulative plains with groundwater level above 3 m, with migration of technogenic elements in descending waters. Geochemical barriers include evaporation, oxygen, alkaline oxygen, glue oxygen. Micro-elements accumulated at the barrier: Sr, Co, Hg, Be, Se, Cr, Ra. Calcium and salt-bearing nature landscapes are changed by agro-landscapes: rice bands, planned fields separated by forest bands, dense network of inter- and inner-farming channels, fish-farming ponds in places of salinated rice bands. Types of geochemical landscapes: loess-like loams on sands and clays; loess-like loams on clays with hard-rock fragments; aleuritic mud and mudded sands on loams, clays and limestones.

A-II (Ca^{2+}, Ca^{2+} - Na^{+}) – calcium, calcium-sodium landscapes of Tarkhankutskiy elevated-plain steppe. Fescue-absinth steppe and motley grass-fescue-absinth steppe and agro-landscapes in its place. Soils – black-earth gravelous and southern black-earth low-humus laying over eluvium of carbonate rocks or eluvial-deluvial, proluvial-deluvial loess rocks. Geochemical barriers: alkaline oxygen, sorption oxygen, evaporate oxygen with micro-elements accumulating at these barriers: Cr, Sr, Ra, Co, Hg, As, Be, P. Landscape types: limestones, loess-like loams above limestones, loess-like loams above clays with hard-rock fragments; along sea coast – aleuritic mud and mudded sands above limestones, loams and clays.

Technogenic charge. Main factors of technogenic charge include: industry (chemical plants located in Krasnoperekopsk town, quarries for construction materials); agriculture (mineral and organic fertilizers, pesticides, cattle-farming); irrigation (branched network of regional, inter- and inner-farming channels, large fields of irrigated lands, rice bands); water drainage (centralized and local-farming water scoops).

Industry. The major agents of technogenic charge in Prysyvasko-Pryazovska lowland include soda plant "Krymskiy sodoviy zavod" and Perekopskiy bromine plant. Total drops from small enterprises in Pervomaysk and Chornomorske towns provide respectively 14 and 613.33 t/year of harmful substances (SO_2, NO_x, CO, manganese compounds).

Agriculture. Extensive farming requires huge amount of mineral and organic fertilizers and pesticides. Major contaminating component of cattle-farming – mineralized drops, where mineralization is: livestock complexes – 11 g/dm^3, swine-breeding – 20 g/dm^3. They contains: hydrocarbonates – 2.5-5.7 g/dm^3, ammonia – 0.5-0.7 g/dm^3, nitrates and nitrites – 0.4-0.7 g/dm^3, sodium + potassium – 0.2-0.4 g/dm^3. Almost 50% of micro-flora comprises pathogenic types [42].

Irrigation. Pivnichnokrymskiy channel and its branches provide broad network. Artificial water-flows occupy more than 6 thousand hectares. Wide development of irrigation network of channels and irrigation over broad territories had caused groundwater level ascending, their desalination and change in the soil salt regime. Irrigating lands occupy 4.2% of the agriculture lands in Chornomorskiy area and up to 42% in Krasnoperekopskiy area.

Water drainage. It is one of the prominent factors affecting groundwater hydrochemical and hydrodynamic regime. It is being done through three centralized water scoops: Vorontsivskiy, Rozdolnenskiy and Pervomayskiy.

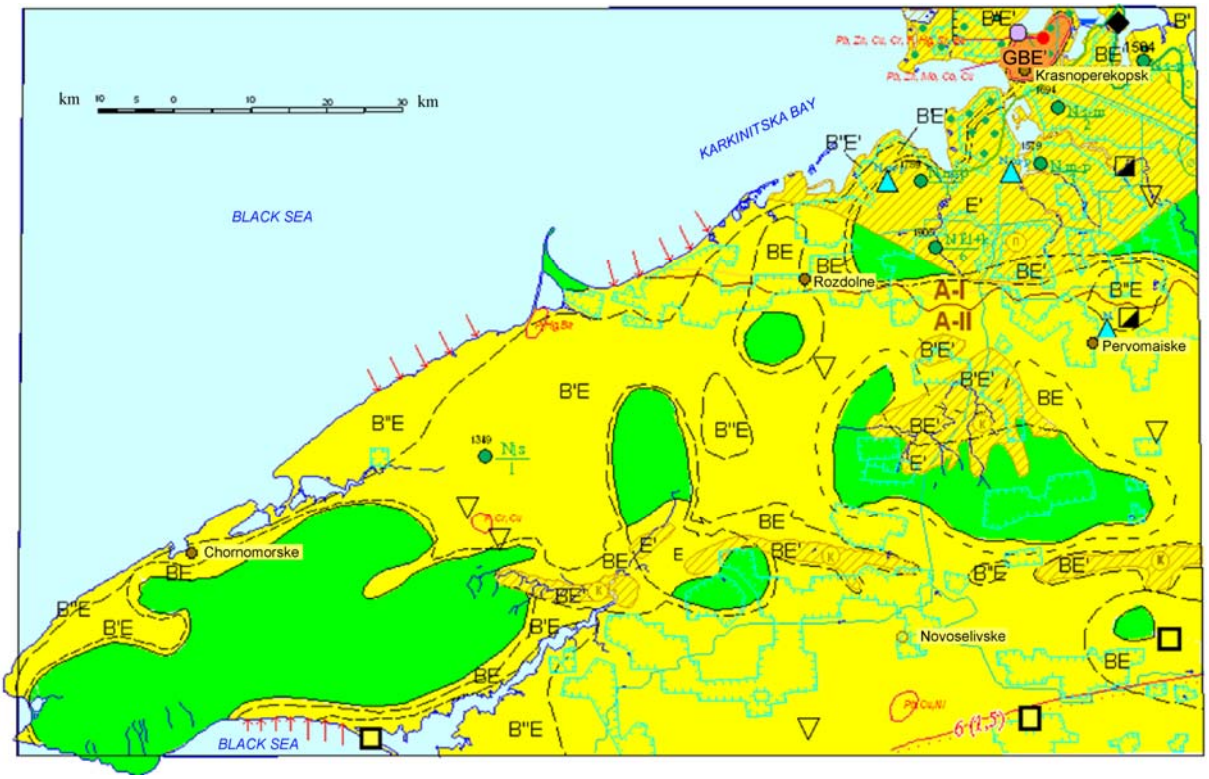

Fig. 10.1. Schematic map for ecological state of geological environment.
Figure legend is given below and in the next pages.

1. Ecological state of geological environment

Levels of ecological state of geological environment		Contamination level		Degree of territory defeating with dangerous geological processes
		Soils	Groundwaters	
	Charged	Dangerous	Dangerous	Strong
	Moderate charged	Moderate dangerous	Moderate dangerous	Medium
	Appropriate	Admissible	Admissible	Moderate and insufficient

1.1. Assessment of contamination degree for soils and bottom sediments

Pseudo-formula index	Heavy metals contamination degree	Danger classes, TAC/background			
		I	II	III	BCI
A’	Dangerous	2-3 4-6	5-10 10-15	10-20 15-30	32-128
A	Moderate dangerous	1-2 2-4	1-5 2-10	1-10 2-15	16-32
	Admissible	≤1 1-2	≤1 1-2	≤1 1-2	<16

1.2. Assessment of groundwaters contamination degree

Pseudo-formula index	Chemical elements and compounds contamination degree	Mineralization, g/dm^3	Danger classes		
			II	III	IV
B”	Very dangerous	>3			
B’	Dangerous	1.5-3.0	2-3	5-10	
B	Moderate dangerous	1.0-1.5	1-2	1-5	1-10
	Admissible	<1	<1	<1	<1

Fig. 10.1. Continued. Legend.

1.3. Assessment for territory defeating degree by dangerous exogenic and endogenous processes and phenomena

Pseudo-formula index	Territory defeating degree by dangerous EGP and phenomena	Total territory defeating, %	Development of dangerous EGP and phenomena including technogenic activation	Seismicity including technogenic increments, scores
E'	Strong	25-30	Extensive flooding, slides, karst in open and semi-open forms, technogenic activation	5-6 (1.5)
E	Medium	10-25	Karst in open and semi-open forms, gully and planar erosion	5-6 (1)
	Moderate and low	<10	Low and moderate development of some EGP and phenomena	5-6 (0.5)

2. Landscape zonation

A-I – Prysyvasko-Pryazovska lowland

A-II – Tarkhankutskiy elevated-plain steppe

3. Technogenic objects affecting state of geological environment

Chemical industry

Non-ore mineral mining

Agriculture complex units which are proved to be the sources of groundwater contamination

a) cattle and poultry farms

b) mineral fertilizer and pesticide shops

Area centers

major channels

irrigation systems

Industrial and housing waste storages:

a) solid

b) liquid

Water reservoirs, lakes

Water scoops operating with exploitation groundwater reserves approved by State Commission of Ukraine on Mineral Reserves; above symbol – index of water-bearing horizon

4. Protection of major water-bearing horizon under exploitation

Protected

Conventionally protected

Unprotected

5. Contamination of geological environment components

Soil contamination with toxic elements:

a) Ni, Cu, Ni fields with local heavy metal contamination, BCI = 8-32

b) Pb, Zn, Cu, F, Hg, Sr, Ba extensive spot soil contamination with BCI > 128

N,S Spot groundwater contamination with nitrogen compounds: numerator – index of water-bearing horizon, denominator – rate above TAC

6. Other symbols

Sites with defeating by dangerous EGP and phenomena in excess of 50% by square:

П - underflooding, K – karst

Abrasion (more than 5 m^2 per meter an year)

Isoseists, inside contour – rate, in parentheses – technogenic increment

B'E Pseudo-formula to assess the state of geological environment

Boundaries:

a) territories with different integral assessment for ecological state of geological environment

b) sites with assessment for changes in contamination of geological environment by specific components

landscape provinces

boundaries between ground and inter-bed waters in Sarmatian-Meotychniy-Pontychniy water-bearing complex

boundaries between the sites with different protection degree of Sarmatian-Meotychniy-Pontychniy water-bearing complex from vertical invasion of contaminating elements

Ecological state of geological environment. Entire studied territory is located under unfavourable conditions of technogenic charge. It especially concerns Prysyvasko-Pryazovska lowland. Over there, ecological breaking of the landscape attains 96.4% while in Tarkhankutskiy elevated-plain steppe it is 55-70% [42].

Major factors of lithosphere contamination include industrial pollutions, fertilizers and pesticides. Over the operating period of chemical enterprises the geochemical anomalies have been formed with element association Pb, Zn, Mo, Co, Cu, confined directly to the territories of chemical plants, housing massifs of Krasnoperekopsk town and its Sovkhozne suburb with TIC from 16 to 32 [74]. In the soil layer accumulation of chemical elements occur which participate in technological process and are contained in the wastes. Directly in the industrial sites of chemical plants in the soils anomalous content of heavy metals Pb, Zn, Mo, Cu, Cr, F, Hg, Sr, Ba with TAC more than 128 has been determined.

Besides that, in the mid of 80^{th} in the area of Krasnoperekopskiy industrial hub the persistent source of groundwater contamination with heavy metals has been formed which involved three water-bearing horizons with active water circulation: in Quaternary, Pliocene and Pontychni-Meotychni-Sarmatian sediments. Contamination site is 160 km^2 in size, its northern boundary is located outside the map sheep group, and southern boundary follows the line of Tavrycheske, Ishun, Zelena Nyva villages and further to the east. The anomaly is extended in the north-western direction along the line: southern part of Krasne Lake – acid tank in "Tytan" enterprise, with concentration of contaminating substances increasing towards the latter.

Heavy metals content in groundwaters of Pliocene sediments exceeded TAC with Li, Al, Mn by 10 times, Sr – by 3 times, with mineralization higher than 3 g/dm^3. Contamination source comprises distillate liquid pond in Krasne Lake. In the water of Pontychni-Meotychni-Sarmatian water-bearing horizon content of Li is from 0.03 to 0.09 mg/dm^3 (1-3 TAC), Mn – from 0.1 to 1.0 mg/dm^3 (1-10 TAC), and Al – from 0.5 to 1.5 mg/dm^3 (1-3 TAC). Heavy metals enter groundwaters at the industrial sites of chemical plants which have been set in the fields with first category of groundwater protection. But with groundwater level ascending the efficient thickness is decreased and this led to the regional decline in the degree of groundwater protection and made Quaternary water-bearing horizon accessible for contaminating substances infiltration.

Pontychni-Meotychni-Sarmatian water-bearing horizon in the area of chemical plants is ascribed to the category of conventionally protected. In addition, according to S.B.Morozov (VSEGINGEO), in case of clay interaction with acid, filtration properties of clays increase by 30 times, and development of weakness zones in water-proof layers due to neo-tectonic activation, makes shorter filtration time from hundred thousand years to first hundreds of days. However, under influence of improved hydrodynamic state over last times (regional level ascend of Pontychni-Meotychni-Sarmatian water-bearing horizon), the value of convective exchange has been decreased and less active diffusion mass transfer became predominated resulted in heavy metals content decreasing in groundwaters.

Over remaining territory, under influence of irrigation, especially active in rice bands, the major factors for soil and aeration zone rock contamination include mineral and organic fertilizers. Most extensive heavy metal contamination is provided by phosphorus fertilizers – superphosphate and ammophos. In the vertical cross-section maximum element enrichment coincides with humus horizon. Besides heavy metals, the nitrogen in nitrite, nitrate and amide forms enters the soils with fertilizers. Last two ones are being kept by soils. Nitrogen remnants, not used by the vegetation, are being transformed into nitrate, quite mobile form, which under soil over-wetting is being removed from the soils and goes down entering the groundwaters. Long-term input of fertilizers, pesticides and mechanic soil handling with significant fuel losses has led to the changes in macro- and micro-element balance in soils, micro-organism activity suppress, and changes in soil structure [79]. Evaporation provides the major barrier that stops the elements. The groundwater flow, discharging through evaporation, does bring the elements entered this flow in the rice bands and near-watershed ploughed sites. Therefore, contamination sources are comprised of the rice bands and ploughed sites where fertilizers are being used and transportation function is carried out by groundwaters. The permanent sources for heavy metal contamination also include cattle farms and complexes (sewages).

Radiologic state is studied in the northern part of map sheet L-36-XXII in the field from the coast of Karkinitska Bay further to the east [79]. By 1992, Cs-134 is determined in 12.5% of samples, in amount 1-2 bc/kg; Cs-137 content varies from 0 to 70 bc/kg; Sr-90 – from <1 to 10 bc/kg; $A_{spec.}$ – 600-900 bc/kg. In the water samples collected from Chatyrlyk, Vorontsivka, Tsilynna, $A_{spec.}$ is 0.1-0.45 bc/l; in groundwaters of Pontychni-Meotychni-Sarmatian sediments $A_{spec.}$ is from <0.05 to 1 bc/kg, $A_{spec.}$ of bottom sediments is 500-680 bc/kg. According to data from radiologic laboratory of Crimean Sanitary-Epidemiologic Station, radionuclide content in soils and surface waters did not exceed the norms over last 10 years.

Extensive groundwater consumption over last tens of years had led to the changes in groundwater hydrochemical and hydrodynamic regime of Pontychni-Meotychni-Sarmatian water-bearing horizon in Pivnichnokrymskiy artesian basin and Sarmatian water-bearing horizon over remaining territory. This process

had commenced in 50th and has risen especially faster from the beginning of 60th to the mid of 70th. The groundwaters have been used both for water supplying and irrigation. Non-controlled water consumption had led to the sharp drop in groundwater quality and caused negative processes, including enhanced interaction of water-bearing horizons, moving of waters with different mineralization and chemical composition inside the exploiting layer in horizontal and vertical direction, mechanic and chemical suffusion, infiltrative salt leaching from the aeration zone rocks, development of karst, groundwater level descending, formation of local depressive "funnels"|, establishing or enhancing infiltration from the surface water flows and reservoirs.

By 1982, the fields with groundwaters complying with requirements of DGS 2794-82 in Pontychni-Meotychni-Sarmatian sediments have been strongly reduced. Approaching of salt waters from the higher mineralized underlaying horizons had occurred. Along the sea coast, due to breaking in hydrodynamic equilibrium, approaching of sea waters is commenced and mineralization is increased because of chlorine-ion content rise in groundwaters. And only upon water input from Pivnichnokrymskiy channel the hydrodynamic situation was getting to be better although it is still complex. For instance, in Rozdolnenskiy area in some cases for housing-potable water supplying the groundwaters with mineralization up to 8.1 g/dm^3 are being used. In Pervomayskiy area, where consumption from Sarmatian water-bearing horizon has exceeded natural water recovery for many years, mineralization attained 4.1 g/dm^3. In Chornomorskiy area hydrochemical situation is very hard and 14 entities use water with mineralization 1.2-5.1 g/dm^3. In Chornomorskiy port desalination device is operating which drops groundwater mineralization from 3.3-5.1 to 1.1 g/dm^3.

Of the exogenic negative processes, the under-flooding and karst are most developed, and in lesser extent – salination, slides, suffusion, erosion processes etc. Prior to 1963 the natural high groundwater level had occurred around Stare, Kiyatske, Krasne lakes. Once Pivnichnokrymskiy channel had became operating and broad irrigation network was developed, almost entire area of Pivnichnokrymskiy lowland steppe was under-flooded. Under-flooding was caused by inappropriate state of drainage network, high degree of water consumption without proper control over irrigation norms, and defects in the channel protection against filtration. And only after construction of drainage system for strengthening the channel bottoms and carrying out some other protection actions the areas with groundwater level less than 3 m have ceased although they still occupy significant territory.

Karst is developed over entire distribution territory of Neogene limestones with thickness 50-160 m. In the area of Tarkhankutskiy elevated-plain steppe the open karst is developed at the sites where limestones, susceptible to the karst, are exposed at the surface or overlain by soil-gravel sediments up to 1 m thick. These areas are distinguished in the valleys of Samarchyk, Kerleutska, Stariy Donuzlav, Berezovska, Dort-Sokalska gullies, and along sea coast. Over remaining areas karst is observed in semi-closed or closed forms. In Pivnichnokrymskiy lowland steppe the covered deep karst is developed and intensity of karst processes is very high which is evidenced by the increased water-permeability of the rocks attaining 20-50 th.m^3/d.

In relation to extensive irrigation over large areas of agriculture lands the technogenic karst activation had commenced and this process is growing. Water losses from irrigation systems attain: in Krasnoperekopska irrigation system (water consumption 569 mln.m^3/year) – 26%; in Rozdolnenska (consumption 242.1 mln.m^3/year) – 17% [67]. In many cases aggressive carbon dioxide is noted in groundwaters. Its appearance is related to the input of irrigation waters which are being enriched in CO_2 in bio-chemical way. At some sites technogenic karst activation is caused by extensive groundwater exploitation. Changes in hydrodynamic conditions lead to the changes in groundwater chemical and gas composition, feeding conditions, flow speed and formation of deep basis for karsting resulted in karst processes activation. These phenomena are observed in the valleys of Dort-Sokalska and Kerleutska gullies, as well as along the coasts of Black Sea and Donuzlav Lake.

Salination is most developed in Prysyvasko-Pryazovska lowland. The type is chloride-sulphate or mixed sulphate-hydrocarbinate-chloride. Rock salination is observed to the depth 3-5 m. Salination degree is medium and slight. Some rock horizons are highly salinated. Salt and acid soils are developed widely enough. In the irrigated lands of Prysyvashshya, because of groundwater elevation to the depth less than 2.5 m from the surface and their evaporation, the processes of secondary soil salination are observed. In the salinated fields, at the river mouth parts and former rice bands, the fish farming is established.

The value of abrasion parameter over most part of the coastline does not exceed 0.5 m^3/m per year. In the areas to the west from Donuzlav Lake and up to Lazurne ravine and to the south-west and north-east from Bakalska spit the value of coast abrasion in some stormy years attains the catastrophic amounts: from 6.39 to 129 0.5 m^3/m per year.

Almost entire Plain Crimea is defeated by erosion processes. The wind erosion (deflation) in Steppe Crimea comprises major erosion type. As a result of the dust (black) hurricanes, repeating up to 7 times per 10 years, about 20-30 cm of arable soil is being removed. The dust, removing from agricultural lands, is depositing in the lowered relief forms and forest bands. In the gullies such sediments in places attains 4 m thick [74, 79]. As

to the water erosion, the lands with high and medium-removed soils comprise up to 5% of the total arable and grazing square, and in Tarkhankutskiy peninsula – up to 10%.

The land slides are known from some sites along the coast of Tarkhankutskiy peninsula (Dzhangulskiy slid massif is the greatest). The slides over there are being formed under influence of abrasion and related to deformations over layered Sarmatian clays.

Suffosion and collapsing phenomena are noted in the course of irrigation system exploitation in the zone of Pivnichnokrymskiy channel. Specifically, in its Chornomorska branch at some sites the deformation on the channel edges and concrete faces are observed.

Table 10.3. Assessment criteria for ecological state of geological environment.

Ecological state of geological environment	Natural factors		Technogenic factors					
	Pressurized groundwater protection from vertical input of contaminating components	Territory defeating by EGP, %	Soil contamination by heavy metals (BCI), %	Groundwater contamination by chemical elements and their compounds				Module of technogenic loading, th.m^3(t)/km^2
				mineralization, g/dm^3	TAC			
					I	II	III	
Charged	Non-protected $H_2<H_1$ and $m_0<10$	25-50	32-128	1.5-3 and >3	2-3	5-10	>10	50-100
Moderate charged	Conven-tionally protected $H_2>H_1$ and $m_0<10$ or $H_1\leq H_2$ and $m_0>10$	10-25	16.32	1.0-1.5	1-2	1-5	1-10	10-50
Appropria te	Protected $H_2>H_1$ and $m_0>10$	10	≤16	≤1	≤1	≤1	≤1	≥10

Notes: H_2 – pressure of underlaying water-bearing horizon;
H_1 – pressure of overlaying water-bearing horizon;
m_0 – water-proof thickness.

The map sheet area is located in the zone of 5-6 rank of seismicity. Technogenic seismicity increment – 1.5 rank.

Taking into account the changes in quality and quantity parameters of soils, groundwaters and influence of technogenically-activated exogenic processes (Table 10.3), three categories are distinguished for the territories with different degree of geological environment breaking.

1. Territories with appropriate state of geological environment – the latter is close to the natural and is ecologically safe.

2. Territories with moderately-charged state of geological environment – negative changes are identified in one or two components of geological environment by specific contamination parameters.

3. Territories with charged state of geological environment – negative changes are identified in all components of geological environment.

In the area, which includes Krasnoperekopsk town, its industrial zone and satellite suburb Sovkhozne, the zone with charged ecologic state has been formed. It has happened by many reasons: long-term operations of chemical plants resulted in litho- and hydrochemical anomalies; developed under-flooding enhanced by water losses from water and sewage systems; groundwater blocking by the construction basements; lack of rain water drop systems; cancel of groundwater evaporation from the surface in the sites of house building. Mineralization increasing in major exploitation water-bearing horizon, its volume exhaustion, development of technogenic karst and other exogenic processes had led to moderate charged ecological state over most part of map sheet group L-36-XXI, L-36-XXII, L-36-XXVII. In the remaining areas ecological state is assessed to be appropriate.

Study of hydrogeological (hydrochemical and hydrodynamic) regime in Rivnynnokrymskiy basin of bedded pressurized waters is being conducted through the network of observation boreholes; besides that, in Perekopskiy research polygon the observations are being carried out over degree of water-bearing horizons contamination by heavy metals. The landscape-geochemical studies in the area are almost lacking except the fields adjoining Krasnoperekopska group of chemical plants (map sheet L-36-XXI) [74]. In 80^{th}, in the course of geological-ecological studies, under conditions of high-degree technological charge, the unique data were obtained on degree of water-bearing horizons contamination with nitrogen compounds, residual pesticides, heavy metals, and the changes in groundwater hydrochemical and hydrodynamic regimes were assessed. Nowadays amount of the system observations (network of observation boreholes, number of determinations and collected samples) is reduced by 5 times in comparison to 1990. The landscape-geochemical studies in the most part of the area are almost lacking at all. To monitor further and access the state of environment it is recommended:

- to conduct the complex ecological-geological and lithological studies over entire area of map sheet group L-36-XXI, L-36-XXII, L-36-XXVII;
- to continue the system hydrogeological observations in the full extent (on the level of 80^{th}-90^{th}).

These works would allow assessment on the actual ecological state of geological environment, forecasting development of geological-ecological situation and practical recommendations with regard to further industrial development, rational water consumption, optimal use of fertilizers and pesticides in various landscape-geochemical conditions.

CONCLUSIONS

Conducted works on preparation to publishing the set of maps of new Derzhgeolkarta-200 series, the Chornomorsko-Perekopska map sheet group (L-36-XXI, -XXII, -XXVII) allowed adjustments in geology of the area, and solution to some problems of stratigraphy, magmatism, tectonics, history of development, and assessment the area perspectives for various mineral types.

The main results of the studies are as follows:

1. The set of maps of new Derzhgeolkarta-200 series is designed, which includes geological maps and maps of mineral resources of pre-Quaternary units and Quaternary sediments, where all available primary data from previous studies are summarized in compliance with recently approved stratigraphic schemes and instructive documents. In the preparation process the authors have designed and approved stratigraphic correlation schemes of Ryphean-Paleozoic, Miocene and Pliocene sediments that made geological maps more detailed and geological boundaries became more argued. The maps are designed using litho-stratigraphic principle with definition of local and auxiliary subdivisions, sequences and layers.

2. For the first time in the map sheet group area Ryphean Bakalska Series is defined.

3. Paleozoic sediments are subdivided into Zuyska and Novoselivska suites.

4. Based on deep-drilling data analysis, all mapping objects are presented in compliance with new correlation stratigraphic schemes and all even-aged diverse-facies Mesozoic and Cenozoic complexes are correlated.

5. For the first time, in geological maps Pliocene Tyup-Dzhankoyski layers and Eo-Pleistocene Prysyvaska sequence are distinguished.

6. Quaternary sediments are subdivided up to climatoliths and modern structure-geomorphologic zonation of the studied territory is applied.

7. All available data on magmatism in the region are summarized. Four complexes of non-stratified rocks are distinguished – Syvaskiy, Novoselivskiy, Pivnichnokrymskiy, and Tarkhankutskiy.

8. The modern mineral-resources base of the region is described and perspectives are assessed for its upgrading mainly with regard to the traditional mineral types: hydrocarbons, groundwaters and construction materials.

9. Ecological-geological situation in the area is appraised with technogenic landscapes definition, contamination elements are identified as well as the sites of negative technogenic processes related to exploitation of Pivnichnokrymskiy channel and Krasnoperekopska group of chemical plants.

On the completion of works in preparation to publishing the Chornomorsko-Krasnoperekopska map sheet group some issues of geology and history of structure development still do not get unequivocal solution and require further studies. Of these, the main ones include:

1. Adjustment the features of basement geology including Ryphean and Paleozoic sediments.

2. Study the lower column parts in Pivnichnokrymskiy trough meaning possible occurrence in flyschoid terrigenous sequences not only Triassic but also Permian sediments.

3. Adjustment the scheme of magmatism in the region on the ground of additional isotopic age dating and definition of emplacement phases for intrusive complexes.

4. Study of lithological-stratigraphic containers and tectonic structures favourable for hydrocarbon traps formation.

5. Litho-chemical and ecological-geological studies and monitoring of geological-ecological situation of environment.

Solution of mentioned problems requires further geological-exploration and research works which can be based on the prepared set of Chornomorsko-Krasnoperekopska map sheet group.

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ANNEXES

Annex 1. List of deposits and occurrences indicated in the geological map and map of mineral resources in pre-Quaternary units of map sheets L-36-XXI, -XXII, -XXVII

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
Map sheet L-36-XXI				
Combustible minerals Gaseous Natural gas				
III-2-18	Yarylgatske; 18 km to NE from Chornomorske town	Never been exploited	Sheeted with porous-type container	10
III-2-21	Mizhvodnenske; 10 km to E from Mizhvodne village	Never been exploited	Sheeted with porous-type container	10
IV-1-48	Chornomorske; 3 km to NW from Chornomorske town	Never been exploited	Sheeted with fracture-porous-type container	10
IV-1-50	Olenivske; 12 km to SW from Chornomorske town	Never been exploited	Sheeted carbonate with fracture-porous-type container	10
IV-2-52	Krasnopolyanske; 4 km to SW from Krasna Polyana village	Never been exploited	Sheeted with fracture-porous-type and porous-fracture-type container	10
Liquid Gas-condensate				
IV-2-53	Zakhidnooktyabrske; 2 km to NE from Gromove village	Never been exploited	Sheeted with fracture-porous-type container	10
Oil				
IV-2-54	Oktyabrske; 2 km to NW from Medvedivka village	Never been exploited	Sheeted with fracture-porous-type container	10
Liquid and gaseous concomitant				
III-2-25	Karlavske; 4 km to N from Krasna Polyana village	Never been exploited	Sheeted with fracture-porous-type container	10

1	2	3	4	5
Non-metallic mineral resources Construction raw materials Dimension wall raw materials Limestones				
III-2-19	Zaytsivske, Vodopiynenska site; 3 km to SE from Novoulyanivka village	Never been mined	Sedimentary	69
III-2-20	Vodopiyne; 0.5 km to NE from Vodopiyne village	Never been mined	Sedimentary	22
III-2-22	Zaytsivske, Zaytsivska site; 0.3 km to W from Zaytseve village	Never been mined	Sedimentary	69
III-2-23	Chornomorske; 8 km to NE from Chornomorske town	Never been mined	Sedimentary	39
III-2-24	Zaytsivske, Karyerna site; 3 km to NE from Novosilske village	Never been mined	Sedimentary	69
IV-1-49	Kypchatske; 7 km to SW from Chornomorske town	Never been mined	Sedimentary	28
IV-1-51	Olenivske; 3 km to SE from Olenivka village	Never been mined	Sedimentary	22
IV-2-55	Lazurnivske; 2 km to W from Lazurne village	Never been mined	Sedimentary	22
Map sheet L-36-XXII				
Combustible minerals Gaseous Natural gas				
III-3-30	Zadornenske; 2 km to S from Zadorne village	In production	Sheeted with carbonate-fracture-porous-type container	10
III-3-31	Kirovske; 1.5 km to S from Kirovske village	Never been exploited	Sheeted with fracture-porous-type container	10
Liquid Gas-condensate				
II-5-10	Tetyanivske; nearby Krylovka village	Never been exploited	Sheeted with porous and fracture-porous-type container	10
IV-3-57	Glibivske; in between Krasna Polyana and Glibovka villages	Exhausted	Sheeted with porous-fracture-type container	10

1	2	3	4	5
Oil				
III-4-32	Serebryanske; 51 km to N from Evpatoriya town	Never been exploited	Sheeted with mixed porous-fracture and porous-fracture-cavernous-type container	10
Non-metallic mineral resources Raw materials for metallurgy and non-metal ore minerals Flux and chemical raw materials Flux limestones and dolomites and limestones for sugar industry				
III-3-28	Dalne; in between Volodymyrivka and Starosillya villages	Never been mined	Sedimentary	49
III-6-46	Pervomayske; 11 km to SW from Pervomayske town	Never been mined	Sedimentary	71
IV-3-62	Donuzlavske; to W from Donuzlav Lake	Never been mined	Sedimentary	49
Construction raw materials Dimension wall raw materials Limestones				
II-3-3	Slavnenske; 1 km to W from Slavne village	In production	Sedimentary	90
II-3-4	Dalne; 1 km to W from Pivnichne village	Out of production by various reasons without decision on conservation	Sedimentary	22
II-4-6	Slovyanske; 2 km to S from Slovyanske village	In production	Sedimentary	30
II-5-7	Kalininske; 3.5 km to W from Kalinine village	Never been mined	Sedimentary	31
II-5-8	Sinokisne; 5.5 km to E from Sinokisne village	In production	Sedimentary	37
II-5-9	Kyulsyuitske; 6 km to E from Sinokisne village	Never been mined	Sedimentary	22
II-5-11	Komunarske; 3 km to SE from Komunarne village	Never been mined	Sedimentary	77
II-5-12	Kovylne-I; 3 km to NE from Kovylne village	Never been mined	Sedimentary	53
II-5-13	Krylovske; 2 km to W from Krylovka village	In production	Sedimentary	40
III-3-26	Kotovske; 5 km to SW from Kotovske village	In production	Sedimentary	88
III-3-27	Volodymyrivske; 1 km to SE from Volodymyrivka village	Never been mined	Sedimentary	32
III-3-29	Kirovske; 5 km to NW from Kirovske village	In production	Sedimentary	56
III-4-33	Voronkivske; 3 km to W from Voronky village	In production	Sedimentary	55

1	2	3	4	5
III-4-34	Nyvske; 2.5 km to SE from Nyva village	In production	Sedimentary	89
III-4-36	Krasnoyarske, two sites: 1 km to W and 2.5 km to E from Krasnoyarske village	Never been mined	Sedimentary	66
III-5-38	Serebryanka; 4.5 km to E from Serebryanka village	In production	Sedimentary	87
III-5-39	Serebryanske-II; 4 km to E from Serebryanka village	In production	Sedimentary	58
III-5-40	Klenove; 7 km to S from Kovylne village	In production	Sedimentary	38
III-5-41	Novooleksiivske; 2.5 km to NW from Oleksiivka village	In production	Sedimentary	72
III-5-42	Tavriyske; 5 km to W from Oleksiivka village	In production	Sedimentary	78
III-5-43	Oleksiivske; to ESE from Oleksiivka village	In production	Sedimentary	22
III-5-44	Kormovske; 7 km to NE from Kormove village	Never been mined	Sedimentary	22
III-6-45	Kamyanske; 1.2 km to SW from Kamyanka village	Never been mined	Sedimentary	51
III-6-47	Gryshynske; 3.5 km to SE from Gryshyne village	Never been mined	Sedimentary	59
IV-3-58	Khmelyovske; 3.5 km to SW from Khmilyove village	In production	Sedimentary	50
IV-3-59	Glibivske; 2 km to SE from Glibovka village	Never been mined	Sedimentary	62
IV-3-60	Novoivanivske; 2 km to NE from Novoivanivka village	Completely exhausted	Sedimentary	45
IV-3-61	Medvedivske; 7 km to N from Medvedivka village	Never been mined	Sedimentary	57
IV-3-63	Veselivske; 0.5 km to S from Veselivka village	Never been mined	Sedimentary	52
IV-4-64	Novomykolaivske; 7 km to SW from Chekhove village	Never been mined	Sedimentary	33
IV-4-65	Krasnivske; 4 km to E from Krasnivka village	Never been mined	Sedimentary	76
IV-5-66	Novoselivske; 6-10 km to NE from Novoselivske village	Never been mined	Sedimentary	22

1	2	3	4	5
IV-5-67	Prostornenske; 8 km to NE from Novoselivske village	In production	Sedimentary	–"–
IV-5-68	Panfilivske; 4 km to SW from Panfilivka village	In production	Sedimentary	54
IV-5-69	Pervomayske-Nove; 9-10 km to ENE from Novoselivske village	In production	Sedimentary	22
IV-5-70	Severske; 2.5 km to NW from Novoselivske village	Never been mined	Sedimentary	36
IV-5-71	Susaninske; 5 km to S from Susanine village	Never been mined	Sedimentary	44
IV-5-72	Vynogradivske; 1.5 km to SW from Vynogradove village	In production	Sedimentary	63
IV-5-73	Lugivske; 1.3 km to S from Lugove village	Never been mined	Sedimentary	29
IV-5-74	North-Baranivske; 6 km to SW from Illinka village	In production	Sedimentary	43
IV-5-75	Veresaivske; 6 km to SE from Veresaeve village	Never been mined	Sedimentary	61
IV-5-76	Stovpove; 3.2 km to NE from Naumivka village	In production	Sedimentary	80
IV-5-77	Krasnodarske;4.5 km to SW from Illinka village	Never been mined	Sedimentary	60
IV-5-78	Naumivske-II; 2 km to N from Naumivka village	In production	Sedimentary	22
IV-6-79	Chornivske; 1.3 km to SE from Chornove village	Never been mined	Sedimentary	84
IV-6-80	Krasnokrymske; 4 km to SW from Voykove village	Never been mined	Sedimentary	85
IV-6-81	North-Zhuravlivske; 1.5 km to N from Zhuravlivka village	In production	Sedimentary	22
IV-6-82	Zhuravlivske; nearby Zhuravlivka village	In production	Sedimentary	22
IV-6-83	Illinske; 1 km to SW from Illinka village	In production	Sedimentary	26
Aggregate raw materials Limestones				
II-5-14	Kovylnenske; 1.5 km to E from Kovylne village	Never been mined	Sedimentary	73
II-6-17	Stepove; 2.5 km to N from Stepove village	Out of production by various reasons without decision on conservation	Sedimentary	22

1	2	3	4	5
III-4-35	Chekhivske; 1.5 km to S from Chekhove village	In production	Sedimentary	22
III-4-37	Krasnoyarske, Lenska site; 1 km to SE from Lenske village	Never been mined	Sedimentary	22
IV-3-56	Krasnoyarske, Dozornenska site; 1.7 km to SW from Dozorne village	Never been mined	Sedimentary	22
Waters Groundwaters Fresh waters				
	Pivnichnosyvaske, sites:			
I-6-1	Perekopska-1; Voinka village	In production	Sheeted	83
I-6-2	Vorontsivska; Vorontsivka village	In production	Sheeted	83
II-4-5	Rozdolnenska; Botanichne village	In production	Sheeted	83
II-6-15	Perekopska-3; Matviivka village	In production	Sheeted	82
II-6-16	Pervomayska; Makarivka village	In production	Sheeted	83
Thermal waters				
IV-6-84	Novoselivske; area of Illinka, Trudove and Novoselivske villages	Never been exploited	Sheeted	68

Annex 2. List of deposits and occurrences indicated in the geological map and map of mineral resources in Quaternary sediments of map sheets L-36-XXI, -XXII, -XXVII

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
Map sheet L-36-XXI				
Waters Mineral sludge and mud Curative mud				
III-2-86	Dzharylgach Lake; 15 km to NE from Chornomorske town	Never been exploited	Sedimentary	27
III-2-87	Karlavskiy occurrence (Yarylgach Lake); 12 km to NE from Chornomorske town	Sludge type – sulphide, high-mineralized, chloride-magnesium-sodium. Volume mass – 1.4 g/cm^3, admixtures – 0.7%, organic matter content – 1.6%, pH – 7.1	Sedimentary	27
III-2-88	Panske Lake; 6 km to NE from Chornomorske town	Never been exploited	Sedimentary	27
IV-1-89	Karadzha (Lyman Lake); 23 km to SW from Chornomorske town	Sludge type – sulphide, chloride-magnesium-sodium. Thickness of sediments – 0.3 m. By main parameters sludge is similar to that of Karlavskiy occurrence	Sedimentary	27
Map sheet L-36-XXII				
Non-metallic mineral resources Construction raw materials Sand-gravel raw materials Construction sand				
IV-3-90	Donuzlavske; mouth part of Donuzlav Lake	In production	Sedimentary	22
Waters Mineral sludge and mud Curative mud				
II-3-85	Bakalskiy; Bakalske Lake	Sludge type – sulphide, medium-mineralized, chloride=magnesium-sodium. Moisture – 51%, volume mass – 1.5 g/cm^3, admixtures – 4.1%, organic remnants – 1.8%, pH – 7.3	Sedimentary	27

Annex 3. List of geological landmarks and ancient culture landmarks

List number	Number in the map	Name of landmark and brief description	Category by value
1	2	3	4
I. Stratigraphic (S)			
1	3	Stratotype of Upper Quaternary sediments and Neolite settlement nearby Severne village	L
2	14	Outcrop of Maastrichtian sediments nearby Melove village in Tarkhankutskiy peninsula	L
II. Tectonic (T)			
3	7	North-east-trending fault, Paleolite settlement	L
4	11	Occurrence of recent tectonic motions with formation of "hanging" valleys	L
III. Geomorphologic (G)			
5	2	Bakalska spit nearby Steregushche village	S
6	8	Dzhangulske sliding coast and chimera abrasion forms	S
7	15	Erosion coast of Tarkhankut – Big and Small Atlesh, chimera abrasion forms	S
IV. Ancient culture landmarks (A) **a) ancient graves, settlements (primary culture landmarks – 40-1 th.years BC)**			
8	1	Syvaske mound field – anthropogenic relief; Bronze epoch mound of Scyths and late nomads – Pechenegs, Polovtsi, Tatars	L
9	9	Shyroka Mogyla mound	L
10	12	Zeleniy mound	L
11	13	Belyauska Mogyla mound and Belyaus fortress remnants	S
b) archeological (Antic epoch landmarks)			
12	4	Fortress remnants from ancient Greek settlement with Hercules sanctuary nearby Mizhvodne village – II century BC	S
13	5	Antic fortress patrimony and clergy nearby Panske Lake	S
14	6	Ruins of Antic Kalos-Limen town (Nice Harbour)	S
15	10	Remnants of Antic settlement at Karadzha Lake (IV century BC – III century AC)	S

Notes on value categories:
L – local-rank landmarks
S – State-rank landmarks

STATE GEOLOGICAL MAP OF UKRAINE

Scale 1:200 000

Crimean Series

Map Sheet Group
L-36-XXI (Chornomorske), L-36-XXII (Krasnoperekopsk), L-36-XXVII (Morske)

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