



**An Atlas
OF THE GEOLOGY
AND MINERAL
DEPOSITS
OF UKRAINE**



INTRODUCTION

An Atlas of the Geology and Mineral Deposits of Ukraine, with emphasis on the location and description of known mineral showings and prospects, was compiled in Kyiv by a group of researchers under the direction of Dr. Leonid Galetsky of the Ukrainian Academy of Sciences. When Dr. Galetsky approached Mr. James Temerty to support the translation and publication of an English version of the Atlas, Mr. Temerty sought assistance in making the Atlas a more practical tool for foreign investors who might be interested in the mineral opportunities that may exist in Ukraine. A small Mineral Advisory Group was formed with the participation of senior retired mining executives from INCO Limited – Dr. Walter Curlook, former vice chairman, Mr. Terrence Podolsky, former vice president of exploration, and Dr. Walter Peredery, senior geologist.

This group started by assisting Dr. Galetsky in translating the Atlas into English. Under the direction of Dr. Peredery and Mr. Podolsky, the Atlas was expanded with over 60 pages of new text, maps, and descriptions, identifying regions for gold, rare elements, titanium and zirconium placer, kimberlites, and diamonds, and outlining historical mining regions. The additional data provide solid information

that can be helpful in better understanding the commercial potential of Ukraine’s mineral resources.

At the same time, the Mineral Advisory Group offered to share their experience in structuring investments in various foreign jurisdictions with Ukrainian legislators and government officials. Of special note, a series of seminars and discussions were held in Ukraine to explain the concept of the “Contract of Work” that had proven very effective in attracting foreign investment in the mineral resources sector of developing countries. While the Ukrainian authorities have not fully adopted that approach, and the legislative and regulatory framework governing investment in the sector continues to evolve, it is our conviction that this Atlas should encourage foreign investors to explore the opportunities that exist in Ukraine.

As Ukraine continues to develop the institutions of democratic government and expands its market economy, the investment environment for the mineral industry is becoming increasingly attractive for both domestic and foreign investors.

James Temerty and the Mineral Advisory Group

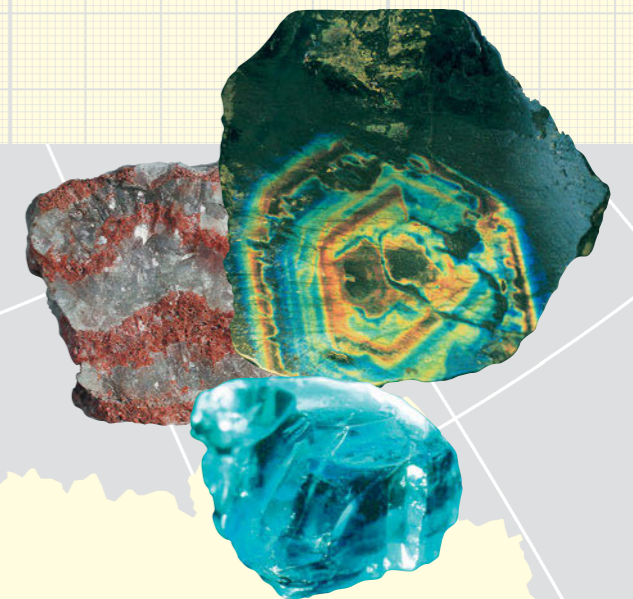
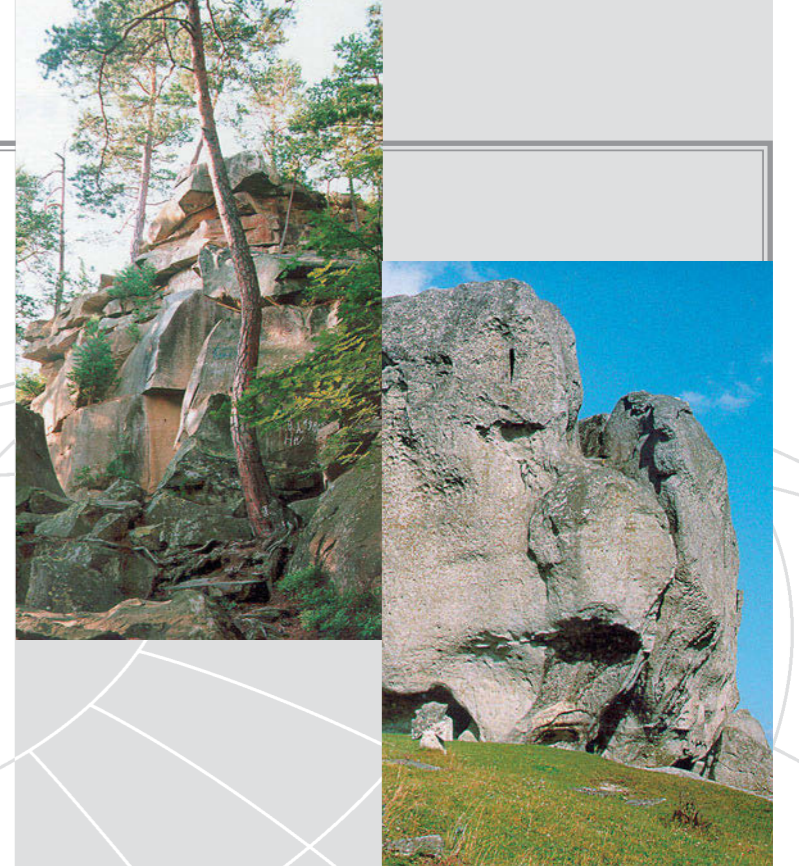
An Atlas

OF THE GEOLOGY AND MINERAL DEPOSITS OF UKRAINE

Scale 1:5 000 000



Kyiv and Toronto
2007



**NATIONAL ACADEMY OF SCIENCES OF UKRAINE
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To the editors and readers of *An Atlas of the Geology and Mineral Deposits of Ukraine*

Dear Friends,

The work before you contains information about some of Ukraine's most significant treasures. Prepared by a group of leading specialists in the field, *An Atlas of the Geology and Mineral Deposits of Ukraine* incorporates a century of geological research of our country's territory.

Reading this book, even people without specialized training will be convinced of the wealth and variety of Ukraine's natural resources, her ancient geological formations and rare mineral deposits. In many areas, Ukraine's deposits represent a substantial proportion of the world's mineral resources, ranking our country among the most important mining regions of the planet.

This new geological atlas should serve as an invitation to the further study and development of Ukraine's resources and encourage international cooperation and investment in this sphere.

I sincerely hope as well that this new publication will help the international community to become better acquainted with the rich history of Ukraine, her land and natural wealth.

President of Ukraine

Victor Yushchenko



*Editor-in-chief
L.S. Galets'kyi*



*Project manager
N.M. Cherniyenko*

UNIQUE UKRAINIAN GEOLOGICAL PUBLICATION

For the first time, leading scientists and researchers associated with the Ukrainian Academy of Sciences and the State Committee on Geology and the Exploitation of Mineral Resources of Ukraine have cooperated in creating a unique Atlas of the Geology and Mineral Deposits of Ukraine. Comprising 75 different maps at a scale of 1:500 000, the publication provides a summary of the geological structure, natural resources, and environmental situation throughout the entire Ukrainian territory.

Ukraine is an outstanding geological region generously endowed with a wide variety of geological structures and minerals. The country's eight thousand deposits contain over 90 types of mineral resources: ferrous, non-ferrous, rare, and noble metals; uranium; graphite; kaolin; coal; oil and gas; mineral waters; and gemstones.

Many deposits described in the Atlas represent opportunities for foreign investors and developers. These include gold, rare and non-ferrous metals as well as iron, manganese and uranium ores, kaolin and clay, gemstones, and mineral water. The maps and text in this Atlas will mark Ukraine's debut in the international world of geological information and draw attention to the possibilities for international cooperation in mining and processing projects.

L.S. Galets'kyi

N.M. Cherniyenko



Topaz "Golden Polissia", Volyn'



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CONTENTS

Introduction	8
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SECTION I. General overview maps

Ukraine. Geographical-economic description	10
Administrative districts of Ukraine	11
Satellite map of Ukraine	12
Physical geography of Ukraine	13
Location of Ukraine within Europe	14
Ukraine in the context of the main geological structures of Europe	15

SECTION II. Geophysical maps

Aeromagnetic surveys coverage	18
Magnetic anomaly field	19
Regional magnetic field	20
Gravimetric surveys coverage	21
Residual gravity anomalies	22
Regional gravity	23
Thermal field	24
Deep penetration geophysics: MTS, DSS and CDPT coverage	25
Apparent conductivity of sedimentary cover	26
Apparent conductivity of the Earth's crust to a depth of 20 km	28
Apparent conductivity of the Earth's crust to a depth of 50 km	29
Integral conductivity of the lithosphere to a depth of 80 km	30
Effective electric resistivity of the Earth's crust at a depth of 50 km	31
Effective electric resistivity of the lithosphere at a depth of 80 km	32
Electric heterogeneity of the lithosphere	33
The Moho discontinuity	34
Deep structure of the lithosphere	35
Deep structure of the Earth's crust along the geotraverses II, VI, VIII	36

SECTION III. Structural maps

Glaciers and Quaternary sediments	40
Quaternary deposits	42
Structure of the sedimentary cover	44
Tectonic map	47
Structure of the basement	50
Linear and ring geological structures	53
Neotectonics and recent vertical movements of the Earth's crust	56
Geodynamic map	58

SECTION IV. Geological slice maps

Geological coverage	64
Pre-Quaternary	66
Pre-Neogene	68
Pre-Paleogene	70
Pre-Cretaceous	72
Pre-Jurassic	74

Pre-Triassic	76
Pre-Permian	78
Pre-Carboniferous	80
Pre-Devonian	82
Pre-Silurian	83
Pre-Ordovician	84
Pre-Cambrian	85
Pre-Vendian	86
Pre-Riphean	87

SECTION V. Lithological-facies maps

Middle Eocene (Kyiv suite and its age analogs)	90
Upper Cretaceous (Turonian-Santonian)	92
Upper Cretaceous (Cenomanian)	94

SECTION VI. Ecological and hydrogeological maps

Hydrogeological districts	98
Surface geological processes	100
Impact of surface geological processes	102
Zones of ecological-geological risk	103
Landscape and geochemical zoning	104
Industrial waste load on geological environment	106
Natural radioactivity	108
Eco-geological situation	110

SECTION VII. Mineralogical maps

Mineralogenic zoning of the sedimentary cover	114
Metallogenic provinces	116
Fossil fuels – oil and gas	118
Coal	122
Ferrous metals (Iron, Manganese and Chromite)	124
Gold deposits	126
Rare metals	128
Titanium and zirconium placers and source deposits	130
Diamonds	132
Gems, semiprecious and decorative stones	134
Geothermal power	136
Mineral water sources	138
Clay and kaolin	140
Enterprises, industrial wastes and mining tailings	142
Mineral deposits	144
Mineral deposits currently in production	146
Mining areas	148
History of mining in Ukraine	151
Unusual geological features	156
References	166

INTRODUCTION

An Atlas of the Geology and Mineral Deposits of Ukraine was first compiled in the Ukrainian language after a long period of geological investigations. Its preparation was carried out using newly developed concepts in geology and geophysics, such as the evolution of the Earth's crust, its fracturing and non-uniformity, its division into geoblocks, its tectonic-magmatic activation, geodynamics, metallogenesis and the emergence of metallogenic provinces.

This English language edition of the Atlas contains 75 maps with short explanatory notes. During the compilation of various maps, extensive research was carried out on the existing literature in both the Ukrainian and Russian languages. Geological literature from the countries bordering Ukraine was also used.

The geology of Ukraine spans a huge time interval, from the ancient Archean to the most recent eras, a period of some 3.5 billion years. In this period the geology passed through several stages of volcanic-sedimentary accumulations, magmatism, orogenic tectonism and mineral deposition. The principal geologic structures include the Precambrian of the Ukrainian Shield, the Proterozoic mobile belts and other structures in the Ukrainian Shield, the old East European Platform, the younger Scythian Plate, the folded areas of the Donbas and the Carpathian and Crimean Mountains.

Ukraine is the geological and geographical center of Europe. The main geological structures of the European continent, such as the East European, the West European and the Central European platforms, the Tethys structures, the Alpine-Carpathian and the Crimean-Caucasus folded structures meet each other on its territory. The geographical center of Europe is situated near Rakhiv in Transcarpathia (Zakarpattia oblast').

Ukraine occupies some 603 700 square kilometers or about 0.4% of the Earth's land surface. It accounts for a significant portion of the total mineral production of the world, including 25% of the manganese, 10% of the iron and 5% of the coal. Ukraine has nearly 8000 deposits and showings, represented by the 90 types of mineral commodities. Of these, about half are explored. Some of the more important deposits include iron, manganese, uranium, coal, titanium, zirconium, sulfur, kaolin, mercury and graphite. Of lesser importance are deposits of gold, phosphorus, rock and potash. There are also deposits of beryllium, lithium, scandium, rare earth metals, base metals such as zinc-copper, and nickel-copper-cobalt and associated precious group elements (platinum, palladium, etc.), fluorite, alunite, barite, gems (beryl, topaz, opal) and semiprecious stones (cristobalite-silicites and chalcedony, etc.) and a variety of facing stones. Recently discovered occurrences of native copper, molybdenum, tin, tantalum, niobium and vanadium are potential targets for exploration and hold promise of becoming economic deposits.

Natural springs in Ukraine are sources for vast quantities of mineral waters.

Other than coal, Ukraine also has oil and gas deposits. These are found in the Dnipro-Donets' Depression, in the Carpathian Mountains, and in the southern part of Ukraine in the Crimean region. Combustible shales and methane-bearing shales are encountered in a number of places in the country. At this time Ukraine is not self-sufficient in oil and gas, and it imports these commodities.

Old tailings deposits have been shown to contain economic concentrations of gold and rare and noble metals, as well as other useful non-metallic minerals. Some of these deposits are mineable under current economic conditions.

About 48% of the country's industry and about 20% of the total labor force are involved in some way with either the mining, processing or exploration of various mineral commodities. At this time there are about 400 underground mines, over 1500 open pits, tens of ore-processing plants, and several oil and gas extraction plants in operation. In total, they provide 23-25% of the gross national product, and about one third of Ukraine's foreign trade income comes from exported minerals.

Ukraine exports kaolin, bromine, sulfur, manganese concentrates, iron, titanium, zirconium and graphite ores; quartz sand for the glass industry; rock and potassium salts; minerals for paints; non-metallic minerals for the metallurgical industry; facing stones; etc.

Production capacities of the following commodities can be easily adjusted to meet demand: beryllium, lithium, scandium, rare earth metals, kaolin, titanium, zirconium, gem stones and facing stones.

The Atlas can be used for a number of purposes. First of all it will serve as a basis for the understanding of the geology of Ukraine and its resource base, and as a quick reference source for a wide spectrum of interests. It can be used to point out areas that require further geological work, be they routine or with a specific problem. It can be used in the appraisal of the ecological environment of the country. It can be used as a base in planning engineering projects. And it can also serve as a source of information for companies interested in the potential for finding new mineral resources in Ukraine. For these purposes, the compiled geophysical maps present a highly organized picture of the entire country and in particular the configuration of major structures deep in the crust of the Earth.

This Atlas illustrates the main results of the geological work carried out in this and the previous century. In a compact form it summarizes accomplishments and provides a base for further geological exploration in the new millennium. To acknowledge all of the individuals who contributed to this Atlas is a difficult task indeed. Some of their names, however, are given in the References at the end of this Atlas. The editorial board is thankful in particular to the teams of authors who put their efforts together to produce results that will, hopefully, stand the test of time. We are very grateful for their cooperation.

NAMES AND REFERENCES

1. Personal names

Personal names are spelled according to the preference of individuals for their common use in English. Where individuals have not used their name in English, it is transliterated according to the modified Library of Congress system.

2. Geographical Names

Geographical names are rendered in the language of the country in which they are found. Polish and Romanian names, for example, are spelled in their original Latin script. Russian and Ukrainian names are transliterated from their respective Cyrillic scripts according to a modified Library of Congress system, as used in the Encyclopedia of Ukraine: Map and Gazetteer (Toronto: University of Toronto Press, 1984).

3. References

References listed at the end of this atlas are rendered in their original languages, Russian and Ukrainian.

4. Transliteration table

Ukrainian	Russian	English	Ukrainian	Russian	English
А а	А а	A a	Н н	Н н	N n
Б б	Б б	B b	О о	О о	O o
В в	В в	V v	П п	П п	P p
Г г	-	H h	Р р	Р р	R r
Ґ ґ	Г г	G g	С с	С с	S s
Д д	Д д	D d	Т т	Т т	T t
Е е	Э э	E e	У у	У у	U u
Є є	Е е	Ye/ie*	Ф ф	Ф ф	F f
Ж ж	Ж ж	Zh zh	Х х	Х х	Kh kh
З з	З з	Z z	Ц ц	Ц ц	Ts ts
И и	Ы ы	Y y	Ч ч	Ч ч	Ch ch
І і	И и	I i	Ш ш	Ш ш	Sh sh
Ї ї	-	I i	Щ щ	Щ щ	Shch shch
Й й	Й й	Y/i*	Ю ю	Ю ю	Yu/iu*
К к	К к	K k	Я я	Я я	Ya/ia*
Л л	Л л	L l	ь	ь	'
М м	М м	M m	-	ъ	"

* The first variant is used only at the beginning of a name. The second is used within the name or at the end of it.

ABBREVIATIONS

CIS	– Commonwealth of Independent States	WEP	– West European Platform	VSP	– vertical seismic profile
DDA	– Dnipro-Donets' Aulacogen	CDPT	– common depth point technique	Ga	– billion years old
DDD	– Dnipro-Donets' Depression	DSS	– deep seismic sounding	Ma	– million years old
EEP	– East European Platform	MTS	– magneto-telluric sounding	mGal	– milligal
KMA	– Kurs'k Magnetic Anomaly	MZ	– metallogenic zone	mW	– milliWatt
US	– Ukrainian Shield	SFZ	– structural-formational zone	nT	– nano Tesla
VCM	– Voronezh Crystalline Massif	SMZ	– structural-metallogenic zone	ohm • m	– resistivity
VPP	– Volyn'-Podillia Plate			S	– electroconductivity
				ρ_{eff}	– effective electric resistance
				Δq	– bouger anomaly

T H E G E O L O G Y A N D M I N E R A L D E P O S I T S O F U K R A I N E

section I

GENERAL OVERVIEW MAPS

- Ukraine. Geographical-economic description
- Administrative regions of Ukraine
- Satellite map of Ukraine
- Physical geography of Ukraine
- Location of Ukraine within Europe
- Ukraine in the context of the main geological structures of Europe





UKRAINE

GEOGRAPHICAL-ECONOMIC DESCRIPTION

Ukraine is a large country in Eastern Europe. With an area of 603 700 sq. kilometers, it extends from north to south 893 km and from west to east 1316 km.

Ukraine borders on Belarus, Hungary, Moldova, Poland, Russia, Romania and Slovakia. In the south Ukraine has a coastline on the Black and Azov seas. The total length of its frontiers is 6500 km, including 1050 km of sea coast.

Population (1.01.2002), 48.0 million; density, 82 persons per sq. km.

Ukraine is inhabited by many nationalities or ethnic groups. According to the population census of December 5, 2001, Ukrainians comprise 77.8% of the population of Ukraine, Russians, 17.3%; Belarusians, 0.6%; Crimean Tatars and Moldovans, 0.5% each; Bulgarians, 0.4%; Hungarians, Poles and Romanians, 0.3% each; and Jews, 0.2%. Over one hundred other nationalities or ethnic groups account for the remaining 1.5% of the population.

Ukraine includes 24 administrative districts, called oblasts (singular = oblast'), and the Autonomous Republic of Crimea. Their rural areas are further subdivided into townships, called raions, and their larger cities contain city raions.

The capital of Ukraine is Kyiv, with 2 602 000 residents (5.12.2001). Other cities with more than 0.5 million residents are: Kharkiv, 1470 th.r.; Dnipropetrovsk, 1064 th.r.; Donetsk, 1016 th.r.; Odesa, 1029 th.r.; Zaporizhzhia, 814 th.r.; Lviv, 732 th.r.; Kryvyi Rih, 667 th.r.; and Mykolaiv, 514 th.r. There are 102 cities in Ukraine that have over 50 th.r. each.

While the official language is Ukrainian, both Ukrainian and Russian are commonly spoken.

The Ukrainian currency is the hryvnia. The measurement system is metric.

The climate of Ukraine is mostly temperate continental, but it approaches subtropical on the south coast of Crimea.

The relief is mainly (95 %) lowlands and gently rolling uplands, whose elevations above sea level rise from 100 to 500 m; the hilly or mountainous landscape (5%) is represented in the western part by the Carpathians (maximum elevation, 2061 m, Hoverla mountain) and Crimean Mountains in the south (1545 m, Roman-Kosh Mountain).

The main rivers are Dnipro (its course through Ukraine is 981 km), Boh or Southern Buh (806 km), Dniester (705 km) and Sivers'kyi Donets' (672 km).

Railways: There are 22 100 km of track, of which about one third is electrified.

Roads: The general extent of paved roads is about 164 000 km.

The major sea ports are: Illichevs'k, Izmail, Odesa, Mykolaiv, Kerch, Kherson, Mariupol', Berdians'k, Yevpatoriia, Feodosiia.

Airports: The major airport is at Kyiv (international); regional centers also have commercial airports, some with international flights.

Mining industry: oil, gas, coal, uranium, iron, manganese, titanium, mercury, nickel, zirconium, graphite, kaolin, sulfur, cooking and rock salt, facing and decorative rocks, etc.

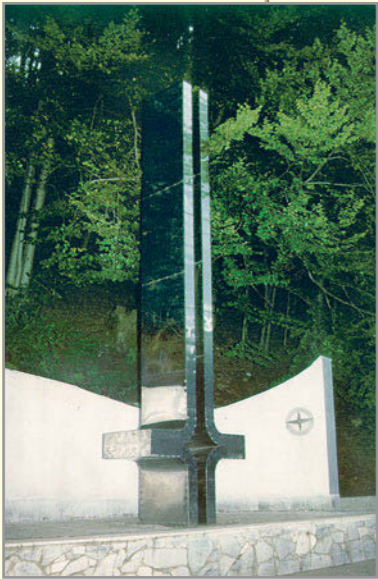
Heavy and light industry: ferrous and non-ferrous metallurgy, metal working, machine and instrument-making, electrotechnical, chemical, textile, construction industry, food processing, etc.

Power facilities: All electric power systems (including thermal, nuclear and hydroelectric power generating plants) are part of a common network serving Ukraine and the adjoining countries of the Commonwealth of Independent States (CIS) and Eastern Europe.

Agriculture: grain, vegetables, fruit (including berries), animal products.

Foreign trade: exports – minerals for processing, cast iron, steel, rolled metal, ferroalloys, equipment, instruments, machines, clothing and footwear, agricultural commodities. Imports – energy resources, non-ferrous metals, small and medium-sized machinery, home appliances, etc.

ADMINISTRATIVE DISTRICTS OF UKRAINE



- ▲ Geographic Center of Europe
- Administrative centers of districts (oblasts)

Note: most districts, or oblasts, bear the name of their administrative center.

**SATELLITE MAP
OF UKRAINE**



PHYSICAL GEOGRAPHY OF UKRAINE



- Reservoirs**
1. Kyiv
 2. Kaniv
 3. Kremenchuk
 4. Dniprodzerzhyn'sk
 5. Dnipro
 6. Kakhovka
 7. Pechenihy
 8. Chervonyi Oskil
 9. Dniester
 10. Ladyzhyn

▲ Geographic Center of Europe

LOCATION OF UKRAINE WITHIN EUROPE



LEGEND

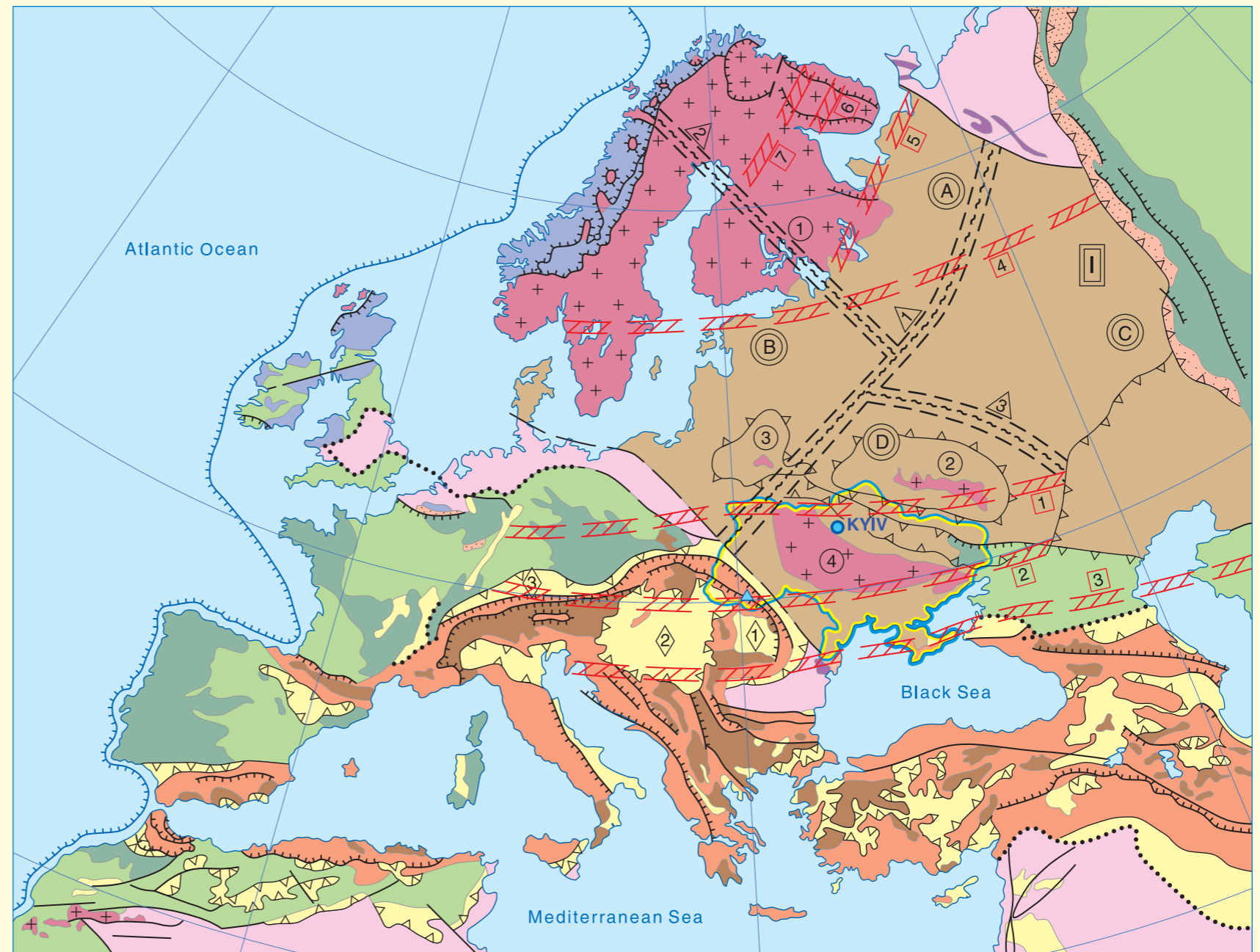
- East European Platform (EEP)
- Plate complexes
- Pre-Cambrian basement horsts:
1 - Baltic Shield; 2 - Voronezh Crystalline Massif;
3 - Belarus Crystalline Massif; 4 - Ukrainian Shield.
- East European Platform geoblocks:
 - Laplandian-White Sea
 - Volga-Ural
 - Botnich-Svecofennian
 - Voronezh-Ukrainian
- Intergeoblock mobile zones:
1 - Volyn'-Dvina, 2 - Raakhe-Rybinsk, 3 - Riazan'-Saratov
- Geodynamic system of transregional megazones of activation:
1 - North Ukrainian, 2 - Central Ukrainian,
3 - South Ukrainian, 4 - Novgorod-Perm,
5 - North-Onega, 6 - Khybyny, 7 - Murmansk-Botnich

- The main structural elements**
- Pre-Cambrian folded basement horsts
 - Plates of the ancient platforms
 - Baikal folded areas
 - Caledonian folded areas
 - Hercynian folded areas
 - Hercynian marginal troughs
 - Plates of platforms with Dalsland, Baikal (partially more ancient) basement
 - Plates of young platforms with Paleozoic basement

- Alpine folded areas
- Ancient cores and massifs within the Alpine folded area
- Alpine intermountain depressions and foredeeps
- Main areas of Alpine folding:
1 - Carpathian Mountains; 2 - Hungarian Depression;
3 - Alps

- Continental (tectonic) ledge
- Western outline of the East European Platform (Teiseire-Tornkvist zone)
- Thrusts and overthrusts
- Faults
- Possible outlines between structural elements
- Uplifts and massifs
- Tectonic depressions
- State boundary of Ukraine
- Geographic Center of Europe

UKRAINE IN THE CONTEXT OF THE MAIN GEOLOGICAL STRUCTURES OF EUROPE

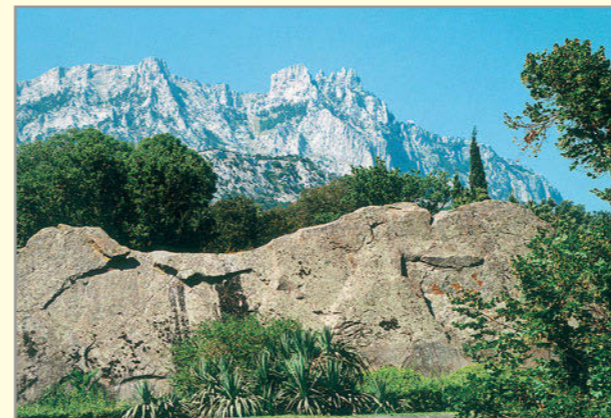




Columnar remnant, volcanics, Karadah, Crimea



"Swallow's nest", Southern Crimea



Ai-Petri Mountain, Jurassic limestones, Crimea



Flysch Carpathians, Volovets', Zakarpattia oblast'



*Silurian sedimentary strata in the Smotrych river canyon;
the Old Fortress, Kamianets'-Podil's'kyi, Khmel'nyts'kyi oblast'*



Cretaceous sedimentary strata, Bel'bek canyon, Western Crimea



Volcanic massif - Karadah natural preserve, Crimea



"Golden Gates", volcanics, Karadah, Crimea



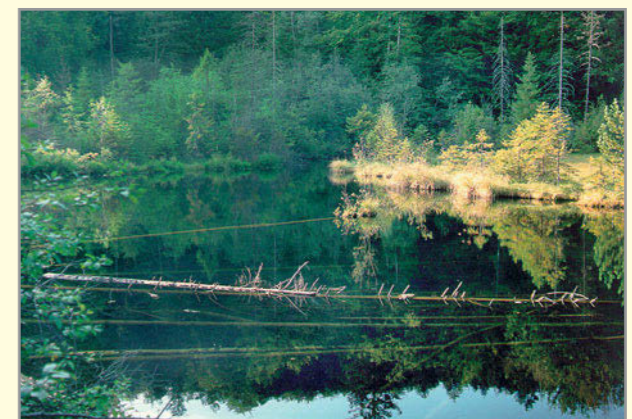
Proterozoic granites, Four Brothers Rock, Zhytomyr



Karhalets' Sphinxes, Western Crimea



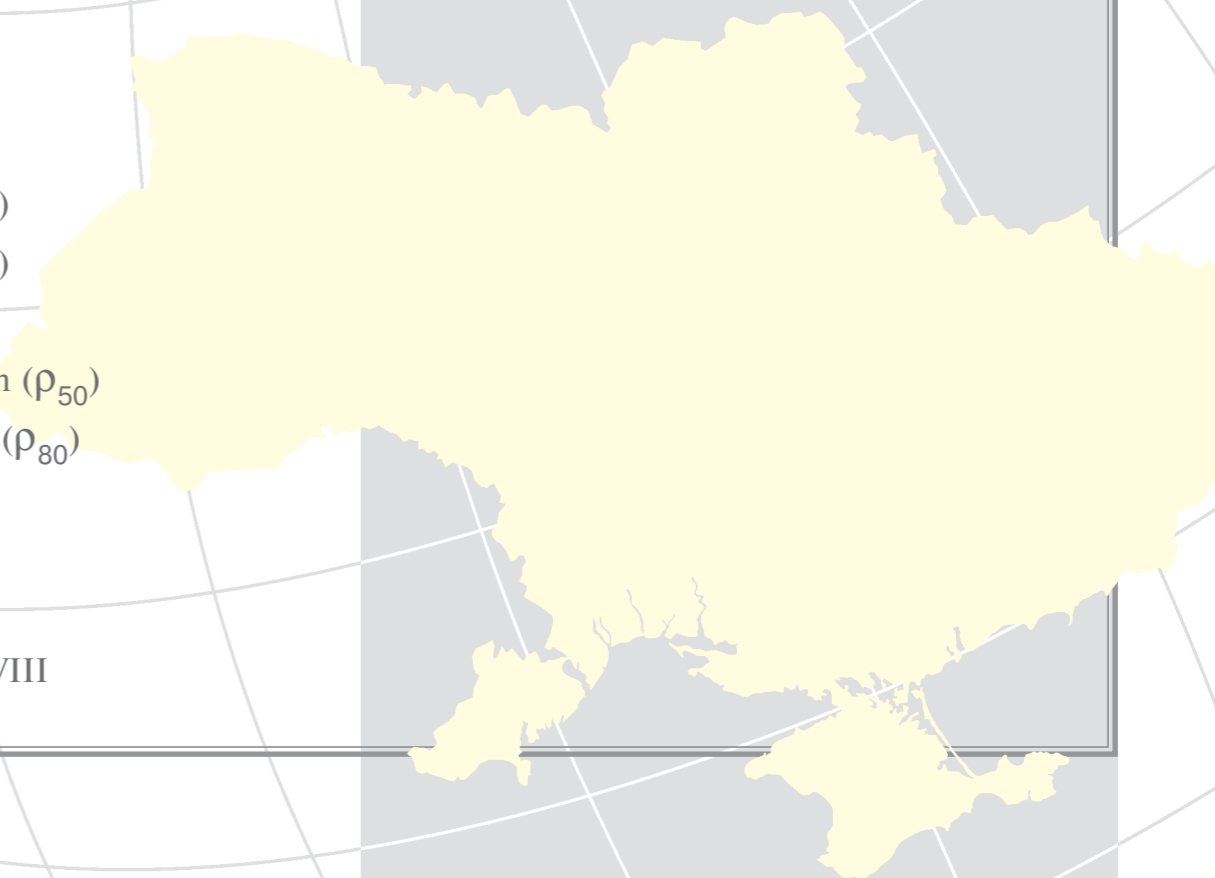
*Silurian sedimentary strata in the Smotrych canyon,
at Kamianets'-Podil's'kyi, Khmel'nyts'kyi oblast'*



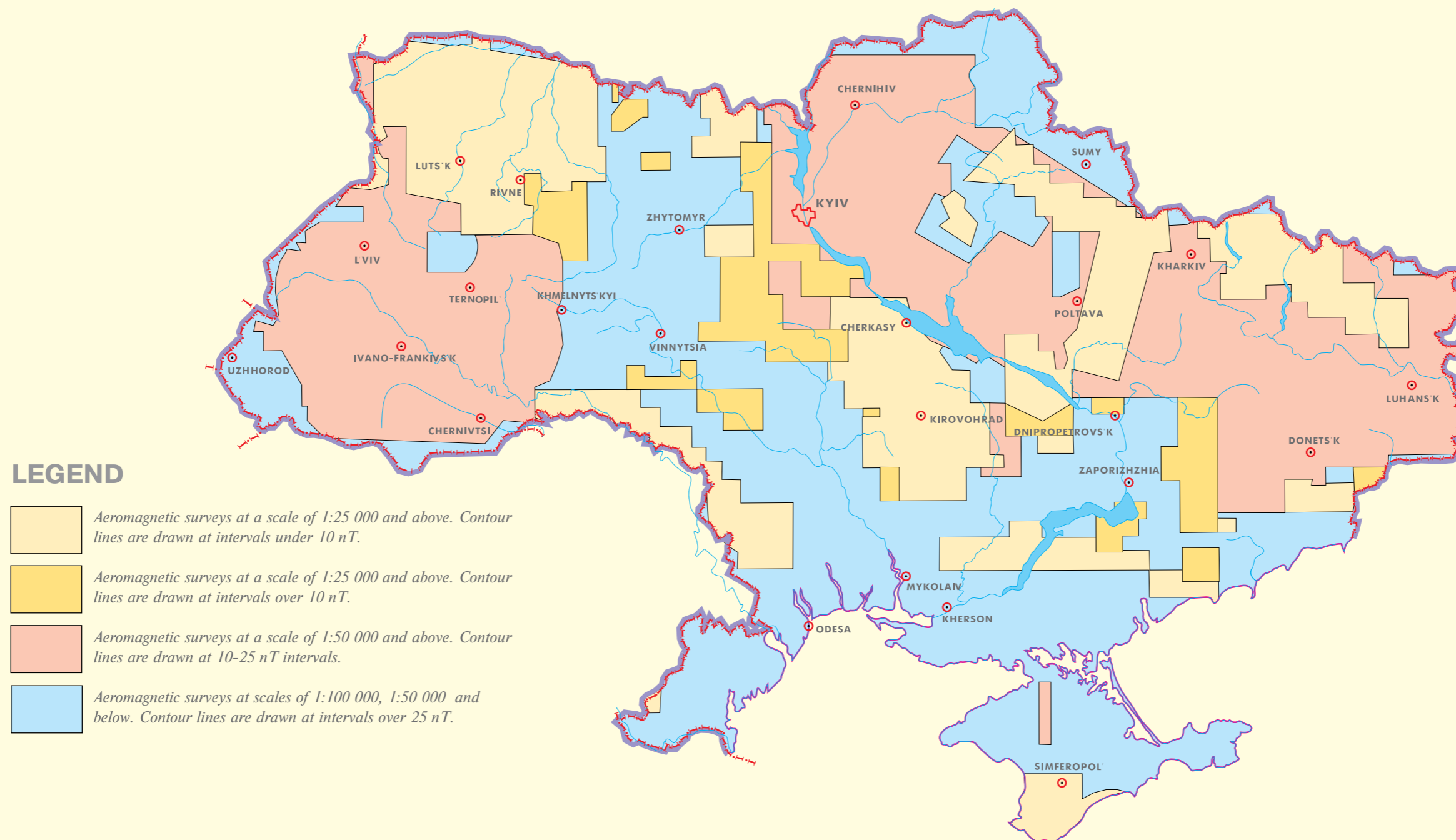
*Lake Mors'ke Oko (Sea Eye), a tarn in the Carpathians,
L'viv oblast'*

GEOFYSICAL MAPS

- Aeromagnetic surveys coverage
- Magnetic anomaly field
- Regional magnetic field
- Gravimetric surveys coverage
- Residual gravity anomalies
- Regional gravity
- Thermal field
- Deep penetration geophysics: MTS, DSS and CDPT coverage
- Apparent conductivity of sedimentary cover (S_1)
- Apparent conductivity of the Earth's crust to a depth of 20 km (S_{20})
- Apparent conductivity of the Earth's crust to a depth of 50 km (S_{50})
- Integral conductivity of the lithosphere to a depth of 80 km (S_{80})
- Effective electric resistivity of the Earth's crust at a depth of 50 km (ρ_{50})
- Effective electric resistivity of the lithosphere at a depth of 80 km (ρ_{80})
- Electric heterogeneity of the lithosphere
- The Moho discontinuity
- Deep structure of the lithosphere
- Deep structure of the Earth's crust along the geotraverses II, VI, VIII



AEROMAGNETIC SURVEYS COVERAGE



LEGEND

- Aeromagnetic surveys at a scale of 1:25 000 and above. Contour lines are drawn at intervals under 10 nT.
- Aeromagnetic surveys at a scale of 1:25 000 and above. Contour lines are drawn at intervals over 10 nT.
- Aeromagnetic surveys at a scale of 1:50 000 and above. Contour lines are drawn at 10–25 nT intervals.
- Aeromagnetic surveys at scales of 1:100 000, 1:50 000 and below. Contour lines are drawn at intervals over 25 nT.

AEROMAGNETIC SURVEYS COVERAGE

The entire territory of Ukraine has been covered by an airborne magnetic survey at 1:200 000 scale, and some areas by more detailed surveys. Preliminary maps of anomalous mag-

netic fields at 1:200 000 and 1:1 000 000 scales have been issued and published.

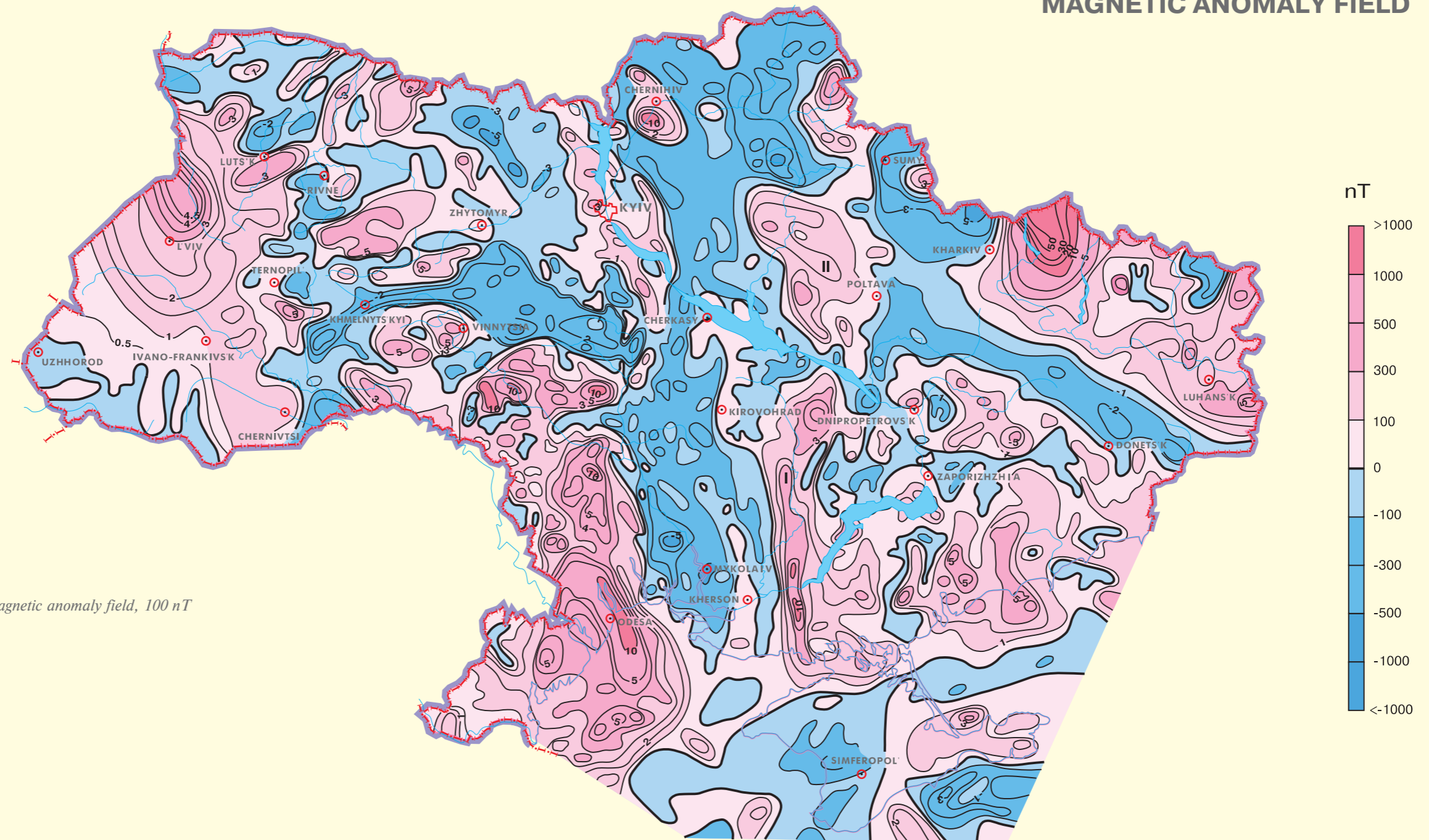
In compiling maps of the anomalous magnetic fields, a reference grid has been used for reducing the field to a common

level. This allowed not only analyses and interpretations of the observed field, but also performance of various transformations without any fear that "false" anomalies may appear on the boundaries of different maps. In this way, the maps may be used

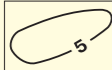
during comprehensive interpretations of geological-geophysical data on regional scales.

Large-scale airborne magnetic surveys (1:5000, 1:25 000) have been carried out in Ukraine mostly in the mining areas. Such surveys cover about 50% of the Ukrainian territory.

MAGNETIC ANOMALY FIELD



LEGEND

 Isolines of magnetic anomaly field, 100 nT

MAGNETIC ANOMALY FIELD

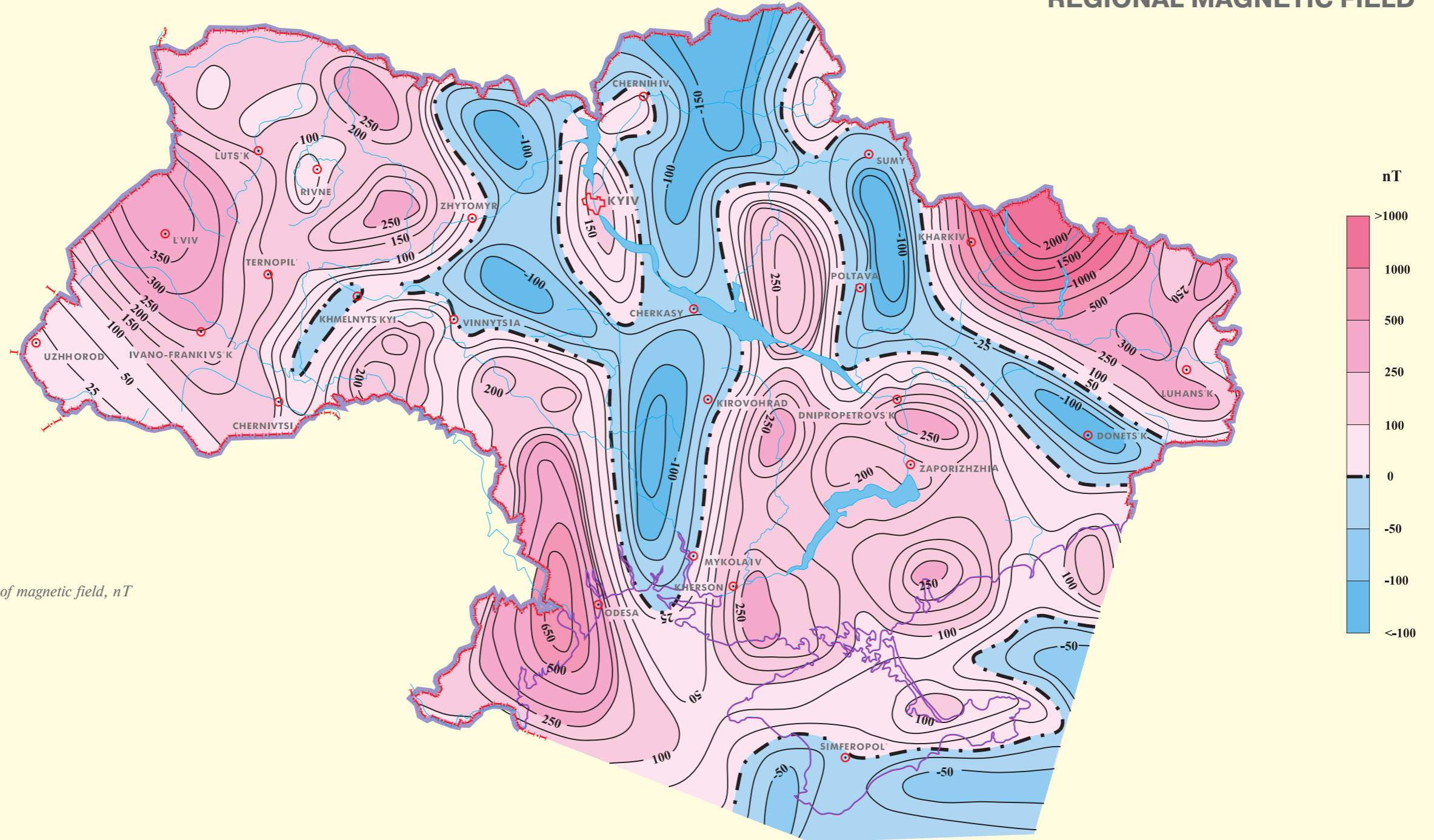
This map of the total magnetic field was compiled using both ground and airborne magnetic surveys. Equal accuracy consistency of the airborne magnetic data allows us to trace and compare magnetic fields for different geological regions and reveal the distribution of anomalies in Ukraine. The magnetic anomaly field varies in terms of its distribution, size and form. The intensity of positive anomalies varies between 1 and 10 000 nT (nano Tesla) but some anomalous zones caused by iron formations reach 20 000-40 000 nT or more. The intensity of a negative field does not exceed 500 nT. By observing the isolines and the field's intensity, all ano-

malies can be divided into three main groups: linear, isometric and background. Linear anomalies of different sizes and orientations are predominant. Trends and forms of the anomalies are in general agreement with principal geological structures. Linear anomalies may extend for tens and even hundreds of kilometers. Generally, they reflect margins of geological structures and disjunctive dislocations. By its nature, a magnetic anomaly is related to rock composition and its ferrous mineral content. Positive magnetic anomalies point to intermediate and basic formations in the crystalline basement. Negative or weakly positive fields reflect nonmagnetic or weakly magnetic sedimentary and felsitic magmatic rocks. Nonmagnetic sedimentary cover does not change an under-

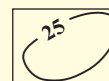
lying field pattern or buried structures of the basement. The magnetic field of the Ukrainian Shield is characterized by a diversity of forms and differentiation of anomalies. The Kryvyi Rih-Kremenchuk (I) anomalous magnetic zone is marked by intense anomalies of extensive strike which coincide with iron formations. The same character of the field was also observed in the Kyiv magnetic province (Yadlivs'k-Trakhtemyriv zone). Both zones are separated by a wide belt (up to 150 km) of dominantly negative magnetism, which cuts the entire Ukrainian Shield in a sub-meridional direction. The Ukrainian Shield is separated from the Voronezh massif (northeast of Ukraine) by the Dnipro-Donets'

Depression (aulacogen) (II). In the central part of the Dnipro-Donets' Depression two regional positive anomalies have been established over an unchanging negative background (from 0 to 200 nT). These regional anomalies may be related to Devonian effusive mafic rocks. The Kursk magnetic anomaly, partially in northeastern Ukraine, is a continuation of the southern slope of the Voronezh massif in Russia. Boundaries of the East European Platform (see p. 34), with folded areas, are traceable by changes in the character of the field and trends of the anomalies.

REGIONAL MAGNETIC FIELD



LEGEND

 Isolines of magnetic field, nT

REGIONAL MAGNETIC FIELD

Regional magnetic anomalies in the Ukrainian territory are well-differentiated, particularly within the Ukrainian Shield and the Volyn'-Podillia Plate, where a magnetic survey is highly effective in delineating iron deposits, ferrous quartzites and other minerals. Regional magnetic data are also useful in studying the geological structure of the upper part of the Earth's crust

and particularly in mapping the petrophysical aspects of some rocks and in the study of tectonics.

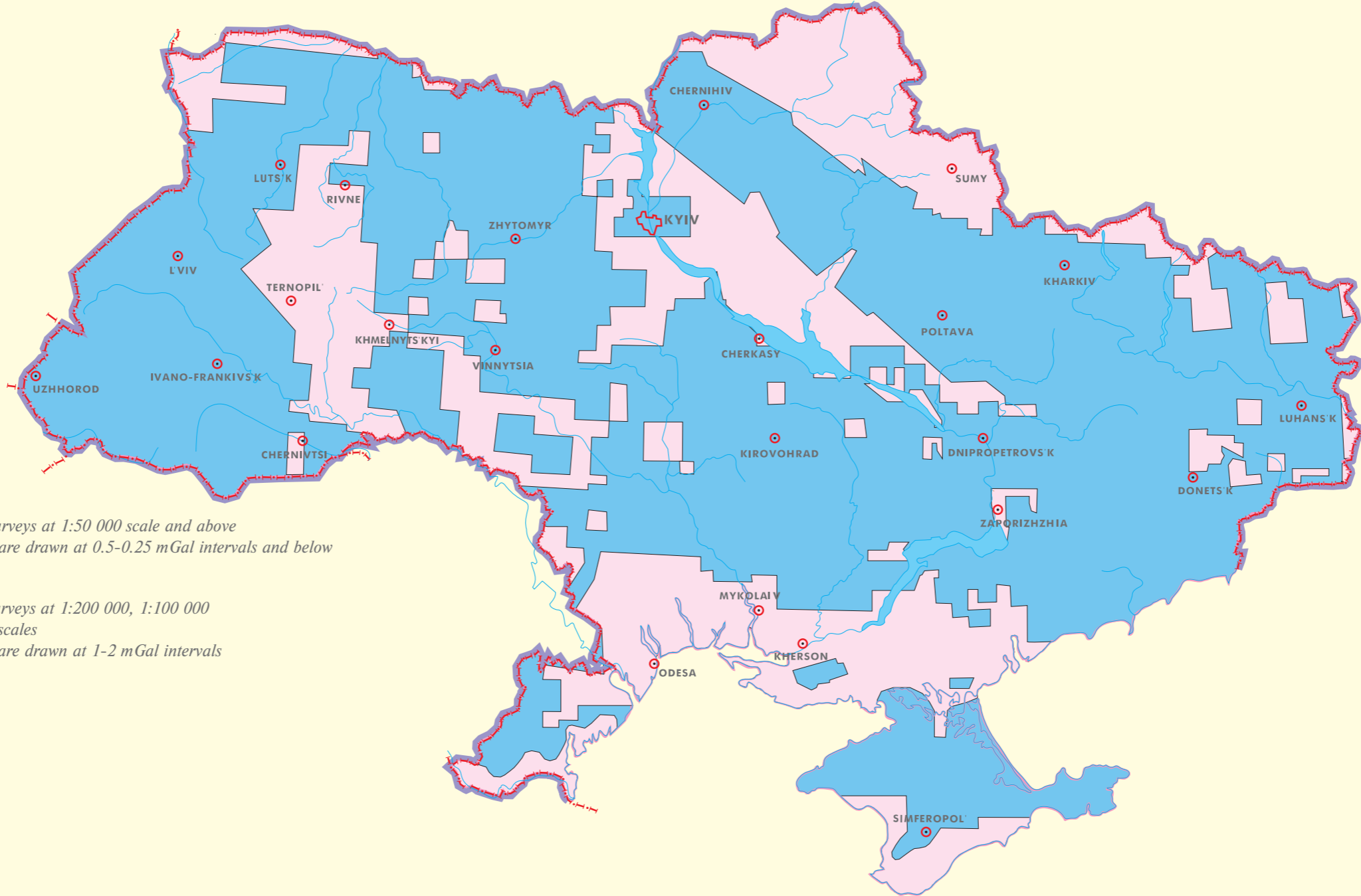
Particular attention was directed in recent years towards applying magnetics in the studies of the distribution of the deeply buried magnetic bodies in the Earth's crust. For this purpose the airborne magnetic data collected at different altitudes were recalculated and the results demonstrated the presence of deeply buried bodies at various depths.

Magnetic data gathered from the satellites contributed to a better understanding of the regional features of the Earth's crust and allowed to exclude the influence of local anomalies caused by near surface magnetic rocks.

On a regional scale several positive magnetic anomalies are noted, including the L'viv, Odesa, Dnipro (Zaporizhzhia) and others. These are interpreted to be caused by large diapirs of basic rocks that penetrated the Earth's crust. Less intense

magnetic anomalies form circular and linear zones. Some of these magnetic anomalies produce a submeridional chain pattern and are probably caused by basic diapirs. They occur in the same location as the inferred Kryvyi Rih Deep Fault (Kryvyi Rih - Sumy) (see p. 51). Negative magnetic anomalies are less widespread and coincide spatially with the Kryvyi Rih Block of the Ukrainian Shield and the Dnipro-Donets' Depression.

GRAVIMETRIC SURVEYS COVERAGE



LEGEND

- Gravimetric surveys at 1:50 000 scale and above
Contour lines are drawn at 0.5-0.25 mGal intervals and below
- Gravimetric surveys at 1:200 000, 1:100 000 and 1:50 000 scales
Contour lines are drawn at 1-2 mGal intervals

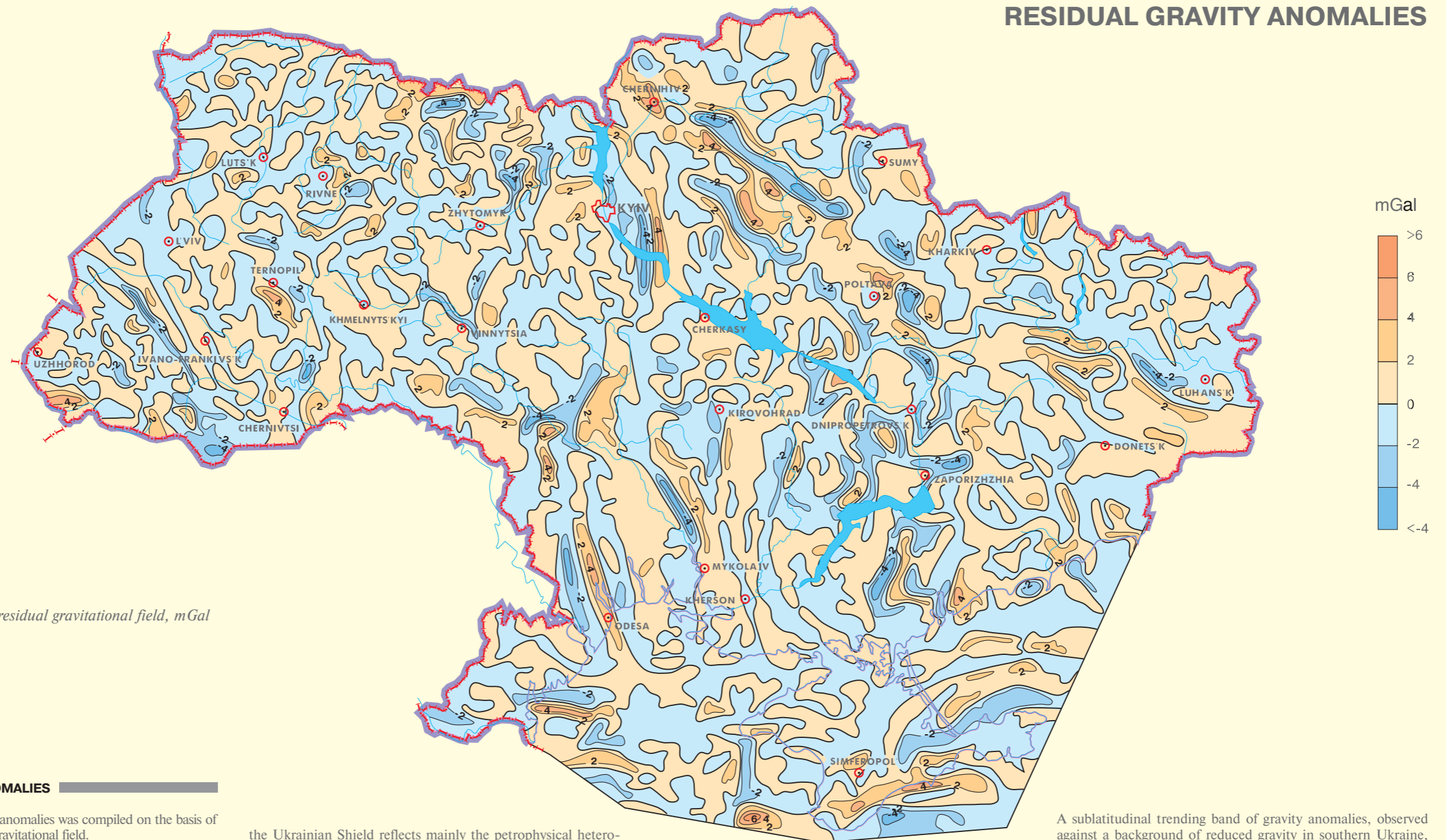
GRAVIMETRIC SURVEYS
The entire territory of Ukraine has been covered by preliminary gravimetric surveys at a 1:200 000 scale, and some at a

1:1 000 000 scale. All the data have been published. In preparing the maps for publication, all the data have been tied into a common network. This allowed, on the one hand, to compile standardized maps of entire geological regions or

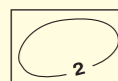
administrative districts, and on the other hand, to make various transformations of the gravity field. The latter produces additional data on the deeply buried structures. Large-scale gravimetric surveys combined with magnetic data at a scale of

1:10 000 are very effective for facilitating geological survey and exploration work. A significant part of Ukraine is covered by these surveys. Nearly all mining areas have been covered by gravimetric surveys at a 1:50 000 scale.

RESIDUAL GRAVITY ANOMALIES



LEGEND

 Isolines of residual gravitational field, mGal

RESIDUAL GRAVITY ANOMALIES

The map of residual gravity anomalies was compiled on the basis of reduction of the measured gravitational field.

This map depicts not only the local anomalous elements which reflect the near-surface structure of the Earth's crust but also elements of the regional anomalies of the deep structure of the Ukrainian territory. Regional gravity anomalies correspond to the main components of the East European Platform. On the Ukrainian territory they include the Ukrainian Shield, the Dniro-Donets' Depression, the Donets' Basin, the Volyn'-Podillia Plate, as well as the Alpine Carpathians and the Crimean and the Hercynian (Dobruja) folded complexes.

Within the residual gravity field of the Ukrainian Shield, the following structures are outlined: a mosaic structural pattern of the Volynian Block and the Kirovohrad submeridional zone (see pp. 50-51), an isometric form of anomalies of the Dniro-Donets' Basin and a complicated linear mosaic field of the Near-Azov Sea area. The characteristic pattern of the gravitational field of

the Ukrainian Shield reflects mainly the petrophysical heterogeneity of the Precambrian basement.

Linear anomalies, as a rule, are caused by fault structures. A low gravity area occurs in the northwestern part of Ukraine, corresponding to the zone between the East European Platform and the Carpathian folded structures. It has distinct linear bands with a northwestern trend. Within this gravitational field area the Rava-Rus'ka series of faults are fairly well defined. These faults demarcate the suture zone between the ancient Archean-Proterozoic and Baikal basements.

Another terrain of low gravity is located in the northeastern part of Ukraine. It reflects the structural features of the transitional zone between the Voronezh Crystalline Massif (Southern Russia) and the Dniro-Donets' Depression. The Depression itself is characterized by alternating bands of positive and negative anomalies with north-western trends. Positive gravity

anomalies caused by the Devonian basic effusions form a wide band in the central part of the Depression while on its flanks narrow bands of negative anomalies occur. The latter are attributed to the salt deposits in the sedimentary cover.

A wide band of elevated gravity is observed towards the folded Donets' Basin (see p. 51) where positive and negative anomalies are replaced by predominantly positive ones towards the folded Donets' Basin.

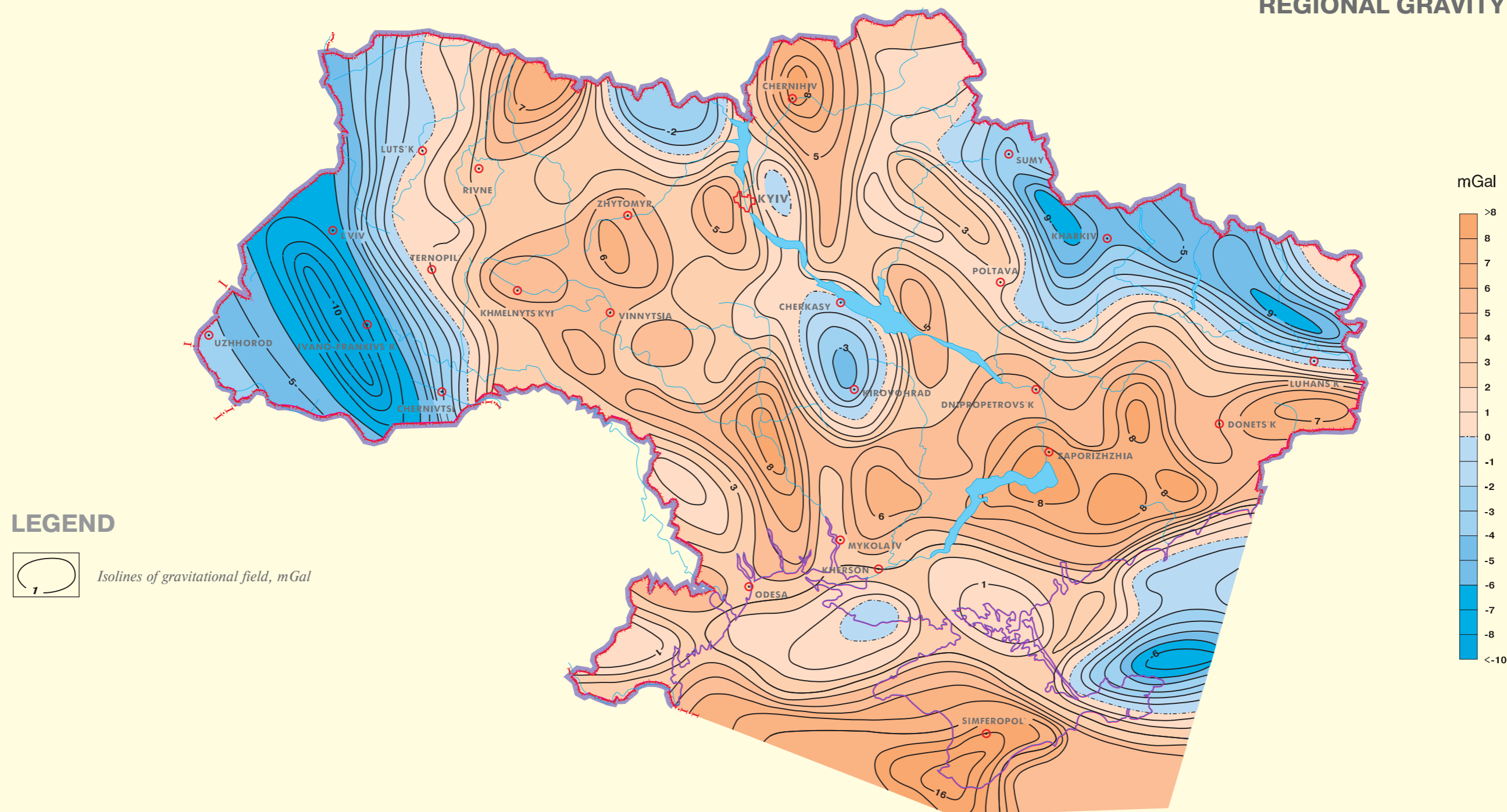
A transitional zone between the folded Donets' Basin (see p. 51) and the Azov Sea Coastal Massif of the Ukrainian Shield is notable for its increased gravity patterns with sublatitudinal trends. The gravitational field features of the southeastern Dniro-Donets' Depression and the northwestern Donets' Basin show abrupt sutures between these structures.

A sublatitudinal trending band of gravity anomalies, observed against a background of reduced gravity in southern Ukraine, corresponds to the suture zone between the East European Platform and the Scythian Plate. This suture zone is also known as the zone of the Paleozoic-Mesozoic suture grabens.


Gravitational field alternations and linear anomalies make it possible to map at least two sublatitudinal zones: one of them follows the 48° N latitude, from the south-east (the southern Donets' Basin) through the Ukrainian Shield (the Devladiiv fault) to the west (the Carpathians); the other one trends to the south of the 52° N latitude, along the southern slope of the Voronezh Crystalline Massif (the Obolon' fault) through the Chernihiv gravitational maximum, the Ovruch graben-syncline and then to the west beyond the territory of Ukraine.

Thus, the map of residual gravity anomalies reflects internal features of geological structures and the nature of the boundaries between them.

REGIONAL GRAVITY



LEGEND

 Isolines of gravitational field, mGal

REGIONAL GRAVITY

The regional gravity map (reduction of gravity field taken into account) reflects the distribution of the anomaly-producing geological bodies deep in the Earth's crust.

A good proportion of the Ukrainian territory, including the Ukrainian Shield, the Volyn'-Podillia Plate, the Dnipro-Donets' Depression and the Black Sea Coastal Depression, is char-

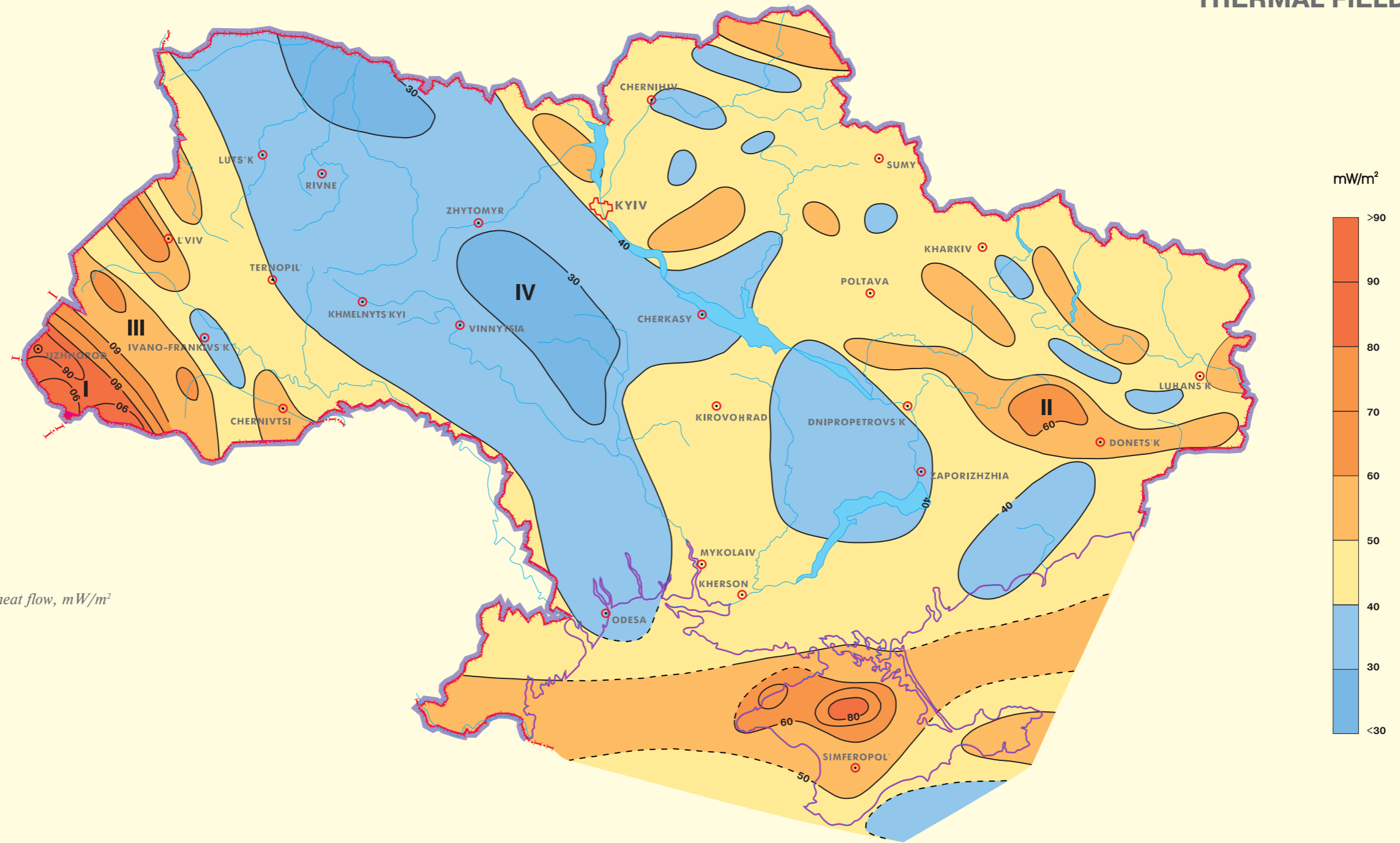
acterized by positive gravity anomalies. Among them, the Zaporizhzhia and Vinnytsia maxima are caused by high-density rocks, including rocks in the lower part of the Earth's crust. The Chernihiv, Pryluky, Holovaniv and Volyn' positive anomalies are related to the Chernihiv Uplift, the Central Dnipro Graben, the Kirovohrad Block and the Korosten' Pluton respectively.

Negative gravity anomalies of the gravity field, reflecting the highly fractured rocks at great depths, are found in the Uk-

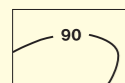
rainian Carpathians (the Ivano-Frankivsk minimum), along the southern slope of the Voronezh Crystalline Massif (the Kharkiv minimum) and the Indolo-Kuban' Depression. A number of local gravity minima, known within the Ukrainian Shield (Ovruch, Kirovohrad) and the northern Black Sea coastal area, are inferred to be related to the suture zones. Hence a map of the regional gravity field (including the influence of the local gravity field) reflects the deeply buried

anomaly-forming geological objects in the Earth's crust. Analyses of gravity and magnetic fields shows that, in terms of density and magnetism, the abnormal rocks do not have the same geological nature. For instance, no dense rocks are observed in the Holovaniv and Pryluky positive gravity structures in a regional positive magnetic field, whereas the Odesa regional positive magnetic anomaly is clearly reflected in the gravitational field.

THERMAL FIELD



LEGEND

 Isolines of heat flow, mW/m^2

THERMAL FIELD

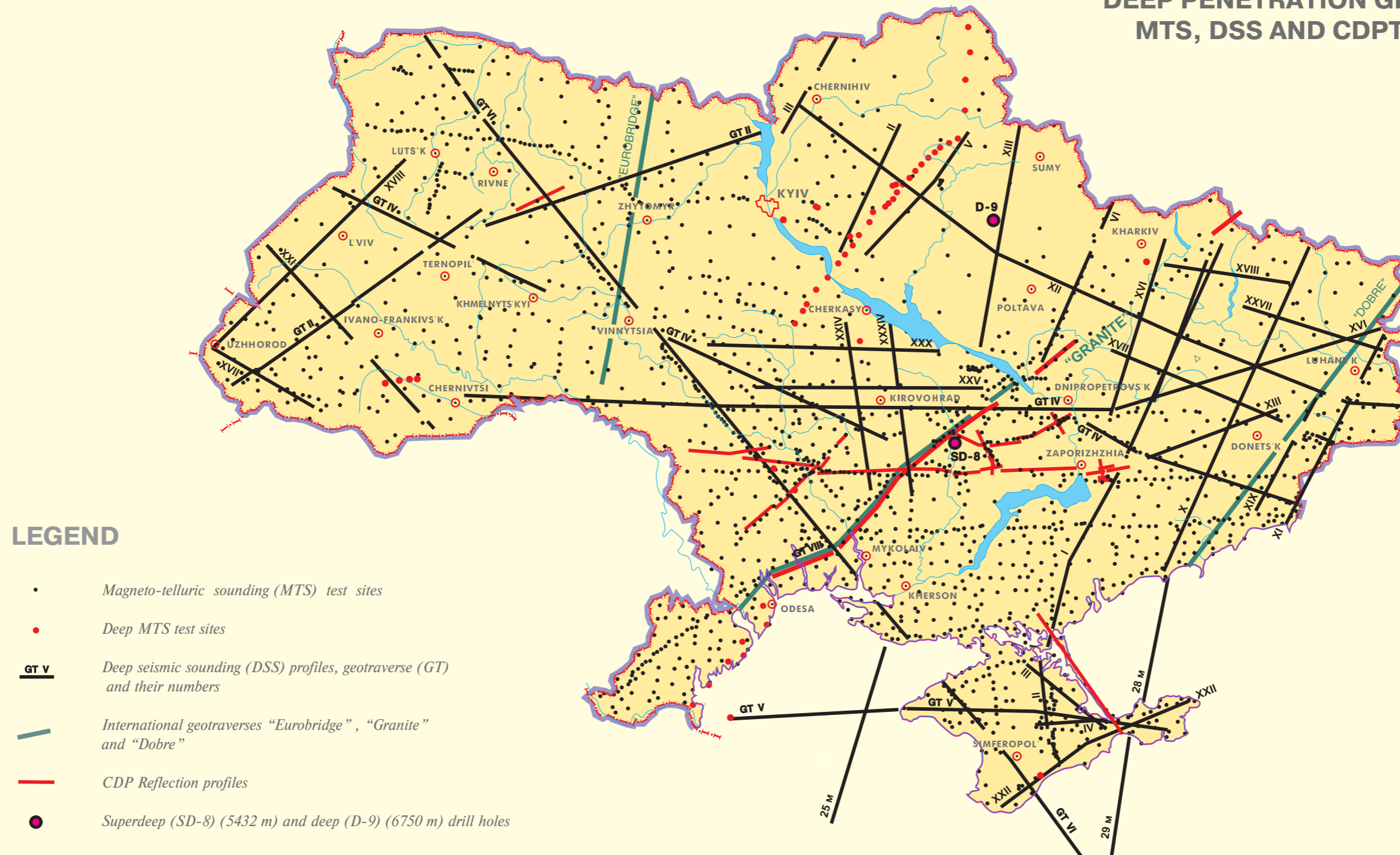
Several hundred reliable heat flow determinations have been done over the territory of Ukraine. Heat flow arrangement is governed mainly by the tectonic pattern and the geological evolution in any given region. Tectonic movements and magmatism are accompanied by a release of energy from the Earth's depths, which plays a major role in the formation of positive thermal anomalies. This energy disperses very slowly, thus showing a dependence between

the size of the heat source and the age of the structures. The heat flow values range from 22 to 120 mW/m^2 . Depending on the type and the age of the structures, three different thermal field areas are distinguished. The old East European Platform is characterized by low heat flows (22-60 mW/m^2) and is fairly well outlined by the 50 mW/m^2 heat flow isoline. As a general rule, common minimum values (22-45 mW/m^2) are observed within the Ukrainian Shield. The intermediate heat flows (50-70 mW/m^2) correspond to the structures stabilized during the Paleozoic period and are

observed in the Crimean steppe, the Donets' Basin, and the Fore-Dobruja and L'viv Depressions. In the zones underlain by Meso-Cenozoic rocks, the high heat flow figures are generally within 70-90 mW/m^2 range, and in areas of volcanic and hydrothermal activity, these values reach up to 115 mW/m^2 and more. The Transcarpathian Depression is one such zone. Heat flow there exceeds 80 mW/m^2 . In the Zaluzhzhia, Bihan' and Berehove structures (I), the heat flow figures reach up to 120 mW/m^2 . Some areas in Central Crimea are also characterized by high heat flows.

There are also some heat producing zones in the Donets' Basin (II), the Carpathian Foredeep (III) and the Ukrainian Shield (IV). Thus, the regional heat flow data combined with other geological and geophysical evidence allows us to delineate with greater precision some of the more important geological structures and ascertain their geodynamic character. Delineation of such areas is important in identifying possible sources of geothermal energy which could be harnessed in the future.

DEEP PENETRATION GEOPHYSICS: MTS, DSS AND CDPT COVERAGE



LEGEND

- Magneto-telluric sounding (MTS) test sites
- Deep MTS test sites
- GT V** Deep seismic sounding (DSS) profiles, geotraverse (GT) and their numbers
- International geotraverses "Eurobridge", "Granite" and "Dobre"
- CDP Reflection profiles
- Superdeep (SD-8) (5432 m) and deep (D-9) (6750 m) drill holes

DEEP PENETRATION GEOPHYSICS: MTS (MAGNETOTELLURIC SOUNDING), DSS (DEEP SEISMIC SOUNDING) AND CDPT (COMMON DEPTH POINT TECHNIQUE) COVERAGE

Geophysical investigations of the deep lithosphere and the upper mantle in Ukraine have been carried out for the past 25 years. Systematic gravity and magnetic surveys at 1:200 000 scale covered the entire country. In addition, some irregular profiles of deep seismic sounding have been carried out in this period. Based on these data, the Moho discontinuity map (p. 34) and

some lithosphere sections (p. 37) have been compiled. Since 1980, a number of combined investigations, such as an MTS survey at a 1:5 000 000 scale, a CDPT survey to a depth of 60-90 km and an airborne magnetic survey at 1:200 000-1:50 000 scales have been performed. Data obtained from superdeep boreholes in the Kryvyi Rih and the Dnipro-Donets' Depression have been taken into account.

Since 1988, the geologic-geophysical and geochemical researches of the deep portions of the Earth's crust and the upper mantle, along the Odesa-V. Tura-Urengoi ("Granite" project) geotraverse, have been in progress as part of a joint Ukrainian-Russian program. This

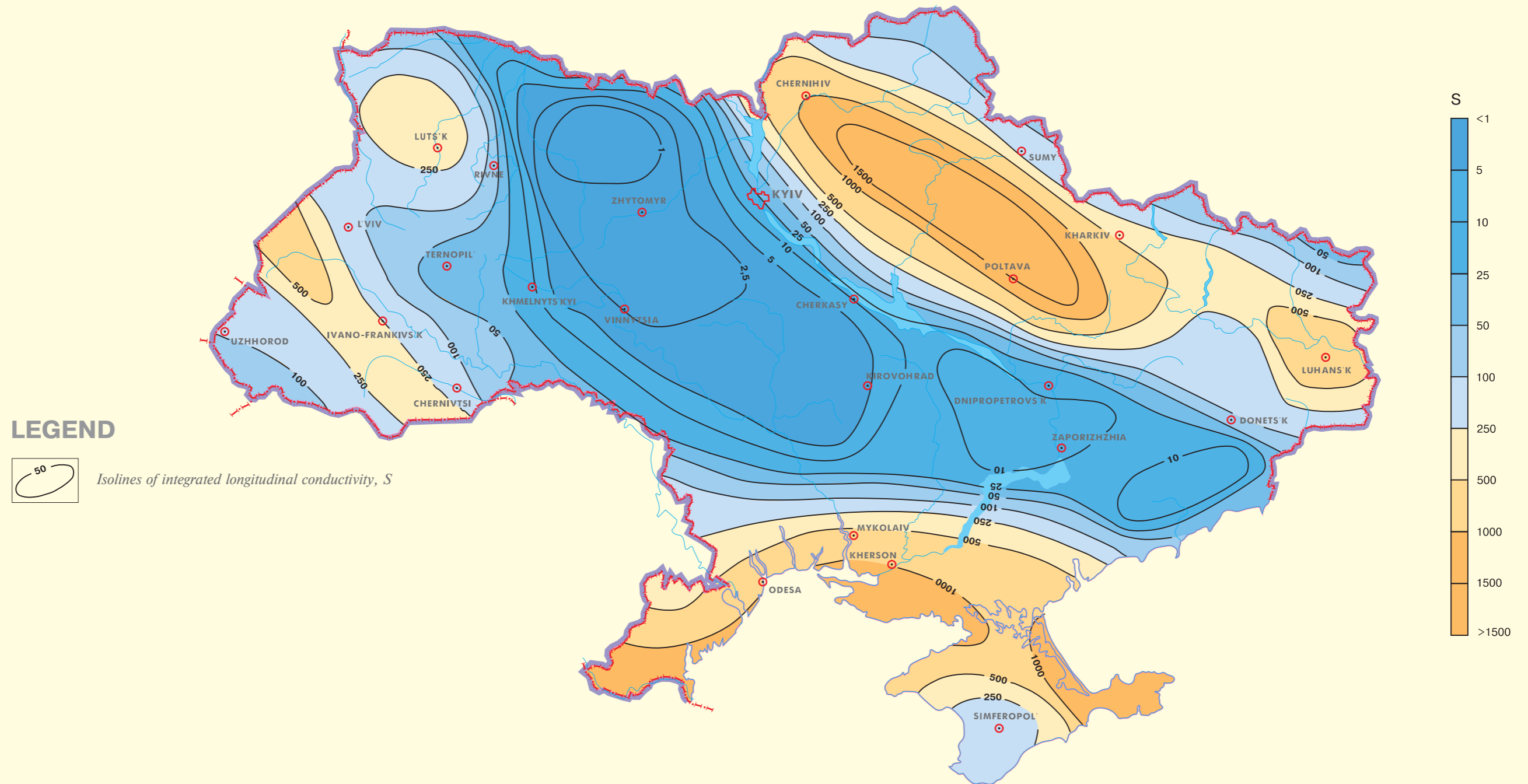
geotraverse crosses three superdeep drill holes (Kryvyi Rih, Ural, Tiumen'). A Ukrainian group of geoscientists is involved in a study of an area measuring 300 km by 1000 km using MTS surveys on a 25x25 km grid pattern, deep CDPT, DSS surveys and aeromagnetic surveys at a height of 200 to 2000 m.

During the past 10 years, much of the territory of Ukraine was covered by MTS surveys on a basis of 50x50 km and 25x25 km grids and along regional profiles with readings taken at 10 km intervals. The profiles include the Uzhhorod-Chernivtsi-Luhans'k, the Mykolaiv-Vinnitsia-Kovel' (VI Geotraverse), the Kilia-Odesa-Kryvyi Rih-Kharkiv (VIII Geotraverse), the

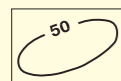
Kovel'-Kyiv-Kharkiv, the Feodosiia-Heniches'k-Kryvyi Rih and others. Altogether, 1500 soundings were taken mainly using electric survey stations CES-2, which enabled the study of the lithosphere down to 50-100 km and deeper.

The LEMU-402 and LEMU-404 (a magnetotelluric method) surveys made it possible to get data on geoelectrical sections of the Dnipro-Donets' Depression and the Ukrainian Shield to a depth of 300-500 km. Moreover, the knowledge of electric parameters at different depths, obtained from the MTS surveys, was essential in the compilation of a map of the deep crustal structures and the upper mantle at a 1:5 000 000 scale.

APPARENT CONDUCTIVITY OF SEDIMENTARY COVER (S_1)



LEGEND



Isolines of integrated longitudinal conductivity, S

APPARENT CONDUCTIVITY OF SEDIMENTARY COVER

The map of apparent conductivity of the sedimentary post-Archean cover of Ukraine has been compiled from geological survey data (1:50 000 and 1:200 000) and electrical log data from deep boreholes. The apparent conductivity of the sedimentary cover varies from

1 to 1500 S and reflects the main geological structures and their characteristics. Sedimentary cover with up to 50 m thick weathering crust (rarely 100 m), has the lowest column conductivity ranging from 1 S (northern part of the Ukrainian Shield) to 3-5 S (central part of the Ukrainian Shield). Within the Kryvyi Rih structure the readings are in the order of 10-15 S. As the thickness of sedimentary cover increases towards the Carpathians (up to 20 km) and the Black Sea Coastal area (up to 10-15 km)

its conductivity increases as well (up to 1000 S and 1500 S, respectively). In the northwestern part of the area where the basement is steeply dipping at depths from 2 to 4 km there are distinct deviations from this regularity. The Luts'k ring-shaped anomaly of about 300 S has been mapped there. Within the Dnipro-Donets' Depression, the column conductivity changes substantially in the following structural units: the Dnipro Graben, 1500 to 2000 S; the eastern Donets' Basin, up to 700 S;

the southern Donets' Basin, 100 to 300 S. The data show essential differences in the lithologic composition of rocks, their grade of metamorphism and their temperature regime in the deep horizons. Hence, such electrical methods relating to the integral conductivity of rocks allow us to distinguish specific lithologies within the sedimentary cover. This is important geological information, particularly for great depths, where drilling data are limited.

APPARENT CONDUCTIVITY OF THE LITHOSPHERE

Maps of the electrical features of the lithosphere have been compiled using MTT (magnetotelluric traverse) surveys. Among others, such maps of the apparent conductivity give an indication not only of the Earth's crust down to depths of 20 km, 50 km (see pp. 28, 29), but also of the upper mantle at depths of 80 km (see p. 30).

The map of the apparent conductivity of the Earth's crust down to 20 km (S_{20}) presents the total linear conductivity of both sedimentary and crystalline formations in the Earth's crust. The map S_{20} is preliminary in nature and depends on the density of observations which give information on the structure of the rocks to a depth of 20 km. In comparison to the S_1 map of sedimentary formations, the S_{20} map displays many similarities. Some differences do exist, however: a redistribution of conductivity in the Carpathians is observed - in one location a ring anomaly is apparent (Rakhiv-Ivano-Frankivs'k), while the conductivity of the Luts'k anomaly is twice as intense; in the Ukrainian Shield, conductivity within the crystalline formations varies from 5 S to 50 S and zones of relatively high resistance occur; within the Dnipro Graben, conductivity is much higher, reaching 2500 S or more; in the northeastern Donets' Basin, the Luhans'k and Svativ ring anomalies are located.

The map of integrated conductivity of the Earth's crust to a depth of 50 km (S_{50}) shows the total conductivity of the sedi-

mentary cover and the Earth's crust. In comparison to the S_{20} , the S_{50} surveys of the Dnipro Graben (I) reveal a two-fold increase of linear conductivity (up to 5000 S, and at some sites more than 10 000 S), providing evidence of higher temperatures at this depth. It should be noted that in the southeastern part of the Graben, sounding was not deep enough at some MTT observation points due to the shielding effect of the low-ohm rock sections. In the Dnipro-Donets' Depression (see p. 51), or the folded Donets' Basin, not much change is observed in the conductivity (conductivity of the Donets'k high resistance area varies by 25-50 S). The conductivity of the Luhans'k structure, however, is much higher (up to 1000 S or more) and is similar to that of the Belgorod anomaly (of up to 500 S), which is located on the border with Russia.

In the Carpathian area, conductivity of the Rakhiv anomaly (II) increases perceptibly up to about 1500 S, but conductivity of the Luts'k anomaly (III) remains relatively unchanging at the level of about 500 S (see pp. 28, 29).

Substantial differentiation of electrical conductivity in the Earth's crust is observed in the Ukrainian Shield. The Odesa-Kirovohrad trend is a wide zone with values of 250 S to 1000 S of linear conductivity (running northeast within the Riasnopil' anomaly) and occurs under a high-resistance (low-conductivity) cover up to 30 km thick. It seems to divide the Ukrainian Shield into the Volyn' and the Dnipro high-resistance areas where linear conductivity is relatively unchanging (10-50 S), and only seldom increasing up to 100 S.



Proterozoic granites, Polonne, Khmel'nyts'kyi oblast'



Columnar basalt, Basaltove village, Rivne oblast'

A well-marked Dnipro-Kherson anomaly (IV) of more than 1000 S conductivity, extends into the Black Sea in the south of Ukraine.

The map showing integrated linear conductivity of the lithosphere to a depth of 80 km (S_{80}) presents the total electrical conductivity of the sedimentary cover, the Earth's crust and the upper mantle. As shown on the map S_{80} , similar patterns of linear conductivity in the geological environment, typical of the Earth's crust (S_1 , S_{20} , S_{50}), occur also in the upper mantle down to 80 km.

The Odesa-Kirovohrad zone of high electrical conductivity, which is not observed at a depth of 20-30 km (from 2.5 S to 25 S), is clearly traced in the lowest part of the Earth's crust. For this reason the longitudinal conductivity of the Earth's crust increases by a factor of 2 and reaches 250-1000 S down to a depth of 50 km, and at 80 km depth in the lithosphere it reaches even higher values of 500-1500 S. A chain of local conductivity anomalies stretching northeastward was found in the upper mantle across the whole territory: Rozdil'na-Pervomais'k-Cherkasy-Pryluky-Hlukhiv (V).

The most stable values of electrical conductivity are found in the Dnipro high-resistance field, where conductivity remains unchanging and is in the order of 10-50 S. A certain increase in the linear conductivity, up to 50-100 S, is observed in the Volyn' high-resistance area.

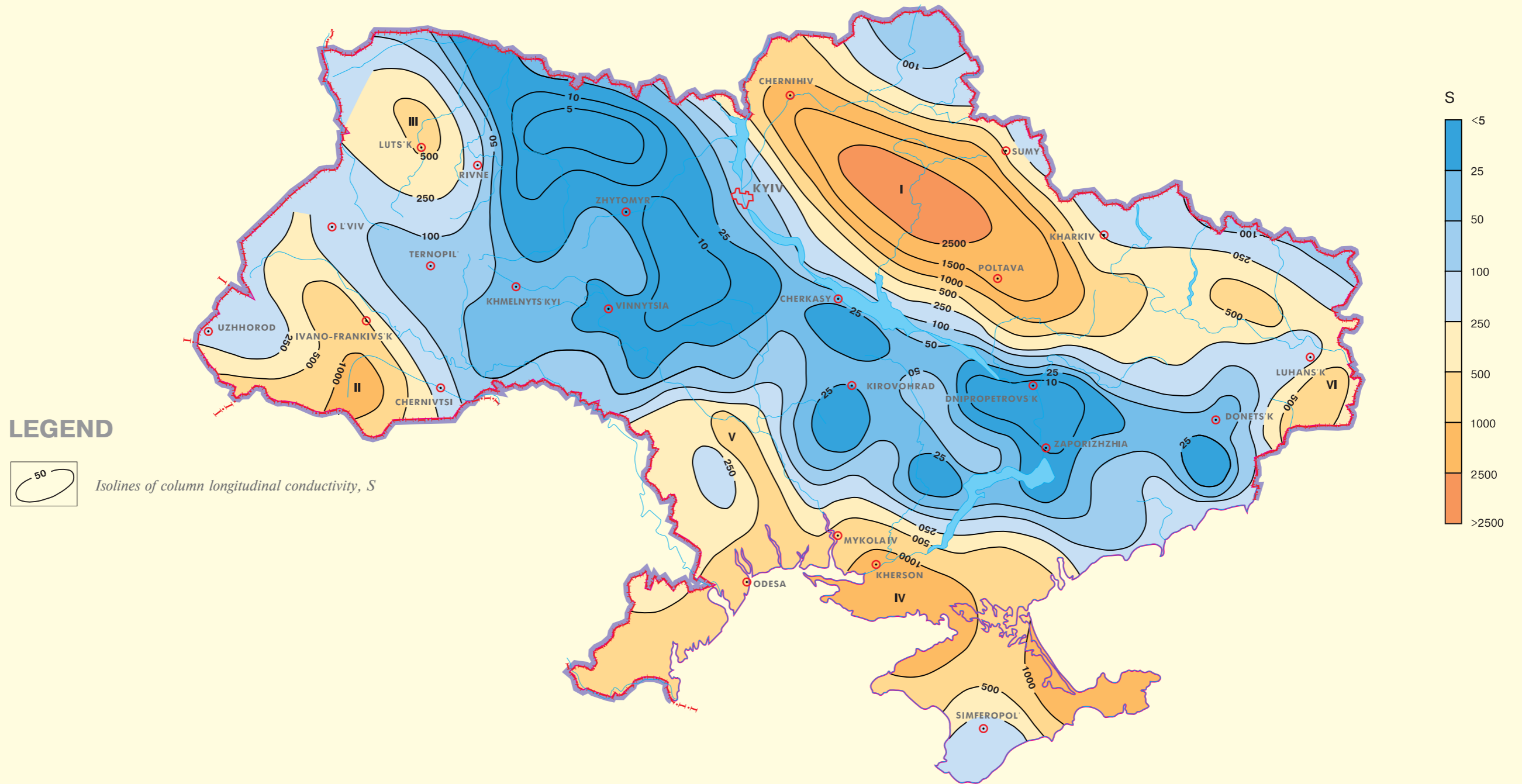
A high conductivity zone of up to 1000-1500 S is traced in

southern Ukraine along the Kerch-Kherson-Rozdil'na-Mohyliv-Podil's'kyi line.

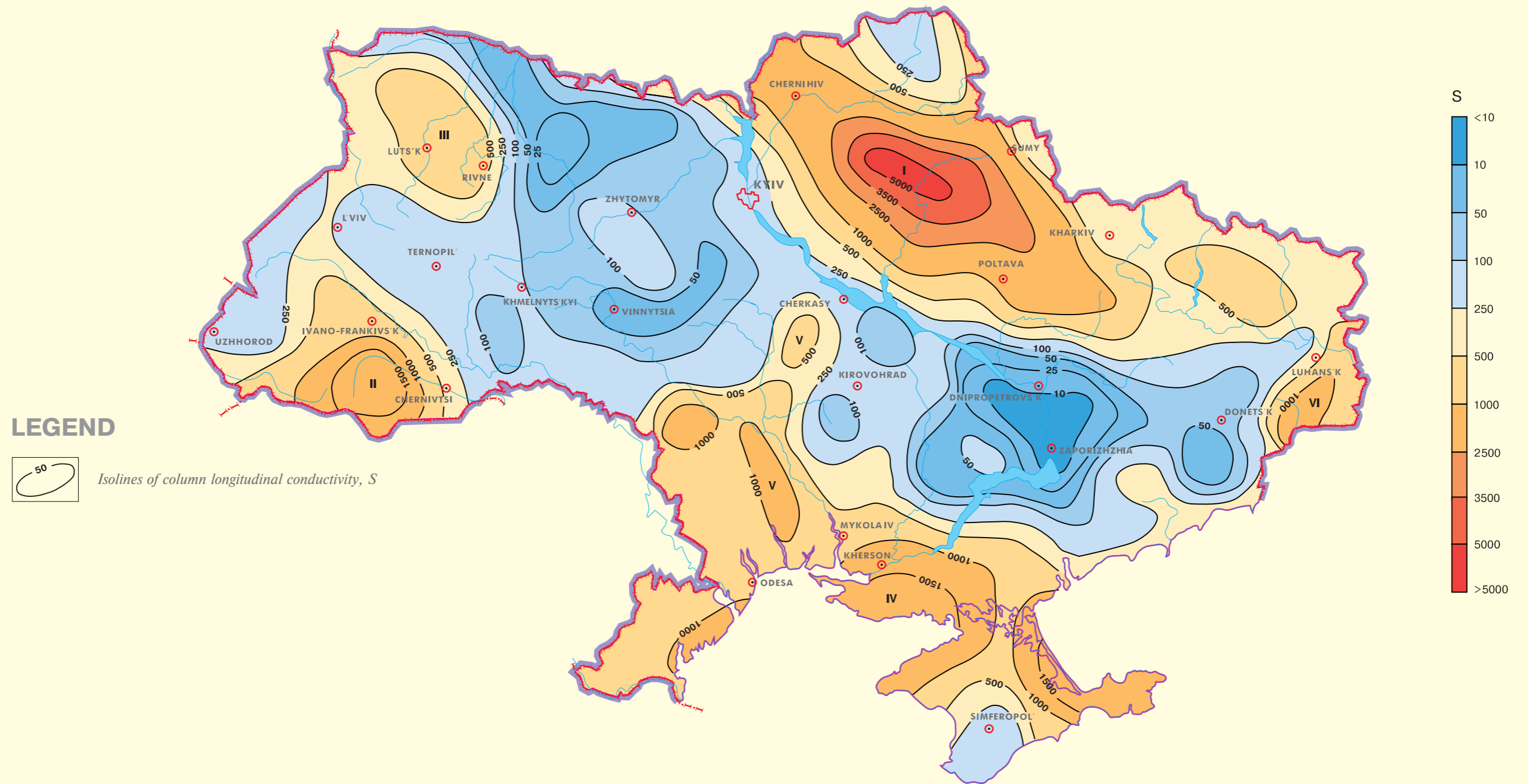
Both the Rakhiv and the Luts'k regional ring anomalies occur in the upper mantle in the western part of Ukraine. Their values of electrical conductivity reach up to 1500 S. Conductivity of the Luts'k anomaly increases gradually up to 1000 S, while the Rakhiv anomaly changes little with depth. This gives an indication of their different depths of development.

A unique and most intense anomaly of electrical conductivity (up to 5000 S, and in some places up to 10 000 S) has been discovered in the Dnipro Graben, in the Dnipro-Donets' Depression. It should be noted that the southern part of the Graben has been only partly studied because of the shielding effect of the low-ohm rock section. Electrical characteristics of the Donets' Basin are essentially different from those of the Dnipro Graben. Although the sedimentary cover is twice as thick there, reaching up to 20 km or more, the Earth's crust and sediments are characterized by relatively low linear conductivity of 500 S to 100 S or less. This may result from the abundant high-resistance sedimentary formations in the geological section, the effect of metamorphism and the relatively cool Earth's crust and upper mantle. The Luhans'k-Belgorod zone of conductivity (VI) consists of three local anomalies. The Luhans'k anomaly is within the boundaries of the Donets' Basin (conductivity up to 1500 S), while the Belgorod anomaly is associated with the Voronezh Massif (conductivity values of 500 S and more) in Russia.

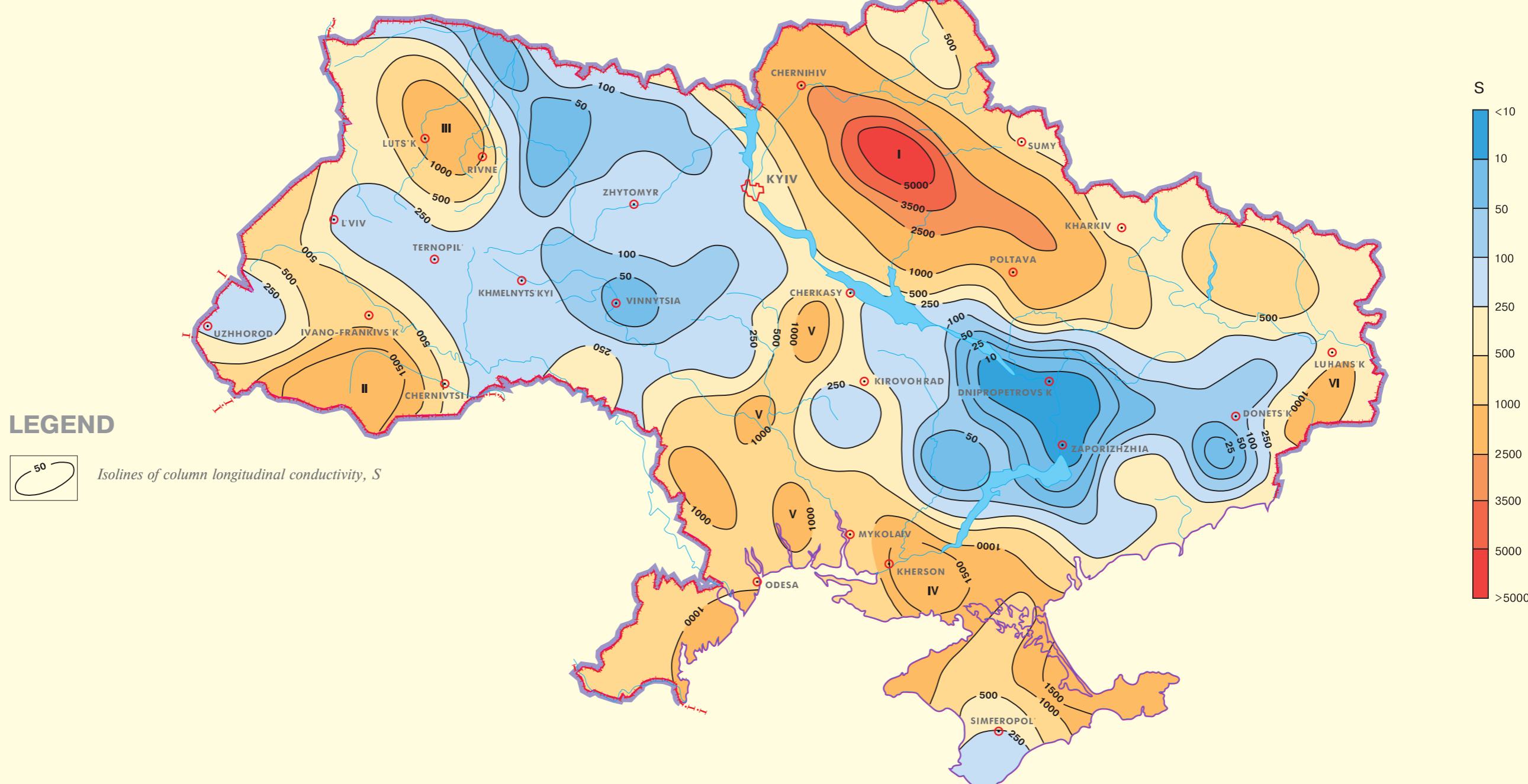
APPARENT CONDUCTIVITY OF THE EARTH'S CRUST TO A DEPTH OF 20 km (S_{20})



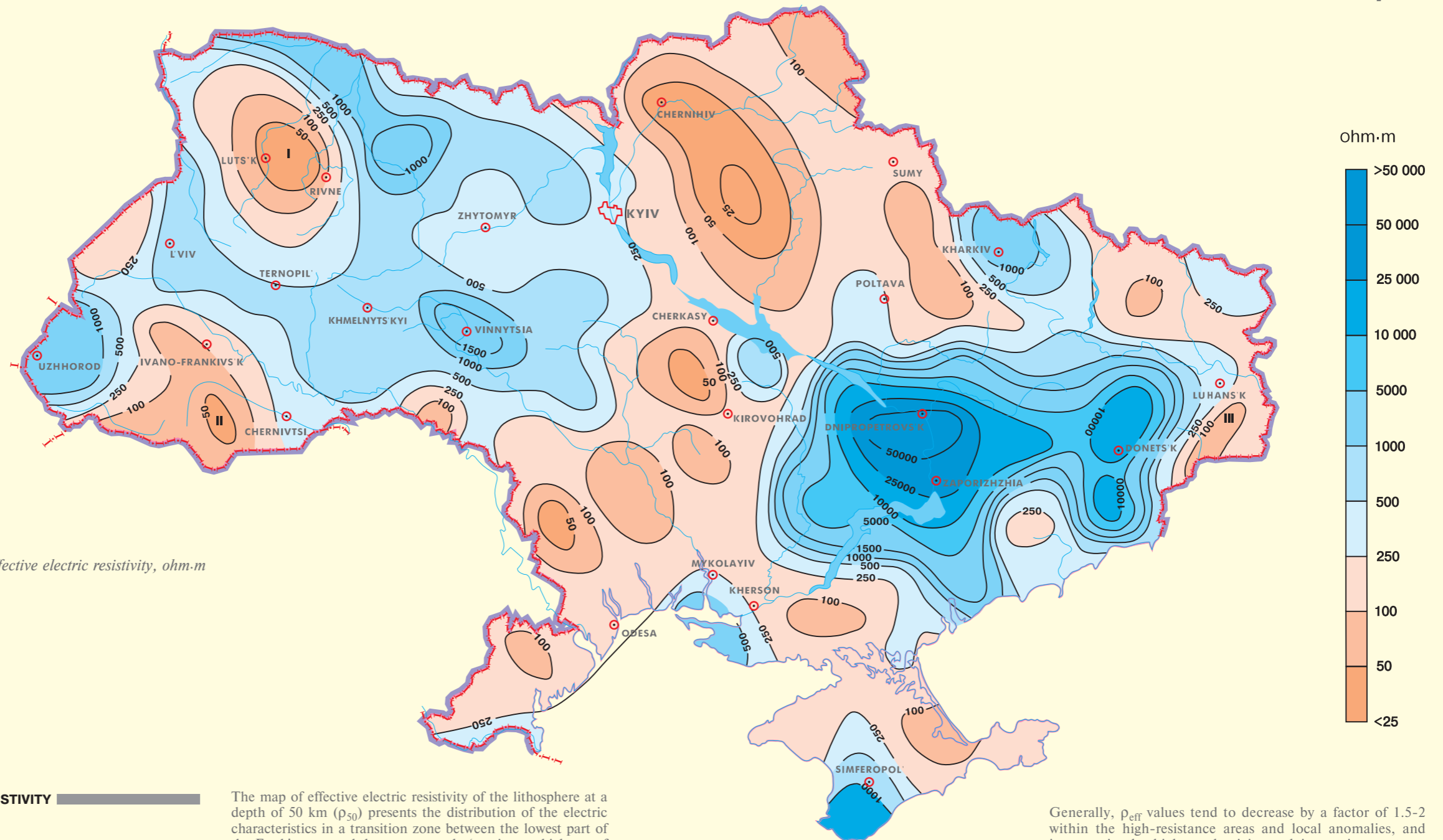
APPARENT CONDUCTIVITY OF THE EARTH'S CRUST TO A DEPTH OF 50 km (S_{50})



APPARENT CONDUCTIVITY OF THE LITHOSPHERE TO A DEPTH OF 80 km (S_{80})



EFFECTIVE ELECTRIC RESISTIVITY OF THE EARTH'S CRUST AT A DEPTH OF 50 km (ρ_{50})



LEGEND

 Isolines of effective electric resistivity, ohm·m

EFFECTIVE ELECTRIC RESISTIVITY OF THE LITHOSPHERE

The maps of apparent conductivity of sedimentary formations (S_1), the Earth's crust (S_{20} , S_{50}) and lithosphere to a depth of 80 km (S_{80}) include also information on the electric characteristics of the studied section as a whole. These are complemented by the maps of effective electric resistivity (ρ_{eff}), calculated using the MTT data for a certain depth, on which the influence of the overlying (especially low-resistant) formations is essentially excluded. In this exercise the ρ_{eff} is quite sensitive to the anomalous values (both high and low) of effective electric resistivity of rock formations. Brief analyses of the effective electric resistivity are presented for maps at 50 km and 80 km depths.

The map of effective electric resistivity of the lithosphere at a depth of 50 km (ρ_{50}) presents the distribution of the electric characteristics in a transition zone between the lowest part of the Earth's crust and the upper mantle (maximum thickness of the Earth's crust in Ukraine based on the DSS data is about 50 km), where ρ_{eff} varies widely from 25-50 ohm·m to 70 000 ohm·m or more. Minimum ρ_{eff} values of up to 25 ohm·m are typical for the Pryluky anomaly of electric conductivity located at the intersection of the Dnipro paleorift and the Odesa-Kirovohrad-Pryluky zone of high electric conductivity. Within the latter one, as well as in the Luts'k (I), Rakhiv (II), Luhans'k (III) and other isometric anomalies, ρ_{eff} ranges from 50 to 70 ohm·m.

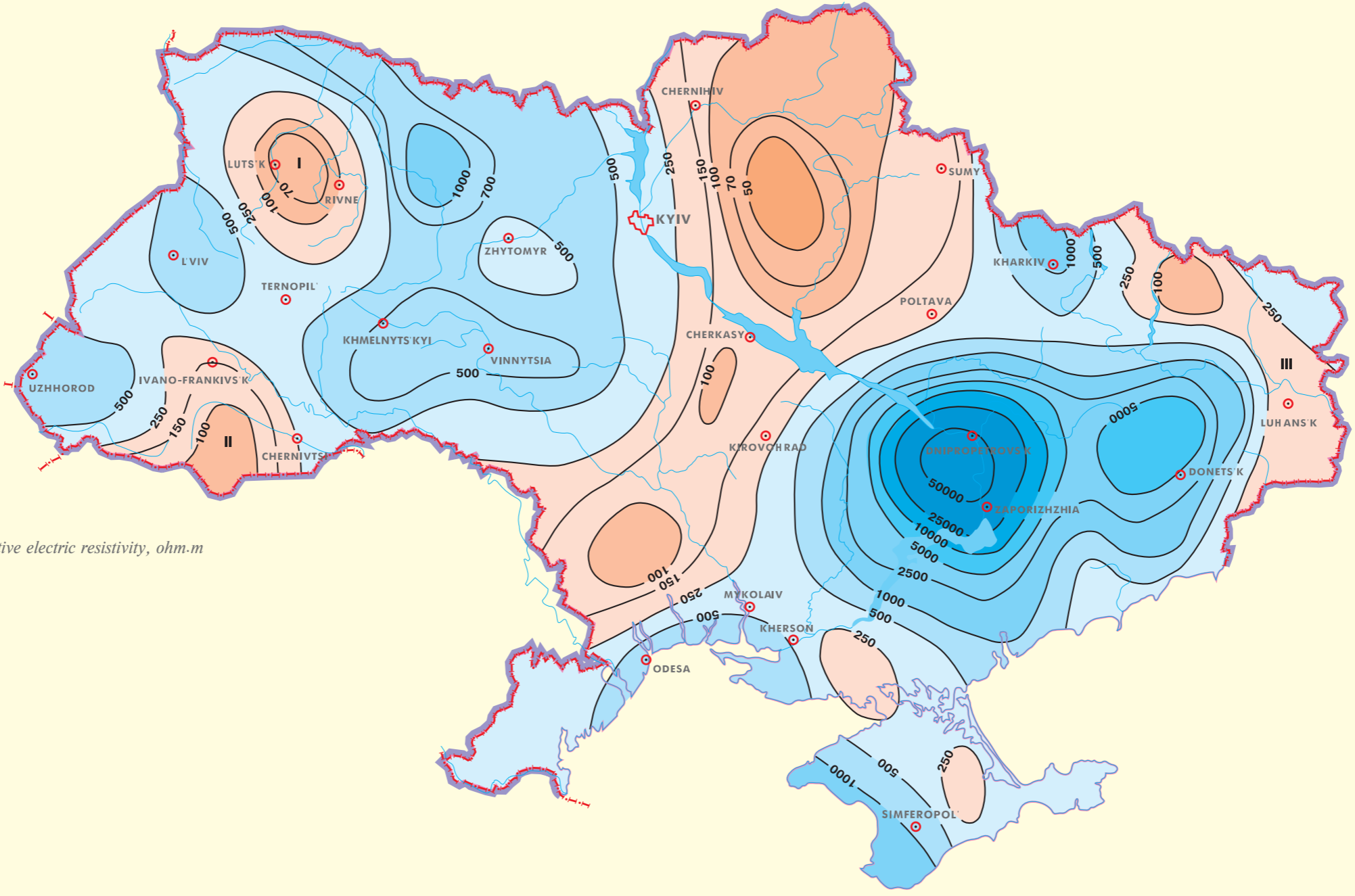
Formations of the central part of the Dnipro high-resistance field reach a maximum ρ_{eff} of 70 000 ohm·m or more. Local

anomalies of ρ_{eff} are substantially lower (up to 1000 ohm·m). The Kharkiv high-resistance anomaly, located on the northern flank of the Dnipro field, attains a ρ_{eff} of about 1000 ohm·m. The Volyn' high-resistance field is a relatively uniform area where the ρ_{eff} varies from 500 ohm·m to 1000-1500 ohm·m within the limits of the local high-resistance anomalies (Vinnytsia, Olevs'k and others).

The map of effective electric resistivity of the lithosphere at a depth of 80 km (ρ_{80}) reflects distribution of effective electric resistivity in the upper mantle showing the characteristic features of its structure and the state of matter.

Generally, ρ_{eff} values tend to decrease by a factor of 1.5-2 within the high-resistance areas and local anomalies, and increase in the high-conductivity and isometric structures with values from 50 ohm·m to 100 ohm·m or more. Anomalies where ρ_{eff} remains at about 50 ohm·m suggest a deeper origin. Data concerning ρ_{eff} to a depth of 200 km and deeper have been obtained across a large area, making it possible to assess penetration depths for the most important anomalous zones and fields. The Yalta and Kharkiv local anomalies are adjacent to the Dnipro high-resistance area at a depth of more than 100 km and form a deep meridional band. The Odesa-Kirovohrad-Pryluky high-conductivity zone, as well as the Luts'k, Rakhiv, Luhans'k and Belgorod ρ_{eff} anomalies, are traceable to depths of about 200 km.

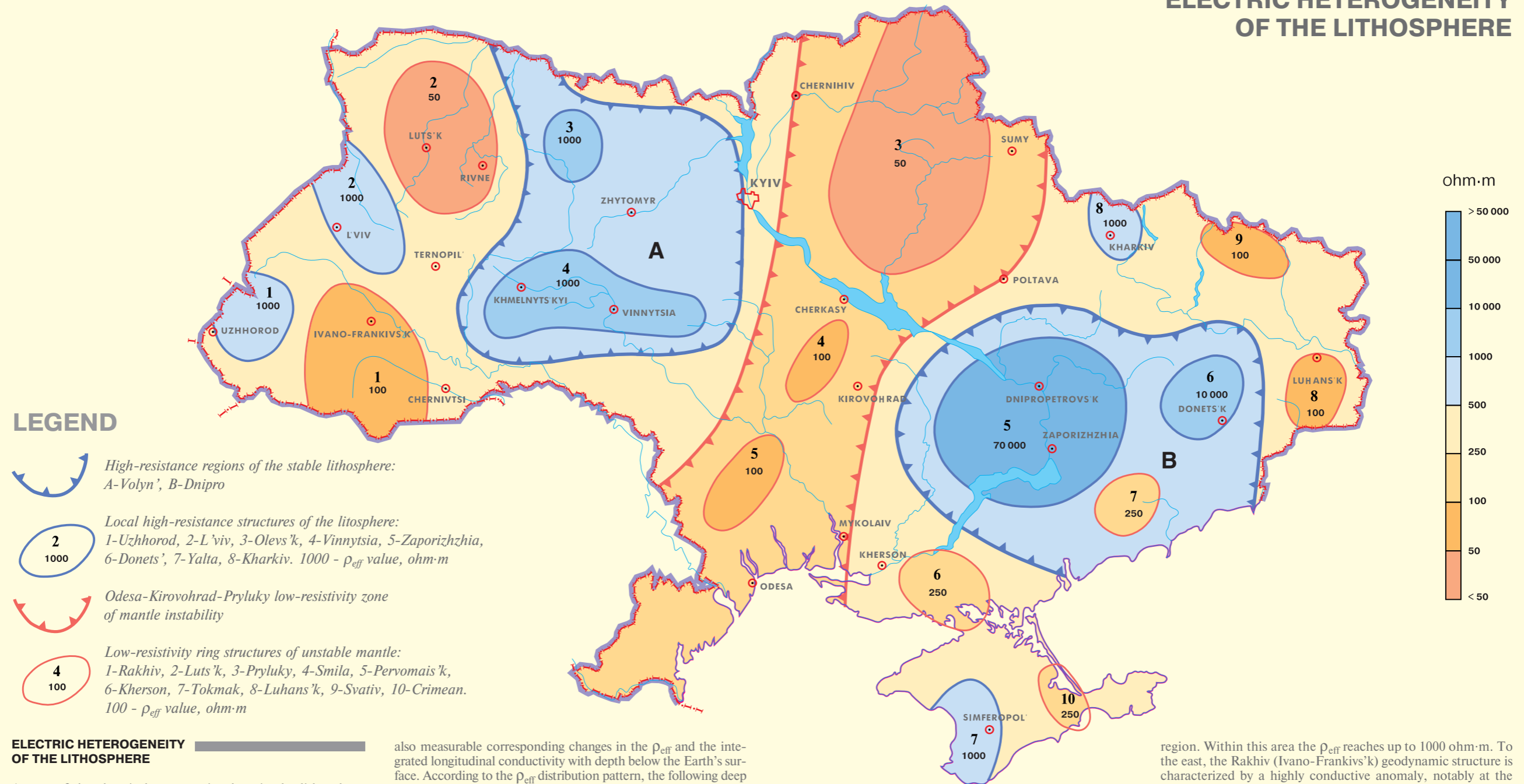
EFFECTIVE ELECTRIC RESISTIVITY OF THE LITHOSPHERE AT A DEPTH OF 80 km (ρ_{80})



LEGEND

 Isolines of effective electric resistivity, ohm·m

ELECTRIC HETEROGENEITY OF THE LITHOSPHERE



ELECTRIC HETEROGENEITY OF THE LITHOSPHERE

A map of the electric heterogeneity deep in the lithosphere has been compiled on the basis of magnetotelluric sounding (MTS) at depths of 50-80 km in the Dnipro Graben of the Dnipro-Donets' Depression, up to 300 km in the Ukrainian Shield and 80-100 km in the rest of the Ukrainian territory. Application of the MTS in the study of the lithosphere structure made it possible to use electric characteristics of rocks, which depend on their composition, temperature and pressure, to reflect mainly the present rock dynamics (PT regime) deep in the Earth.

Analyses of the MTS data revealed the following regularities in the geoelectric section. Within the Ukrainian Shield, Volyn'-Podillia and along the Donets' Basin, the geoelectric section at depths of 10-15 km is characterized by high resistivities (ρ_{eff} reaches 1500-7000 and even 70 000 ohm·m). There are

also measurable corresponding changes in the ρ_{eff} and the integrated longitudinal conductivity with depth below the Earth's surface. According to the ρ_{eff} distribution pattern, the following deep structures are distinguished: stable areas of high resistivity, activation zones of high electric conductivity and local ring anomalies. The Odesa-Kirovohrad-Pryluky (Odesa-Chernihiv) activation zone is the most outstanding structure of the region. It is characterized by the intensely reworked crust, by the dynamic activity and heterogeneity of rocks. This zone is a regional structure with a northeastern strike. In the Ukrainian Shield it coincides spatially with the Kirovohrad Block, and within the Dnipro-Donets' Depression it is complicated by the Dnipro Graben paleorift. The Dnipro stable area of the lithosphere comprises the Ukrainian Shield (to the east of the Kryvyi Rih-Kremenchuk fault) and the southern part of the folded Donets' Basin.

In the central part of the high resistivity area within the greenstone belts (the Sura, the Verkhivtseve and the Chortomyk structures), the rocks are characterized by very

high ρ_{eff} values (over 70 000 ohm·m) and by high values in the Donets' Basin (from 7000 to 15 000 ohm·m), thus attesting to the high stability of the area.

The Volyn' area of stability is situated in the western part of the Ukrainian Shield and Volyn'-Podillia. By comparison to the Dnipro area of stability, its crust is characterized by rather low ρ_{eff} values (about 1000 ohm·m at a depth of 80 km and 1500 ohm·m at a depth of 300 km). In this region the rocks are less stable. The Luts'k ring structure, which exceeds 150 km in diameter, is manifested as a distinct anomaly of electric conductivity to a depth of 300 km.

The Uzhhorod area of stability (high-resistivity), with ρ_{eff} of about 1000 ohm·m, has been outlined within the Carpathian

region. Within this area the ρ_{eff} reaches up to 1000 ohm·m. To the east, the Rakhiv (Ivano-Frankivs'k) geodynamic structure is characterized by a highly conductive anomaly, notably at the depth of 5 to 20 km, where ρ_{eff} is only 10-20 ohm·m.

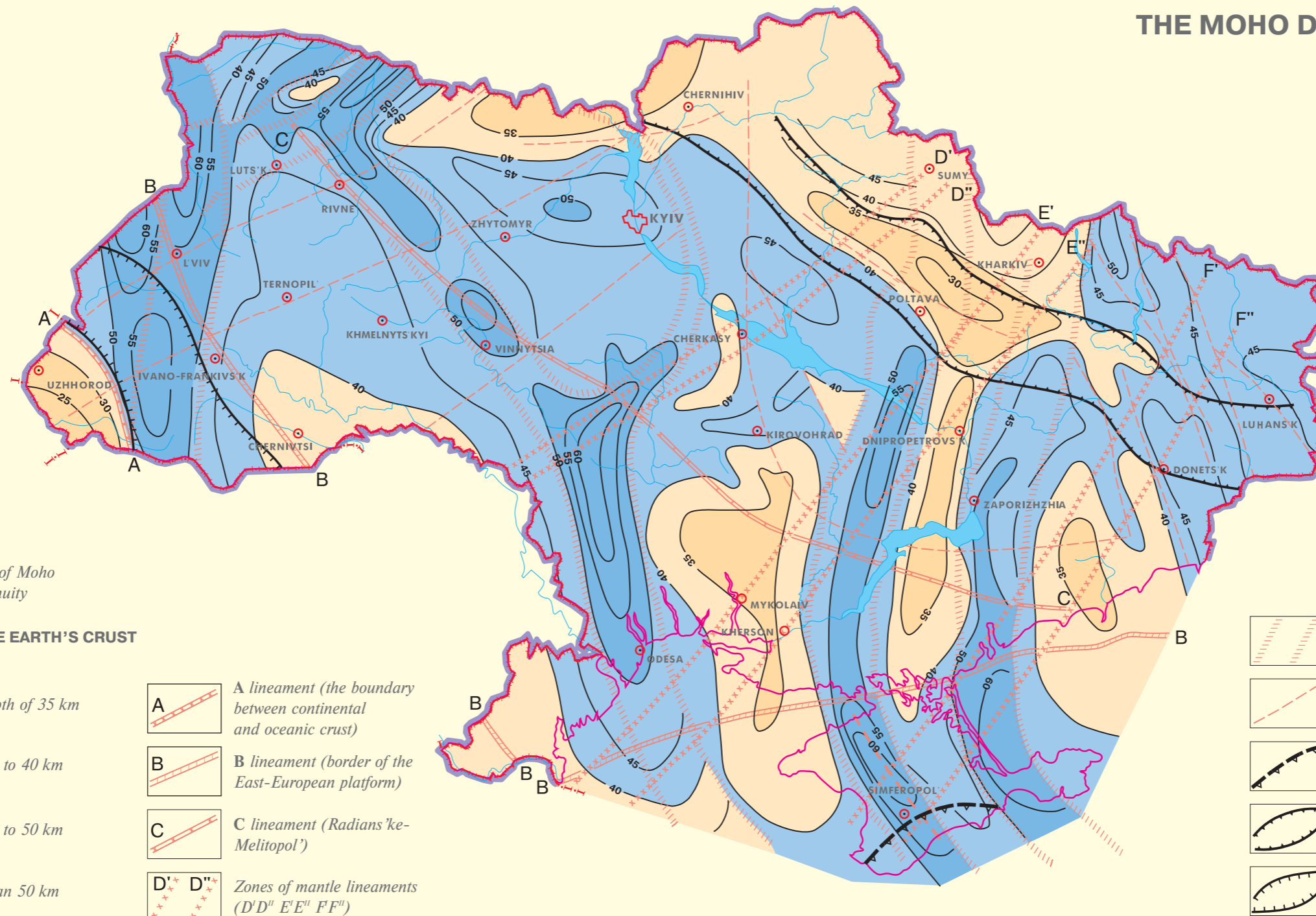
The Kerch (Crimean), Krasnoperekop (Kherson) and Tokmak local electric conductivity anomalies, with ρ_{eff} 70, 100 and 250 ohm·m respectively, are observed in southern Ukraine at depths of 50-65 km.

Thus, the MTS data show subvertical heterogeneity produced by dynamic zones, activated ring structures and stable areas in the Earth's crust and upper mantle.

The Volyn' and Dnipro high-resistivity areas of stability, traced to depths of 200-300 km, are considered to be important geological structures governing the stability of the lithosphere in Ukraine.

According to the MTS data, there are regional geoelectric heterogeneities on the territory of Ukraine which characterize geodynamically stable areas and active zones in the Earth's crust and mantle.

THE MOHO DISCONTINUITY



LEGEND

Isolines of Moho discontinuity

THICKNESS OF THE EARTH'S CRUST (below sea level)

- To a depth of 35 km
- From 35 to 40 km
- From 40 to 50 km
- More than 50 km

- A lineament (the boundary between continental and oceanic crust)
- B lineament (border of the East-European platform)
- C lineament (Radians'ke-Melitopol')
- Zones of mantle lineaments (D'D'' E'E'' F'F'')

- Zones of deep faults
- Deep faults between blocks
- Edge of Crimean Mountains
- Outline of the Riphean graben within the Dnipro-Donets' Depression (DDD)
- Edge of Carpathian Mountains

THE MOHO DISCONTINUITY

The Mohorovicic or Moho discontinuity is considered to be a complicated transitional zone of varying thickness at the boundary between the Earth's crust and the upper mantle. Within Ukrainian territory, the Earth's crust thickness varies from 25 km to 65 km. Maximum crust thicknesses are found beneath the Carpathian Mountains (65 km) and the Crimean Mountains (up to 60 km). Minimum thicknesses are observed within the Transcarpathian Depression (25 km) and in the Dnipro-Donets' Depression (30-35 km). Within the Ukrainian Shield and its slopes the Moho

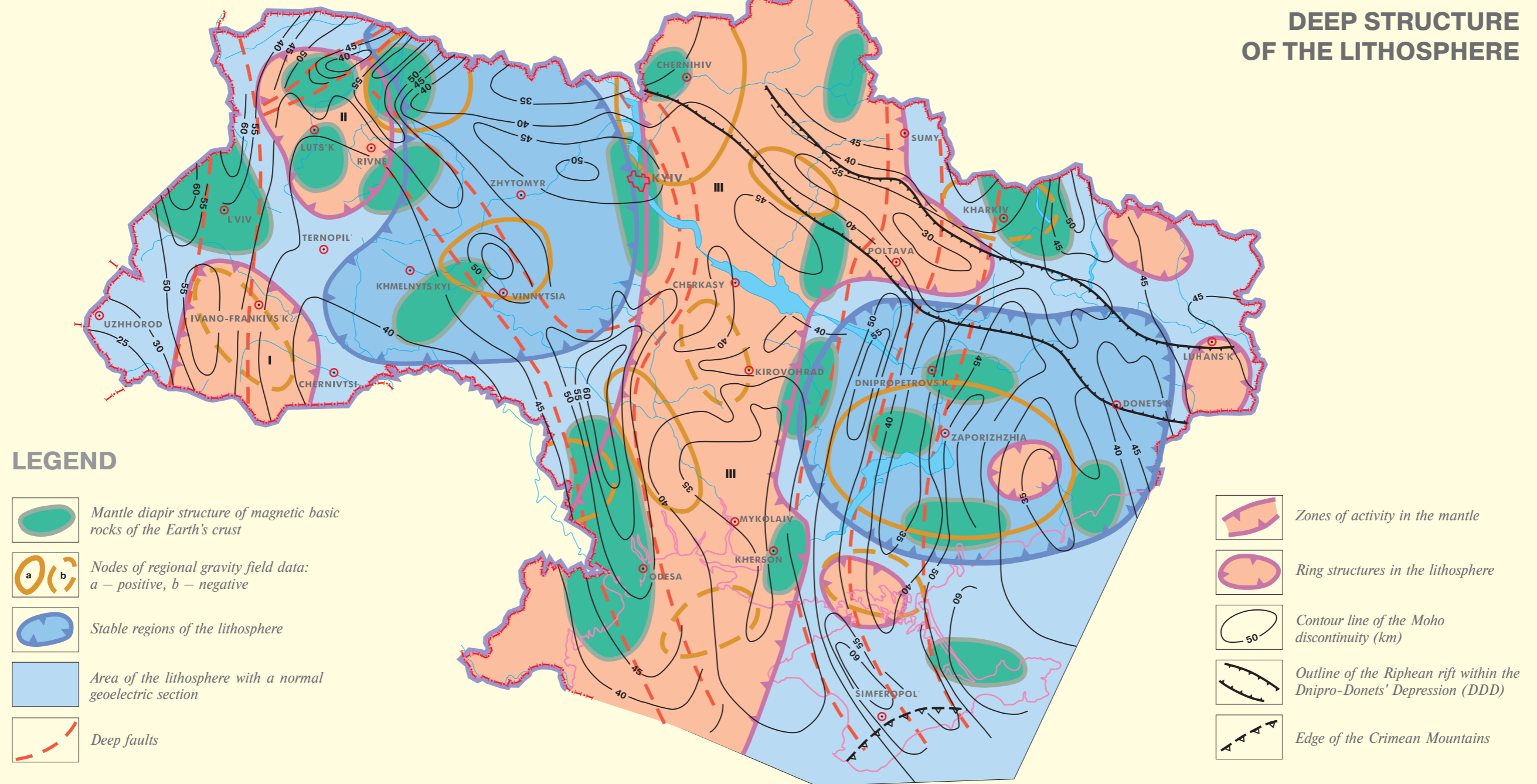
discontinuity is characterized by submeridional patterns of thickened crust coinciding with the Lower Proterozoic zones of rocks. The older structures are crossed by younger ones and, at the intersections, there are commonly two Moho discontinuities inferred. Localities with different crust thickness are usually divided by large faults. The following types of fault zones are distinguished in Ukraine:

1. Lineaments A, B and C are characterized by considerable length and play an important role in the formation of the Earth's crust. Lineament A divides the territory into two segments, one




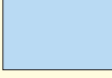

- with a "thin" (less than 30 km) and the other with a "thick" (over 40 km) crust. Lineament B coincides with the northwestern and southern boundaries of the East European Platform. Lineament C (Radians'ke-Melitopol') represents a subvertical fault zone dipping to the north and northeast. It forms the northeastern limit of the high grade granulite facies terrain.
2. Inferred lineaments or deep transitional faults with north-eastern strikes stemming from the asthenosphere (D' D'', E' E'', F' F''). Lineament D' D'' – Tyrrenian-Vrancea-Sumy-Urals Lineament E' E'' – Burgas-Mykolaiv-Kharkiv



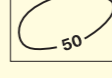


- Lineament F' F'' – Istanbul-Sevastopol'-Slavians'k.
3. Marginal faults of the main tectonic regions (Crimean and Carpathian Mountains, Dnipro-Donets' Depression). Seismic investigations, including Deep Seismic Sounding, allowed tracing continuous seismic sections to depths of 70-90 km with horizontal, inclined and steeply dipping reflecting surfaces. It was found that the Moho discontinuity with multi-surfaces might be a thinly bedded transitional zone. Its thickness is variable and exceeds 10 km in some places. According to the Kryvyi Rih superdeep drill hole data, the best reflectors of the multi-surfaces correlate with crushed low-density fault zones in the Earth's crust.

DEEP STRUCTURE OF THE LITHOSPHERE



LEGEND

-  Mantle diapir structure of magnetic basic rocks of the Earth's crust
-  Nodes of regional gravity field data: a – positive, b – negative
-  Stable regions of the lithosphere
-  Area of the lithosphere with a normal geoelectric section
-  Deep faults

-  Zones of activity in the mantle
-  Ring structures in the lithosphere
-  Contour line of the Moho discontinuity (km)
-  Outline of the Riphean rift within the Dnieper-Donets' Depression (DDD)
-  Edge of the Crimean Mountains

DEEP STRUCTURE OF THE LITHOSPHERE

This map has been compiled on the basis of the results derived from the analysis of seismic data and measurements of potential fields.

The Dnieper and Volyn' high resistivity in the lithosphere and mantle down to depths of 200-300 km have been interpreted on the basis of the MTS data. These two zones are separated by the Odesa-Kirovohrad-Pryluky mantle activity zone of high conductivity. There are also several other structures of uplifted mantle, such as the Rakhiv (I) in the Carpathians and Luts'k (II) in the Volyn' region.

The Dnieper stable field of the lithosphere, involving the eastern part of the Ukrainian Shield and the folded Donets' Basin, is characterized by maximum values of the effective electric resistivity from 50 000 in the crust, to 100 000-150 000 ohm·m at

depths of 200-300 km. Within this area, a unique anomaly of regional positive gravity, whose origin is related to deeply buried rocks of high density, was recognized.

The Volyn' stable area, encompassing the western part of the Ukrainian Shield and the Volyn'-Podillia Plate, is relatively uniform in structure. The effective electric resistivities of deeply buried horizons of the lithosphere do not exceed 1000-1500 ohm·m. This value is several orders of magnitude lower than that of the Dnieper field. The thickness of the Earth's crust in the Volyn'-Podillia Plate, however, reaches maximums of 50-60 km, whereas its layering is not at all well developed. The peripheral parts of the Plate are irregular in terms of its magnetic features and the density.

The Odesa-Kirovohrad-Pryluky zone (III) of activity is up to 200 km wide and is a deeply buried geodynamic structure







trending in the southwesterly direction. It crosses the Black Sea Coastal Depression, the Ukrainian Shield and the Dnieper-Donets' Depression. The zone is clearly manifested at 50-70 km depth, where the electric resistivity decreases to 50 ohm·m or less. Deep Seismic Sounding data indicate that the Earth's crust is 35-40 km thick there, and that the zone is bounded by deep faults with up to 10 km offsets of the Moho discontinuity.

The geological structure at Luts'k was traced down to 200-300 km. The diameter of this structure exceeds 150 km. Within the structure, Deep Seismic Sounding data demonstrated a complicated pattern of the Moho discontinuity which is about 40 km deep here at its center and plunges down to 55 km depths in the peripheral parts (depth differences along the fault system reach up to 15 km). A marker horizon was revealed at a depth of 110 km (VI Geotraverse

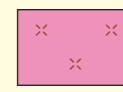
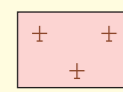
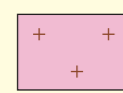
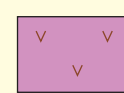
data) that points to differentiation in the mantle. The presence of a basalt cover, kimberlite breccia pipes and the variation of electric conductivity at depth (where ρ_{eff} decreases to 10 ohm·m at a depth of 100 km) point to the presence of melted mantle somewhere in the interval between 70 and 140 km depth where the temperature is estimated to have reached 1000-1300° C.

In the Ukrainian Carpathians, there are the Uzhhorod highly resistant field and the unique Rakhiv highly conductive, ring-like dynamic geological structure, 200 km in diameter, which coincides with the regional negative gravity anomaly. Such a relationship between the density and the electric conductivity of the geological environment may indicate a heating and destabilizing (increase of rock volume) of the structure. This is also supported by up to 80-100 m W/m² heat flow readings in the area.



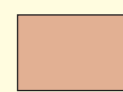

LEGEND

-  Volyn'-Dvina transregional interblock zone – volcano-plutonic belt
- Megablocks:
 -  A – Briansk-Podillia
 -  B – Kursk-Dnipro
-  Kryvyi Rih-Krupets intermegablock zone
- ① First-order blocks:
 - 1 – Volyn' (mobile belt), 2 – Podillia,
 - 3 – Kirovohrad (mobile belt), 4 – Dnipro,
 - 5 – Azov, 6 – Briansk, 7 – Rossosh',
 - 8 – Kursk, 9 – Scythian plate,
 - 10 – Dnipro-Donets' Depression
-  Interblock suture zones:
 - 1 – Bila Tserkva-Odesa
 - 2 – Orikhiv-Pavlohrad
-  Interblock zones of faulting
- ⓓ Folded regions:
 - D - Donets'k, KM - Crimean Mountains,
 - FC - Flyschoid Carpathians, FD - Forecarpathian Depression, TD - Transcarpathian Depression





BASIC COMPLEXES OF THE PRECAMBRIAN MASSIF

-  Basic granulites, Granulite gneisses
Basic-ultrabasic rocks, Granitoids
-  Granite-greenstone, Amphibolite-plagiogneisses,
Plagiogranitoids
-  Gneissic schists, Basic-ultrabasic rocks,
Granitoids
-  Leptite-keratophyres, Gabbro-diorite-
granodiorite


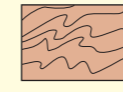
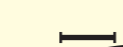
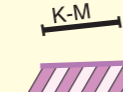

VOLCANOGENIC-SEDIMENTARY COMPLEXES

-  In depressions and downwarps
-  In folded terrains
-  In mountainous folded terrains
-  In the Scythian Plate



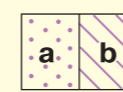
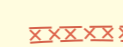



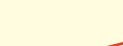





BOUNDARIES:

-  Ukrainian Shield and Voronezh massif (southern part)
-  Platforms
-  Folded regions
-  Geotraverses with constructed sections

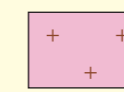
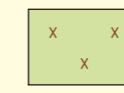
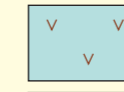
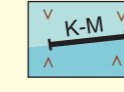

Legend for the section along geotraverse GT II

-  Sedimentary deposits
-  Folded complexes
-  Reflecting areas
-  Cover of the transitional zone from mantle to crust
-  Wave guides
-  Moho discontinuity
-  Cover of the asthenosphere based on geothermal data

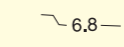
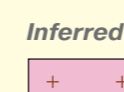
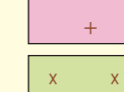
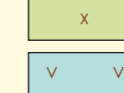
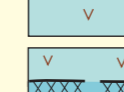





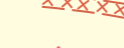





Sources of geothermal anomalies, estimated age in millions of years:

-  160–180 Ma
-  4–15 Ma
-  Fractured mantle (a), compact mantle (b)
-  Deep faults
-  Possible boundary between Mesozoic-Paleozoic (MZ-PZ)
and Riphean basement (R_p)
-  Possible boundary of the Riphean and
Archean-Proterozoic basement (AR-PR-R_p)
-  Regional thrusts
-  Faults of large magnitude, including the deep ones
-  Volcanic rocks of the Vyhorlat-Hutyn ridge
-  Felsitic magmatic center
-  Basic magmatic center
-  Magnetically active layer and its magnetization, A/m (ampere/m)
-  Density g/cm³

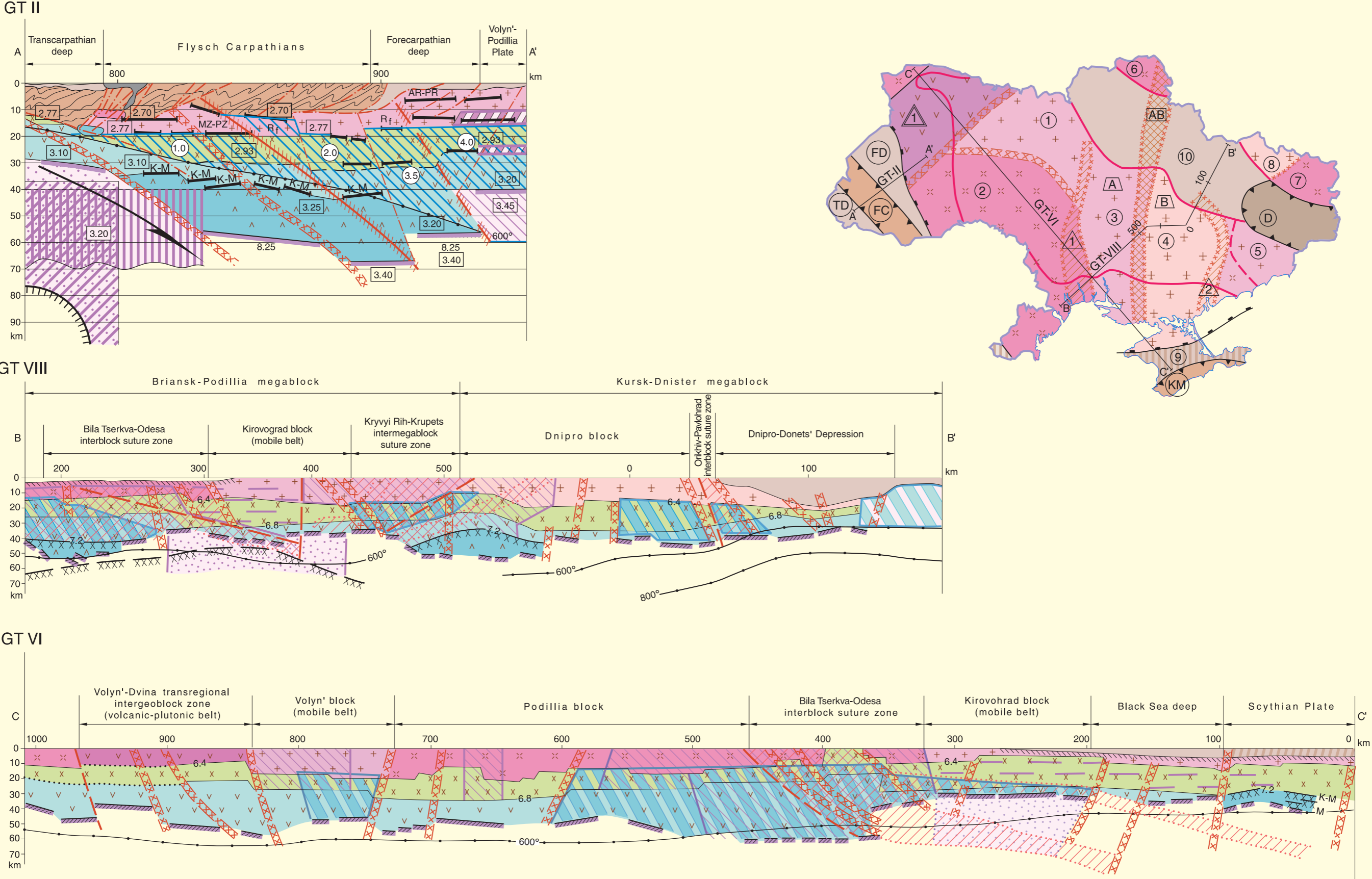
Inferred layers in the Earth's crust

-  Granitic
-  Dioritic
-  Basaltic
-  Crust-mantle mixture
-  Direction of displacement

Legend for the sections along geotraverses GT VI and GT VIII

-  ~6.8— Velocity isolines, km/sec
-  Granitic (V_p < 6.4 km/sec)
-  Dioritic (6.4 < V_p < 6.8 km/sec)
-  Basaltic (V_p > 6.8 km/sec)
-  Crust-mantle mixture (V_p > 7.2 km/sec)
-  M Moho discontinuity, upper mantle
-  Surface of the protoasthenosphere
-  Transcontinental tectonic sutures (a)
-  Trans-crustal faults (b)
-  Zones of inclined faults
-  Surface of the pre-Riphean basement
-  Isotherms, 600 °C
-  Anomalous elevated crustal density
-  Anomalous decreased crustal density
-  Decreased mantle density
-  Highly magnetic blocks

DEEP STRUCTURE OF THE EARTH'S CRUST ALONG THE GEOTRAVERSES II, VI, VIII





"Golden Gates", volcanic, Karadah, Crimea



Demerdzhy pillars, limestone, Crimean Mountains



Volcanic massif – Karadah natural reserve, Crimea



Flysch rock in the Carpathians, Volovets', Transcarpathian oblast'

DEEP STRUCTURE OF THE EARTH'S CRUST ALONG GEOTRAVERSES II, VI AND VIII

Studies of the deep structure of the lithosphere of Ukraine were carried out using a complex quantitative interpretation of Deep Seismic Sounding (DSS), gravimetric, magnetometric, geoelectric and geochemical data. Interpretation of DSS was carried out using a dense network of profiles which included international geotraverses. Seismic data give an indication of various velocity layers in the Earth's crust, its thickness and blocky structure, and the relief of the upper part of the mantle.

Construction of a solid model of the Earth's crust is based on the interpretation of the layering and density of the crust with depth. The calculation of density of the model relies on the detailed two-dimensional velocity sections based on gravity modelling of the crustal matter, where the correlated density is dependent on the velocity with some corrections for crystalline rocks of different compositions.

Studies of deep magnetic nonhomogeneities have been carried out utilizing a combination of data from DSS and geothermal sources. As a result, two-dimensional magnetic models along the geotraverses have been constructed. Deep magnetic nonhomogeneities have been analyzed, taking into account such variables as the gravity data, the thickness of the crust, the relationships of its layers, the degrees of metamorphism and the structure. The distribution of temperatures along the traverses was obtained on the basis of solving a two-dimensional stationary equation of thermal conductivities from the calculated crustal and mantle components of the thermal flow. Schematic petrological models of the consolidated pre-Riphean crust were constructed on the basis of complex geophysical data. Thus, a number of complexes were recognized and inferred to be "granitic", "dioritic" and "basaltic". Within the Ukrainian Shield they are characterized by the following longitudinal velocities: 5.7-6.4, 6.4-6.8, and 6.8-7.6 km/sec. In distinguishing various complexes in the depressions of the

crust, adjusting for lesser pressures and higher temperatures, somewhat lower velocity parameters were used: 5.7-6.3, 6.3-6.7, 6.7-7.4 km/sec.

An analysis of the "petrological" model of the Earth's crust along the profiles indicates that the thickness of individual layers in the complex changes rapidly laterally. The layers may even seem to disappear. Such changes are not chaotic, since the dominance of one layer in a given section of the crust reflects the petrological composition of blocks on the surface.

The Kryvyi Rih-Krupets, Bila Tserkva-Odesa and the Orikhiv-Pavlohrad intermegablock suture zones have complicated structures (see GT VIII section, p. 37).

The superimposed structures – the Dnipro-Donets' Depression and the Volyn'-Dvina volcano-plutonic mobile belt are characterized by an abruptly reduced thickness of the consolidated crust with an actual enlargement of its base (see GT VI and GT VIII). Sections illustrate faulted tectonic patterns, and in particular the inclined nature of the deep faults are

established for the first time.

Geotraverse II (see p. 37) in the western part of Ukraine illustrates a complex structure. This is an assemblage of tectonic blocks of similar origin, consolidated with time, and subsequently substantially changed and mobilized as a result of a long evolution, including the effects of Alpine orogeny in Neogene-Quaternary times.

On the basis of GT II a number of features of the Earth's crust have become apparent and it is possible to construct – a schematic view of the relief of Moho, large lineaments of the lithosphere, a blocky structure of the Earth's crust, and the faulted tectonic patterns.

The main feature of the thermal field of the Carpathian region is the increase of its thermal flow from the ancient platform towards the internal portions of the Carpathian mountains.

The blocky and the deep structures of the Earth's crust in Ukraine correlate well with the metallogenic provinces of the country.

T H E G E O L O G Y A N D M I N E R A L D E P O S I T S O F U K R A I N E

section III

STRUCTURAL MAPS

- Glaciers and Quaternary sediments
- Quaternary deposits
- Structure of the sedimentary cover
- Tectonic map
- Structure of the basement
- Linear and ring geological structures
- Neotectonics and recent vertical movements of the Earth's crust
- Geodynamic map





Glacial boulder (erratic), brought from Karelia to the Romny region (Sumy oblast') 180 000 - 200 000 years ago.

GLACIERS AND THEIR QUATERNARY DEPOSITS

The Quaternary deposits (anthropogenic) are widespread in most of Ukraine, except on the steep slopes of the Carpathian and Crimean Mountains, the Donets' Ridge and the beds of rivers cutting the crystalline Ukrainian Shield. These deposits are characterized by variable lithological composition, relative thinness, and genetic variety. The most common genetic varieties are: eolian-deluvial loesses, glacial and glacial-water deposits, alluvial, eluvial, deluvial-colluvial and marine deposits. The thickest deposits (40-60 m) occur on lower ground which has undergone some neotectonic subsidence. At higher elevations, or uplifted grounds, the thicknesses of such deposits range from 5 to 12 m, and in the mountainous regions they are from 0.5 to 2.5 m.

In the northern regions of Ukraine and partly in the Forecarpathian area there are widespread glacial and glacial-water deposits of two different ice ages: Early Pleistocene (South Polish) (440 000-690 000 years ago) and Middle Neo-Pleistocene (Dnirovian) (180 000-300 000 years ago). The first one covered the northwestern part of the Forecarpathians and the Volyn' region, and the second one covered almost all of the Polissia region, part of the Dniro

upland and the Dniro lowland, stretching in a tongue-like fashion along the Dniro valley to the city of Dniprodzerzhynsk. The glacial deposits, or moraines, are represented by unsorted fragments of basement rocks, boulder-bearing sandy loams, clays, and loamy sands. Their thickness varies considerably, from 0.5 to 18 m. In the middle Dniro area there are some large glacial dislocations and separations. This is one region in the world where the present erosional level allows one to observe the entire glaciotectionic complex. The glacial-water deposits underlie and overlie the glacial deposits, and also form other glacial features such as kames, drumlins, and frontal aprons. They are represented by sands, loamy sands, sandy loams and loams varying in thickness from 3 to 50 m, but in the glacial valleys they are up to 100-120 m thick. In the Polissia region the glacial and glacial-water deposits form frontal aprons and moraine frontal apron flatlands. Beyond the Polissia region and to the outer limit of the glacier, the glacial-water deposits are overlain by eolo-deluvial sheets of Middle-Late Neo-Pleistocene age, represented by loess with relict soils. To the south of the glacier there are widely distributed eolo-

deluvial loess deposits of Neo-Pleistocene age with relict soils. In the Dniro and the Donets' regions the loess deposits are also of the eolo-deluvial and eluvial origin.

The loess deposits as a general rule are represented by coarse grained sandy loam, and less commonly by loamy sand. Their thicknesses are in the order of 5-10 m on the elevated grounds, and 40-50 m in the lowlands. In general, loess deposits cover close to 70% of the territory of Ukraine.

The alluvial deposits formed the flood plains and terraces of the rivers. River beds in the mountainous Forecarpathian region contain pebbles and boulders, gravel and well-sorted sands, 2 to 12 m in thickness. River beds in the lowlands are characterized by gravels, sands, sandy loams, and loamy sands measuring from 10 to 30 m in thickness. In regions which have been uplifted during the Quaternary period, up to nine terraces may be distinguished in the river valleys. In the Transcarpathian lowland, as a result of its subsidence and the uplift of the Carpathian Mountains, the alluvial deposits reach or exceed 100 m in thickness.

Marine deposits are found not only at the bottom of the Black and Azov seas, but also form terraces along their shorelines.

During the ice age, when the sea level was lower, loess was deposited on the present-day shelves of the Black Sea. At that time, the rivers cut deeply into the bedrock. Subsequently, when the sea level rose, large estuaries were formed. For this reason, the deposits more common to the Black Sea shoreline are not of marine but of estuarine-marine or estuarine origin. As a general rule they comprise sands, silts and, less commonly, shells. At the delta of the ancient Dniro River there is a 40-50 m thick layer of alluvial-marine sediments such as sands and silts.

Eluvial deposits are represented by the eluvial sediments derived from the basement rocks and by the relict soils. The latter are rather thick (10-18 m) in the Early-Pleistocene of the Black Sea area and underlie the loess deposits of the Neo-Pleistocene.

In the Carpathian and Crimean Mountains, and to a lesser extent over the Donets' Ridge there are widely distributed eluvial-deluvial and deluvial-colluvial pebbly-loamy deposits, up to several meters in thickness. In Crimea there are relatively widely developed deluvial-proluvial and alluvial-proluvial pebbly-loamy deposits. In places their thickness reaches 30 to 40 m.

Amongst other genetic types, there are mud and lake deposits that are locally developed.

LEGEND

	<i>a</i> – 1-9 alluvium, 1-9 terraces		<i>f</i> – glacial-water		<i>dc</i> – deluvial-colluvial
	<i>a f II</i> – alluvial-glacial water		<i>f, g</i> – glacial-water, glacial		
	<i>ap</i> – alluvial-proluvial		<i>g II</i> – glacial		<i>vd</i> – eolo-deluvial <i>vd I-III</i> – eolo-deluvial Early-Late Neo-Pleistocene <i>vd II-III</i> – eolo-deluvial Middle-Late Neo-Pleistocene
	<i>La, a I</i> – estuary-alluvial, alluvial-estuarine <i>Lm II</i> – estuarine-marine (ancient euxenic) <i>La I</i> – estuarine-alluvial Early Neo-Pleistocene <i>La II</i> – estuarine-alluvial Middle Pleistocene (ancient euxenic) <i>aL II</i> – alluvial-estuarine Middle Pleistocene		<i>e</i> – eluvial		<i>vd, e</i> – eolo-deluvial, eluvial <i>vd, e I-III</i> – eolo-deluvial, eluvial Late Neo-Pleistocene
	<i>am</i> – alluvial-marine <i>am I</i> – alluvial-marine Early Neo-Pleistocene <i>am II</i> – alluvial-marine Middle Pleistocene		<i>ed</i> – eluvial-deluvial		<i>m</i> – marine <i>m I</i> – marine Early Neo-Pleistocene (Chaudyn) <i>m III</i> – marine Late Neo-Pleistocene
			<i>dp</i> – deluvial-proluvial		



GLACIERS AND QUATERNARY SEDIMENTS



LEGEND




- $\frac{vd\ II-III}{a\ 4-5}$ Eolo-deluvial loesses, Middle-Late Neo-Pleistocene, 4-5 terraces on the alluvium
- $\frac{vd\ II-III}{f, g\ II}$ Eolo-deluvial loesses, Middle-Late Neo-Pleistocene, on the glacial-water and glacial deposits of the Dniprovan ice age

BOUNDARIES AND AREAS

-  *g I* – Early Neo-Pleistocene glaciation (440 000-690 000 years ago)
-  *g II* – Middle Neo-Pleistocene glaciation (Dniprovan) (180 000-300 000 years ago)

DEPOSITS

- f I* – Glacial-water deposits, Early Neo-Pleistocene
- f II* – Glacial-water deposits of the Dniprovan ice age

-  Glacial dislocations (faults)
-  Glacial detached mass
-  Mud volcanoes



Quaternary deposits, Viazivok village, Poltava oblast'

QUATERNARY DEPOSITS

The division of Quaternary deposits of Ukraine is based on the anthropogenic features of the cover, taking into account the structural-geomorphological conditions of their formation. In particular, the age, the genesis and the thickness of the deposits were differentiated.

Quaternary deposits are divided into areas, regions (oblasts), subregions and districts. Areas are the largest units, representing the major geological structures of Ukraine: the Carpathians (A), the Crimean Mountains (B) and the Ukrainian Platform

Plain (C). Regions are distinguished within each area. For example, the Forecarpathian region (A-II) is within the (A) area and the North Ukrainian region (Polissia, C-I) in the (C) area. Subregions are the main units on the map, having different sets of characteristics (facies composition, structure and thickness). For instance, the Zhytomyr Polissia subregion (C-I-2) is characterized by the prevailing Middle Pleistocene (Dnipro) moraine and thin glacial lacustrine deposits, while the Kyiv Polissia subregion (C-I-3) has a more complete and thick geological section of Quaternary rocks. Most of the subregions are named after settlements, rivers, etc.

Some subregions are divided into districts, which depict the details in Quaternary sedimentation (the presence of marine and loess deposits, etc.). Districts can have their own names (such as Inhulets', C-II-13-c and Kerch, C-II-16-c) or are named after sections of subregions (Eastern Poltava, C-II-9-b and others).

In addition, the map shows the boundaries of the Lower Quaternary and the Middle Quaternary (Dnipro) moraine deposits. Quaternary rocks of different origins are represented by various colours: eluvial-deluvial, colluvial-deluvial, deluvial, loess and soil, loess, outwash plain and alluvial.

In the Quaternary deposits of the lake-muddy flats facies, there are large resources of peat and sapropelite. Associated with the river sediments, there are alluvial gold deposits in the Carpathian Mountains, and deluvial gold deposits in the Nahol'nyi Ridge of the Donbas area. In the Osnyts'k-Volyn' region, the alluvial placer occurrences and deposits of ilmenite, zircon and cassiterite are associated with the terrigenous Pliocene-Quaternary formations.

This compilation for the entire territory of Ukraine is the first of its kind.

Area	Region (Oblast')	Subregion	District	3	4	
1	2	3	4	3	4	
A Carpathians	A-I Carpathian Mountain			C-II-3 Liubar		
	A-II Forecarpathian	A-II-1 North-Western		C-II-4 Podillia		
		A-II-2 Central		C-II-5 Trans-Buh		
A-II-3 South-Western			C-II-6 Ros'			
A-III Transcarpathian	A-III-1 Western		C-II-7 Central Dnipro			
	A-III-2 Eastern					
B Crimean Mountains	B-I Mountainous	B-I-1 Central Mountainous		C-II-8 Hlukhiv		
		B-I-2 Southern Coastal		C-II-9 Poltava		
	B-II Foothills			C-II-10 Bohodukhiv		
C Ukrainian Platform Plain	C-I North Ukrainian (Polissia)	C-I-1 Volyn' Polissia	C-I-1-a Western Volyn'	C-II-11 Velykyi Burluk	C-II-11-a Northern Velykyi Burluk	
		C-I-2 Zhytomyr Polissia	C-I-1-b Eastern Volyn'		C-II-11-b Southern Velykyi Burluk	
		C-I-3 Kyiv Polissia	C-I-2-a Western Zhytomyr	C-II-12 Oril'-Donets'		
		C-I-4 Chernihiv Polissia	C-I-2-b Eastern Zhytomyr	C-II-13 Southern Ukrainian		
		C-I-5 Desna-Dnipro Polissia	C-I-2-c Ovruch		C-II-13-a Western Dnister	
			C-I-5-a Oster	C-II-14 Donets'	C-II-13-b Dnister	
			C-I-5-b Desna		C-II-13-c Inhulets'	
			C-I-5-c Southern Snov		C-II-13-d Dnipro Rapids (Zaporizhzhia)	
			C-I-6 Novhorod-Sivers'kyi Polissia	C-I-6-a Central Novhorod-Sivers'kyi		C-II-13-e Azov Sea
			C-I-7 Shostka Polissia	C-I-6-b Southern Novhorod-Sivers'kyi		C-II-14-a Central Donets'
	C-II Central and Southern Ukrainian (Loess)	C-II-1 Volynian	C-II-1-a Western Buh		C-II-14-b Western Donets'	
C-II-2 Malopolissia		C-II-1-b Styr-Horyn'	C-II-2-a Western Malopolissia		C-II-14-c Northern Donets'	
		C-II-2-b Eastern Malopolissia		C-II-15-a Northern Black Sea		
				C-II-15-b Southern Black Sea		
				C-II-15-c Lower Dnipro		
				C-II-15-d Danube		
				C-II-16-a Syvash		
				C-II-16-b Tarkhankut		
				C-II-16-c Kerch		

QUATERNARY DEPOSITS



LEGEND

Dominant Quaternary deposits

- Eluvial-deluvial
- Colluvial-deluvial
- Deluvial
- Loess and soil
- Loess
- Outwash plain accumulation
- Alluvial low-terraced floodplain
- Alluvial high-terraced floodplain

Boundaries and their symbols

- Areas
- Regions
- Subregions
- Districts



Pliocene deposits, Odesa



Miocene deposits, Liadove village, Vinnytsia oblast'




Poltava sand outcrop, Vytachiv village, Kyiv oblast'

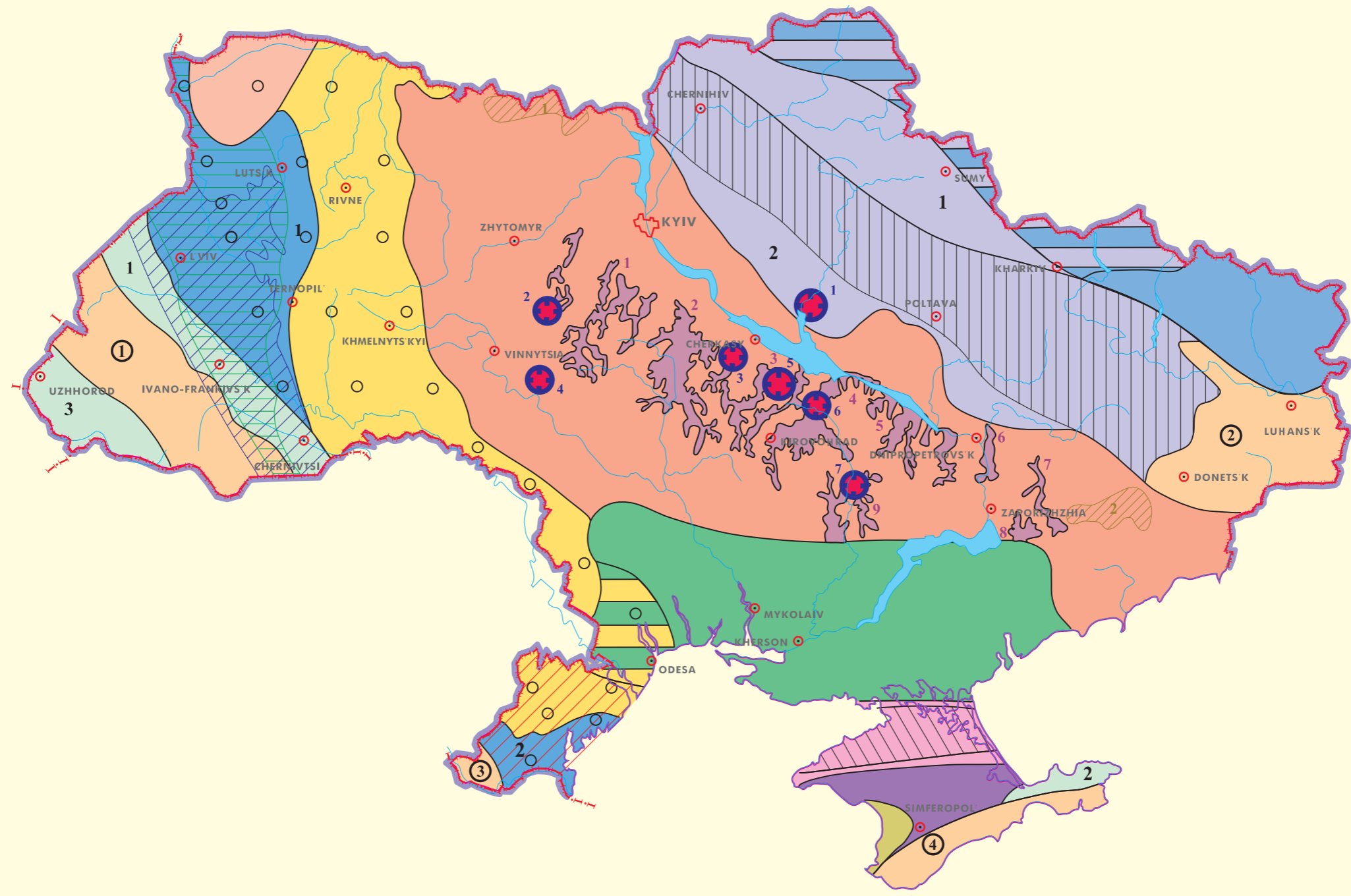


Pliocene Kuial'nyk horizon stratotype, Odesa

LEGEND

	<i>Mesozoic-Cenozoic cover of the Ukrainian Shield</i>		<i>Fore-Dobruja Jurassic Trough</i>		<i>Dnipro-Donets' Mesozoic Depression: northern flank (1), southern flank (2)</i>
	<i>Grabens and erosional-tectonic depressions (1 – Ovruch, 2 – Kins'ka-Yaly)</i>		<i>Stryi Jurassic Trough</i>		<i>Prypiat'-Dnipro Devonian Graben</i>
	<i>Astroblemes (1* – Obolon', 2 – Bilyivka, 3 – Rotmistrivka, 4 – Illintsi, 5* – Bovtyshka, 6 – Zelenyi Hai, 7 – Ternivka). * - more than 10 km in diameter</i>		<i>Lviv-Lublin Cretaceous Trough</i>		<i>Voronezh Anticline (southern slope)</i>
	<i>Main coal-bearing depressions (1 – Ryzhanivka, 2 – Tetiyiv-Orativ-Tarnivka, 3 – Hlyns'k-Bohdanivka, 4 – Krynychuvate-Mykhailivka-Marianivka, 5 – Novo-Oleksandrivka-Domotkan', 6 – Synel'nykove-Dnipro, 7 – Sanzhary, 8 – Orikhiv, 9 – West and East Kryvyi Rih)</i>		<i>Southern Ukraine Monocline</i>		<i>Folded structures: Carpathians (1), Donbas (2), Dobruja (3), Crimea (4)</i>
	<i>Volyn'-Podillia Plate with sections of the Moldovan Plate</i>		<i>Karkinit-Northern Crimean Late Cretaceous-Paleogene Trough</i>		<i>Alpine troughs: Carpathian (1), Indolo-Kuban' (2), Inner Transcarpathian (3)</i>
	<i>Volyn'-Odesa Monocline</i>		<i>Karkinit-Northern Crimean Triassic-Early Cretaceous Graben</i>		<i>Southern Ukrainian Monocline superimposed on the Volyn'-Odesa monoclinical structure</i>
	<i>Paleozoic troughs (1 – Lviv, 2 – Fore-Dobrudzhian)</i>		<i>Central Crimean Cretaceous-Paleogene Uplift</i>		<i>Northern flank of the Dnipro-Donets' Depression superimposed on the Voronezh Anticline</i>
	<i>Volyn' Paleozoic Uplift</i>		<i>Al'ma Cretaceous-Paleogene Depression</i>		<i>Boundaries of geological structures</i>

STRUCTURE OF THE SEDIMENTARY COVER



STRUCTURE OF THE SEDIMENTARY COVER

In the platform structures with sedimentary cover, some of the earliest periods of deposition are the Riphean-Early Vendian. They correspond to the aulacogenic, transitional period of development, which started forming in the late Vendian time. Among the aulacogenic structures one of the best known is the Dnipro-Donets' Aulacogen. The Aulacogen is linear, trends in a northwesterly direction, has faulted boundaries and is underlain by a Precambrian basement. The basement rocks at the margins of the Aulacogen are as shallow as 150 m but towards the center they are 5 km deep, and in the southeast reach 12 km depths. Under the folded formations of the Donets' Basin the basement rocks, according to our geophysical data, lie at about 22 km depth.

The Brahyn basement ridge divides the aulacogen structure into the Prypiat' and the Dnipro-Donets' grabens.

The Prypiat'-Donets' Aulacogen, one of the largest in Europe, was formed during the Devonian stage of platform development. This structure is about 1000 km long, 150 to 300 km wide, and separates such large structures as the Voronezh and Mazur-Belarus anticlines from the Ukrainian Shield.

The Aulacogen has a complicated faulted blocky structure. A system of sublatitudinal and submeridional faults, and perpendicular to these additional faults form a series of horsts and grabens at various levels. At its northwestern end, the Aulacogen abuts on the Polissia saddle. In the southeast it comes in contact with the folded Donbas region, forming a transitional zone marked by the development of the Bakhmut and Kal'mius-Torets' troughs.

The Dnipro-Donets' Aulacogen has a long history, being initiated, probably, in the Riphean period. It was reactivated in the Devonian, Carboniferous, Permian and Mesozoic, so that it was essentially complete by the end of the latter period. And finally it was reactivated in the Cenozoic period.

According to the character of its structure and the associated magmatism, the Aulacogen is classified by most investigators as a riftogenic type. The aulacogenic deposits are covered by less complicated strata and produce the structure of the Depression as we see it today. Above the Aulacogen, synclines were formed, and over the uplifted basement rocks anticlines and arches were produced.

The Ukrainian Shield is a crystalline basement that has a relief of about 200 m on average and, in places, rises to 320 m above sea level. It is covered not only by Quaternary but also in places by Mesozoic-Cenozoic deposits. Depending on the location, their thicknesses vary from 10-20 m to 300-500 m. The boundaries of the Shield are generally marked by deep seated faults. To the west the basement gradually sinks beneath a thick Phanerozoic cover, or the pericratonic Dnister Depression trending in the north-south direction. On the southeastern side, the Shield is in contact with the Scythian Plate, and the contact is also marked by a deep-seated fault.

The Dnister Depression, on its north side, abuts against the Lukiv-Ratne basement ridge: on its southwestern side, the Depression passes into the Carpathian Foredeep along a series of steps. On its western and southwestern sides the basement gradually sinks from 3.5 to 4.0 km depths, and in the Carpathian Foredeep it reaches 7 to 8 km depths. The thickness of the sedimentary strata in the Dnister Depression ranges from 1.5 to 6 km. This Depression contains the Upper Paleozoic Lviv Trough (or the Lublin Trough, as it is known on the territory of Poland). On the south side the Dnister Depression sedimentary rocks rest on the crystalline basement rocks, and on the north side they are found on the Riphean strata.

The main structural features of the Dnister Depression were formed under the influence of both vertical and tangential movements of the basement blocks. There are the Pre-

Mesozoic Podillia monocline, the North Moldovan and the Kovel' ridges, and on its southwest side, there are blocks with later dislocations.

The Voronezh anticline (in Russia), separated from the Ukrainian Shield by the Dnipro-Donets' Depression, represents an uplifted basement covered by sedimentary strata. The southwestern limb of the structure (in Ukraine) occurs at 200-250 m depth. On the Ukrainian territory the limbs of this anticline have also depressional and synclinal structures.

The structural shapes of the sedimentary cover, formed at different times in the platform history, have an inherited character from the basement. During the accumulation of sediments, however, the structural conditions were changing. There were changes in the shape of the cover, size, and configuration of the structures.

Thus, the formation of both the Dobruja Foredeep (southwest of Odesa) and the Karkinit Depression began in the Late Paleozoic-Early Mesozoic folding. The maximal sinking in the Dobruja Foredeep occurred in the Jurassic period. On the surface this depression is not evident, but it was established on the basis of geophysical surveys and extensive deep diamond drilling. The northern and southern margins of the Dobruja Foredeep are faulted with downthrow components in the order of 1-2 km. These features give it the shape of a graben. In Ukraine its length is over 200 km, and its width varies from 35 km near the Prut river, to 60 km near the Black Sea. The bottom of this graben structure is 5-7 km deep, according to the seismic data. The lower part of the sedimentary pile consists of marine carbonate and terrigenous Silurian, Devonian and lower Carboniferous deposits measuring 3-4 km in total thickness. The Upper Jurassic, Paleogene, Miocene, Pliocene and Quaternary sediments form the upper part of the geological section. These strata are lying conformably on the lower Paleozoic pile.

The Karkinit Depression (northern Crimea) is a 10-11 km deep trough of near latitudinal strike, filled with Lower Cretaceous clayish terrigenous strata and volcanic rocks, Upper Cretaceous-Eocene clayey-carbonate, Oligocene-Miocene clayey terrigenous, and Miocene-Pliocene carbonate-clayey accumulations. The Depression corresponds to the boundary zone between an old and a young platform, complicated by ridges, structural wedges, and locally some folded rocks which appear in the lower part of the sedimentary cover. In its Aptian-Albian stages a distinct graben structure is evident which is related to a Jurassic age depression. In the Upper Cretaceous and the overlying strata, the graben loses its character and is more like a platformal depression.

The Volynian uplift in the western part of Ukraine is distinguished by the elevated basement and by rocks in the old sedimentary cover (Vendian, Cambrian, Ordovician and Silurian). Strata of the Mesozoic and Cenozoic deposits, up to 250 m in thickness (Jurassic, Upper Cretaceous, Paleogene, Neogene and Quaternary) are nearly flat lying and discordantly overlap the old sedimentary cover.

The Indolo-Kuban Depression (Crimea), covering the southern part of the western Cis-Caucasia, Azov Sea and Kerch-Taman' district, is filled with Oligocene-Miocene terrigenous clays (Maikop series), and Pliocene-Pleistocene carbonate and clayey sediments, up to 10-13 km in total thickness. Its eastern side is also part of the marginal depression of the northwestern Caucasian Mountains.

The near-latitudinal Ovruch graben-syncline is located within the Ukrainian Shield. Its geological section consists of effusive rocks with minor layers of sandstones and phyllites (Zbran suite of Upper Proterozoic) in its lower part, and a cover of terrigenous rocks rich in flora and fauna remains dated as Devonian and Carboniferous.

The submeridional Jurassic Stryi Depression (western Ukraine) was formed in the Kimmeridgian stage. Its lower sedimentary

fill consists of terrigenous continental (Bajocian-Bathonian, 160.0-173.0 Ma) deposits, and in the upper part it consists of Upper Jurassic lagoon and marine sediments.

The South-Ukrainian Monocline consists of Lower Cretaceous strata. In the west it is bordered by the Volyn'-Podillia Plate, and the eastern side is limited by the Azov-Pavlohrad fault and the Near-Azov ridge of the Pre-Riphean rocks. The basement of the Monocline is dipping to the south and has been traced down to a depth of 5-6 km. To the northeast of the Monocline, there is the Kins'ka-Yaly Depression located in the Ukrainian Shield. This asymmetric structure formed during the Alpine orogeny and is filled with the Mesozoic and Cenozoic strata. During the Alpine tectonic stage, the Monocline was also the site of deposition of transgressive-regressive sedimentary deposits, indicating an active tectonic environment.

The Carpathian Foredeep is a large tectonic structure divided into three zones - Bil'che-Volytsia, Sambir and Boryslav-Pokuttia. The latter two have been transformed into covers.

The Transcarpathian Deep is a young (Neogene) depression formed on a very complicated heterogeneous basement. The basement has a blocky-folded structure and consists of sedimentary and volcanic rocks of the Paleogene, Cretaceous, Jurassic, Triassic ages and possibly metamorphic Paleozoic rocks. The Neogene consists of molass-type sediments, originally up to 3 km in thickness, which are now dislocated into a series of subhorizontal slices.

Folded Structures. Structural-stratigraphic studies indicate that there were periods of restructuring of the original tectonic plan brought on by changes in the tectonic regime. In the Donbas area, the Hercynian age folded structures involving the Carboniferous coal-bearing strata, commonly form numerous folds of variable amplitudes, in places decoupled and faulted. The folded structures of the northern Dobruja are characterized by complex folding of Paleozoic and early Mesozoic strata which are covered by the undeformed Upper Cretaceous and Cenozoic sediments.

The northern Dobruja is composed of folded Paleozoic and Lower Mesozoic sediments and the Dobruja Foredeep is adjacent to it.

Although separate parts of the Carpathians were involved in folding at different geological times and have their own distinctive historical-geological character, including some formational peculiarities, morphology of folds and dislocations, the final phases of the tectogenesis occurred almost simultaneously - in the Miocene. In general, the Carpathians represent an asymmetrically structured mountain system with adjacent depressions.

The mega-anticlinorium of the Crimean Mountain system was formed at the Kimmeridgian stage of tectogenesis, and involved folding of the Scythian plate margin. The main role was played by forces pushing from the south to the north, corresponding to the closure of the Tethys Sea in the Mediterranean area.

In the Triassic and Jurassic periods, separate graben-like depressions were formed in the southwestern part of the Crimean flatlands. They correspond to the near-latitudinal present-day Al'ma Depression, and the northern part of the Indol Depression. The Al'ma Depression is a large synclinal structure along the limbs of which there are flysch strata over a kilometer in thickness. At the fault boundaries there is also a well-developed folding. Minor dislocations are associated with dragfolds.

Characteristic structures were produced in the Ukrainian Shield during the Meso-Cenozoic activity. These are depressions and paleovalleys associated with the deep-seated faults that were filled by continental coal-bearing sediments and deposits of the transgressive-regressive varieties.

An east-west trending mega-uplift occupies the central and southwestern parts of the Crimean flatlands and some terrain under the Black Sea. Its boundary with the Crimean



Paleogenic flysch deposits on Prut river, Dyliatyn village, Ivano-Frankivsk'k oblast'



Cretaceous deposits, Bel'bek canyon, Western Crimea

Mountains is along the Simferopol' fault. The age of this mega-uplift is Cretaceous-Paleogene. Some rather high topographic features are present in this type of terrain (Novoselivka, Kalamit and Simferopol').

The map on p. 45 illustrates the evolutionary history of the sedimentary cover and reveals a strong relationship between the structure of the cover, the basement and the folded systems. It shows clearly the differences between various geological regions formed during various periods of their evolution. The divisions incorporate tectonic evolution that makes it possible to trace the history of structures. The divisions are of utmost importance for metallogenic analyses.

TECTONIC MAP

The tectonic divisions are established on the historical geological principle, which involves distinguishing between territories that have different histories of their geological development. The platforms, which occupy over 90% of the Ukrainian territory, are subdivided on the basis of the age of consolidation of their basements (taking into account the time of formation of the basal sedimentary complexes) and the main ages of their folded regions. Smaller subdivisions of the platforms are based on their structural differences, which determine the current structural state of their separate parts and are the products of various tectonic processes over time. In addition some paleotectonic structures are outlined on the basis of which other major geotectonic elements developed on the Ukrainian territory.

The platforms include: 1) an ancient (Pre-Riphean) East European Platform (EEP) – its basement consolidated during a number of Pre-Baikalian tectonic epochs; 2) a young West European Platform with Baikalian (the Roztochchia zone and Lezhaisk (Pol. Lezajsk)) and Caledonian (Rava-Rus'ka and Kokhanivka zones) folded basements; and 3) a Scythian Plate of Baikalian and Variscan age basements, totally restructured and consolidated in the Kimmeridgian stage of tectogenesis. The western edge of the EEP is generally accepted to run along the eastern margin of the Roztochchia zone (Belz-Baluchyn and Rohatyn faults) and farther to the southeast along the Rava-Rus'ka fault. The southern boundary of the EEP is taken to be along the Kahul-Izmail fault, along the northern Dobruja, along a fault crossing Lake Syvash and running to the Black Sea. The reason for including the Dobruja terrain into the EEP is based on the similarity of the structural-lithological complexes of the basements of the Dobruja Depression with analogous complexes in the southern slopes of the Ukrainian Shield, and also on the platform character of the Vendian and Lower Paleozoic cover rocks of the Depression.

The Scythian Plate includes the Crimean flatlands and terrains under the Black and Azov seas. Its basement consists of folded complexes of late Baikalian and Variscan cycles of tectogenesis reworked in the Kimmeridgian orogenic period. In terms of geology, character of metamorphism and petrochemical features, the Scythian Plate basement rocks are very close to the Upper Paleozoic metamorphic and magmatic complexes of the northern Dobruja. In spite of the incomplete paleotectonic reconstruction, the metamorphic character and intense dislocation of the Kimmeridgian structural metamorphic complex indicate that it could be also a part of the Scythian basement. The sedimentary cover of the Scythian Plate consists of four structural-stratigraphic complexes – the Lower Cretaceous (terrigenic clays), Upper Cretaceous-Eocene (carbonates), Oligocene-Lower Miocene (clayey terrigenous) and the Middle Miocene-Pliocene carbonate-clayey deposits.

The EEP includes the following main structural components – the Ukrainian Shield and its slopes, Volyn'-Podillia Plate and fragments of its southeastern extension or the Moldovan Plate, the Paleozoic Dobruja Foredeep, the Black Sea Coastal Depression, the Dnipro-Donets' Depression and the southern slope of the Voronezh Massif. The Ukrainian Shield is the largest geological structure occupying the center of the Ukrainian section of the EEP. The Shield includes a number of structural formational folded zones which are distinguished by their specific features of early Precambrian history of geological development and are separated by deep-seated faults. These features are illustrated on the structural map of the basement in this Atlas. As a region of the Earth's crust that was subjected to mainly upward movements, the Ukrainian Shield persisted as a positive feature throughout its history since it became a craton. Its present shape, however, was essentially formed in the Middle Paleozoic (Devonian) which is associated with the breaking apart of the Sarmatian Shield and the formation of the Dnipro-Donets' Depression.

The Volyn'-Podillia Plate, with parts of the Moldovan Plate, is

adjacent to the Ukrainian Shield in the west and southwest. Near the western edge of the EEP, where the folded areas are, the thickness of the sedimentary cover reaches 6-7 km. In the early history of the development of its cover there are two stages: the pre-plate stage, during which the Volyn'-Podillia Depression of Riphean age was formed, and the plate stage, when the pericratonic Dnister Foredeep (Upper Vendian-Lower Devonian) was initiated and developed under the influence of the Baikalian Halychyna geosyncline and the Caledonian Middle European (Pre-Carpathian) geosyncline. Other than the structural stratigraphic complexes of the pericratonic development, included in the sedimentary cover of the Volyn'-Podillia Plate, are the Middle-Upper Devonian terrigenous carbonate and evaporite-carbonate formations, the Cretaceous coal-bearing strata, the Jurassic and Cretaceous terrigenous carbonate rocks, the terrigenous Paleogene and Neogene evaporites and the terrigenous carbonate formations.

The Dobruja Foredeep was formed as a marginal depression in the Upper Paleozoic, inheriting elements of different ages and genetically two different paleostructures – the Baikalian marginal depression of Dobruja and the Upper Vendian-Lower Paleozoic pericraton. The depression was filled by terrigenous and marine carbonate formations (Vendian-Devonian), coal-bearing lagoon-continental strata (Carboniferous), red-colored salt-bearing lagoon-continental molasse formations (Permian), continental-lagoon terrigenous, carbonate and salt-bearing formations (Jurassic) and carbonate-terrigenous Cretaceous, Paleogene and Neogene formations.

The Black Sea Coastal Depression formed in the Cretaceous-Paleogene. It inherited its structure from the Mesozoic grabens of Dobruja and the Syvash area. The northern edge of the Depression is in contact with the Ukrainian Shield, while its southern side is in contact with the Crimean flatlands or a zone of uplifts and depressions of the Scythian Plate. The dominant sedimentary sequence in the Depression consists of terrigenous and carbonate-terrigenous strata of the Cretaceous, Paleogene and Neogene.

The Mesozoic Dnipro-Donets' Depression is the largest negative structure in the southwestern part of the EEP. It formed as a result of the deepening of the structure in the Devonian. The sedimentary cover varies considerably, and ranges from 1.5 km to 22.5 km in the deepest parts of the Depression. Four structural-stratigraphic sequences are recognized – 1) Devonian-Lower Visean, represented by salt-bearing terrigenous, effusive volcanics, and carbonate strata, 2) Upper Visean-Lower Permian represented by terrigenous and salt-bearing strata, 3) Upper Permian-Cretaceous represented by dominantly terrigenous and carbonate-terrigenous formations, 4) Cenozoic, mainly terrigenous deposits. The southwestern flank of the Depression is in contact with the Ukrainian Shield. Here the oldest strata are coal-bearing. The northeastern flank lies on the Voronezh sloping part of the complex. In this area the basement is only at 100-200 m depths, but farther to the southeast it is at about 6 km depth, where it comes in contact with the Donbas folded area. The basal section here consists of Middle-Upper Devonian strata.

Within the orogenic folded portions of the platforms three periods are recognized – the Variscan, the Kimmeridgian and the Alpine. The Donets' Basin was formed during Variscan orogeny and is considered to be the northern wing of a geosynclinal belt embracing the EEP in the south which was folded in the end of the Upper Paleozoic during the Saalic orogeny. Studies of the Donets' Basin have indicated that the Basin was structurally connected with the Dnipro-Donets' Depression from the Riphean to the Carboniferous.

Another Variscan age region of folded rocks is the northern Dobruja and is known as the Prut prominence. It consists of metamorphosed and complexly folded greenstones formed during the Breton phase. These rocks have been affected by later overthrusting related to the Kimmeridgian tectogenesis.

The Marmarosh massif was also affected by the Variscan folding event. Its northwestern part reaches the Carpathians and forms two blocks – the Chyvchyn and the Dilove. The massif consists of Riphean-Early Paleozoic metamorphic rocks that were folded in the early Carboniferous, and were later reworked by a series of Alpine tectonic phases. As a result, the folding is very complex and there is superimposed a later regional metamorphism. In addition, two major allochthonous covers (Bilopotok and Dilove) were added by overthrusting on the flysch rocks of the Carpathians.

Folding in the Crimean Mountains and its eastern wing (the southern section of the Kerch peninsula) is attributed to the Kimmeridgian-Alpine tectogenesis. The Crimean Mountains are considered to be a complicated folded-blocky geological structure which resulted mainly from the horizontal movements. This produced structures with tangential compressions. Western, Central and Eastern parts of the Crimean Mountains differ in geological history in the Mesozoic and Cenozoic, and in the time of completion of the geosynclinal stage, from the Lower Kimmeridgian in the west to the latest phases of the Alpine orogeny in the east. The Crimean Mountains have an overall character of a mega-anticline, but in detail consist of a number of structural-tectonic elements that have synclinal and anticlinal aspects. These structures are complicated by the gently dipping overthrusts that dip to the south.

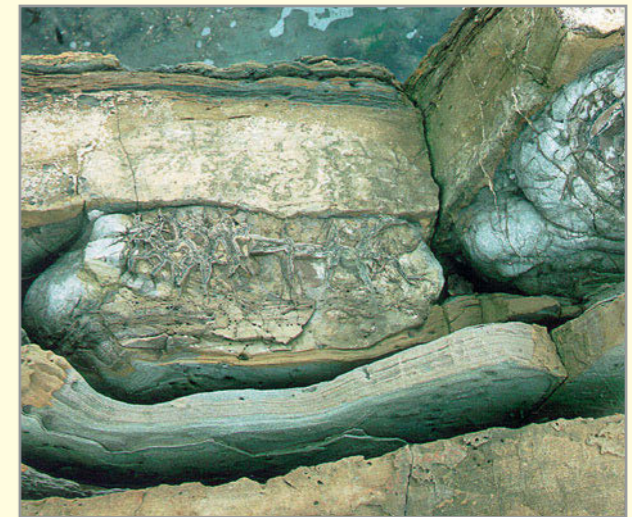
The Carpathian Mountains in Ukraine are part of the European Mediterranean Carpathian arch. Studies have indicated that there are large subhorizontal displacements which complicate the initial folding and give the appearance of a complexly stacked deck of thrust sheets. The Carpathians in Ukraine are divided into the inner and the outer Mountains. The inner Carpathians are characterized by a geosynclinal development during the early Alpine stage which culminated in the Upper Cretaceous and the Paleogene. The main folding and thrusting occurred between Lower and Upper Cretaceous (Austrian orogeny) and between Cretaceous and Paleogene (Laramide orogeny). The largest tectonic units of the inner Carpathians are the zones of the Peniny and the Marmarosh Mountains. The southeastern extension of the latter is the Marmarosh crystalline massif. The outer Carpathians are part of the late Alpine geosyncline which developed in the late Jurassic, Cretaceous and Paleogene, with its last stage culminating in the Miocene. This geosyncline is comprised of flysch deposits. It also has evidence of thrusting and stacking of thrust sheets. Some of the largest thrust structures include those at Skyba, Krosnen', Duklia and Porkulets'.

A large deep-seated Penine fault separates the Carpathians from the inner Transcarpathian Deep. The Carpathian basement consists of dislocated Triassic, Jurassic, Cretaceous and Paleogene sediments and metamorphic complexes of the Paleozoic. In the Neogene cover rocks there is a zonality in terms of the specific features of the strata, the character of the structural forms, the local development of the salt dome tectonics and others. The Vyhirlat-Hutyn volcanic rocks, comprised of basic tuffs and lavas, are present in various zones within the Transcarpathian Deep.

The Carpathian Foredeep is located between the folded Carpathians and the adjacent platforms. Three separate zones, Bil'che-Volyts'ke, Sambir and Boryslav-Pokuttia, are recognized within it. The first one covers a young platform in the west and an old one in the east. Its monoclinial Pre-Miocene basement (along with the Sarmatian cover) is dipping beneath the Sambir zone. The Sambir zone is a system of linear folds and slivers of Lower Miocene rocks which form a cover pushed on top of the autochthonous part of the Foredeep. The Lower Miocene are molasse-type deposits which in the northwest are lying on the Riphean and Paleozoic basement rocks, and in the southeast on the Mesozoic strata of the epi-Paleozoic platform. The Boryslav-Pokuttia zone, considered to be a marginal part of the outer Carpathian geosyncline, continued to submerge, relative to the other parts of the Foredeep, even in the Miocene period.



"Dinosaur backbone", Sudak area, Southern Crimea



Detail of strata in the "Dinosaur backbone", Sudak area, Southern Crimea

The zone represents a large cover which has been pushed on top of the autochthonous part of the Foredeep and consists not only of a series of folds of Cretaceous and Paleogene rocks, but also of Miocene molasse rocks.

Three large near latitudinal tectonic megazones, the Northern, the Central and the Southern Ukrainian, are shown on the map. They experienced associated magmatism, metasomatism, mineralization and movements along faults during the entire Riphean and Later Phanerozoic periods. Evidence of Neotectonic movements, even in the stable adjacent crystalline Ukrainian Shield rocks, is well preserved to the present day.

Thus, various structural elements indicated on the map, having undergone a complicated and long history of geological development, are commonly complex (polystructural) and heterogeneous in character. Their structure reflects a certain succession in the distribution, and also regularity of formations, which characterize a given tectonic regime. Imprinted in the folded zones framing the EEP, including their platformal equivalents (structural stages and structural-stratigraphic complexes), are the results of the Baikalian, Caledonian, Variscan, Kimmeridgian, and Alpine epochs of tectogenesis. The Pre-Baikalian epochs are also recorded in the basement structures of the East European Platform.

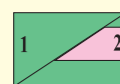
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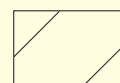
Ancient (Pre-Riphean) East European Platform



Ukrainian Shield within basement isoline of 0 m (1), slopes of the Shield within 500 m deep basement isoline (2, 3, 4)



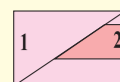
Volyn'-Podillia Plate with sections of the Moldovan Plate (1) Plate within the boundaries of the Ukrainian Shield slope (2)



Volyn'-Polissia Riphean Deep



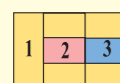
Dnister Upper Vendian and Lower Paleozoic Foredeep



Cretaceous-Paleogene Black Sea Coastal Depression (1) Depression within the boundaries of the Ukrainian Shield slope (2)



Triassic-Lower Cretaceous Karkinit-Northern Crimean Deep



Mesozoic Dnipro-Donets' Depression (1), within the boundaries of the Ukrainian Shield slope (2) and Voronezh Massif (3)



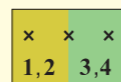
Devonian Prypiat'-Dnipro Deep



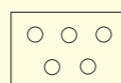
Hypothetical Riphean rift zone of the Prypiat'-Dnipro Deep axial section



Voronezh Massif slope



Young (epi-Paleozoic) West European Platform with structural elements of its basement
Lezajsk Massif (1) and Roztochia Zone (4) of Baikalian orogeny, Kokhanivka (2) and Rava-Rus'ka (3) Zones of Caledonian orogeny



Young (epi-Paleozoic) Scythian Plate



Central Crimean Zone of Cretaceous and Paleogene uplifts and depressions

FOLDED STRUCTURES



Variscan: Marmarosh Massif restructured during Alpine orogeny (1), Northern Dobruja (2), Donets' Basin (3)



Kimmeridgian and Alpine: Crimean Mountains and Kerch Peninsula



Alpine: Carpathians (1 – Inner, 2 – Outer)

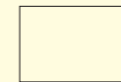
FOREDEEPS



Lower Devonian and Carboniferous Dobruja Foredeep



Miocene Carpathian Foredeep (A); Oligocene-Miocene Indolo-Kuban' Foredeep (B)



Miocene and Pliocene Transcarpathian Inner Deep

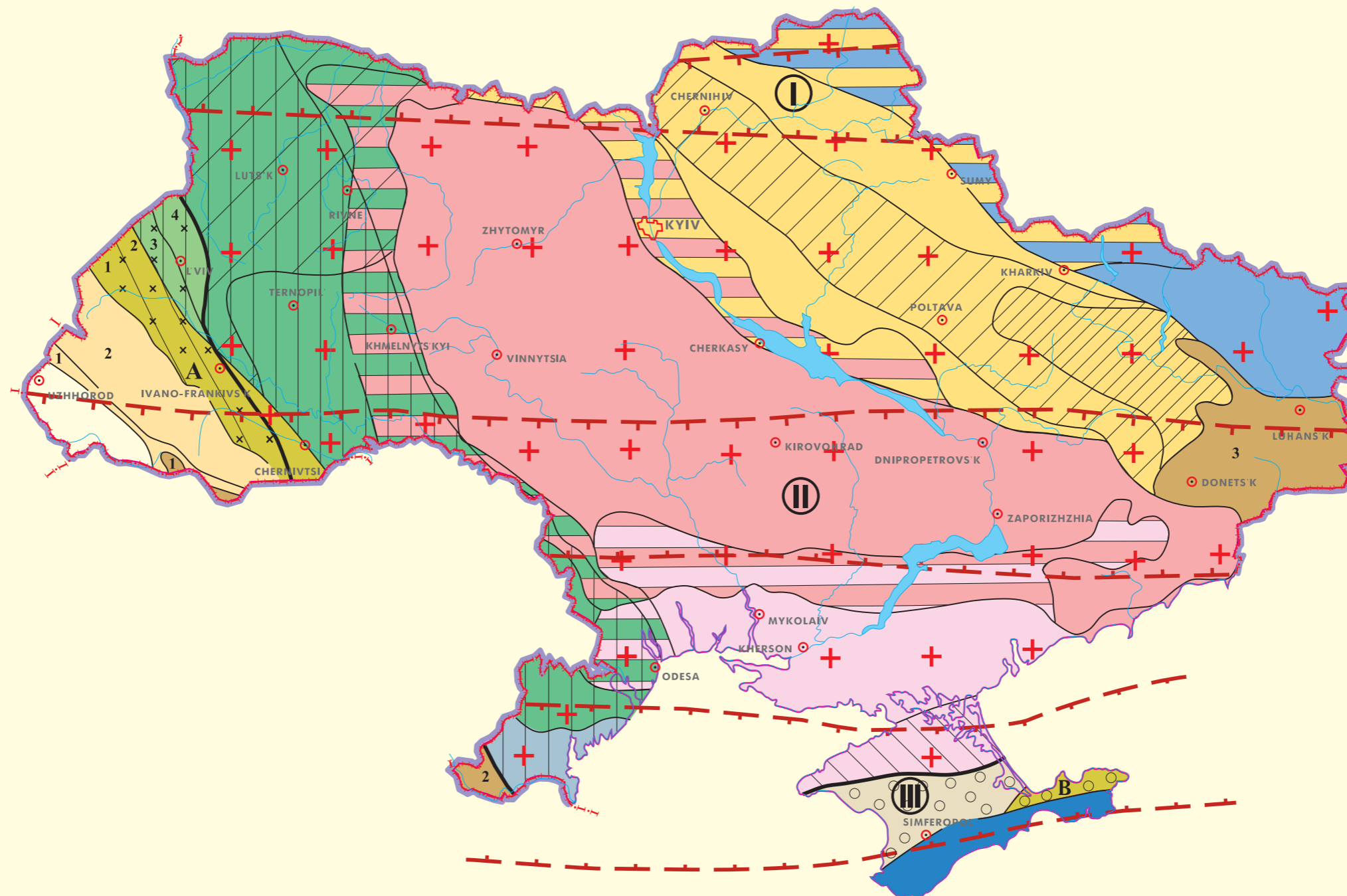


Boundaries of large tectonic zones
I – Northern Ukrainian; II – Central Ukrainian;
III – Southern Ukrainian




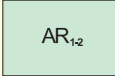
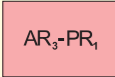
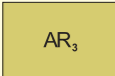

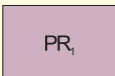
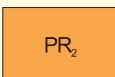

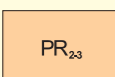
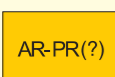
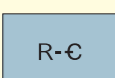
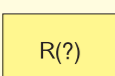
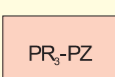
Boundaries of tectonic structures

TECTONIC MAP








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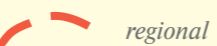

I. AGE AND COMPOSITION OF THE BASEMENT

	Basic granulite (AR ₁), basic-ultrabasic granulite-gneiss (AR ₃) and granite (PR ₁) complexes
	Amphibolite-plagiogneiss (AR ₁) and plagiogranite (AR ₁₋₂) complexes
	Gneiss-amphibolite and diaphthorite (AR ₃), plagiogranite (AR ₃) and granite (PR ₁) complexes
	Granite-greenstone (ultrametamorphic and intrusive) complexes
	Jaspilite-schist siliceous complex
	Gneiss-schist, granite and basic-ultrabasic complexes
	Leptite-keratophyre and gabbro-diorite-granodiorite complexes of the Volyn'-Dvina volcanic-plutonic belt
	Gabbro-anorthosite-rapakivi complex
	Alkaline and subalkaline complexes of tectonic activation zones
	Problematic complexes of the Donets' Basin basement
	Gneiss-schist complexes of the Marmarosh Crystalline Massif
	Not well-defined complexes of the Roztochchia Zone basement
	Schist-granite complexes of the Scythian Plate (Central part) basement

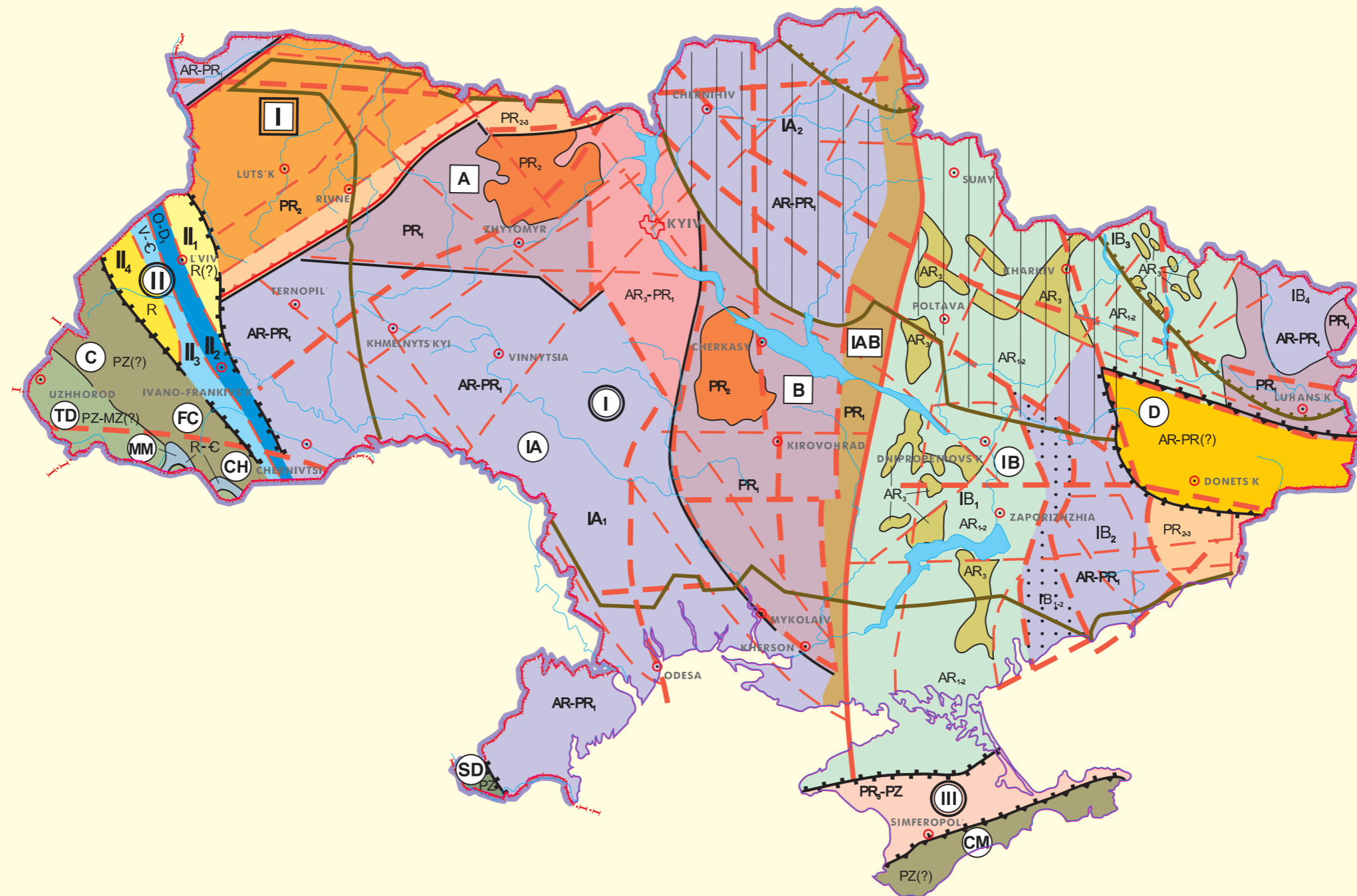
	Greenschist complexes of the Lezajsk Massif
	Non-metamorphosed flysch complexes of the Kokhanivka Zone
	Problematic complexes of the Rava-Rus'ka Zone basement
	Not well-defined complexes of the Mountainous Crimea and Flysch Carpathians basements
	Schist-volcanic complexes of the Prut (Tulcha Zone)
	Not well-defined pre-molasse complexes of the Transcarpathian Deep basement

II. STRUCTURAL ZONING

	Platforms (sections): I – East European (EEP), II – West European (WEP), III – Central Euroasian (CEP) (Scythian Plate)
	Structures of the East European Platform Volyn'-Dvina tectonic belt (Volyn'-Polissia section)
	Large blocks IA – Brians'k-Podillia, IB – Kursk-Dnipro
	Kryvyi Rih-Krupetsk suture zone
	First-order blocks IA ₁ – Podillia, IA ₂ – Brians'k, IB ₁ – Dnipro, IB ₂ – Azov Sea Coastal, IB ₃ – Kursk (section), IB ₄ – Rossosh' (section)
	Orikhiv-Pavlohrad suture zone

	Tectonic belts (section) A – Volyn', B – Kirovohrad
	Ukrainian Shield (boundaries along the marginal faults)
	Southern boundary of the Voronezh Massif
	Structures of the West European Platform
	Zones (consolidation stages) II ₁ – Roztochchia (post-Baikalian), II ₂ – Rava-Rus'ka (Caledonian), II ₃ – Kokhanivka (Sairian), II ₄ – Lezhai Massif (post-Baikalian)
	Structures of the Central Eurasian Platform (Scythian Plate) III – Central (Crimean segment)
	Folded areas SD – Southern Dobruja, D – Donets' Basin, CM – Crimean Mountains, C – Carpathians, FC – Flysch Carpathians, TD – Transcarpathian Deep, MM – Marmarosh, CH – Chyvchyn Massifs
	
	III. OTHER SYMBOLS
	Platform boundaries
	Folded area boundaries
	Interplatform trough: Dnipro-Donets' Depression (DDD)
	Faults
	transregional
	regional
	other

STRUCTURE OF THE BASEMENT



STRUCTURE OF THE BASEMENT

In the development of its long and complicated geological history, the Ukrainian territory inherited a variety of tectonic structures. Most of Ukraine is covered by platforms and only about 5% are occupied by the Phanerozoic folded areas (the Carpathian and Crimean Mountains and the Donets' Basin).

The East European Platform (EEP) is the largest geological structure and occupies a significant portion of Ukraine. It consists of basement rocks formed during a number of Pre-Riphean (Pre-Baikalian) stages of tectogenesis. These basement rocks are part of the Ukrainian Shield.

The main geological structures distinguished in the Ukrainian part of the EEP are as follows: the southwestern branch of the transregional Volyn'-Dvina mobile belt, the Ukrainian Shield, and the southern, deeply depressed slope of the Voronezh Massif. The Dnipro-Donets' Depression, which includes the Dnipro Graben, is located between the Ukrainian Shield and the Voronezh Massif. The Graben is located centrally to the Depression which, on its flanks, involves both the Ukrainian Shield and the Voronezh Massif rocks.

The basement has been affected by the Proterozoic and later arch-like deformation zones producing heterogeneous blocky structures. The southwestern part of the EEP is represented by two mega-blocks — the Briansk-Podillia and the Kursk-Dnipro blocks, separated by the Kryvyi Rih-Krupetsk intermega-block suture zone. A system of faults of different depths and directions divide the megablocks into smaller ones of different orders of magnitude. As a general rule the faults are complicated and variable. There are compressional faults with up and down movements, and extensional faults with down and lateral movements. The blocky nature of the basement is also reflected in the changing character of their magnetic and gravitational signatures, and the degree of development of the characteristic "structural matter complexes" (SMC). In fact, the SMC can involve any combination of plutonic, volcanic and sedimentary rocks.

The Volyn'-Dvina mobile belt trends in the northeastern direction and occurs in the northwestern part of Ukraine. It is several hundred kilometers in length in Ukraine, crosses into Belarus and continues into Russia. The belt has been traced over a distance of some 2500 km in total. Its basement consists of two tiers of rocks. The Lower Archean granulitic rocks are deeply buried and are practically not exposed at the present erosional surface (but have been intersected by drilling). The overlying rocks have a discordant relationship with the granulites, and consist of a series of highly metamorphosed intrusives of gabbro-diorite-granodiorite complexes and volcanic rocks of various compositions ranging from Lower to Middle Proterozoic ages. The volcanic rocks are weakly folded and are preserved in some depressions which have not been deeply eroded. Within the mobile belts there are alkaline and subalkaline granites and metasomatites of the late Proterozoic age. These are related to the late tectonic activity in the area.

The Ukrainian Shield is a large positive feature of the EEP. In total it is comprised of about 256 600 square kilometers. The internal structure of the Ukrainian Shield basement consists of ancient blocks that have been healed together along sutures. These blocks differ from each other by the particularities of their deep structure and by the SMC.

The Early Archean basic granulitic rocks generally represent the lower section of the basement and are present practically in the whole Ukrainian Shield. The granulites are well developed in the Podillia block which throughout the Early Precambrian history had a relatively uplifted position and hence was subjected to deep erosion. This is supported by the abundant distribution of enderbite schists throughout the block, relatively simple brachioformal folding, granulite metamorphism under intermediate pressures, intense appearance of the isofacies of ultrametamorphism and the plate-shaped structure of the plutonic-metamorphosed rocks.

A general vertical section of the granulite rocks consists of the following SMC — enderbite schists, kinzigites, leucogranulite quartzites and carbonate-gneiss granulites which originally represented a plutonic-supracrustal assemblage. The granulite assemblages of the Near-Azov block are distinguished by the complicated folding, higher pressures of formation, less intensely developed isofacies of ultrametamorphism, and by the sheet lens-like shape of the plutonic-metamorphic rocks. Here the upper part of the granulite section is composed of the granulite gneisses, which occupy the interdomal depressions that are intensely dislocated and compressed into isoclinal folds. In the lower part of the granulite gneisses there are numerous bodies of basic and ultrabasic rocks.

The amphibolite-gneissic complexes of the Early Archean age are sialic and are generally known as the gray gneiss component of the greenstone belts. The typical structures of these complexes are the granite-gneiss domes, and linear schists in the inter-dome areas. The sedimentary-volcanogenic rocks of the amphibolite-gneissic complexes are intensely granitized and are generally preserved as xenoliths and slivers.

The granite-greenstone assemblages of the Upper Archean age have complicated relationships with the amphibolite-gneissic complexes and have not been well studied.

In the granite-greenstone assemblages there are sedimentary-volcanogenic rocks which have been metamorphosed to the greenschist facies. They comprise komatiite-tholeiite, jaspillite-tholeiite, rhyolite-dacite, jaspillite-chert-shales and other assemblages. They also contain bodies of basic and ultrabasic compositions, and tonalite-migmatites and later potassic granites. The sedimentary-volcanogenic assemblages form greenstone-plutonic depressions between large granite-gneissic domes.

The gneissic-amphibolite diaphorite complex of the Upper Archean age forms the surface of the Bila Tserkva block of the Ukrainian Shield. These rocks form folds trending in the north-westerly and north-south directions or are present as relics in the granitoids of migmatite-diorite and migmatite-plagiogranite formations. There are also plutonic sheet-like bodies of basic-ultrabasic compositions.

In the Early Proterozoic SMC, the volcanic-sedimentary, sedimentary, metamorphic and intrusive rocks form the overlying tier of rocks above the basement of the mobile belts and in the Kryvyi Rih-Krupetsk suture zone. A general feature of these belts is the predominance of sedimentary rocks, and of the K-Na- and K-granite type of intrusions.

In the Ukrainian Shield there are some granitoid-terrigenous complexes that form independent covers on the basement rocks. They lie unconformably on the granulitic rocks, and on plagiogranite-amphibolite and granite-greenstone SMC. The stratified formations have a zonal metamorphism that varies from granulite to greenschist facies.

In the Kryvyi Rih-Krupetsk suture zone there are jaspillite-chert-slate assemblages of Early Proterozoic age. They are lying on a greenstone basement.

The suture zone includes the west-Inhulets part of the Kirovohrad mobile belt, and in the east it is limited by the Kryvyi Rih-Kremenchuk fault. This fault has been defined as a complex thrust, with amphibolite-plagiogneisses and greenstone rocks displaced to the east. In the inter-megablock position there are a series of formations. In section, starting with the base, there are andesite-basalts, jaspillite-chert-slate assemblages, and chert-carbonate-sandstone assemblages.

Farther to the west, in the west-Inhulets zone, the sequence of formations changes. The entire section is covered by the siltstone-sandstone gneissic-shistose complex.

The central structures in the Kirovohrad and Volyn' mobile belts are complex gabbro-anorthosite-rapakivi granite plutons of the Middle-Upper Proterozoic age.

The subalkaline and alkaline granites are associated with the alkaline and siliceous alkaline metasomatism in the activated

zones of long-lasting deep-seated faults of the marginal north-western and eastern (Near-Azov) parts of the Ukrainian Shield. The Western European Platform represents a mosaic of Hercynian and Pre-Hercynian basements and has a wedge-like shape. Its eastern side corresponds to the Rava-Rus'ka zone, and the western side plunges under the Carpathian Mountains. Within this Platform there are four main structures: the Rava Rus'ka, the Kokhanivka, the Roztochchia zones and the Lezajsk massif.

The Rava Rus'ka basement rocks, together with the Salairian rocks, include the carbonate-terrigenous graptolite-bearing Ordovician-Lower Devonian sediments. These rocks have undergone folding in the middle of the Lower Devonian period and were later reworked by the Hercynian movements. These movements, along the Rava-Rus'ka fault, were responsible for thrusting the zone onto the Middle Paleozoic L'viv Depression. The depth of the Rava-Rus'ka basement is at 0.5-1.5 km. The western part of the L'viv Depression, in contact with the Rava-Rus'ka zone, has a basement similar to that at the Roztochchia zone and is inferred to be of the early Baikalian age.

The Kokhanivka zone is considered to be the only region of folded Salairian age rocks that were not dismembered. They were later reworked by the late Caledonian and Hercynian movements. The Kokhanivka zone is thrust to the east over the Rava-Rus'ka zone along the Kalush fault. The folded basement is in places at greater than 4 km depths.

The Lezajsk massif is probably a consolidated Ripheid, located to the southwest of the Kokhanivka zone. This Precambrian belt separated the geosynclinal region from the Platform during the deposition of the flysch strata of the eastern Carpathians and the molasse rocks of the Carpathian Foredeep.

The inferred folded Riphean basement rocks (quartzites and phyllites or "green schists") are considerably dislocated and have undergone epizonal metamorphism.

The Central Eurasian Platform on the Ukrainian territory is represented only by its western margin part — known as the Scythian Plate. It has a folded basement of more than one age, a sedimentary cover discovered by diamond drilling at the 200 m depth in the Simferopol' area, at 5000 m depth in the region of Hubkin swelling, and at 8000 m or deeper in the northern part of Kerch peninsula. Drilling results and geophysical data indicate that the basement rocks were probably formed during the Baikalian, Hercynian and early Kimmeridgian cycles of tectogenesis.

The largest structure in the Ukrainian part of the Scythian Plate and its Central Segment is the Crimean arch. Along its northern side are the northern Crimean and the northern Azov buried depressions (suture grabens), and on the southern side is the Indol Depression located in front of the Alpine orogenic uplifts.

The internal structure of the basement of the Western Segment is very complicated. There are schistose volcanogenic complexes of Early Paleozoic age. These rocks form narrow linear zones with northwestern and east-west trends and reverse fault patterns. The basement rocks of the Central Segment consist of folded late Baikalian, Hercynian and Kimmeridgian cycles of tectogenesis.

The basement shows considerable segmentation, and its depth varies from 200 m to 3 km. The late Baikalian rocks include greenschist facies clayey-terrigenous and less commonly volcanogenic rocks of possible Riphean-Cambrian age. Hercynian age deformed rocks have been noted in the drilling of the Simferopol' uplift. They are characterized by considerable thicknesses, low grade of metamorphism, and intense dislocations. They include diabase schists, flysch, carbonate, molasse, gabbro-diorite-granodiorite and other rock types.

Folded regions in Ukraine include the Carpathians and Eastern Crimea formed during the Alpine orogeny, the Crimean Mountains formed in the Kimmeridgian, the

buried Hercynian complexes of the Donets' Basin and the Prut part of Northern Dobruja.

Reliable sources of information on the basement rocks of the Donets' Basin are lacking. It is inferred that the deepest portions of the Devonian and Lower Carboniferous strata in the central part of the Basin probably have undergone high grade metamorphism, become folded and thus form a basement at about 23 km depth or more. A seismic survey indicates that the basement at about that depth is probably of Riphean age rocks or regenerated Pre-Riphean basement of the EEP.

Crimean Mountains

South of the central segment of the Scythian Plate are the folded, blocky structures of the Crimean Mountains. The internal structure and composition of the basement are problematical. The earliest rocks are the Tavrian series of Middle to Upper Triassic-Lower Jurassic ages. They consist of terrigenous clayey strata with still older pillow lava, sills and dykes and other rocks.

Carpathian Mountains

The Carpathian Mountains in Ukraine are part of the Alpine Mountain Belt in Europe. They are part of the northern branch of this mountain system. The structure of the autochthonous and para-autochthonous rocks under the flysch cover is inferred mainly from seismic surveys. The dislocated cover, of possibly allochthonous pre-flysch basement, is at about 10-12 km depth. The deepest portions of the basement, at 16-17 km depths, are associated with the inner flysch deposits of the Carpathians. The Skyba cover is probably lying on the sedimentary strata of the epi-Caledonian edge of the ancient platform. Where the flysch covers lie on their geosynclinal basement rocks, the latter show complicated dislocations and may be in part torn off their crystalline core.

The Paleozoic-Mesozoic heterogeneous basement of the Carpathian Foredeep is well known from numerous drillings. There is evidence of considerable vertical and horizontal movements of different blocks, resulting in the emplacement of Proterozoic to Paleogene rocks under the Neogene cover. The depth of the folded basement is generally from 600 m to 4 km, and in places even deeper.

The Marmarosh crystalline massif in the Carpathian Mountains in Ukraine has the shape of a wedge and consists of two segments — the Chyvcbyn and the Dilove massifs. The contacts between the massifs and the adjacent flysch strata are tectonic and the massifs are thrust over the flysch strata. The Marmarosh massif has a heterogeneous basement consisting of Proterozoic gneissic schist rocks of amphibolite grade of metamorphism (Bilyi Potik suite) and Upper to Middle Proterozoic quartzite-schist rocks (Dilove, Berlebas and Mahura suites) and a carbonate-phyllite complex of the Middle Carbonaceous-Permian age. Hence the Marmarosh crystalline massif appears to be an old folded structure which has been strongly reworked during the Alpine orogeny.

In this Atlas, the map depicting the basement structure of the East European Platform, the West European Platform, the Scythian Plate and their folded regions are compiled for the first time. The information on the Ukrainian Shield is also based on very extensive factual data.

The data on the deep-seated basement are less well known and relied heavily on information from deep diamond drilling. In the Donets' Basin the nature of the deep basement is unknown. New data are especially necessary to resolve some of the problems associated with the nature of the southern and the southwestern boundary of the East European Platform, and the nature of its boundary with the Scythian Plate. These are some of the more important problems that require additional work. Summarizing the aforesaid, the Ukrainian Shield and its slopes consist of Archean and Lower Proterozoic rocks and the West European Platform and Scythian Plate consist of Riphean to Lower Devonian complexes. The basement of the folded regions is of different ages, from Riphean to Lower Proterozoic within the Donets' Basin, and from Paleozoic to Mesozoic in the Carpathians and the Crimean Mountains.



Pliocene limestone in Odesa



Paleogene deposits, Dora flexure, Deliatyn village, Ivano-Frankivsk oblast



Cretaceous deposits, "Rock Sphinxes", Churuk-Su, Western Crimea

LINEAR AND RING GEOLOGICAL STRUCTURES

Interpretations of data from satellite imagery of the Earth led to the identification of a multitude of long linear series of structures and some very large circular or ring structures in Ukraine. These are further interpreted now as features related to the orogenic stages and to the reactivation stages of the development of the Earth's crust. They appear to have played an important role in the evolution of land masses and probably set the pattern for future restructuring.

It is considered that such processes as arching, which affected much of the Earth's crust including that in Ukraine, resulted by the development of diapiric structures in the underlying mantle. Their presence and the associated "flowing" asthenolithic bodies are detected in a number of locations in Ukraine, including the Carpathians, the Dnipro-Donets' Depression, the Ukrainian Shield and areas near the Black Sea. Mantle diapirism caused most of the tectono-magmatic activity in the Ukrainian territory from the early Precambrian to the Neogene-Anthropogene period.

Ring structures developed as a result of the inherited structures related to orogenesis or mountain-building processes. They are related to the lifting of the crust, and their circular patterns suggest that they are also diapiric in nature. They were formed as early as the initial stages of the development of cratons (the first land masses of the Earth) or during the formation of the epiplatformal stages which, at various times, affected different parts of the territory of Ukraine.

The time of arching is generally determined by the age of the dome-shaped granitic bodies which are the constituent parts of the infrastructure of crustal uplifts. Following this principle, the arches belong to the Archean age. Examples include the Podillia and Dnipro region diapirs which emerged in the ancient Archean (3.8 Ga old crust). The diapiric structures consist of enderbite-migmatitic and plagiogranite-migmatitic complexes with associated granitoid rocks (Nemyriv, Dnipropetrovsk, Sura-Tokiv complexes). Domes of this type are typical of the ancient Archean period and are not developed at later times.

In the Dnipro arch there is a distinct structural paragenetic association — plagiogranite migmatitic domes and greenstone belts. The latter are partially preserved in synclines, anticlines, and monoclinical structures (Verkhivtseve, Sura, Kins'ka, Bilozers'ke, Chortomylyk, Derezuva and Malosofiivka). Hence, arching during the Archean period could be considered to have formed the oldest crust of the Earth. The crust initially consisted of relatively thin mafic lava outpourings which are preserved now as greenstone remnants.

Such "islands" of crustal materials existed in the oceanic environment, and in the transitional environment between the protocon-

tinents and the oceanic environment (Kins'ka-Verkhivtseve, central Azov, Ros'-Tikych series). These rocks are characterized by ultramafic komatiite, tholeiite basalt, dacite-andesite-basalt assemblages, and spillite-diabasic volcanics of the ophiolitic island arc association. The accumulation of these rocks in arching structures was accompanied by deposition of either terrigenous deposits or oceanic carbonate rocks (central Azov and Buh series).

The arching uplifts of the early Proterozoic are further developments in the construction of the continental cratonic masses. They are characterized by numerous domal structures with granitic massifs such as the Kirovohrad-Zhytomyr, Osnyts'k, and Azov complexes. These have been dated at 2.1-1.8 Ga. Towards the end of the formation of these complexes there was a period of a more basic magmatism, including gabbro-anorthosite-rapakivi-granitoid and alkaline granites (Korosten' and eastern Azov complexes) dated at 1.75±0.10 Ga. The processes of granitization in the early Proterozoic were occurring mainly in the former shelf environments near the Archean continental massifs and extended partially into the Archean rocks as well. It should be noted that, at the present erosional level, the intersection junctures of the ring structures of the early Proterozoic and Archean are occupied by the granitoid massifs of the same periods.

The ring structures are of more than one age. Related to the late Proterozoic activity are the ring structures of the Dnipro-Donets' Depression (the Pyriatyn, the Poltava and the Donets' arch uplifts), and of the Volyn' area (the Volyn' arch). These ring structures form a belt trending in an east-southeasterly direction and include the early Proterozoic Korosten' arch uplift, which possibly developed by inheritance at a later date.

All ring structures have some general features which are helpful in uniting them into a single genetic group related to the arching uplifts. They all have a more or less concentric pattern. From the geological-geophysical points of view they also have central axes, which are generally marked by the development of structures, such as grabens, which were formed in the Late Proterozoic or Riphean times.

The ring structures in the Black Sea Depression are related to the Late Paleozoic-Early Mesozoic epiplatformal activity, and specifically to the Fore-Dobruja, Odesa, Syvash and Azov arching uplifts. These structures form an east-northeasterly trend and are located close to the boundary zone between the East European Platform and the Scythian Plate. They all have central axial grabens as in the other ring structures described above. These grabens have been well studied and are described as peculiar suture-related structures.

The arch uplifts in this period developed over an extended time span. The Fore-Dobrujan arch was developed in the Devonian-

Jurassic interval, while the Odesian and the Syvash arches were formed in the Cretaceous period. The development of the Azov arch uplift continued perhaps into the Paleogene period.

The Kins'ka-Yaly crustal uplift, located on the boundary between the Ukrainian Shield, the Dnipro-Donets' Depression and the Donets' Basin emerged in the Mesozoic. On the satellite imagery it appears distinctly as a concentric structure with radial elements. There is also a graben structure of early Cretaceous age in this crustal uplift. It is possible that this Mesozoic uplift was inherited from an earlier circular structure of Precambrian age.

The Pannonian ring structure is about 500 km in diameter and corresponds to the Carpathian-Dinaric tectono-magmatic mega-arch of the Neogene-Quaternary age. Ukraine contains only a small part of this structure (the Carpathian Foredeep, Transcarpathian Deep and a margin of the Pannonian Depression).

Thus, in the context of structural data for adjacent territories, it appears that the assemblage of structures, identified through satellite imagery are related to each other both genetically and in the hierarchy of events that produced them. Hence, in the early Precambrian the main influence on the geological development of regions in Ukraine was the development of an East European giant arch and one of the elements of its infrastructure — the Sarmatian mega-arch, the axial graben of which is the Inhulets-Kryvyi Rih-Krupets'k suture zone.

Starting from the late Proterozoic, the geological development in Ukraine was also under the influence of the gigantic Caspian paleo-arch. Such tectonic elements as the Dnipro-Donets' Rift, the system of sutured grabens in the Black Sea area, the Black Sea-Adzhar-Tryalet Depression, are seen as radial riftogenic elements of this gigantic ring structure. Similarly, a significant influence on the formation of the Carpathian and Crimean Mountains is related to the ancient Pannonian and Black Sea mega-arches.

Linear structures are interpreted to be commonly present throughout the Ukrainian territory and form a fairly dense pattern. On the map only the first order transregional zones of lineaments are given.

One of the conditions for indicating a lineation zone was that there should be at least three lineaments not far from each other, and that they should have considerable continuity over much of the zone. The width of the zones was not limited, but depended on the degree of development of parallel and subparallel lineaments. Thus the width of the first order lineaments is in the order of 20 to 125 km. Based on this principle, 18 zones of first order lineaments have been established. These zones form a distinct pair of systems — one orthogonal and the other with a diag-

onal orientation. The distances between the zones do not change very much. Thus, the meridional zones are about 220-300 km apart, the latitudinal zones are about 190-210 km apart, the northeastern zones are 190-220 km apart, and the northwestern ones are about 190-240 km apart. In relation to the main geotectonic regions of Ukraine, the zones are transitional; in the western regions of Ukraine, the northwestern trending zones cut through both the various platformal regions and the folded Carpathian Mountains.

Such characteristics make these zones similar to the fracture faults, whose origin is believed to be related to changes in the rotation of the Earth, while the trends of the zones appear to be related to the current axis of the Earth. Hence, these lineaments could be a planetary fracture pattern. Geophysical data indicate that the "orthogonal" system is older than the "diagonal" one.

Zones of the first order lineaments, particularly the northwestern trending group, have a variable interaction with the arch structures of different ages. With respect to the Archean and Early Proterozoic arch structures they are of the fracture type. At the same time, these zones separate the arch uplifts of the Late Proterozoic from the Paleozoic. On this basis it can be assumed that the zones of lineaments were formed on a mature continental crust after it acquired the necessary rigidity. The formation of the diagonally oriented zones of lineaments are, however, considered to have a different nuance. The tendency for their concentration to be in the central parts of the arch structures in the Early Precambrian suggests that these lineaments, by triggering a strong change in pressure under high temperature gradients, led to granitization, enabling the development of the arch structures. This reasoning, therefore, suggests that the lineaments may be some of the earliest structures in the Earth's crust.

The relative ages of various systems of lineaments can be inferred to some extent from the geophysical data. Within the gravity field data, recalculated to a height of 10 km, there are well-discernible diagonal lineaments over the Ukrainian Shield area, whereas the orthogonal system is only weakly evident. This suggests that the two systems are of different ages. The orthogonal system is older since it is masked by supposedly later reworkings.

Hence, the interpretation of the satellite imagery allowed for an emergence of a new picture of geological development on Ukrainian territory. It identified some very large structural elements that were not obvious in the past, which must have very deep roots beyond the Earth's crust. These implications will have to be evaluated in the future. In particular the role of these structures in the deposition of various mineralizations has not been adequately considered.

LEGEND

TECTONIC STRUCTURES BASED ON REMOTE SENSING DATA

Ring structures

Uplifts in the Earth's crust

I Early Archean (AR): I – Podillia, II – Dnipro Region

III Late Proterozoic (PR₁): III – Korosten', IV – Kirovohrad, V – Azov Sea Coastal

Epochs of tectono-magmatic activity

VI Upper Proterozoic: VI – Volyn', VII – Pyriatyn, VIII – Poltava, IX – Donets'

X Upper Paleozoic and Lower Mesozoic: X – Fore-Dobruja, XI – Odesa, XII – Syvash, XIII – Azov Sea


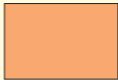






XIV Mesozoic: XIV – Kins'ka-Yaly

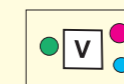
Linear structures

// Fault zones

OTHER SYMBOLS

Geotectonic zoning

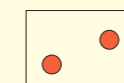
-  Ukrainian Shield
-  Volyn'-Podillia Plate
-  Dnipro-Donets' Depression and Donets' Basin
-  Black Sea Depression
-  Folded area of the Crimean Mountains
-  Folded area of the Carpathians
-  Carpathian Foredeep
-  Transcarpathian Deep
-  Dobruja Foredeep



Axial grabens of crustal uplifts

I – Prypiat', II – Ovruch, III – Pyriatyn, IV – Poltava, V – Donets', VI – Moldovan, VII – Karkinit, VIII – Syvash, IX – Northern Azov, X – Kins'ka-Yaly

Note. Color of the dots indicates timing of graben origination.



Axial graben of the Sarmatian Mega-uplift

Boundaries Mega-uplifts:



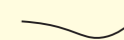
Sarmatian



Pannonian



Black Sea

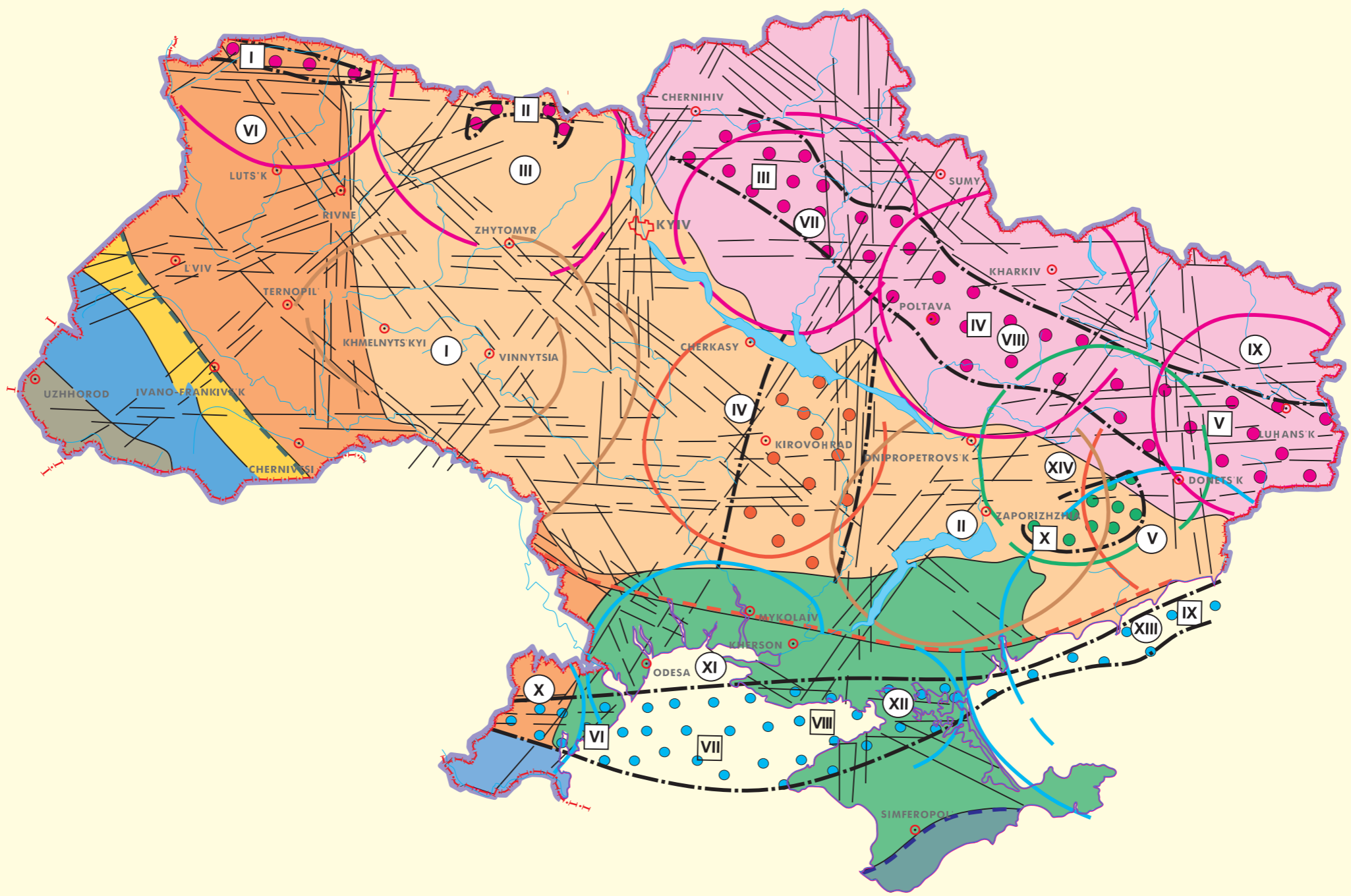


Geotectonic regions



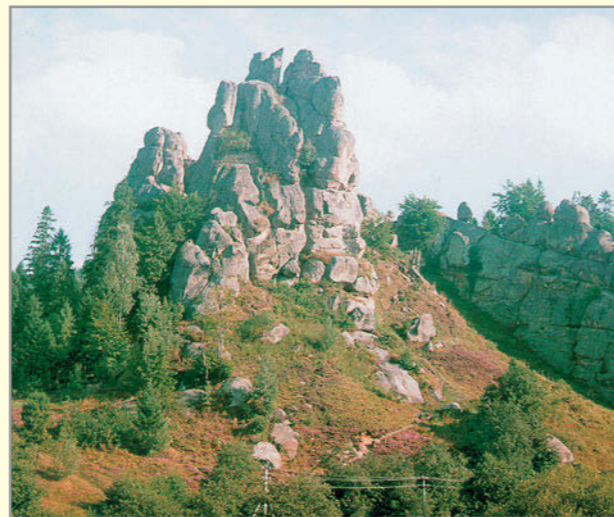
Axial grabens of crustal uplifts

LINEAR AND RING GEOLOGICAL STRUCTURES

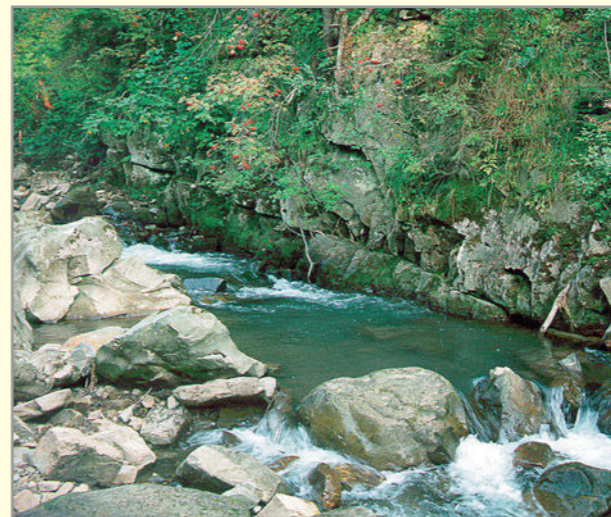




Basalt nature preserve Ivanova Dolyna (Ivan's Valley), Berestovets' village, Rivne oblast'



Paleogene deposits, Urych Rocks, L'viv oblast'



Kamianka river, Ivano-Frankivs'k oblast'



Big Gothic folds in Paleogene deposits, Yaremcha, Ivano-Frankivs'k oblast'

NEOTECTONICS AND RECENT VERTICAL MOVEMENTS IN THE EARTH'S CRUST

Movements along geological blocks in Neotectonic and in more recent times have been well established. However, the methods of studying such movements, and especially, their quantitative aspects (the degree of denudation that affects the estimates, the thickness of the key members of the strata, and the isoline method of arriving at an estimate of their amplitude and velocities) make the actual estimates of the movement rather difficult. Also, there is a lack of reliable determination of movement in the transregional Neotectonic faults. This induced the investigators to look for correlational connections between the Neotectonic movements and the movements along faults in the Earth's crust of Pre-Neotectonic time.

In very recent times, a new method has been added that has become very useful in making interpretations. This is satellite

imagery based on the multiple channels of geophysical data that it provides. The remote sensing data so acquired helped map the transregional zones of lineaments in Ukraine, and in conjunction with previous data, allowed considering them as zones of neotectonic activity. These zones control most of the boundaries between various Neotectonic regions, which differ by the character and/or amplitude of movements. Perhaps some of the boundaries are related to lineaments of low order magnitude. They are interpreted to be present everywhere on the Ukrainian territory. All in all, the zones of lineaments under discussion correlate with the characteristics of the present vertical movements in the Earth's crust, and also correlate well with the anomalous gradient velocities of movements occurring at the present time. Out of 120 such zones, most of them are places of contact, with positive and negative gradient velocities, of which 90 (about 77%) are closely associated with zones of lineaments. A network of transregional zones of

lineaments controls surface geological processes on a regional scale, and the density of these features controls the degree of their influence on topography.

The map of Neotectonics and recent vertical movements of the Earth's crust in Ukraine, shows that the most active large faults are of the orthogonal (north-south and east-west orientations) and of the northwestern directions. Movements of the Earth's crust along the northeastern faults were less intense. In summary, this indicates that the Neotectonics inherited the Pre-Neotectonic fault patterns.

In principle, a different picture is derived from the character of today's vertical movements in the Earth's crust. Movements of the Earth's crust along the northeastern lineaments are much more active than along the other orientations. Obviously, we are now observing a changing pattern of vertical movements. These tendencies are typical not only for the slow movements of the Earth's crust but also for the quick (sudden) ones. Thus,


the north to east trending faults propagate the seismic waves of strong Carpathian earthquakes in the northeastern direction far beyond the Ukrainian territory, while they shield Ukraine from the seismic waves generated by disastrous earthquakes in the Caucasus.

In the preparation of this map, the following were utilized: Neotectonic regionalization and the average gradient velocities in the Earth's crust of Ukraine (V.P. Paliienko, 1987, 1992), and maps (1 : 2 500 000 scale) of recent vertical movements of the Earth's crust in eastern Europe (1971 edition), in Bulgaria, Hungary, Poland, Rumania, the USSR (European part) and Czechoslovakia (1986).

In conclusion, an understanding of Neotectonic activity in the transregional fault zones is important for the interpretation of data in seismic studies and in the modern studies of the permeability of the Earth's crust. It also has an influence on human activity and the ecology of Ukraine.

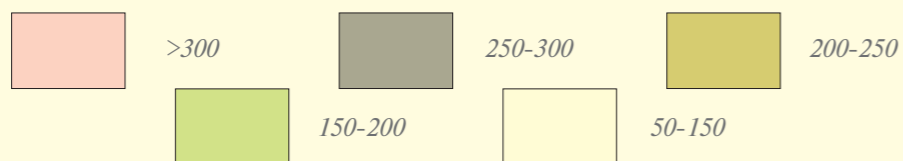
NEOTECTONICS AND RECENT VERTICAL MOVEMENTS IN THE EARTH'S CRUST

LEGEND

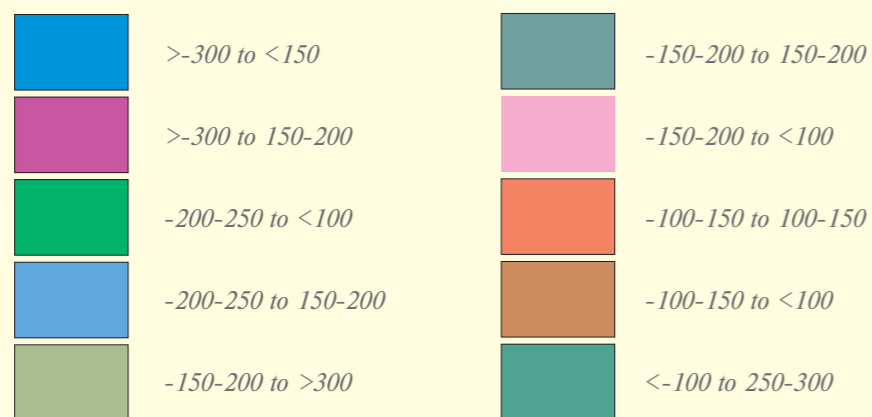
 Fault zones based on remotely sensed imagery


NEOTECTONIC ZONING

Areas of separate unidirectional structural heights of total amplitude, in meters

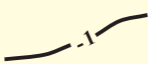




Areas of opposite direction movements; pre-inversion subsidence/post-inversion uplifting of total amplitude, in meters

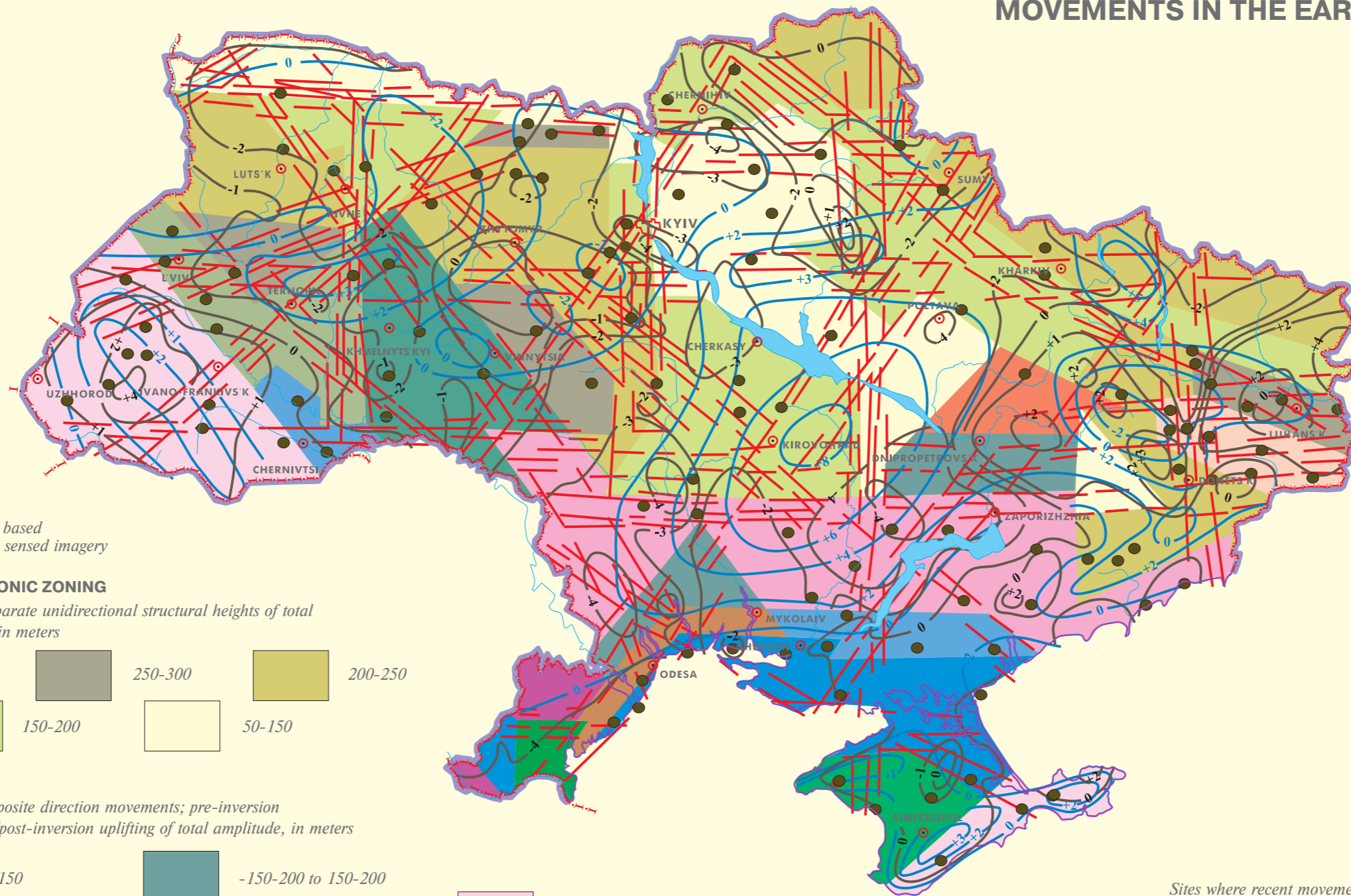


 Areas of block, monocline, folded and thrust structures of total amplitude up to 1800-2000 m (Carpathians) and 400-600 m (Crimea)

VELOCITY ISOGRAM OF RECENT VERTICAL MOVEMENT IN THE EARTH'S CRUST (MM/YEAR)

 1971 Measurements  1986 Measurements

 Sites where recent movements of abnormal velocity gradients of the Earth's crust were recorded



LEGEND

GEOLOGICAL FORMATIONS

Sedimentary formations

	Carbonaceous
	Carbonaceous-terrigenous
	Terrigenous marine
	Terrigenous continental
	Coal-bearing terrigenous carbonaceous
	Flysch
	Flyschoid
	Turbidite
	Molasse
	Flysch molasse
	Coarse fragmentary (related to graben)
	Jaspilite

	Evaporite
--	-----------

Volcanic formations

	Trap
	Alkaline basalt
	Bimodal volcanics
	Tholeiitic basalt
	Bimodal limey-alkaline volcanics
	Trimodal limey-alkaline volcanics

Intrusions

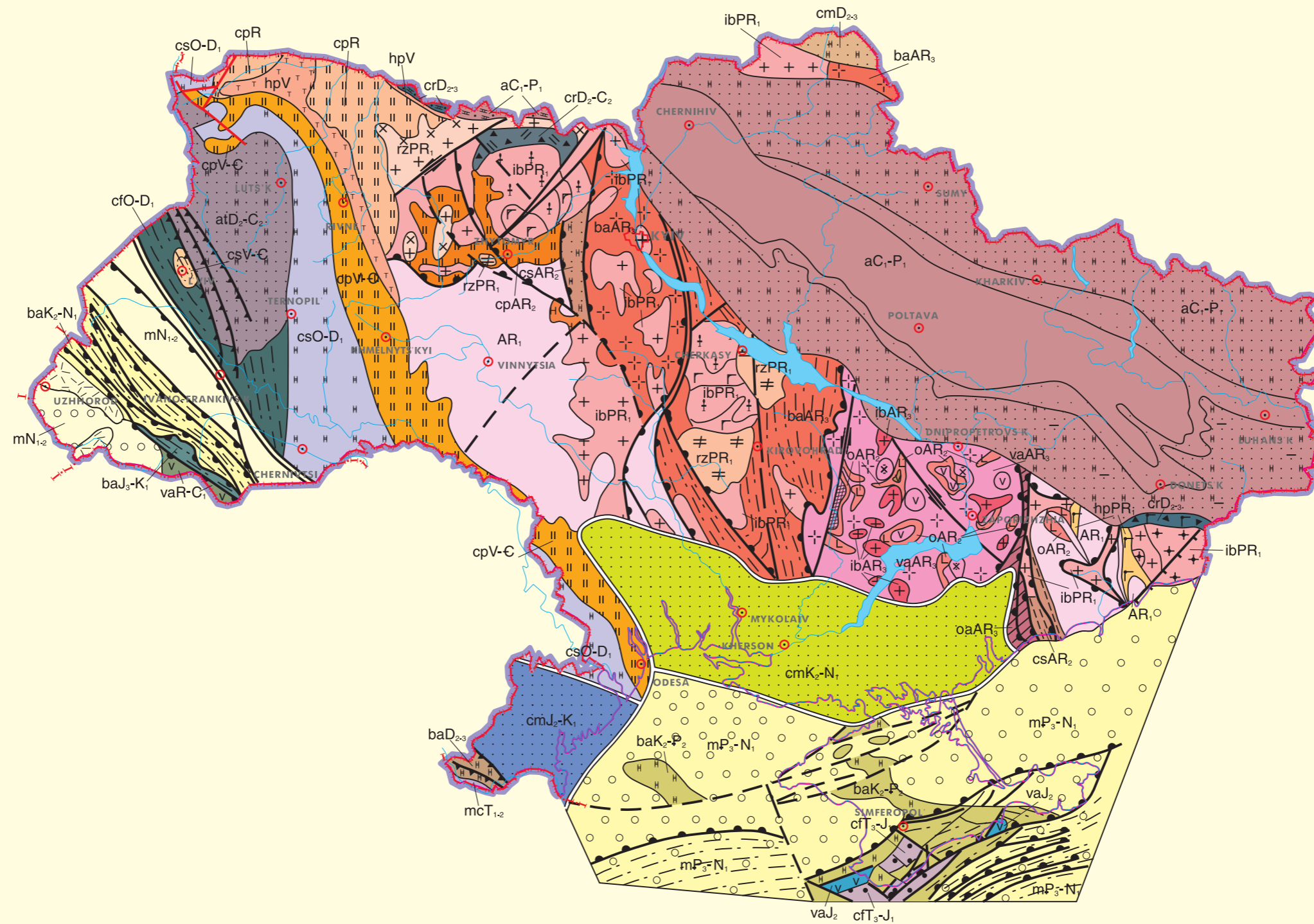
	Gabbro-tonalite-trondhemite
	Tonalite-trondhemite-granodiorite
	Gabbro-diorite-granite
	Gabbro-monzonite-granite

	Potassic granite
	Alkaline and subalkaline granite
	Rapakivi-granite
	Anorthosite

OTHER SYMBOLS

	Boundaries between areas
	Stratigraphic and formation boundaries
	Overthrusts
	Reverse faults
	Displacements
	Faults
	Other faults, determined and inferred
	Suture zone

GEODYNAMIC MAP



GEODYNAMIC TABLE

Geodynamic environment			Inner parts of the plates							Oceanic	Island arcs			Active continental margins		
			Lower Archean continental crust	Continental plain (cp) and epicontinental marine basin (cm)	Microcontinent cover (mc)	Hot point (hp)	Continental rift (cr)	Aulacogen (a) and intercontinental trough (it)	Continental shelf (cs)		Continental slope and footing (cf)	Outer non-volcanic arc and accretion trenches (oa)	Volcanic arc (va)	Back-arc basin (ba)	Rear zone (rz)	Collisional
Geodynamic complexes																
Phanerozoic	Cenozoic	N	cmK ₂ -N ₁													
		25														mN ₁₋₂
		P														
		66														baK ₂ -N ₁
		K														
		137														baJ ₃ -K ₁
		J														
	185	cfT ₃ -J ₁														
	T		mcT ₁₋₂													
	265	crD ₂ -C ₂														
	Paleozoic		P	atD ₂ -C ₂												
			280		aC ₁ -P ₁											
			C			csO-D ₁										
			345				cfO-D ₁									
D			vaR-C ₁													
400								baD ₂₋₃								
S	cmD ₂₋₃															
435		cpV-C														
O				hpV												
490					csV-C											
Upper			€			hpPR ₁										
			V				rzPR ₁									
	570		rzPR ₁													
Lower	R	ibPR ₁														
	680			ibAR ₃												
	1600		ibAR ₃													
Archean	Upper	AR ₃			oAR ₂											
		2800		oaAR ₃												
	3000	vaAR ₃														
Lower	AR ₂		baAR ₃													
	3200			csAR ₂												
3400	cpAR ₂															
AR ₁		3600	AR ₁													

GEODYNAMIC MAP

The geodynamic map of Ukraine is the first attempt to generalize geological and geophysical information of the area from the point of view of plate tectonics. The map is based on the recognition of the structural matter complex (SMC) concept. Within the Ukrainian Shield and the Early Proterozoic, the SMC of the island arc, the margin of the continent and the continental geodynamic environments are distinguished, and their formational assemblages are shown. The importance of the ancient SMCs throughout the Phanerozoic period is emphasized and the role they played in the geodynamic environment of the new complexes is defined. The geostructural zones and regions of Ukraine are illustrated on the geodynamic map. They show a sequential evolution of the geodynamic conditions and the geology of Ukraine through time. These include: 1) Pre-Mesozoic (Ukrainian Shield and Volyn'-Podillia), 2) Pre-Upper Permian (Donets' Basin and Dnipro-Donets' Aulacogen), 3) Pre-Cretaceous (northern Dobruja), 4) Pre-Pliocene (Crimea, Black Sea Depression, terrain under the Black and Azov Seas), 5) Pre-Quaternary (Carpathians). In the legend are shown lateral and vertical arrangements of structures and complexes and their forms of accumulation.

1. Ukrainian Shield

The Ukrainian Shield is subdivided into four major areas – the Volyn'-Podillia, the Azov, the Dnipro and the Kirovohrad segments. The first two segments are the oldest Archean cratonic regions, located on the western and eastern portions of the Shield. They are represented by the high-grade granulite to amphibolite facies sedimentary-volcanic (the Dnister-Buh and the western Azov series) assemblages and M and I types of granites (M granites are of the oceanic island arcs, I granites are of the active continental margins and island arcs) and other structural matter complexes. Both the granites and the SMC are covered either by the metamorphic riftogenic (Vasylyv suite) rocks, or by the metamorphic shelf deposits (Kocheriv and Horod suites of the Teteriv series, and Buh and central Azov series).

The Dnipro segment consists of a granite-greenstone assemblage. Volcanic rocks occur in the greenstone belts and are subdivided into lower metabasalts TH1 (TH1 are tholeiites with nonfractionated rare earth elements – Slavhorod and Tomakivka deposits of the Auly series, and Surian suite of the Kins'ka series), and upper basalts TH2 (TH2 are tholeiites enriched in light rare earth elements and fractionated rare earth elements), andesites AA, CA and HKA (AA are andesites from immature oceanic island arcs, CA are calc-alkaline andesites of mature arcs, HKA are andesites with high potassi-

um content) and felsic volcanics FI and FII (FI are felsic volcanics with depleted heavy trace elements – Kins'ka and Bilozerka series). The internal structure of these rocks is characterized by complex deformation patterns and the development of diapiric structures in the last phase. The younger plutonic complexes are represented by the M and I type tonalite-trochjmites (the Bazavluk granite-gneisses, the Slavhorod, the Dnipro and the Sura complexes) and by the I and S type granites (S granites are related to the collisional tectonics – the Demuryne, the Mokra Moskovka and the Tokiv complexes). The Dnipro segment could be regarded as a deformed volcanic arc limited on the east side by the Orikhiv-Pavlohrad suture.

The Kirovohrad segment consists of metamorphosed Archean SMC formed in a marginal sea (the Ros'-Tikykh, Buh and Inhul-Inhulets' series, and the Saksahan' and Artemivka suites). The SMC types described above mark the end of the Archean island arc stage of development. After this follows the formation of the Early Proterozoic rocks along the active continental margin of the Archean. Its formation is related to the young Benioff-style paleozone found outside Ukraine, in the Voronezh zone of southern Russia. Along the margins of the SMC, or its active edge, there are granitoids of the I type (Shevchenko, Tokmak, Tetiiv and Zvenyhorodka), and younger I and S type granites (Uman', Osnyts'k and others) and associated volcanic-sedimentary assemblages (Huliaipole, Klesiv, Novohrad-Volyn's'kyi). The end of the development of the active margin is marked by the intrusion of S type granites (Kirovohrad and others).

A reinterpretation of the geological data in the Ukrainian territory, from the tectonic point of view, demonstrates the necessity of reviewing many of the traditional understandings of the stratigraphy and structure of the Ukrainian Shield, which is similar in many respects to other shields in the world, and particularly in that they all have a cover. Within such covers there are found in places rootless assemblages of the ophiolitic association. Such assemblages are generally known to carry precious metals. In the Buh river area the ultramafic ophiolitic rocks are known to carry chromite deposits and the lateritic portions also have silicate nickel deposits.

2. Volyn'-Podillia Edge of the East European Platform

This terrain is located along the western and southwestern edge of the Ukrainian Shield. It is subdivided into the slope of the Shield, Volyn' ridge (Kovel' area) and Paleozoic L'viv Depression. The slope of the Shield part is a wide submeridional belt, whereas the Volyn' ridge has a longitudinal orientation. The oldest deposits are of sedimentary and volcanic rocks lying unconformably on the Pre-Riphean basement

which has been depressed down to about 1500 m. In section there are Upper Proterozoic SMC represented by continental and epicontinental marine basins (Polissia series), "hot spots" (Volyn' series) and Vendian-Cambrian SMC also represented by continental and epicontinental marine basins. In the southwestern direction the above-mentioned SMCs are replaced by the flysch deposits of the continental slope and are in turn covered by the carbonates of the Ordovician shelf deposits and Lower Devonian. The latter are covered by the Middle Devonian coals of the L'viv Depression, and mark the end of the development of the Denmark-Poland furrow-trench.

The Meso-Cenozoic carbonate and terrigenous deposits of the epicontinental seas within the continental flatlands are not shown on the map.

3. Dnipro-Donets' Aulacogen

This region is part of the Sarmatian-Turanian lineament. Initial stages of its development are considered to be either in the Devonian or in the Riphean time. The central portion of the Aulacogen basically comprises riftogenic complexes. These have been studied in the core of the dome structures, and in the zone of contact between the Azov segment of the Ukrainian Shield and the Aulacogen. This latter zone is the location of the "hot spots", and is marked by the development of the Azov SMC – the ultramafic and mafic magmatism and continental rifting. The rifting was accompanied by the effusions of alkaline basalts and trachybasalts (Volnovakha-Yelanichykh complex), nepheline syenite intrusions (Pokrovka-Kyryivka complex), tholeiite basaltic flows and the formation of graben structures.

During the Late Devonian the territory of the Aulacogen was subjected to sinking. In this process the earlier formed salt strata were covered by carbonate-terrigenous and coal deposits of the Lower to Middle Carboniferous period. After this aulacogenic period of formation, the red terrigenous deposits of the Upper Carboniferous and Lower Permian accumulated. The latter included also some carbonate-halogenic deposits. The typical platform regime in the Aulacogen was established in the Triassic period. The SMC of this period and of the younger ones are not shown on the geodynamic map.

4. The Northern and Northwestern Part of the Black Sea Area

This area consists of the Paleozoic Folded Dobruja, Crimean Lowland and that system of structures which belongs to the Alpine belt and the associated epicontinental marine basins (the Black Sea Lowland, the Moldovan Depression, and land under the Black and Azov Seas).

The system of the northern Dobruja and the Crimean Lowland is a continuation of the Paleozoic structures of the Greater Caucasus. Along its entire length, except on the boundary with

Romania, it is covered by the Meso-Cenozoic SMC, which fill the Moldovan Depression, the Crimean Lowland, the northern shelf of the Black Sea and the terrain under the Azov Sea. This system consists of volcanogenic, sedimentary marine, lagoon, continental and red-colored rocks of the SMC of the Early to Late Paleozoic period. They are also intruded by granites.

The Alpine folded zone is found in the Crimean Mountains. There are flysch-turbidites related to the continental slope, and roots of the Gondwanian basement covered by the flysch-molasse SMC of the marginal sea. Younger molasse and flysch deposits cover the Crimean Lowland, the adjacent territories and the Black Sea basin.

5. Carpathian Mountains

This region is part of the Alpine Mediterranean belt of Eurasia. From the northeast to the southwest, it consists of a frontal depression, filled with flysch, and an internal depression.

The frontal depression is represented by three zones, two of which have been transformed into the Sambir (Lower to Middle Eocene molasse) and the Boryslav-Pokuttia (marginal part of the flysch basin) covers. Its other zone (Bil'che-Volytsia) represents the western part of the East European Platform that has been dragged into the depression and covered by molasse sediments.

The frontal depression, filled with flysch, is of the Valanginian-Lower Miocene age. The flysch rocks here measure up to 10 km in thickness. They have been studied in the Borkut-Rakhiv and the Marmarosh areas. In the Borkut-Rakhiv area there are Late Albian olistostromal horizons, and in the Marmarosh area there are diabases (Kamiany Potik), tuffs of diabasic composition, Upper Jurassic limestones and lenses of gravelites, and Permian and Triassic olistolites. These rocks have been interpreted as melange-type deposits. The Marmarosh massif consists of Lower Proterozoic crystalline rocks, overthrust by the Upper Riphean-Lower Paleozoic shales, porphyroids, and amphibolites of the calc-alkaline series. In both areas there are covers of Paleozoic and Mesozoic strata.

The overthrust crystalline rocks appear as a zone of cliffs, with some Triassic-Cretaceous limestones contained within the Albian-Maastrichtian clayey-marly envelopes. Most of these cliffs are composed of shales, diabases, porphyrites, jasper and basite-hyperbasites contained in a matrix of black crushed argillites.

The Transcarpathian Depression is composed of the Miocene-Pleistocene molasses, with widely distributed calc-alkaline volcanic rocks in the Vyhorlat-Hutylnian belt.

The Carpathian Mountains contain oil and gas deposits in the flysch cover. In the past they were not the prime targets of exploration.

GEOLOGICAL SLICE MAPS

The geological slice maps reveal deep structures after the sedimentary cover is “peeled away”, layer by layer, from its surface.

These maps were compiled for each of the main stratigraphic units of the sedimentary cover. Drawn to a scale of 1:5 000 000 to cover the entire country, these geological slice maps have been produced for the first time. A sedimentary cover on the Ukrainian territory (platform and folded complexes) is of variable but considerable thickness and has a complicated internal structure. The latter is caused by a great number of unconformities and erosional surfaces. Large, regional unconformities outline structural boundaries corresponding to the main time intervals of geological evolution. The geological slice maps have been compiled for these structural boundaries.

The "Stratigraphic Code of Ukraine" contains all the standards and the basic criteria on which the geological slice maps were compiled (typification, taxonomy, correlation and indexing parameters).

The Archean, Lower Proterozoic, Upper Proterozoic and Paleozoic geological slice maps are based on drilling and geophysical data. Only large faults in the basement and cover rocks are shown on the map. Inversion structures are common. They are of different sizes, form and genesis and are located mainly in

the upper part of the sedimentary cover. They commonly show evidence of great tectonic activities in the Precambrian and Paleozoic eras.

The geological slice maps are of great importance for the metallogenic division of the sedimentary cover. Thus the three-dimensional maps of geological structures with data on mineral genesis make it possible to visualize spatial arrangements of various mineral deposits.

A complex problem of map coordination was resolved through compilation of the geological slice maps, starting from the geological map of Pre-Riphean formations as a basic one. All of the other geological slice maps were drawn on this basis.

The trend of deep depressions within the western areas of Ukraine and the mode of distribution of the sedimentary rocks in them testify to the strong influence of the Early Baikalian and Caledonian tectonic belts of western Europe. A break of the Sarmatian Shield into the Ukrainian Crystalline Shield and the Voronezh anticline due to the initiation and formation of the Dnipro-Donets' Depression is considered to be the main event of the Hercynian orogeny. Yet the most distinctive structures are of the Kimmeridgian-Alpine orogeny, influenced by the Mediterranean tectonic belt.

T H E G E O L O G Y A N D M I N E R A L D E P O S I T S O F U K R A I N E



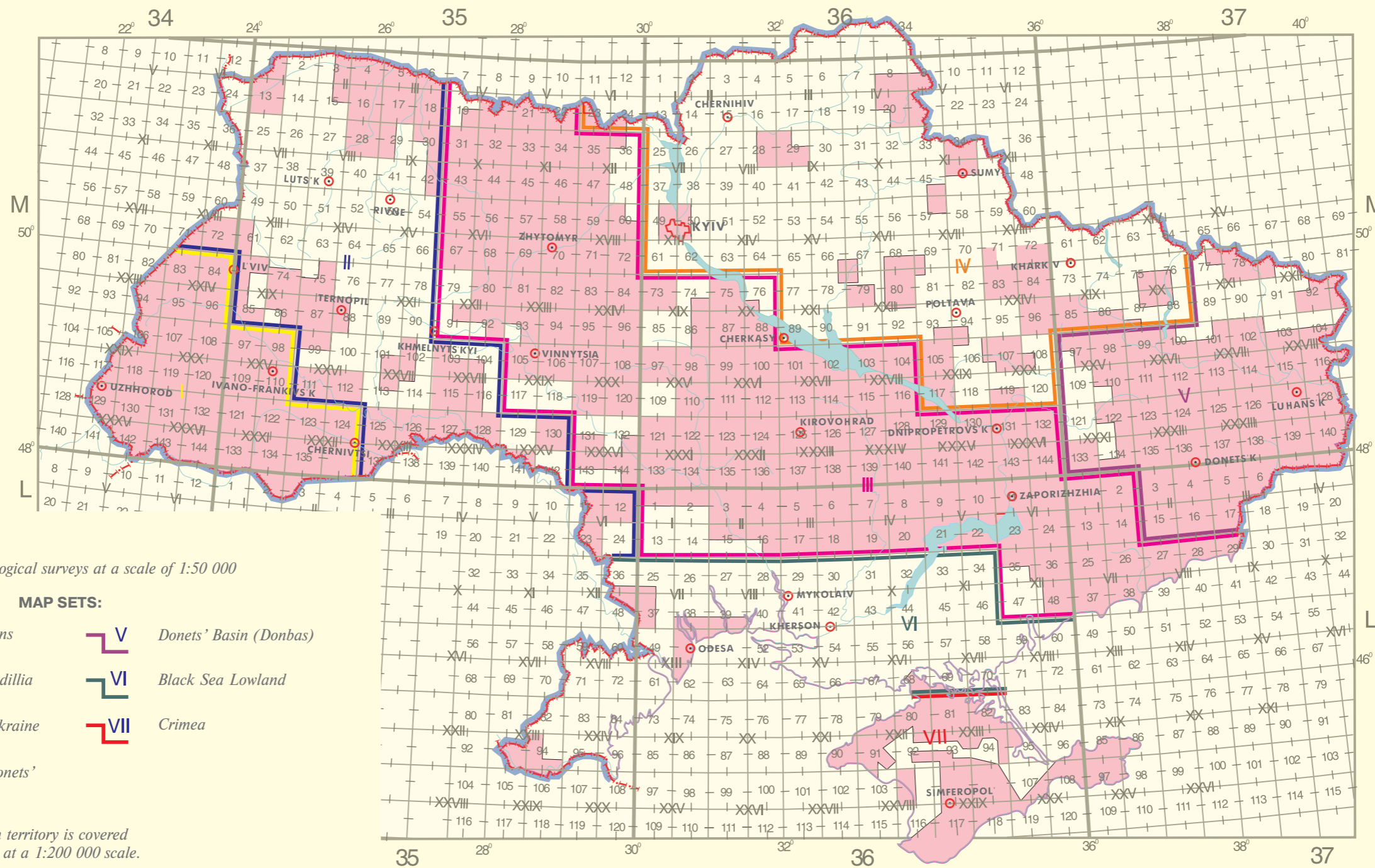
section IV

GEOLOGICAL SLICE MAPS

- Geological coverage
- Pre-Quaternary
- Pre-Neogene
- Pre-Paleogene
- Pre-Cretaceous
- Pre-Jurassic
- Pre-Triassic
- Pre-Permian
- Pre-Carboniferous
- Pre-Devonian
- Pre-Silurian
- Pre-Ordovician
- Pre-Cambrian
- Pre-Vendian
- Pre-Riphean



GEOLOGICAL COVERAGE



LEGEND

Geological surveys at a scale of 1:50 000

MAP SETS:

- | | | | |
|--|-----------------|--|------------------------|
| | Carpathians | | Donets' Basin (Donbas) |
| | Volyn'-Podillia | | Black Sea Lowland |
| | Central Ukraine | | Crimea |
| | Dnipro-Donets' | | |

The entire Ukrainian territory is covered by geological surveys at a 1:200 000 scale.

GEOLOGICAL COVERAGE

The level of geological coverage is determined first of all by the results of regional geological surveys. From the 1950s to the 1970s the entire country was mapped at a 1:200 000 scale. Medium-scale geological mapping was used in cases where more detailed data were required which were used for planning, detailed work and research. At the beginning of the

1970s, in the waning stages of the medium-scale mapping, large-scale geological mapping became widespread. It was during this time that new methods of regional investigation were applied, including "deep geological mapping" and "supplementary geological investigation" of areas.

Today, about 50.0% of the Ukrainian territory is covered by geological mapping at a 1:50 000 scale. Large-scale mapping of the following regions has a variable

coverage: Ukrainian Shield, 81.2%; Volyn'-Podillia Plate, 48.5%; Dnipro-Donets' Depression (aulacogen), 20%; Donets' Basin, 64%; Carpathians and Forecarpathians, 99.5%; Black Sea Lowland (with the southern slope of the Ukrainian Shield), 6.9% and Crimea and Dobruja, 19%.

At the current stage of economic development, geological mapping of the Ukrainian territory is directed towards the compilation of the new State Geological map at a 1:200 000

scale. This map should be useful in geological exploration, development of the mineral industry, and for hydrogeological and environmental studies in Ukraine. This map is an essential part of the regional geological studies of the country. It is to consist of the following map sets:

- 1) Carpathians, 2) Volyn'-Podillia, 3) Central Ukraine, 4) Dnipro-Donets', 5) Donets' Basin (also known as the Donbas), 6) Black Sea Lowland, 7) Crimea.

LEGEND TO GEOLOGICAL SLICE MAPS

<p>N₂ Pliocene (clay, silt, sand, sandstone)</p>	<p>T₂₋₃ Middle-Upper Triassic (sandstone, argillite, siltstone, limestone, dolomite)</p>	<p>S₂ Upper Silurian (limestone, dolomite, marl, siltstone, argillite)</p>	<p>R₂ Middle Riphean (quartz-porphry, porphyrite, diabase, phyllitic schist, sandstone)</p>
<p>N₁ Miocene, Miocene-Lower Pliocene (N_{1,2}) (sand, sandstone, clay, limestone, marl)</p>	<p>T₁₋₂ Lower-Middle Triassic (sand, varicolored clay, sandstone, argillite, siltstone, limestone, dolomite)</p>	<p>S₁ Lower Silurian (limestone, marl, argillite, dolomite, siltstone)</p>	<p>UPPER PROTEROZOIC-PALEOZOIC PR₃-PZ</p>
<p>P_{3-N₁} Oligocene-Miocene (sand, sandstone, clay, silt)</p>	<p>T₁ Lower Triassic (sand, sandstone, pebble gravel, clay, silt, siltstone, marl)</p>	<p>O Ordovician (dark-colored argillite)</p>	<p>PR₃-PZ Quartzite-sandstone, diabase, trachyandesite, quartz porphyrite, shale, siltstone, tuffite, conglomerate</p>
<p>P₃ Oligocene (clay, silt, sand, sandstone)</p>	<p>P-T Permian-Triassic (sandstone, clayey shale, siltstone, limestone, dolomite)</p>	<p>O₂₋₃ Middle-Upper Ordovician (limestone, sandstone)</p>	<p>UPPER-MIDDLE PROTEROZOIC PR₂₋₃</p>
<p>P₂ Eocene (clay, marl, limestone, opoka, sand, silt, lignite)</p>	<p>PZ Paleozoic (limestone, dolomite, siltstone, argillite, sandstone, schist, syenite, porphyritic syenite)</p>	<p>O₂ Middle Ordovician (sandstone)</p>	<p>PR₂₋₃ Alkaline metasomatite, syenite, subalkaline granite (Perha complex)</p>
<p>P₁₋₂ Paleocene-Eocene (sand, sandstone, clay, secondary kaolin, lignite)</p>	<p>PR₂-PZ Upper Riphean-Paleozoic (shale, marble limestone, limestone, dolomite, quartzite, basalt, andesite-basalt)</p>	<p>O₁₋₂ Lower-Middle Ordovician (limestone)</p>	<p>MIDDLE PROTEROZOIC PR₂</p>
<p>K₂ Upper Cretaceous (chalk, marl, limestone, sand, sandstone, opoka)</p>	<p>P Permian (gravelstone, sandstone, clayey shale, limestone, dolomite, anhydride, argillite, felsic lavas)</p>	<p>Є₃ Upper Cambrian (black siltstone with sandstone intercalations)</p>	<p>PR₂ Alkaline syenite, nepheline-syenite, granosyenite, gabbro-wehrlite (Oktiabr, South-Kal'chuk complexes)</p>
<p>K₁₋₂ Lower-Upper Cretaceous (claystone, siltstone, sandstone, carbonate rocks)</p>	<p>P₁ Lower Permian (siltstone, argillite, anhydride, gypsum, rock salt, limestone, dolomite, clayey shale, sandstone)</p>	<p>Є₂ Middle Cambrian (sandstone, siltstone)</p>	<p>a PR₂ b Granite-porphyrates, rapakivi-granite and rapakivi-like (a), gabbro, anorthosite (b) (Korosten' complex)</p>
<p>K₁ Lower Cretaceous (marl, limestone, sand, sandstone, conglomerate, clay)</p>	<p>C₃ Upper Carboniferous (argillite, silt, limestone, sandstone, coal seams)</p>	<p>Є₁ Lower Cambrian (sandstone, siltstone, argillite)</p>	<p>PR₂ Granite, granodiorite, diorite, gabbro (Osnyts'k complex), Undivided Proterozoic (Crimea)</p>
<p>J₃ Upper Jurassic (dolomite, limestone, marl, clay, sand, sandstone, conglomerate, claystone, silt)</p>	<p>C₂ Middle Carboniferous, Middle-Upper Carboniferous (C_{2,3}) (limestone, argillite, siltstone, coal seams)</p>	<p>V_{2-Є₂} Upper Vendian-Middle Cambrian (sandstone, argillite, gravelstone, flysch deposits – black argillite with intercalations of sandstone and siltstone)</p>	<p>PR₂ Klesovite, leptitic gneiss, metavolcanics</p>
<p>J₂ Middle Jurassic, Middle-Upper Jurassic (I_{2,3}) (clay, sand, silt, siltstone, sandstone, gravelstone)</p>	<p>C₁₋₂ Lower-Middle Carboniferous (limestone, sandstone, argillite, coaly-clayey shale)</p>	<p>V_{2-Є₁} Upper Vendian-Lower Cambrian (sandstone, argillite, gravelstone)</p>	<p>LOWER PROTEROZOIC PR₁</p>
<p>J₁ Lower Jurassic (sandstone, sand, limestone, argillite)</p>	<p>C₁ Lower Carboniferous (limestone, dolomite, argillite, siltstone, sandstone, coal seams)</p>	<p>R_{3-Є₁} Upper Riphean-Lower Cambrian (gneiss, amphibolite, quartzite, shale, dolomite, liparite-dacitic tuff, andesite, basalt)</p>	<p>a PR₁ b Granite (a), migmatite (b) (Zhytomyr, Kirovohrad, Uman', Stavyshe and other complexes)</p>
<p>T-J Triassic-Jurassic (argillite, siltstone, sand, sandstone)</p>	<p>D₃ Undivided Devonian (D), Upper Devonian (dolomite, sandstone, breccia, limestone, rock salt, clayey shale, gravelstone, tuff, basalt (Pokrovka-Kyryivka intrusive nepheline-syenite complex))</p>	<p>V₂ Upper Vendian (sandstone, argillite, siltstone, volcanoclastics)</p>	<p>PR₁ Granodiorite, diorite, monzonite, gabbro, pyroxenite, dolerite (Buky, Prut complexes)</p>
<p>T_{3-J} Upper Triassic-Jurassic (clay, marl, limestone, siltstone, sandstone)</p>	<p>D₂₋₃ Middle-Upper Devonian (sandstone, limestone, argillite, dolomite)</p>	<p>V₁ Lower Vendian (basalt, tuff, tuffite, red sandstone, gravelstone, conglomerate)</p>	<p>PR₁ Carbonatite, nepheline syenite (Chernihiv complex)</p>
<p>T-J₂ Triassic-Middle Jurassic (limestone, dolomite, argillite, siltstone, rarely sandstone)</p>	<p>D₂ Middle Devonian (limestone, conglomerate, siltstone, argillite, sandstone, Azov intrusive pyroxenite-peridotite complex)</p>	<p>R_{2?} Riphean rocks (interpreted from geophysical data)</p>	<p>a PR₁ b Granite, migmatite (a), charnockite (b) (Berdychiv complex)</p>
<p>T_{3-J₁} Upper Triassic-Lower Jurassic (limestone, argillite, rarely sandstone, flysch sandy-argillaceous)</p>	<p>D₁ Lower Devonian (siltstone, argillite, marl, limestone, dolomite, sandstone)</p>	<p>vβR₃ Upper Riphean (gabbro-diabase, gabbro-dolerite)</p>	<p>PR₁ Granite, migmatite, granodiorite, diorite (Haisyn complex)</p>
<p>T Triassic (sand and varicolored clay, silt with sandstone, limestone, dolomite, rarely sandstone and diabase)</p>	<p>S₂-D₁ Upper Silurian-Lower Devonian (dark-colored siltstone and argillite, limestone, dolomite, marl, sandstone)</p>	<p>R₃ Upper Riphean (shales, phyllite, quartzite, quartzite-like sandstone)</p>	<p>PR₁ Ferruginous quartzite, BIF-schist, meta-sandstone, marble and other rock types (Kryvyi-Rih series)</p>
<p>T₃ Upper Triassic (sandstone, limestone, argillite, silt, clay, siderite)</p>	<p>R₂₋₃ Middle-Upper Riphean (red sandstone, siltstone, argillite)</p>	<p>PR₁ Gneiss, schist, marble, calciphyre (Teteriv, Inhul-Inhulets' series)</p>	<p>UPPER ARCHEAN AR₃</p>
			<p>AR₃ Plagiogranitoid, diorite, granodiorite, gneiss, amphibolite (Tetiiv complex, Ros'-Tikych series)</p>
			<p>AR₃ Gneiss, ferruginous quartzite, marble, schist, gabbro, peridotite, pyroxenite (Buh series, Dereniukha, Kapitanivka complexes)</p>
			<p>AR₃ Granite (Mokra Moskovka, Tokiv complexes)</p>
			<p>AR₃ Schist, komatiite, andesite-basalt, ferruginous quartzite (Bilozerkha, Kins'ka series)</p>
			<p>LOWER-MIDDLE ARCHEAN AR₁₋₂</p>
			<p>AR₁₋₂ Migmatite, plagiogneiss, amphibolite (Dnipro complex, Aul, Oboyan series)</p>
			<p>LOWER ARCHEAN</p>
			<p>AR₁ Enderbite</p>
			<p>AR₁ Gneiss, schist, amphibolite, calciphyre, ferruginous quartzite, basic, ultrabasic rocks (Dnister-Buh, Western Azov, Brians'k series)</p>
			<p>AR:PR(?) Possible Archean or Lower Proterozoic</p>
			<p>? No data available or controversial data</p>
			<p>PR₁ Transregional faults</p>
			<p>PR₁ Regional faults</p>
			<p>PR₁ Other faults</p>
			<p>PR₁ Geological boundaries</p>
			<p>PR₁ Boundary of the East European Platform</p>



Stratotype of Pontic deposits, Odesa



Remnant of Tortonian deposits, Trynih Mountain, Lviv oblast'



Poltava sand outcrop, Vytachiv village, Kyiv oblast'



Remnant of Tortonian deposits, Veleten' (Giant) Rock, Lviv oblast'

PRE-QUATERNARY (1.8 Ma)

As a result of thematic and geological survey studies carried out in recent years, some new concepts have been developed on the stratigraphy of the Neogene and the Quaternary deposits. The Neogene of Ukraine has the following subdivisions: bathysiphonic (the Black Sea Lowland, the Crimean part of the Scythian Plate), ombroic (Carpathians), and the Novi Petrivtsi horizons (Volyn'-Podillia, Ukrainian Shield, Dniipro-Donets' Depression, Donets' folded complex). Regional variations have been recognized in the following layers or horizons: the Caucasian, Sakaraulian, Kotsaturian, Tarkhanian, Chokrakian, Karachanian, Konkian, Sarmatian, Meotian, Pontian, Cimimerian, Akchahylian (or Kuialnykian) and Apsheronian. Various facies and geostructural features were conducive to the formation of a large variety of lithological compositions and their unusual association with the old (buried) fauna and flora. This made it easier in some cases to define more precisely some of the horizons, and their subdivision into smaller taxonomic units, which was useful in carrying out correlations of the strata, particularly with those beyond Ukraine. The map also shows elongated zones of recent disturbances, which were determined by a number of methods.

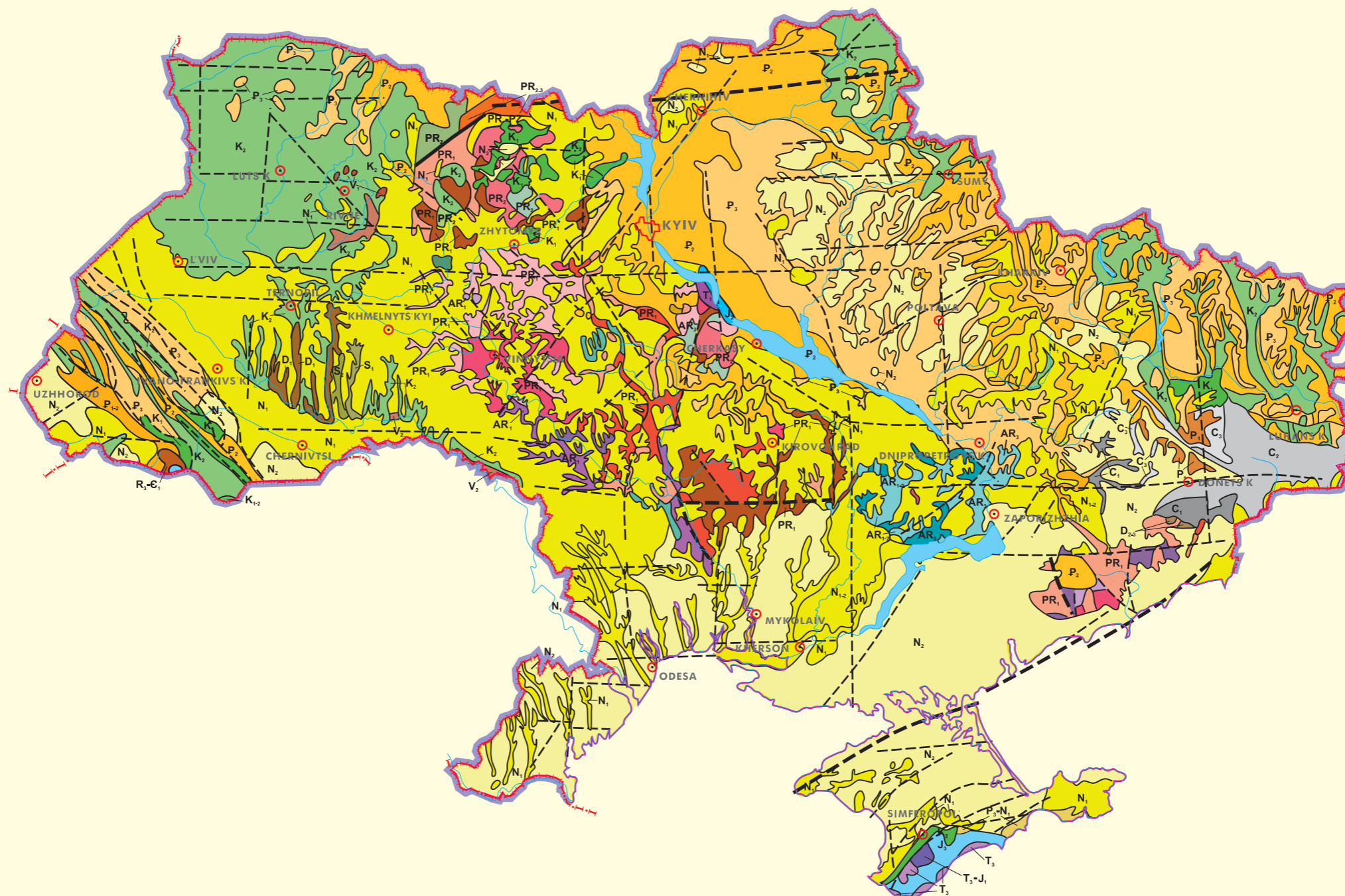
The structural-paleovolcanic studies carried out by the National Academy of Sciences and the Geological State Committee of Ukraine allowed to resolve in a new fashion a number of questions relating to the volcanic geology of the Carpathians. The formation of the Forecarpathian Depression was accompanied by magmatic activities throughout the Neogene period. The Miocene and the Pliocene magmatisms differ considerably in terms of their composition, and by their territory of activity. The Miocene rocks are of the liparite-dacite and andesite associations, whereas those of the Pliocene are essentially of an andesitic association. The Pannonian intrusive-extrusive series are of intermediate age, and in terms of the territory and structure are close to the Miocene liparite formations. The possibility of accumulations of high concentrations of metals and economic deposits in the magmatic systems are determined largely by the dynamic-structural conditions of their development. Extrusive cupolas and intrusive domal structures are more viable for high metal accumulations than other volcanic edifices. As a result of these studies on the geology and the metallogeny of the Pre-Quaternary rocks the following general conclusions can be made:

1. Sedimentary rocks were deposited during the Early and

- Middle stages of the Alpine tectonogenesis.
2. Large geological structures are separated by regional tectonic faults.
3. A gradual wave-like sagging of the Earth's crust is observed from west-southwest to east-northeast.
4. Changes are noted in the direction of migration of regions where thick sedimentation has occurred.
5. These changes between the thickness and the limits of the formations in different regions are the result of the movement of blocks of basement rock, mainly along old lines of weakness. These movements produced the new (Oligocene-Quaternary) structure of the territory.
6. The outlines of zones of sedimentation are inherited from previous older structures.
7. Block movement intensified in Pliocene-Quaternary times.
8. There is an erosional leveling of boundaries between geological structures (with the exception of the folded ones).
9. Characteristic metallogenic indications:
 - The volcanogenic and volcanogenic-sedimentary strata of the Transcarpathian Depression contain deposits of perlite, alunite and kaolinite. The Miocene rocks contain occurrences and deposits of lead-zinc with silver and gold (Muzhiiievo and Berehove), and in the Pliocene and Miocene rocks there are

- deposits of mercury and arsenic-mercury (Berkut, Shaian, Hrendesh, and others).
 - In the Forecarpathian Depression there are large deposits of native sulfur (Rozdil and others) and associated celestite. They occur in beds of Ratne limestone of Upper Tortonian age. Copper-bearing sandstones and argillites of the Lower-Stebnyk sub-suite of the Miocene age are found in the Boryslav-Pokuttia sub-zone of the depression. Within the carbonate-sandy-clayey strata of the Vorotyshche suite, there are stratiform occurrences of galena-sphalerite (Truskavets'). The Lower Miocene conglomerates of the Slobidka suite carry gold placer deposits. The terrigenous-halogenic Miocene rocks of the Forecarpathians contain large deposits of potassic salts and galena.
 - Overlying the Ukrainian Shield there are marine placer deposits of titanium and zirconium minerals. They occur especially in the sands of the Poltava suite of the Neogene period, and include the Samotkan' deposit and others. In addition, the Pliocene strata contain secondary kaolin, bentonite and fireclay deposits, and sands for the glass and metallurgy industries. In the Neogene, the Kimmeridgian strata contain huge sedimentary iron deposits of the Kerch peninsula and the Azov Sea. The ores commonly have elevated phosphorus content, and locally vanadium and manganese.

PRE-QUATERNARY (1.8 Ma)



PRE-NEOGENE (23.8 Ma)

The Pre-Neogene or Paleogene stage of development is a period of very intense movements and significant structural changes on the Ukrainian territory.

Paleogene deposits are characterized by variable structural-facies zones leading to sharply different variations in the associated deposits and their fauna and flora. Much of the terrain was under shallow-water seas and the deposits that formed were of the platform type, whereas in the Carpathian and Crimean Mountains flysch deposits were accumulating. Fauna was characterized by various ecological types, and their relationships in various basins were not the same.

The Paleogene is subdivided into a number of horizons, (grouped from older to younger), as follows.

Paleocene. The Bilokamiyani horizon in southern Ukraine is represented by carbonate deposits up to 30 m in thickness, and elsewhere in Ukraine it corresponds to the Psel and Merlo horizons in the Dnipro-Donets' Depression, Volyn'-Podillia and Ukrainian Shield, and the Stryi and Yamne horizons in the Carpathians. They are comprised of sandy-clayey limestones, siltstones, clays, sands with phosphorites (up to 4 m thick, with the Makartyn suite lying on the crystalline basement of the Ukrainian Shield, the Kryven'kyi and Psel suites of the Depression), thinly rhythmically banded series of multicolored argillites, siltstones and sandstones (the Stryi and Yamne suites, up to 3000 m thick, located in the Carpathians).

Eocene. Whereas the Bakhchysarai horizon in southern Ukraine is rich in a variety of organic remains, the deposits in the Kaniv horizon are much poorer in fauna. They include sandy and organogenic detrital limestones, clays and sands up to 25 m in thickness. A time analogue of this horizon in the north is most of the Buchach horizon which is poor in organogenic remains. It is represented by organo-detrital limestones, marls, sandstones (continental and marine shores), and coal-bearing sandy-clayey deposits, measuring on average between 15 and 20 m in thickness. The upper part of the Buchach horizon corresponds to the lower part of the Novopavlivs'ke horizon or the Kuberlin subhorizon. Analogues of this subhorizon are known in the southern slopes of the Ukrainian Shield, and in the upper part of the Buchach series. These deposits include marls, sandy limestones and sandstones, in total up to 50 m in thickness. A corresponding Vyhoda horizon in the Carpathians consists of roughly rhythmical flysch deposits of thinly bedded but massive sandstones and siltstones, ranging in total thickness from 110 to 350 m.

The Kyiv horizon in the northern Ukraine is correlated with the upper part of the Novopavlivka and Kumove horizons of Crimea and the Black Sea areas. They consist of marls, carbonate-clays, tripoli-like and limey sandy-clayey deposits, up to 30 m in total thickness. In the core of the section of these rocks, there are phosphorite-bearing sands, and limey glauconites. They are generally 3-4 m in thickness, but in places 4-5 m in thickness. The Obukhiv horizon in the northern part of Ukraine belongs

to the Upper Eocene. It is present in the Volyn'-Podillia, Ukrainian Shield, Dnipro-Donets' Depression and along the margins of the Donets' Basin. In each region there are some specific lithological and organic remains which allow to correlate suites, or its subdivisions with the Obukhiv horizon. Their total thickness varies from 5 to 30 m.

The Obukhiv suite of various parts of Ukraine, to a greater or lesser extent, is characterized by similar lithofacies features. The deposits of this suite do not have any associated carbonates. One of the lithological components of this suite is a silty clay which, in the Kyiv region, is micaceous and glauconitic. Other than this, the characteristic feature of this suite is the variability of its sandstones, especially those that contain silicified remains.

Oligocene. The Mezhyhiria horizon of northern Ukraine is correlated with the Planorbil horizon (Borysthenian suite, part of the Maykop series, Indol and Kyzylzhar suites, and Zubakyné deposit) of the Black Sea Depression and Crimea. Lithologically, it consists mainly of a variety of sands (greenish-yellow, patchy-colored, fine grained, clayey, glauconitic, phosphorite-bearing) and clayey-cherty sandstones, generally 15-20 m in thickness and in places up to 85 m in thickness. In the Kins'ka-Yaly Depression there are glauconite-bearing clayey sands with some mangano-calcite. Their total thickness here is up to 30 m.

The Bereka horizon in northern Ukraine is correlatable with the Molochna horizon and the lower half of the Kermut horizon (Molochna, Sirohozha and Askania suites) of the Black Sea Depression and Crimea. Lithologically, they consist of calcareous clays, siltstones and sandstones with organic remains, in total measuring from 20 to 100 m in thickness. These remains allow for reliable correlations with other horizons.

Of special interest are the felsic volcanic-looking rocks of a new type. Lava-like and pyroclastic-looking rocks are chemically similar to the dacites and andesite-dacites. There are also some variants of basic rocks that have more basic chemistries. These rocks are found at the base of the sections in the Bovtyshka and Rotmistrivka depressions which are believed to be meteorite impact sites, or astroblemes as they are commonly known. Some investigators have proposed that these volcanic-looking rocks are impact melts of the target rocks. In the Paleocene, a second phase of vulcanism produced pyroclastic deposits and volcanogenic-sedimentary deposits, both on land and in a marine basin with islands. (These are possibly also related to the astrobleme).

The existence of volcanic centers during the Cretaceous-Paleogene period, the classification and recognition of a series of tectono-magmatic and volcanic structures in the central part of the Ukrainian Shield, allows for new insight into the problems of the Alpine type of volcanic structures (and volcano-plutonic associations) of the ancient platforms. This provides a possibility to evaluate their potential for a variety of mineralizations and to appreciate their role in the formation and distribution of the fossil fuels.

The history of the geological development of the coal-bearing basins over the Ukrainian Shield demonstrates a distinct in-

heritance of tectonic and tectono-magmatic elements and their influence on the distribution of the coal-bearing strata.

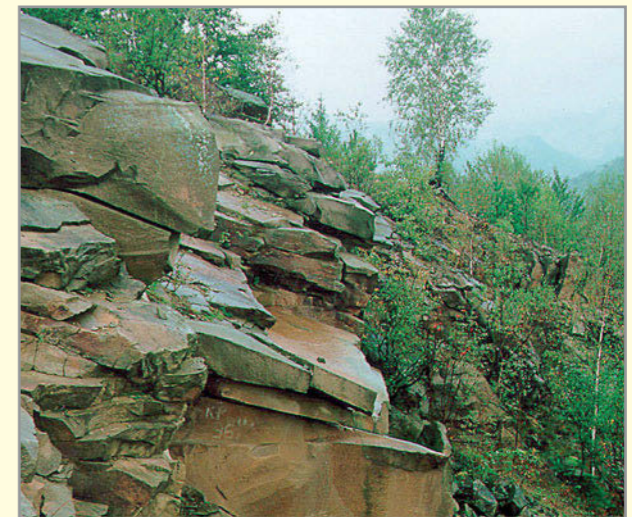
The regions of sedimentation with coal strata, starting from the Paleozoic to the Cenozoic eras, tended to migrate from the mobile areas to the interior of the continent, occupying terrains with the most stable geotectonic regime, or the most mature Earth's crust. This process is well illustrated in the migration of the coal-bearing strata from the mobile part of the depression of the Donets' Basin towards the Shield area during the Carboniferous period, in the Jurassic and in the Paleogene.

The map also illustrates a number of major faults which have been determined by a number of methods. The system of faults have their differences in the order, style of development and metallogenic associations.

On the basis of the above data, the following conclusions can be made:

1. During the Paleocene-Middle Eocene, large erosional tectonic valley-like depressions were formed.
2. Favorable climatic conditions were conducive to the chemical weathering of the crystalline basement and formation of large deposits of kaolin over much of the Ukrainian Shield.
3. There were periods of coal accumulation.
4. Weathering, transport by water, sorting and washing of minerals produced placer deposits of ilmenite-rutile-zircon assemblages and cassiterite.
5. These deposits have a relatively unchanging composition and are flat lying.
6. During the Paleocene-Eocene and Oligocene periods, deposits of glauconite-phosphorites, and carbonate-terrigenous strata were formed. On the northern side of the Black Sea Depression terrigenous-carbonate manganese deposits formed during the Oligocene-Miocene.
7. Reactivation of the Caucasian east-westerly trending faults (280-290°) and partly north-westerly trending Donets' faults (310-320°) occurred.
8. During the Paleocene and Early and Middle Eocene a number of lithofacies and zones of maximum accumulation of terrigenous carbonate rocks were developed. They inherited westerly and northwesterly trends of the underlying structures.
9. Within the platform blocks, the main ore controlling structures were tectonic zones and deep-seated faults.
10. There are current long-lasting zones of activation, which are related to the deep-seated causes in the geological blocks.
11. The deep water depression under the Black Sea was formed in the Late Eocene-Early Oligocene.
12. The movements display orthogonal azimuthal directions and the platform structures have a latitudinal orientation.
13. The Bovtyshka and other astroblemes were formed.
14. Characteristic metallogenic indications include:

The early part of the Paleogene is characterized by a continental and later by a transgressive regime over much of the Ukrainian Shield. The continental deposits contain brown coals (Dniprobass), secondary kaolin deposits, and placers of titanium and zirconium minerals (also found in the marine near-shore



Open pit in Paleogene sandstones of Skole, Lviv oblast'

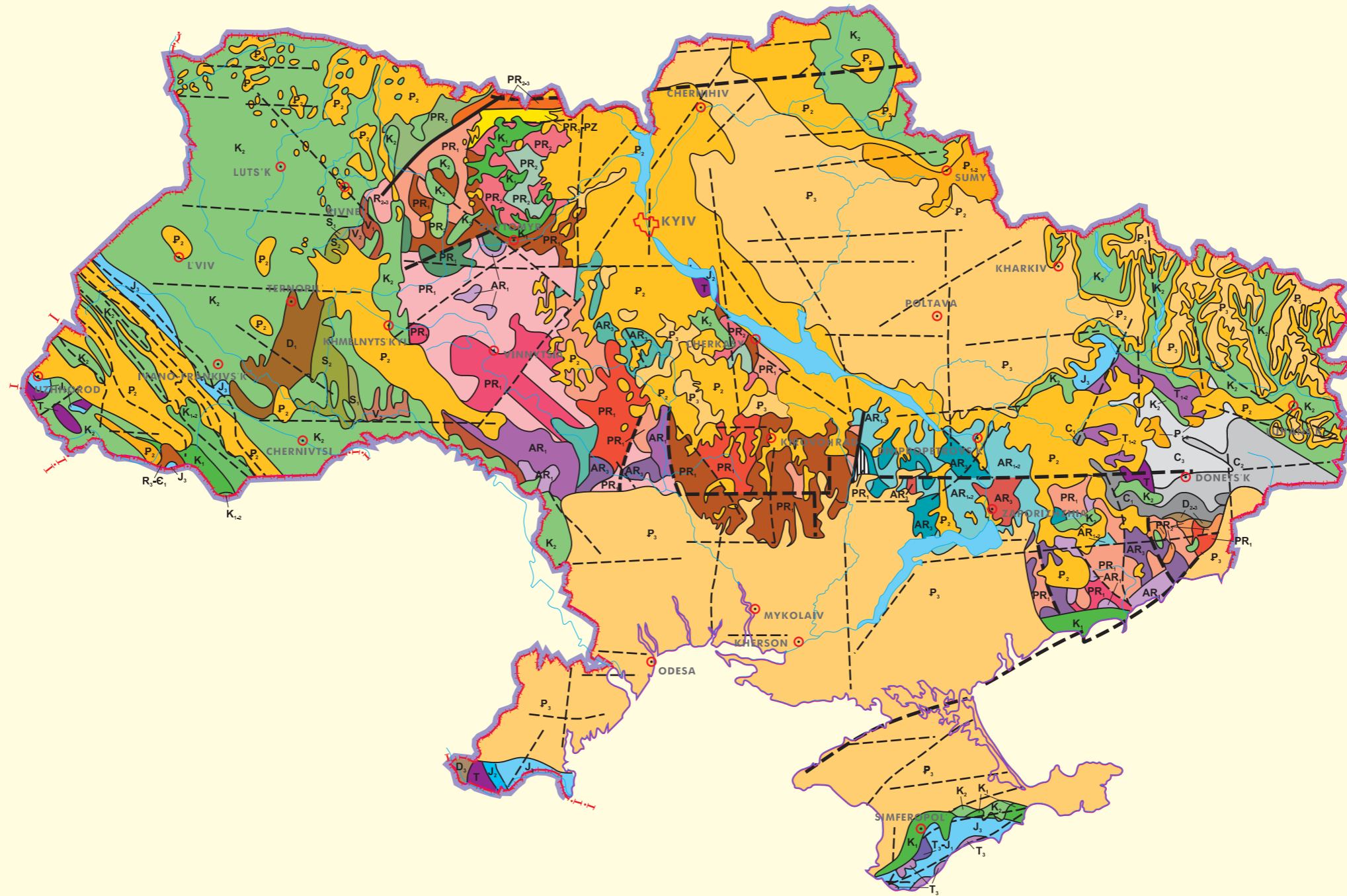
environments). In the Osnyts'k-Volyn' region there are placer deposits and occurrences of ilmenite, and occurrences of zirconium and cassiterite associated with the terrigenous Pliocene-Quaternary strata. Within the Oligocene there are deposits of amber (Vyshhorod, Klesiv).

In the areas of brown coal deposits, the alluvial sands of the Paleogene contain infiltrated uranium deposits (in places with Mo and Re) and occurrences of Pliocene-Quaternary age. Some of these deposits have been mined out by an underground leaching method.

The main ore deposits of the Paleogene age in Ukraine are the sedimentary manganese deposits of the Nikopol' basin. They are some of the largest in the world and are associated with the marine Oligocene strata located over the southern slope of the Ukrainian Shield.

The Paleogene strata on the northern slope of the Carpathians contain menelite schists, and on the southern slope the Paleogene flysch rocks have small hydrothermal showings of mercury, antimony and arsenic.

PRE-NEOGENE (23.8 Ma)



PRE-PALEOGENE (65.0 Ma)

Deposits of the Cretaceous are widely distributed in the platform portion of Ukraine, as well as in the folded complexes of the Crimea and the Carpathians. They are absent in most of the Ukrainian Shield, in the exposed part of the Donets' Basin and in some of the domal structures of the Dnipro-Donets' Depression. They are lying unconformably over Jurassic, Triassic, Permian, Lower Paleozoic and Upper Paleozoic rocks. And in places they are also lying over the Precambrian rocks. They reach the surface at the Dnister river and its tributaries, along the shorelines of some of the rivers in the Ukrainian Shield, along the slopes of the Voronezh Complex (in the basins of the Desna, Seim, Psel, and Vorskla rivers), and in the Kaniv dislocation area.

Numerous Cretaceous occurrences are also found in the Carpathians and the Crimean Mountains. The distribution of Cretaceous deposits, their composition, thickness and size depend on the structural pattern of the regions, and the action of various physical and geographical factors, the most important of which was climate.

At times of inundation by the sea, even over the Shield areas, some carbonate deposits were formed. In some cases the details of the specific lithologies are characterized by local structures or walls, by domes and other structures.

Some of the thickest and largest Cretaceous deposits are associated with troughs, which are divided into two types. The first type of trough is associated with depressions, confined to the Dnipro-Donets' aulacogen and other structures. Troughs of this type occupy large areas and have developed mostly as a result of the Hercynian tectonism. Some of the thickest deposits of this type measure from a few tens of meters to a few hundred meters.

The second type of trough is associated with zones of accretion between platforms and folded structures.

In the Triassic period the distribution of land and sea was dictated by the tectonic development of various regions of that time: the Crimea, the Black Sea Lowland, the Pre-Dobruja, the Carpathians, the Volyn'-Podillia Plate, the Ukrainian Shield, the Donbas and others. A lesser effect was related to the eustatic levels of the oceans. During almost the entire Early and Late Cretaceous period, except for small interruptions, there were marine basins in the area.

The Berias layer, from 40 to 100-200 m in thickness, consists of conglomerates and sandstones with intercalations of clays and marbles carrying organic remains. It has a limited distribution. It is present essentially in the Crimean region in the Kerch district, and in the central part of a graben located on the southeastern edge of the Dnipro-Donets' Depression, where it is represented by a sequence of greenish-gray clays with glauconite and remains of plant life, and in places by siltstones and sandstones carrying complex organic remains (up to 25%). The Valanzhyn layer has a much wider distribution. It is found in the Crimean Mountains, on the Kerch peninsula and in various structural-facies zones of the Dnipro-Donets' Depression where it is represented by reworked clays and small fragment conglomerates with intercalations of sandstones, siltstones, limestones and organic marbles (the Horlynka and Mykolaivka sequences). In total, they measure up to 400 m.

The Hoteryv layer is present in the central and eastern portions of the Crimean Mountains, in the Forecarpathians, in the L'viv-Lublin Depression and in the Dnipro-Donets' Depression. It contains dark-colored pyritized clays, siltstones, fossiliferous (fragmentary) limestones, pseudo-oolitic sandstones, quartz-glauconite sandstones and siltstones. This sequence attains thicknesses up to 300 m. The organic remains indicate a Hoteryv age in these deposits.

The Barem layer appears to be present in all structural-facies zones. It is represented mainly by the marine and the near-shore marine terrigenous deposits, locally with multicolored

and gray shades, that measure up to 400 m in thickness. Locally there are relics of charred trees.

The marine and shallow-water marine near-shore deposits of the Aptian layer are widely distributed in most of the regions of Ukraine. They consist dominantly of sandy clays (30-300 m), kaolinitic, sometimes coal-bearing, or glauconitic, and with organic remains indicating an Aptian age for these deposits. Locally they can be further subdivided into smaller units.

The Albian layer (10-320 m) is present practically everywhere. Thin units of it (2-5 m) are present even over the Ukrainian Shield. They are mainly carbonates and terrigenous deposits with phosphorites. There is in places a porous horizon very rich in water.

The contact with the Upper Cretaceous deposits, in the Crimean flatlands and the southwestern Crimean Mountains, is gradual. In the Black Sea Depression and on the Kerch peninsula, and also in the central and eastern Crimea, the Upper Albian deposits are partly washed out and are covered by the Cenomanian deposits.

The Upper Cretaceous deposits (K_2) are widely distributed in all zones of the Carpathian region. They are differentiated from others by their strong facies variation. This was conducive to many local subdivisions into smaller units.

The Upper Cretaceous consists basically of sandy-clay flysch, carbonate-bearing flysch, rhythmically layered flysch, multicolored argillites with packages of massive limestones, and sandstones. The ages of these flysch deposits all indicate an Upper Cretaceous period.

The Mesozoic magmatism in the Carpathians is characterized by the predominance of effusions over intrusions, by their basic character of the magma, and the development of obducted ophiolites. The latter complexes are represented by small bodies, veins and dykes of gabbro-diorite, gabbro-porphyrite and bodies of serpentinite. Cretaceous age gabbro-diorites and porphyrites are known in the Chyvychny area and along the northeastern edge of the Rakhiv crystalline massif. Cretaceous and Mesozoic serpentinites are known in the basin of the Uhol'ka river, where they occur as relatively small lenses.

The boundary between the Cretaceous and the Paleogene, in terms of the litho-facies, is not a sharp demarcation. It is represented by coarse and moderately rhythmic flysch rocks, sandstones and argillites. On the map the deposits of the Cretaceous-Paleogene are indicated on the southern slope of the Carpathians.

In the Forecarpathian Depression all members of the Upper Cretaceous deposits are present, for a total of about 390-400 m in thickness.

In the Azov region, over the southern slope of the Ukrainian Shield and under the Azov Sea, there is a well-developed sequence of the Upper Cretaceous. It consists of shallow water organogenic detrital limestones. On the southern and eastern slopes of the Azov crystalline massif, the Upper Cretaceous sections are shortened (on the southern side mainly the Cenomanian and partly the Lower Turonian deposits are represented by marbles and chalk, and to the east of these there are the Lower Santonian and Campanian deposits represented by similar facies of marbles and chalk).

Within the Dnipro-Donets' Depression, according to the features of their composition, size and paleontological characteristics, three regions are recognized – the northwestern, central and southeastern. The most complicated Upper Cretaceous is found in the northwestern region. Here the sections are incomplete, with commonly variable lithological assemblages and variable thicknesses. There are interruptions which affect various parts of the stratigraphy. In the Santonian-Campanian deposits there is evidence of introduction of sand into the system, especially in the salt domes and the anticlinal uplifts, with the sand content increasing from east to west. These deposits are of terrigenous-carbonate character which have been noted over large areas start-

ing from the city of Nizhyn and towards the Chernihiv rise. Here the thickness of the Upper Cretaceous deposits (142 m) decreases by a factor of 2-3, in comparison with the rest of the region. In the central region the marbles-chalk assemblage is dominant and increases in thickness to about 890 m.

The southeastern region is characterized by the appearance of new and continuous sections measuring over 760 m in thickness. Here the relatively unchanging chalky-marbles are present, with a very minor terrigenous component.

The Dnipro region of the Ukrainian Shield and the Dnipro-Donets' Depression are closely tied in terms of the stratification features of the Upper Cretaceous deposits. They have an island-like distribution and appear to be related to a decrease in the Pre-Cretaceous relief of the area. Sections of the Upper Cretaceous deposits are represented here by the Cenomanian, Turonian, Coniacian, and Santonian deposits, which are mainly of terrigenous-cherty compositions.

Within the Donets' Basin the Upper Cretaceous deposits were forming under more than one set of facies conditions and were influenced largely by the structural-tectonic peculiarities. The Upper Cretaceous deposits of the northern and southern parts of the Basin are different in terms of their facies and faunal features. In the northern part, three regions are distinguished – the western, the northwestern and the northern (marked by a zone of tight folding).

The southern slopes of the Donbas form a separate region which is characterized by a distinct tectonic activity during the Late Cretaceous period. This resulted in variable sections in different places and the production of bottle-like structures in the Upper Campanian and Lower Maastrichtian submembers. The southern part of the platform of Ukraine includes the Black Sea and the Kins'ka-Yaly troughs and the southern slope of the Ukrainian Shield. Here, according to the Upper Cretaceous sections, a number of structurally related facies of rocks are recognized.

The Kins'ka-Yaly trough is part of a complex blocky structure containing an almost complete assemblage of the Upper Cretaceous deposits, but with a highly irregular distribution. They are represented by the Coniacian, Santonian and the lower part of the Campanian members consisting of chalk-like limestones and marbles. On the south side of the Near-Black Sea trough (an area between the Dnister and south Buh rivers) all members of the Upper Cretaceous are developed except for the Upper Maastrichtian submember. The Upper Cretaceous deposits are represented by chalk-like marbles and chalk having a relatively small thickness of about 250 m. In the Forecarpathian-Syvas region a complete Upper Cretaceous section is present, and consists of relatively deep water limestones (rarely marbles) with thicknesses over 1000 m in places.

In the Black Sea sloping area of the Ukrainian Shield there are mainly Cenomanian and partly Turonian deposits. In the Bilozerka-Velykyi Tokmak region, close to the locally preserved Cenomanian deposits, the most widely distributed are the Upper Campanian deposits which consist of variable rock facies.

In the Crimean Mountains the Upper Cretaceous deposits measure from 400 to 600 m in thickness. Their thickness on the Kerch peninsula does not exceed 500 m, but to the west of Dzhankoi, their thickness increases to 1500 m, and on the Tarkhankut peninsula, their thickness exceeds 2400 m.

The Cenomanian, Turonian and Koniakian members in the Crimean Mountains are 25 to 240 m in thickness and are present everywhere on the underlying Lower Cretaceous and Middle Jurassic. The underlying rocks in places show evidence of erosion. In the Northern Crimean and Northern Azov depressions there are Cenomanian-Turonian-Koniakian deposits measuring 100 to 1000 m in thickness. At the base there are marbles with intercalations of limestones, clays with lenses of spongolites (spicule-bearing siliceous chemical sediments), tuffs, tuffites and



Cretaceous deposits, Donbas

tuff-sandstones. The Santonian-Campanian-Maastrichtian layer is not commonly subdivided, and consists of marbles and chalk-like limestones with intercalations of clayey marbles. Two stages of volcanic activity are noted in Crimea – Early to Middle Albian which is characterized by lavas emanating from fractures, and Late Albian-Cenomanian which is characterized by explosive volcanism.

The Pre-Paleogene rocks have the following characteristics:

1. Large-scale rearrangements of geological structures at the Cretaceous-Paleogene boundary.
2. Activation of transregional and regional faults which separate large geological structures in the sedimentary cover (the Carpathians, the Carpathian Foredeep, the East European Platform, the Scythian Plate).
3. Evolution of linear dislocation zones related to deep faults (Oster-Zolotonosha rampart, Kins'ka fault and others).
4. Discordance between paleotectonic and neotectonic areas, expressed by a displacement of their axes of flexuring.
5. Accumulation of glauconite-phosphorite and carbonate formations in the Cenomanian times.
6. Magmatic activity in the Crimea and in the Donets' Basin, related to the stages of platform activation.
7. In the Lower Cretaceous, most of the sedimentation within the Ukrainian Shield occurred in valley-like depressions formed in Pre-Cretaceous times. Such valleys are mainly of erosional-tectonic origin.
8. Characteristic metallogenic indications include:

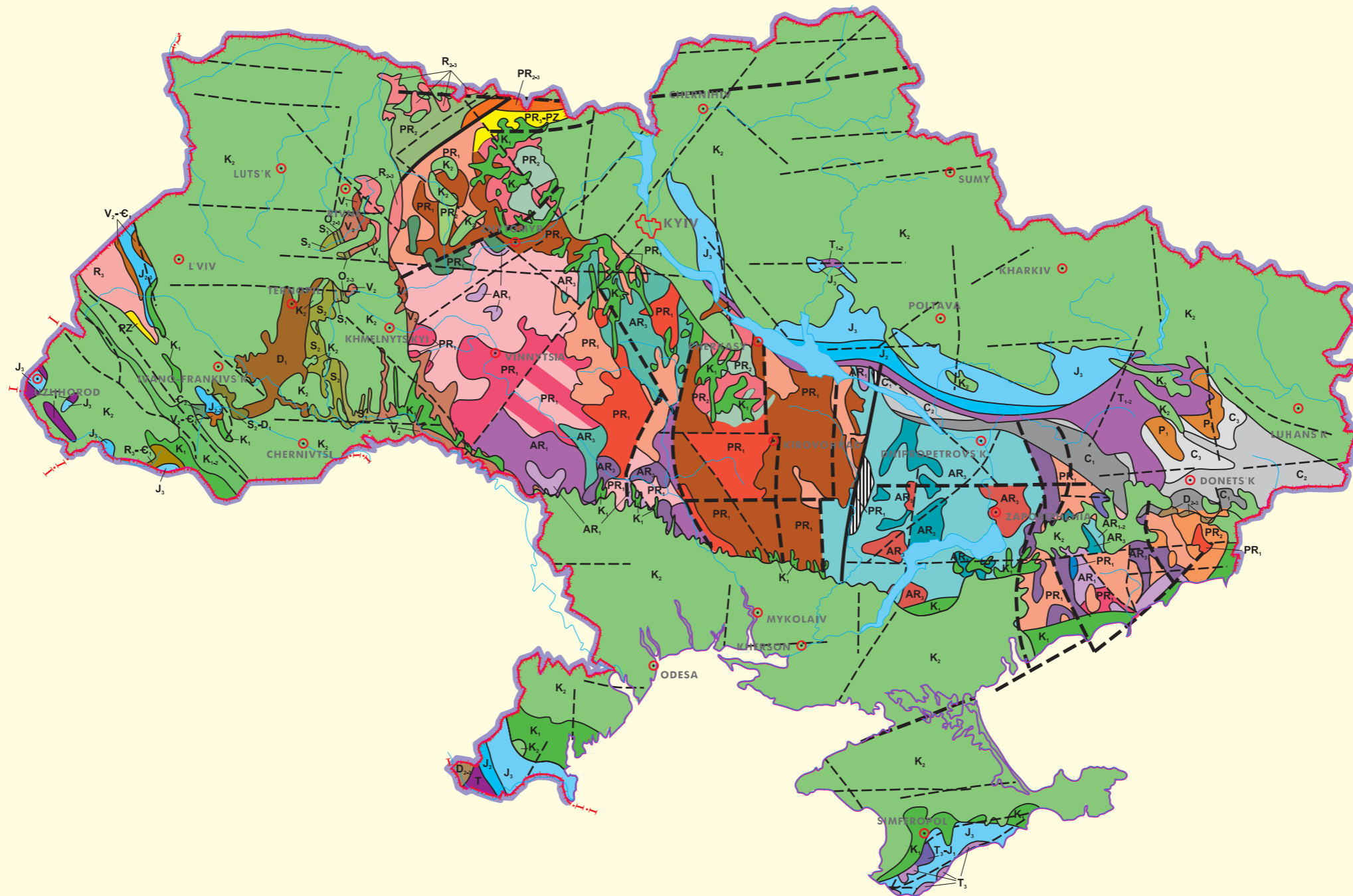
On the Ukrainian Shield under the Paleogene strata there is a widespread weathering crust with primary kaolin deposits. Within the paleovalleys filled by Lower Cretaceous strata there are minor gold placer deposits found over the northern slope of the Ukrainian Shield. On the southern slope of the Ukrainian Shield there are sedimentary-diagenetic occurrences of uranium in similar environments.

Cretaceous bauxite deposits of moderate size (Vysokopillia and Nikopol') are associated with lateritic weathering of the crust. The Smila bauxite deposit appears to be of sedimentary origin. In the Dnister river area there are paleovalleys of the Cenomanian age that contain high-grade bauxite deposits.

In the marine strata of the Albian-Cenomanian age in the Volyn'-Podillia Plate there are occurrences and deposits of sandy, lens-like and plate-like phosphorus.

Of some economic significance to the sugar-producing factories, cement industry and others are the deposits of chalk and limestone. These deposits were commonly developed in the Upper Cretaceous and are widespread over the Ukrainian territory.

PRE-PALEOGENE (65.0 Ma)





Polygonal basalt flows, Berestovets' village, Rivne oblast'



Aiudag (Bear Mountain), a Jurassic laccolith, at Partenit, Southern Crimea



Runa alpine meadow (polonyna), Carpathians, Lviv oblast'

PRE-CRETACEOUS (142±2.6 Ma)

The Pre-Cretaceous deposits of the Jurassic period are well developed in all Paleozoic assemblages throughout Ukraine. They are found in the Carpathian and Crimean Mountains, in the Dnister River and in the Donbas areas. They are divided into the Upper, Middle and Lower Jurassic series which are further subdivided into groups, subgroups and in many cases even into zones. The most fully developed assemblages are found in the northwestern part of the Donets' Basin, and in the Dnipro-Donets' Depression.

The Jurassic strata are lying at an angle, stratigraphically parallel to various underlying Triassic rocks, and on the slopes of the Ukrainian Shield where they are in contact with the basement rocks.

The Lower Jurassic strata of the Crimean Mountains contain a thick assemblage of flysch rocks, which are part of the Tavrian Series localized in the Kacha, Southshore and Tuats'k uplifts. They are represented by the complexly rhythmically banded assemblage 200-700 m in thickness, interbanded with units of sandstones, siltstones and argillites and with lens-like layers of siderites and limestones.

The Middle Jurassic rocks in the Crimea come to the surface in the peripheral parts of large uplifts. Here two assemblages are well developed – a lower terrigenous and an upper volcanogenic stratum having a total thickness of about 1000 m on average. The volcanogenic assemblage consists of tuffs and lavas of different compositions and vary in thickness from 700 to 1500 m. The most fully developed section is in the area of the Karadah Mountain. Here it consists of andesitic and diabasic

porphyrites, andesites, diabases and diabasic tuffs, and liparites and overlies argillites which, according to the faunal record, belong to the Lower Jurassic period.

The Middle Jurassic represents the most active magmatic period in Crimea, and is characterized by large-scale extrusions of different compositions. The spillite-keratophyre type of volcanism is widely developed and is associated with multiphase extrusions of the central type. It is accompanied by a subvolcanic intrusive dyke activity. The Middle Jurassic interval includes also the granodiorite, plagiogranite, gabbroic diapir, and gabbro-diabase intrusive magmatism. The massifs of such mountains as Ayudag, Kastel', Shakhra, and others are related to this magmatism.

The Upper Jurassic series are divided into the Oxfordian, Kimmeridgian and Volga members. They consist (from the bottom to the top) of limestones, oolitic, biohermal and cherty rocks (60 m), which are overlain in places by unconformable layers of glauconitic clay and shell-bearing limestones (30-65 m), sandstones and shell-bearing limestones (30-35 m), and by multi-coloured clays and sandstones (100-180 m). All of the above-mentioned deposits commonly contain organic matter, which has been dated to be of Kimmeridgian to Volga stages.

The Jurassic rocks in the Dnipro-Donets' Depression are represented by their Middle and Upper series. The Upper series are represented by the Oxfordian, Kimmeridgian and Volga members. In the northwestern part of the Donbas region all three series are present. In the northwestern and western parts of the Dnipro-Donets' Depression mainly the Oxfordian and the lower Kimmeridgian members are present, represented by lime-

stones with interlayers of clay, siltstone, and sandstone (50-130 m). Their organic materials are dated to belong to the Oxfordian to early Kimmeridgian. In the eastern part of the Depression, the Oxfordian and Kimmeridgian analogs are represented by limey clays with oolites of chamosite, up to 30-40 m in thickness.

The Jurassic volcanism in the Donets' folded region and in the Dnipro-Donets' Depression has been of interest to geologists in the past and continues to be so to the present day. The Middle Jurassic volcanics of the Obolon' Depression are represented by tuff-breccias and breccias with angular fragments of granitoids and mineral fragments of feldspar, quartz, garnet, biotite, chlorite, muscovite and graphite. The breccias are reworked or pass laterally into tuffogenic sandstones, quartzite-like sandstones, arkoses, and tuff-breccias with complex textures. In the tuffs there are, locally, units of amygdaloidal lava breccias with well-developed flowage features. The tuffogenic rocks show evidence of silicification, carbonation, and intense chloritization. Pyrite and arsenopyrite are commonly developed along fractures and as segregations.

In the Boryspil' tectono-magmatic structure there are volcanic glasses of felsic and intermediate compositions, and there are also fragments of andesites in the Middle Jurassic clayey sandstone rocks. The Boryspil' structure is defined by the Dnipro, Yadviv-Trakhtemyriv and Stuhniv faults.

A belt of dykes with monchiquite and camptonite compositions of Late Jurassic to Early Cretaceous age define the Mius lamprophyric complex. It is located in the Amvrosiivka raion of the Donbas, and is exposed along the Mius and Krynka rivers. These

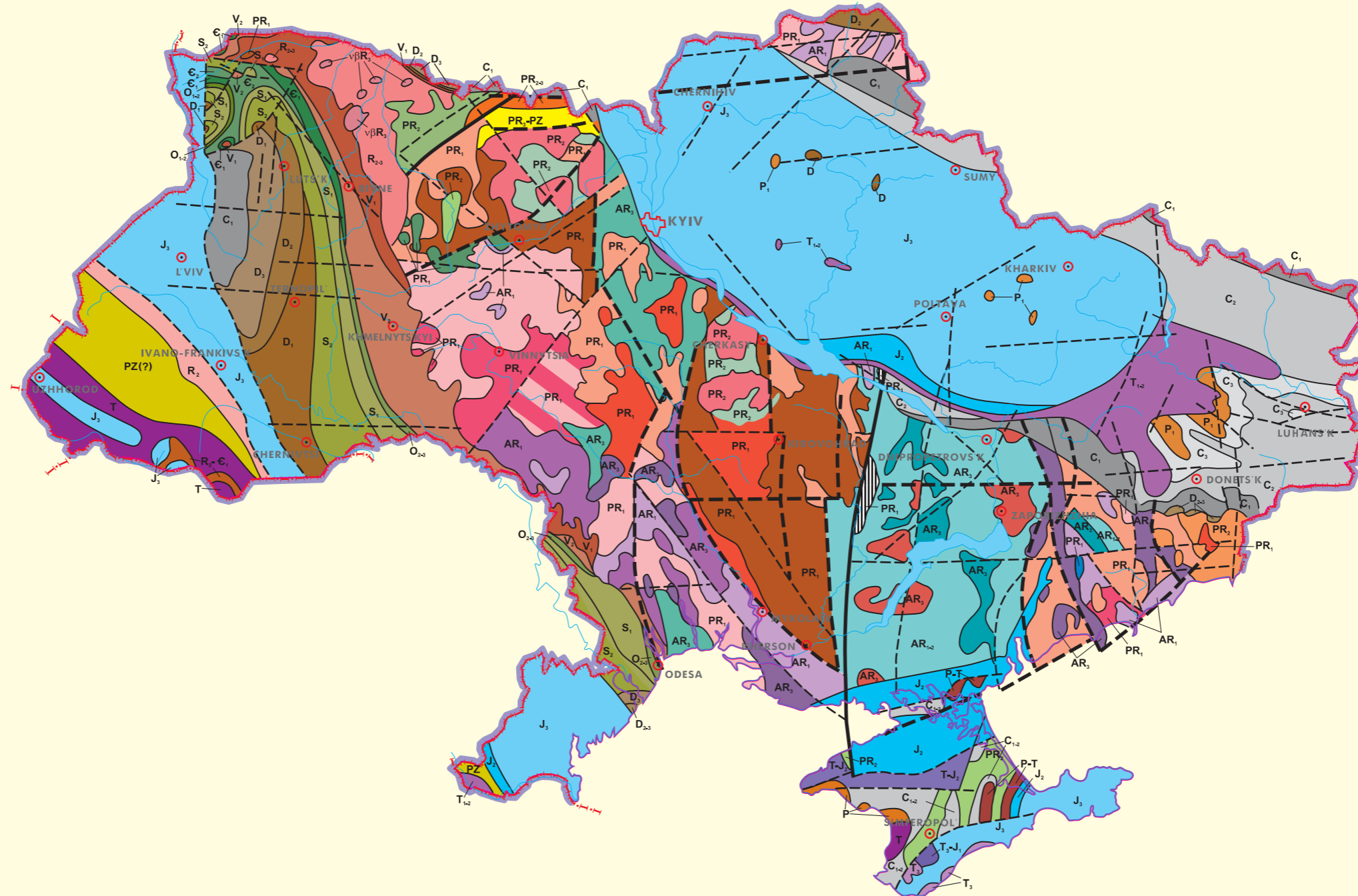
are the youngest magmatic rocks in the Donbas region.

Dykes of lamprophyres and gabbro-diabases of the Mesozoic age are found in the Mariupol' area. The dykes are localized along the marginal parts of the Mariupol' horst structure. The latter is separated by an East-Mariupol' zone of faults from the adjacent graben-like structure that is part of the Northern Azov Depression.

The discoveries of lamprophyric dykes of the Late Triassic age, and dykes of gabbro-diabase of the Jurassic age in the East-Mariupol' zones confirm a cycle of Mesozoic magmatic activity. In summary, the Pre-Cretaceous or the Jurassic periods are characterized by the following:

1. The transregional and regional deep faults, with their short duration activation periods, played an important role in forming various structures in the Jurassic period.
2. There is stratigraphic control in the distribution of the chamosite iron deposits and the evaporitic deposits in the Jurassic period.
3. The Jurassic coal-bearing terrigenous formations are localized in valley-like depressions, both in the Ukrainian Shield and in the Dnipro-Donets' Depression.
4. In the L'viv Depression the Jurassic strata contain deposits of kaolinitic clays and brown coals at depths of about 1 km. In the Dnipro-Donets' Depression there are sedimentary iron deposits at 200-500 m depths in the southeastern part of the Depression. The mineralization consists of a bedded sequence of chamosite-bearing sandstones and clayey siderites. Recently, similar deposits have been discovered in the Jurassic rocks of the Dobruja Depression in Odesa oblast'.

PRE-CRETACEOUS (142±2.6 Ma)





Proterozoic granite, the Vysokyi Kamin' cliff, Zhytomyr oblast'



Blyzniata (the Twins) Rock, at Adalary, Crimea



Khrebet dynozavra (the Dinosaur Backbone) Rock, in the Sudak raion, Southern Crimea

PRE-JURASSIC (206.5±4 Ma)

In the Early Mesozoic era a new stage of development occurred on the territory of Ukraine. There was a wide deposition of Triassic rocks in the Carpathian and Crimean Mountain areas, in the Donbas and the Dnipro-Donets' Depression, on the northern slopes of the Ukrainian Shield and the Voronezh Complex, and in the Pre-Dobruja Depression.

In the western part of the Donbas and the Dnipro-Donets' Depression, the Triassic rocks include a thick sequence of multicolored sandy-carbonaceous units. They are characterized by a strong lithological variability, common thinning-out of some layers, and paucity of organic remains. The Triassic rocks are found on top of the Permian, but along the edges of the Dnipro-Donets' Depression they are in some places underlain by siliceous coals and by the Precambrian rocks, and overlain unconformably by the Jurassic and Paleogene, and rarely by chalky deposits. The thickest Triassic sequences are associated with the deep portions of the depressions. Other Triassic rocks are found as fills in the graben-like Pre-Dobruja structures and erosional depressions, especially over the folded parts of the system. In total, the Triassic sequence here is estimated to be in the order of about 2000 m. The Middle Triassic, measuring about 350 m, consists of brecciated limestones and dolomites, found in the valley of the Danube river, and contains some gastropods. Diamond drilling in the Kiliia graben revealed Middle Triassic rocks comprising mainly limestones with foraminifera and ostracod fossils. In the vicinity of the town of Vylkove and the Kytai Lake the limestones of the Middle Triassic are dolomitized and locally brecciated.

The Upper Triassic rocks, represented by marine and lagoon-continental facies, such as sandstones with intercalations of limestone, argillite, siltstone and marls, measure up to about 1000 m. In the Al'ma Depression of the Crimean Lowland, diamond drilling has intersected Triassic rocks at depths from 90 to 1100 m. They consist of dark gray argillites with intercalations of siltstone, limestone and sandstone. The diamond drill core angles indicate that these rocks have dips of 10-35° to 80°. An analogous section of the Triassic has been also intersected by diamond drilling in the Northern Crimea Depression.

Within the Crimean Mountains there are abundant terrigenous-flysch deposits which belong to the Tavrian series of the Upper Triassic-Lower Jurassic period. The lower parts of the series are composed of argillites, interbanded with siltstones, sandstones and sequences of black argillites, lenses of quartzite-like and

coarse-grained sandstones, and intercalations of conglomerates. The upper part of the series is represented by argillites with lenses of limestone and some flysch deposits. The total thickness of the Triassic rocks is over 2000 m.

In the Tuats'k and the Kacha uplifts, there are deposits of sandstone-argillite flysch, which in their upper portion are intercalated with quartzite-like sandstone. In total this sequence measures 1200-3500 m in thickness. It is faulted and separated into blocks. The fauna in these rocks indicate that they belong to the Carnian and Norian stages of the Triassic period.

In the Carpathian Mountains, the Triassic rocks occur in the Rakhiv and the Chyvchyn zones. Diamond drilling indicates the presence of these above the basement of the Transcarpathian Depression, where Triassic rocks are represented, in their lower sequence (up to 250 m thick), by quartz conglomerates and breccias, sandstones, red siliceous argillites and limestones. A middle sequence, up to 400 m in thickness, consists of diabases, porphyrites, tuffs and some limestones and dolomites. An upper sequence, up to 200 m in thickness, consists of white massive fossiliferous limestones and thinly layered limestones with intercalations of black and green micaceous slivers. In the Donbas region the Lower and Middle Triassic rocks comprise calcareous sandstone (20-90 m) and clayey siltstone assemblages. The first is characterized by multicolored fragmentary materials which are mainly of quartzo-feldspathic sandstones, sand-gravels, and limestones with thin intercalations of clay and, rarely, siltstones. The limestones form layers, generally less than 10 m in thickness, as in the southwestern part of the Kal'mius-Torets' trench.

The Triassic sequence described above stands out in the diamond drill sections on account of its high geophysical resistivity, excellent horizon-marking characteristics and wide utility in correlations of geological sections.

The overlying Lower to Middle Triassic deposits are represented by an interbanded sequence of sandstones and arkosic greenish-gray and reddish-raspberry-colored clays, with rare intercalations of siltstone and granitic bands. The total thickness of this sequence varies between 100 and 310 m. Its maximum thicknesses are found in the synclinal structures. On the other hand, the thinnest Triassic sequences occur in the anticlinal structures, such as the ones in the uplift at Petrovs'ke-Korul' zone, in the Slovians'k dome, and the Druzhkivka-Kostiantyivka structure. The organic materials in these rocks are represented by ostracods and plant life.

In the northeastern part of the Ukrainian Shield and the Dnipro-

Donets' Depression, the Lower to Middle Triassic sequences (Radchenkove and Myrhorod suites) within a graben structure are up to 380 m in thickness. They consist of fine-grained sandstones and siltstones, interbanded with minor multicolored clays. Towards the deeper portions of the Depression, the Triassic section also contains intercalations of gravelites and small fragment conglomerates, and is marked by an increase in the red-colored clays with minor intercalations of siltstone, sandstone, concretionary limestone and argillite. Its thickness is about 100 m. Fossil records here indicate Olenek to Ladinian Triassic stages.

The Upper Triassic sequence in the Donbas region is represented by the Protopyv and Novoray suites. The Protopyv suite, about 95-300 m in thickness, consists of clays and multicolored siltstones, gray and greenish-gray sandstones, reddish-brown siltstones, and clays composed of hydrous mica-kaolin-montmorillonite assemblages. There are relics of charred plant life detritus. The flora of this suite have been assigned to the Norian stage in the Triassic.

The Norian suite, about 100 m in thickness, comprises sandstones and quartz sandstones, as well as siltstones with some flora fossils.

The Triassic-Middle Jurassic deposits of the Crimean Lowland are represented by the sedimentary-effusive rocks, which occupy a wide belt between grabens (Late Paleozoic to Early Mesozoic age) marking a zone of accretion between the East European Platform and the Scythian Plate. Here the Triassic rocks are lying either directly on the Precambrian, or on the Upper Paleozoic deposits (as on the northern edge of the Karkinit-Syvash graben), or on the folded Hercynian basement of the Scythian Plate. The thickness of the sequence of rocks is estimated by geophysical methods to be in the order of 2.5-3.0 km.

There is considerable dislocation of rocks in this area as indicated by the diamond drill core, with the core angles varying from 10-15° to 80°. The intense volcanic activity, (and lesser magmatic activity), so characteristic of the Triassic-Jurassic period in the Crimean Lowland, provide a possible explanation for the Kimmeridgian activation of the deep-seated faults.

In summary, the Pre-Jurassic period is characterized by the following:

1. The continental Triassic rocks in the Dnipro-Donets' Depression, in the Donets' Basin, in the Dobruja Foredeep and other areas are represented by multicolored formations of reddish-brown, gray, light-gray and yellowish-gray color patterns.

2. There is commonly a rhythmic pattern or cyclicity in color, grain size and lithology which is seen in various sections as a sequencing of clays, siltstones, sands and sandstones of variable grain size as well as conglomerates.

3. There is evidence of old weathered rocks in section and over large areas. All reddish-brown layers are considered to be the fossilized weathering products (fegolith), or products of their immediate redeposition.

4. Triassic sediments dominate over Upper Carboniferous-Lower Permian deposits in the Dnipro-Donets' Depression.
5. Triassic deposits have a regional normal stratigraphic relationship with the underlying rocks or in places are lying unconformably over them.

6. Triassic was the closing stage of the Dnipro-Donets' Depression (aulacogen) development.

7. There is evidence of the existence of rivers cutting dry land in Triassic times; river valleys have been shown to exist in the Middle Jurassic also.

8. The boundary between the Permian and the Triassic was internationally accepted as one of the most important boundaries which demarcates the Paleozoic and the Mesozoic eras. There was a great pause in the development of fauna in this time interval.

9. The Triassic period is characterized by a partial reactivation of faults, and an intense manifestation of salt tectonics (Burimka, Ivanhorod, Parafiivka and Ivanytsia stocks).

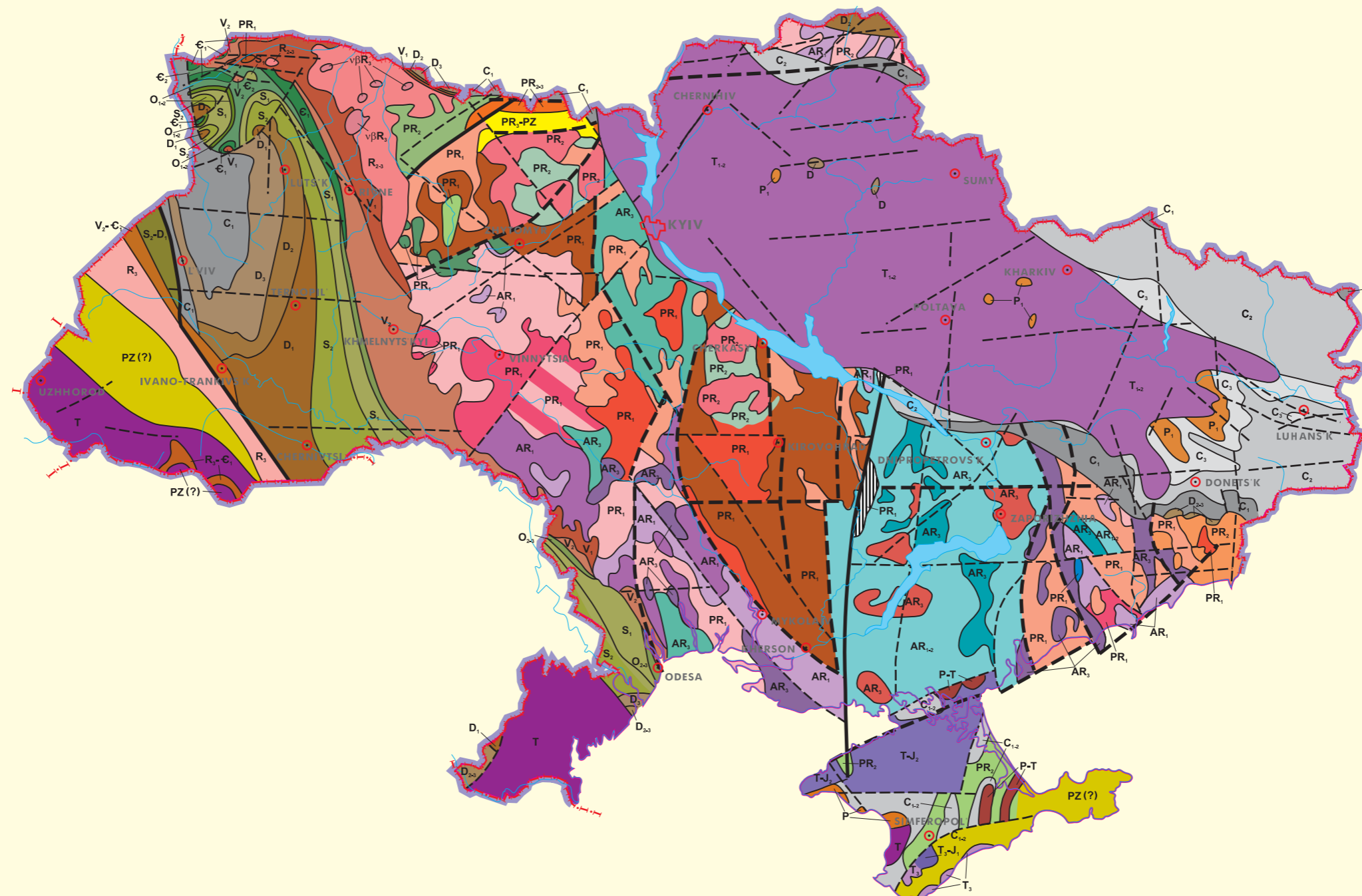
10. Triassic layers inherited the orientation of the older Paleozoic folds (the Bakhmut Depression, Solokhiv, Hlyns'k-Rozbyshivka and other brachyanticlinal structures).

11. Triassic rocks are weakly dislocated in areas with no salt tectonics (Loyiv-Brahyn ridge, flanks of the Dnipro-Donets' Depression). In some cases the edges of the structural zones are complicated by terrace-like structures and structural protrusions.
12. Magmatic activity culminated in the Triassic period.

13. The Triassic rocks are well developed in the Dnipro-Donets' Depression. In the Bakhmut area they contain bentonite clay deposits (Hryhorivka and others). In the southwestern part of the Depression within the red-colored Droniv suite of Permian-Triassic or Lower Triassic age there are the uranium-bearing bituminous showings and deposits (Adamivka, Chervonyi Oskil and Bereka). Such deposits have elevated Mo, Sc and V contents and are also characterized by chrome, mercury and polymetallic mineralization.

In the Rakhiv massif of the Carpathian Mountains there are showings of bauxite related to the Triassic weathering.

PRE-JURASSIC (206.5±4 Ma)



PRE-TRIASSIC (248.2±4.8 Ma)

The Pre-Triassic (Permian) slice map shows further geological developments in the Ukrainian territory. Permian deposits are present in the Donbas, the Dnipro-Donets' Depression, the Prypiat' Graben, the Fore-Dobruzhian Depression and locally in some of the Crimean blocks. The most complete Permian section occurs in the Bakhmut trench in the Donbas. Permian rocks in the Donbas fill the Bakhmut and the Kalmius-Torets' trenches. In the Donets' Basin and in the central part of the Prypiat'-Dnipro Depression, the Lower Permian deposits are present and are subdivided into four suites – the Kartamysha, the Mykytiv, the Slovians'k and the Kramators'k suites. The first three belong to the Asselian sequence and the fourth to the Sakmarian sequence of the Permian assemblage. The Asselian sequence. The Kartamysha suite is 400 to 1100 m in thickness, and is well developed in the Kal'mius-Torets' and Bakhmut troughs where it consists commonly of red and less commonly of multicolored argillites, siltstones, micaceous sandstones, and in places of gravelites. The Mykytiv suite is 100 to 250 m thick, and is lying conformably on the Kartamysha suite. It consists of sandy-clays with layers (1-5 m) of limestones, dolomites and anhydrites. Within the northwestern part of the Bakhmut trough there are also layers of salt of considerable thickness. Close to the boundary with the Dnipro-Donets' Depression this suite has four layers of rock salt, up to 25-55 m in total thickness.

The Slovians'k suite is 250 to 610 m thick, and it lies conformably on the Mykytivka suite. It has been well studied in the environment of the Artemivs'k salt deposit. Within the Kal'mius-Torets' trough this suite consists mainly of sandy-clay multicolored deposits. There are also some carbonate deposits but they are thin, clayey and sandy. Layers of salt are present only in the upper half of the suite. In the Bakhmut trough, the Slovians'k suite consists mainly (70-90%) of salt and anhydrite. The Sakmarian sequence consists dominantly of red chemical precipitates, contains the Kramators'k suite, and measures 50 to 525 m in thickness. The Kramators'k suite is further subdivided into three horizons: the lowermost calcareous siltstones (up to 40 m thick), the middle anhydrite (0-30 m thick), and the uppermost rock salt (40 m thick). In the Donbas there is evidence of magmatic activity in the Permian period. This activity is restricted to the emplacement of dykes of andesitic and trachyandesitic compositions. Within the Fore-Dobruja Depression, diamond drilling exploration encountered chemical precipitates and terrigenous deposits. These rocks are lying unconformably over Lower Carboniferous rocks, and are covered by Middle Triassic and Jurassic rocks. Deep diamond drilling also encountered Permian strata in the Crimean part of the Scythian Plate. In the Al'ma trough (Tarkhankut region) at 817 to 1237 m depth intervals there are Permian dolomites, dolomitized and oolitic limestones. In the same area, some terrigenous Permian deposits also have been intersected. They consist of argillites and sandstones and have

variable core angles of 40 to 75°. Deep diamond drilling, on the south side of the Tarkhankut trough, also intersected a sequence of interbanded rocks (400-600 m in thickness) that consists of metamorphosed sandstones and minor carbonates of Permian age. These rocks are at 2700 to 2800 m intersections and occur under the Lower Cretaceous strata. Permo-Triassic deposits are also present in trough areas inherited from the Middle Paleozoic depressions. In the Heniches'k region, diamond drilling intersected Permian deposits at the 2900 m level consisting of argillites, with intercalations of siltstones, sandstones and gravelites. These rocks have core angles of 40-45°. Upper Paleozoic rocks have been intersected within the Scythian Plate and include volcanic effusives, volcanic sedimentary rocks, multicolored argillites, siltstones, sandstones and conglomerates. They contain spores and pollen of Permian age. Here, bodies of syenite and syenite porphyries have been also intersected. It is assumed that they are of Late Paleozoic age. In summary, the characteristic features of the Pre-Triassic are as follows:

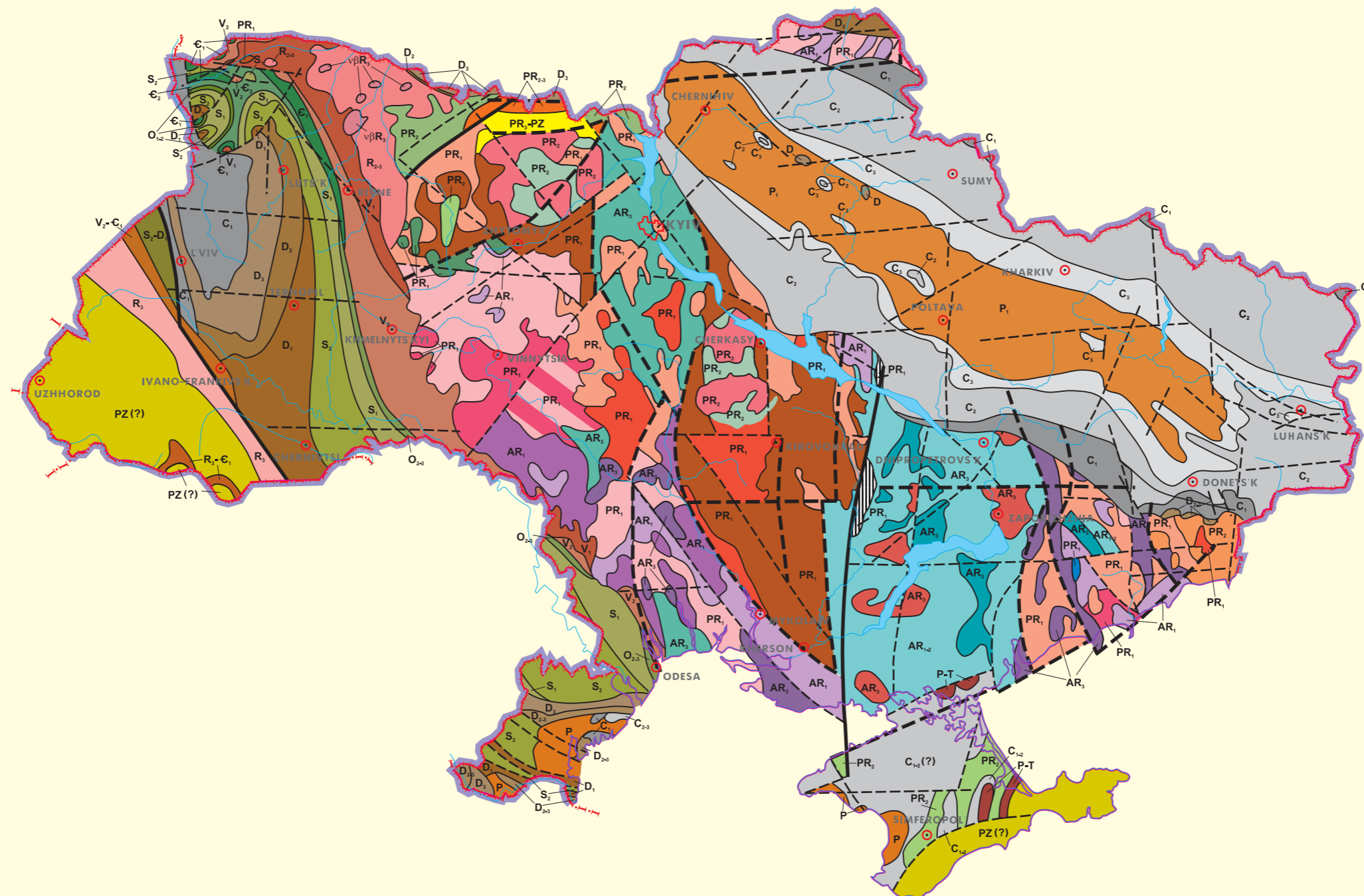
1. During the Permian period the Hercynian orogenic cycle came to an end.
2. Permian tectonic development is mostly related to the Saalian phase of the Hercynian orogeny.
3. The red-colored terrigenous rocks of the Kartamysh suite in the Bakhmut Depression of the Donets'k Basin are evidence of their molasse-like orogenic character.
4. The Dnipro-Donets' tectonic depression started to form only in the Permian period.

5. The development of the eastern Carpathian mountain system was strongly dominated by continental erosion.
6. There is some evidence for a connection at one time between the Dobruja Foredeep and the Silesia-Pokuttia Depression.
7. Permian sedimentation in the basins commonly had a poly-facies character (Dnipro-Donets' Depression, Donets' Basin, Crimea-Azov, Chyvchyn-Rakhiv).
8. Salt formations (common salt, potassium-magnesium salts) accumulated in the Asselian and Sakmarian stages of the Permian period.
9. Magmatic activity took place in the Donets' Basin (alkali basalt and andesite-trachytic intrusions).
10. Upper Permian sediments have been shown to exist, based on the paleontological evidence, only in the Dobruja Foredeep.
11. Permian rocks are widespread in the Dnipro-Donets' Depression. Within the Bakhmut and Kal'mius-Torets' areas there are copper-bearing sandstones, siltstones and argillites of the Kartamysha suite. Higher up in the strata of the Bakhmut area, are economic deposits of rock salt, gypsum, anhydrite, dolomite and limestones with showings of potassic salts, boron and brome. In recent years large deposits of bischoffite have been discovered in the Mykytiv and Slovians'k suites. In the zone of salt domes in the Depression, the Lower Permian dominantly carbonate strata contain hydrothermal-metasomatic deposits of pyrite with zinc and mercury mineralization (Slovians'k deposit), or carbonate veins with galena and sphalerite mineralization (Stepkivka deposit).



Proterozoic granites, Buky village, Cherkasy oblast'

PRE-TRIASSIC (248.2±4.8 Ma)



PRE-PERMIAN (290.0 Ma)

The Pre-Permian slice map of the Carboniferous period illustrates a wide distribution of the coal-bearing strata in the Volyn'-Podillia area, the Dnipro-Donets' Depression, the Prypiat' graben and the Donets' Basin or Donbas.

Deposits of the Carboniferous period are represented by three divisions in the Donets' Basin: the Lower, the Middle and the Upper strata. The Carboniferous section is complete here and is practically uninterrupted. Significant erosion of the strata is evident towards the margins of the Basin. In its central part, generally known in Ukraine as the "open Donbas", the Carboniferous strata reach the surface and form an anticline, which disappears under the Meso-Cenozoic along its periphery. Within this part of the Basin the entire Upper Carboniferous section is missing, and in some sections significant portions of the Middle Carboniferous strata are also missing. A complete Carboniferous section is preserved in the western part of the anticline towards the Dnipro-Donets' Depression, in the Bakhmut and Kal'mius-Torets' synclines. The thickness of the Carboniferous pile and each stratigraphic interval increase towards the axis of the fold. Along its longitudinal section, the thickness also increases from the northwest to the southeast. The maximum reconstructed thickness of the Carboniferous pile is close to 1.8 km in the nose of the fold. On the northern limb (the Starobil's'k-Millerovo monocline) it is about 3.5 km, and on the southwestern limb (Krasnoarmiis'k monocline) it is close to 5.2 km in thickness. A section of the Carboniferous pile in the Donbas and the Don-Dnipro graben is comprised of carbonate and a variety of terrigenous rocks.

In the south and the southwest of the Donbas the ages of the Carboniferous strata fall into the Tournaisian and the Visean stages. The thickness of this section varies from 50 to 600 m. In the north the carbonate assemblage includes the Tournaisian, the Lower Visean and the Serpukhovian stages, and still further to the north, within the carbonate facies, the entire interval from the Tournaisian to the Lower Bashkirian is represented. Its thickness is in the order of 400 to 700 m. On the northern and southern margins of the Basin the carbonate strata are lying directly on the crystalline basement rocks, whereas within the Graben structure there are Devonian rocks beneath them. Above the carbonate strata there are polyfacies deposits of Carboniferous rocks. Here we have a cyclic repetition of marine, continental and transitional facies of rocks. In the terrigenous sequence, consisting of argillites, siltstones and sandstones, there are close to 300 layers of limestone and coal. To the east, the coal-bearing facies of the Carboniferous period gradually change into terrigenous deposits without coal or limestones. This type of transition, from the lower horizons to the upper ones, slides further and further to the east. In the coal-bearing facies there are two maximum accumulations – in the Upper Visean and the Upper Bashkir-Moscovian. The Upper Visean deposits are coal-bearing only in the southwestern margin of the Basin, in a belt from 10 to 20 km in width. Towards the center of the depression the coal beds thin out and there is a corresponding disappearance of limestones. On the northern

margin of the depression the Lower Carboniferous terrigenous rocks are free of coal deposits. The middle Carboniferous strata are coal-bearing over the entire Donbas and along its slopes. The Upper Carboniferous strata do not have any coal deposits of economic significance. This section has a systematic increase in red-colored rocks that pass, without any significant break, into the overlying Lower Permian red strata.

To the northwest of the Donbas, within the Dnipro-Donets' Depression and the Prypiat' Depression, there is a decrease in the amount of carbonate rocks and a corresponding increase in the terrigenous strata. This indicates that the role of the marine environment became less significant and the continental facies became more important.

The character of the coal changes with its proximity to the margins of the Depression and in relation to some local structures. This is reflected in the lesser thicknesses of the coal layers, or even their disappearance. The thickness of the coal-bearing package varies from 500 m at the Chernihiv-Brahyn ridge, to 800 m at the southeastern edge of the Don-Dnipro Graben. In the Prypiat' Depression the maximum thickness of the Carboniferous strata reaches 1300 m.

In the Volyn'-Podillia area the Carboniferous strata fill the Paleozoic age L'viv Trough. Here, the strata have been assigned to the Lower and Middle Carboniferous period. The Tournaisian member measures up to 110 m in thickness, and consists of terrigenous-carbonate deposits – crystalline and clayey-carbonates, interbedded with argillites and siltstones, and carrying intercalations of sandstones and dolomites.

The Visean member, 270 to 700 m in thickness, relative to the other subdivisions of the Carboniferous, is the best developed. It has an erosional disconformity at the base and lies on various rocks of the Tournaisian member and the Devonian strata, and on the Northern Volhynian Uplift it lies directly on the Silurian and Middle Cambrian rocks. The lower section of this member is represented by limestones, siltstones, argillites and sandstones with rare thin layers of coal. The middle part of the section measures 170 to 300 m in thickness. It consists of limestones interbedded with minor sandstones, siltstones and coal, which change into bituminous limestones, intercalated with siltstones and rarely some beds of coal up to 0.35 m in thickness. The upper part of the section is comprised of argillites and siltstones, rarely some minor coal beds, and measures 80 to 180 m in thickness.

The Serpukhovian member, up to 270 m in thickness, is well developed in the L'viv Depression, and lies conformably on the Visean strata. It is represented basically by the terrigenous deposits of the lake-lagoonal type, which locally contain layers of coal up to 2 m in thickness. The Bashkirian member is up to 240 m thick, occurs within synclinal structures and has a very limited extent in Ukraine, since it is close to the international boundary with Poland. Of the 14 layers of coal within its section, 7 have an economic thickness and are mined. The enclosing strata are sandstones, siltstones, argillites, thin seams of coal and organogenic limestone.

In the Fore-Dobruja Depression, Lower Carboniferous strata are not well known. Here, the Tournaisian member (134 m

thick) lies with interruptions on the Devonian. This member consists of pelitomorphic, organic detrital dolomitized limestones. The Visean member (700 m thick) consists also of pelitomorphic detrital dolomitized limestones. In the Tatarbunary area of Odesa oblast', a terrigenous assemblage up to 300 to 400 m in thickness is lying on the Visean carbonates. This assemblage consists of argillites with minor siltstones, sandstones and coal beds 0.2 to 0.3 m in thickness.

The middle portion of the Variis'k structural-formational complex belongs to the coal-bearing units of the Scythian Plate. The lower section comprises rocks of various lithologic composition: variable grain-size sandstones, coal-bearing schists and gray limestones. The upper part of the section consists of coarse grain-sized terrigenous and shallow water carbonate deposits.

In summary, some of the characteristic features of the Pre-Permian period are as follows:

1. During the Carboniferous period, large-amplitude down-dropping of ground produced great depressions (the Dnipro-Donets' Depression, the L'viv-Volyn' Depression, the Dobruja Foredeep).
2. The Carboniferous period is characterized by a cyclicity of sedimentation and a diversity of litho-facies. This was a period of transgression from marine to continental sedimentation.
3. Carbonates gave way to a predominantly terrigenous sedimentation in the second half of the Visean stage, marked by the development of coal beds.
4. During the Middle Carboniferous era, shallow sedimentary basins existed.
5. The Carpathian region has a sedimentary paleobasin of Carboniferous age.
6. The axis zone of the Dnipro-Donets' Depression and the Nahol'nyi Ridge in the Donets' Basin are the deepest portions of these coal-bearing basins. They contain huge accumulations of coal deposits.
7. Early Bashkirian sediments are replete with coal beds from 0.45 to 1.3 m in thickness, as at the Novovolyn's'k deposit.
8. There are 20 mineable coal beds in the Upper Bashkirian sediments in the Donbas.
9. Positive and negative paleostructures are well developed in the Carboniferous period.
10. The Carboniferous Black Sea sedimentary basin is hypothetical. Its existence, however is suggested by the presence in this area, of "exotic" blocks of strata with Upper Visean, Serpukhovian and Bashkirian biota, which indicate that there was an active deep fault in contact with a mega-anticline on its north side.
11. The Moscovian layer in the Donbas consists of 50 mineable coal beds.
12. The Pre-Permian surface has rocks of different Carboniferous ages in the Dnipro-Donets' Depression, in the folded Donbas region, in the Dobruja and the L'viv Depression. In all these regions there are coal beds, with active coal mining in the L'viv-Volyn' and the Donets' basins. In the Dnipro-Donets' Depression the Carboniferous rocks are the main collectors of oil, gas and condensates.
13. Sandstones and argillites of the Middle Carboniferous con-



Proterozoic granites, the cliff "Vysokyi Kamin", Zhytomyr oblast'

tain one of the world's largest antimony-mercury ore deposits (the Mykytiv-Donets'k area). The mineralization is localized in the Upper Carboniferous Druzhkivka-Kostiantynivka anticline of the Donets' basin. Within the Dnipro-Donets' Depression the salt dome structures, comprising Middle to Upper Carboniferous strata, contain barite-zinc-lead and mercury mineralization (such as the Slovians'k, the Novodmytrivka, the Stepkivka deposits).

14. In the folded Donbas there are hydrothermal gold deposits (the Bobrykiv and the Hostrobuhor) and showings (the Mykhayliv and the Yesauliv) in the Middle and Lower Carboniferous strata. The mineralization is polymetallic in nature with lead-zinc-copper-silver assemblages and in places also with antimony-mercury and high lithium (donbasite) contents.

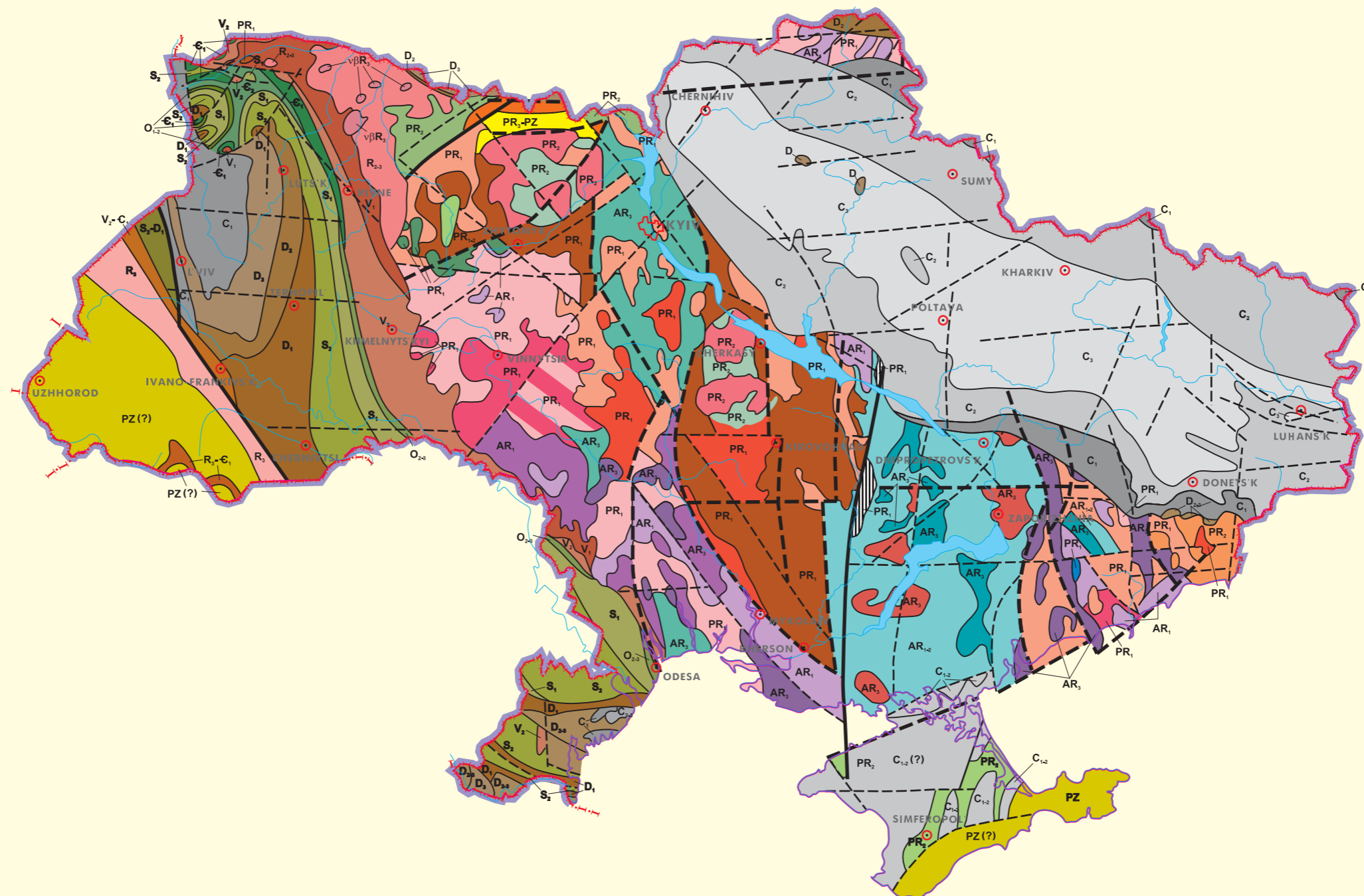
15. Limestones of the Lower-Middle Carboniferous age, within the Starobil's'k-Millerovo monocline on the southern slopes of the Voronezh massif, contain small deposits and showings of stratiform polymetallic mineralization. Here, coal beds in the limestones of the Middle Carboniferous commonly contain high concentrations of uranium and molybdenum (Markove deposit and numerous showings)

16. The Lower Carboniferous carbonate formations in the southern Donbas, close to the boundary with the Azov massif of the Ukrainian Shield, contain hydrothermal-metasomatic fluorite deposits (Pokrovka-Kyriiv) and several vein showings.

17. From the Lower to the Upper Carboniferous there are a number of small exogenous iron deposits and showings which, until 1915, provided the ore for the metallurgical industry in the Donbas.

18. The Carboniferous strata supply construction materials such as sandstones and limestones. A 10 m thick deposit of very fine-grained limestone is used as a decorative facing stone.

PRE-PERMIAN (290.0 Ma)



PRE-CARBONIFEROUS (354.0 Ma)

The Pre-Carboniferous slice map of the Devonian period illustrates the development of the Middle to Upper Paleozoic Hercynian structural column. The lower boundary of the Hercynian has much evidence of slippage and movement. Whereas in the eastern and western regions of the platform, which are parts of the mobile zones and were sites of the transgression of the Devonian sea, there are rocks of the Emsian stage, in the larger central part of the plate there are rocks that correspond to the Eifelian stage.

The Devonian rocks are the most widespread. They include Middle and Upper members and some are found only in Lower member strata. In the southwestern part of the platform, the L'viv Depression of the Eifelian stage was formed, which in part overlapped with the Dnister pericratonic area. Here, rocks of the Eifelian member have not been subdivided. Within the L'viv Depression, the Givetian stage strata, overlying the Eifelian member, consist of terrigenous deposits of quartzo-feldspathic sandstones and clayey rocks measuring from 10 to 100 m in thickness. Organic remains include acanthodes, spores and plants.

In the Prypiat'-Donets' Depression, the Upper Frasnian submember is represented by salt strata up to 900 m in thickness. In the L'viv Depression the deposits consist of limestones with intercalations of anhydrite-bearing dolomites. This sequence is about 114 m in thickness.

Non-subdivided deposits of the Middle to Upper Famennian submember are present in the L'viv and Prypiat' Depressions. In the L'viv section they include carbonate-terrigenous deposits. In the lower part, they consist of an interbedded sequence of dolomites, marls, clays, sands with layers of limestone, and in the upper part there are conglomerates. In total this section is about 300 m in thickness.

The lower Prut synclinorium is composed entirely of deep water sediments. The upper part of the Plate is covered by Devonian strata. A lower Devonian section consists of gray marls, limestones, argillites with remains of brachiopods and ostracods, and a sequence of red-colored siltstones and sandstones without any fossils. This section is about 370 m in thickness. The Middle to Upper Devonian consists of dark-gray limestones commonly dolomitized at the bases of the beds, and dolomites with intercalations of anhydrites and argillites, measuring up to 1086 m in total thickness.

The Lower Devonian deposits (Lochkovian, Pragian-Emsian members) in the Volyn'-Podillia edge of the East European Platform, consist of an assemblage of carbonate-terrigenous marine Tiverian series, and terrigenous continental Dnister series. The deposits dip in the southwestern direction so that they can be found down to 3.5 km depths, and there is a corresponding increase in the thickness of the beds and an increase in the thickness of the section at deeper levels. The maximum thickness is found in the Roztochchia zone of the L'viv Depression, where it reaches up to 1500 m. The Lower

Devonian rocks are lying conformably over the Silurian rocks. In the early development of the Lochkovian stage, the edge and the adjacent regions of the pericraton were deepened (the Erian phase of tectogenesis). The activation of faults (Belz-Baluchyn, Nefediv) resulted in the shortening of the sea basin. The development of the northern part of the pericraton was limited by the emergence of the Kovel' ridge. In the second half of the Early Devonian only the Boyanets' Depression was still an active sedimentary basin in the Praha-Emsian stage. This Depression is related to the Roztochchia mobile zone and was the locus of a thick accumulation of red terrigenous rocks, or the Dnister series of molasses. This series consists of sandstones, clays and siltstones up to 350 m in thickness. The continental red-colored deposits in the Fore-Dobruja Depression (D_1) are up to 100 m in thickness.

The Tiverian series in general is composed of limestones, marls, argillites, siltstones and sandstones.

On Zmiinyi Island, Odesa oblast', diamond drilling intersected Lower Devonian rocks at a 14-300 m depth, where dolomitized limestones and marls with some limestone beds have been encountered. These rocks have not been subdivided.

Middle Devonian strata are deposited on the edge of the East European Platform in the L'viv Depression. They consist of terrigenous-carbonate rocks which locally are sulfate-bearing. Their thickness increases in the south-southeastern direction, from 115-130 m in the north near the Kovel' ridge, to 170-230 m on the southern side near Roztochchia.

In the Donbas region the Middle Devonian strata are about 240 m in thickness. In the Mykolaiv suite ($D_{2,nk}$) there are rhythmically banded gravelites, sandstones and shales, and also sandstones, argillites, platey dolomites and limestones, and limestone breccias. Peridotites-pyroxenites of the Middle Devonian are found on the boundary zone between the Donbas structure and the Azov block of the Ukrainian Shield.

Starting with the Early Frasnian stage, the deposits that fill the Dnipro-Donets' Depression (DDD), both in terms of facies and thicknesses, do not differ that much from the same-age deposits in the regions adjacent to the Depression. They formed under relatively quiet conditions, corresponding to the early stages of the Depression formation.

The Late Frasnian stage marks a sharp change in the deposition of the Devonian sediments – a change connected to the formation of the aulacogen structure (DDD). The unusual conditions of the formation of this depression imposed a specific imprint on this geologic structure, separating it from the other structures within the East European Platform.

One of the distinguishing features of the Depression is the presence of volcanic flows of more than one age in the Devonian period. Vulcanism lasted for a long time, from the Early Frasnian stage to the Late Frasnian stage (D_3). The volcanic rocks of the Voronezh age (D_2) include olivine basalts and alkaline basalts, and rarely andesite-basalts and trachytes. The volcanic rocks of the Yevlaniv-Liven age (D_3) are composed primarily of andesites and andesite-basalts.

In the Zadon-Yelets deposits (D_3) there are tuffs, tuffites, tuffo-conglomerates and tuffo-sandstones.

The Upper Famennian volcanic rocks are well established in a number of places where they occur under the coal deposits. In section there are two distinct sequences – a lower one, consisting mainly of basic and intermediate compositions, and an upper one, consisting of felsic volcanic rocks such as liparites and felsites.

In the Fore-Dobruja Depression, diamond drilling has encountered amphibolites of approximately Devonian age.

The salient features of the Pre-Carboniferous era are as follows: 1. This was a period of active movements and structural transformations (Lochkovian, Pragian and Emsian stages in the end of the Caledonian orogenesis; the Hercynian orogenesis started from the Middle Devonian). The Middle Paleozoic L'viv Depression and the Dobruja Foredeep were formed at that time, and the pericratonic Dnipro structure culminated its formation.

2. During the Pragian and Emsian stages the Volyno-Podillia terrain was a lowland with a network of small rivers. Dobruja Foredeep was a sea basin.

3. The Prypiat'-Dnipro-Donets' graben formed in the Middle Devonian.

4. The volcanic eruptions occurred in the Breton phase of the Hercynian orogenesis (Dnipro-Donets' Depression, Donbas). Vulcanism was most active in the Semyluh time, and significant activity was recorded in the Upper Frasnian stage, or the Voronezh-Yevlaniv-Liven period.

5. The process of sedimentation was complicated and not regular. It was governed by the character of the tectonic movements and changes in the physical and geographical conditions in both sedimentary basins and ablation areas. In general, the trend in sedimentation was transgressive and regressive (Middle Devonian–Middle Famennian), followed by transgressive (Upper Famennian–Upper Viséan) in the Dnipro-Donets' Depression and the Donbas. In other regions (the northern slope of the Ukrainian Shield, the southern slope of the Voronezh Foredeep, the L'viv Depression and Dobruja Foredeep), only some elements of cyclic recurrence and sedimentation in general have been observed.

6. In the Upper Devonian, sedimentary basins occupied the same regions as in the Middle Devonian period. The largest basins were in the territory of the Dnipro-Donets' Depression. The most intense tectonic processes took place in the DDD, where both folding and faulting occurred. Folding was conducive to the formation of salt domes, brachyanticlines and other structures. Magmatic activity resulted in volcanic eruptions. The following stages are distinguished, which characterize the physico-geographic conditions and the process of sedimentation in each region: 1) the Frasnian-Lower Famennian in the Paleozoic L'viv depression, 2) the Frasnian-Middle Famennian in the Dobruja Foredeep, 3) the Frasnian-Middle Famennian in the Donbas, 4) the Frasnian-Middle Famennian in the Dnipro-Donets' Depression, 5) the Middle-Upper Famennian in the



Vysachkiv salt dome, Devonian diapir structure, Poltava oblast'

Paleozoic L'viv Depression, 6) the Upper Famennian stage in the Donbas, Dnipro-Donets' Depression and the northern slopes of the Ukrainian Shield.

7. Hypothetical sea basins were in existence in Crimea and the Carpathians in the Middle and Upper Devonian and possibly earlier.

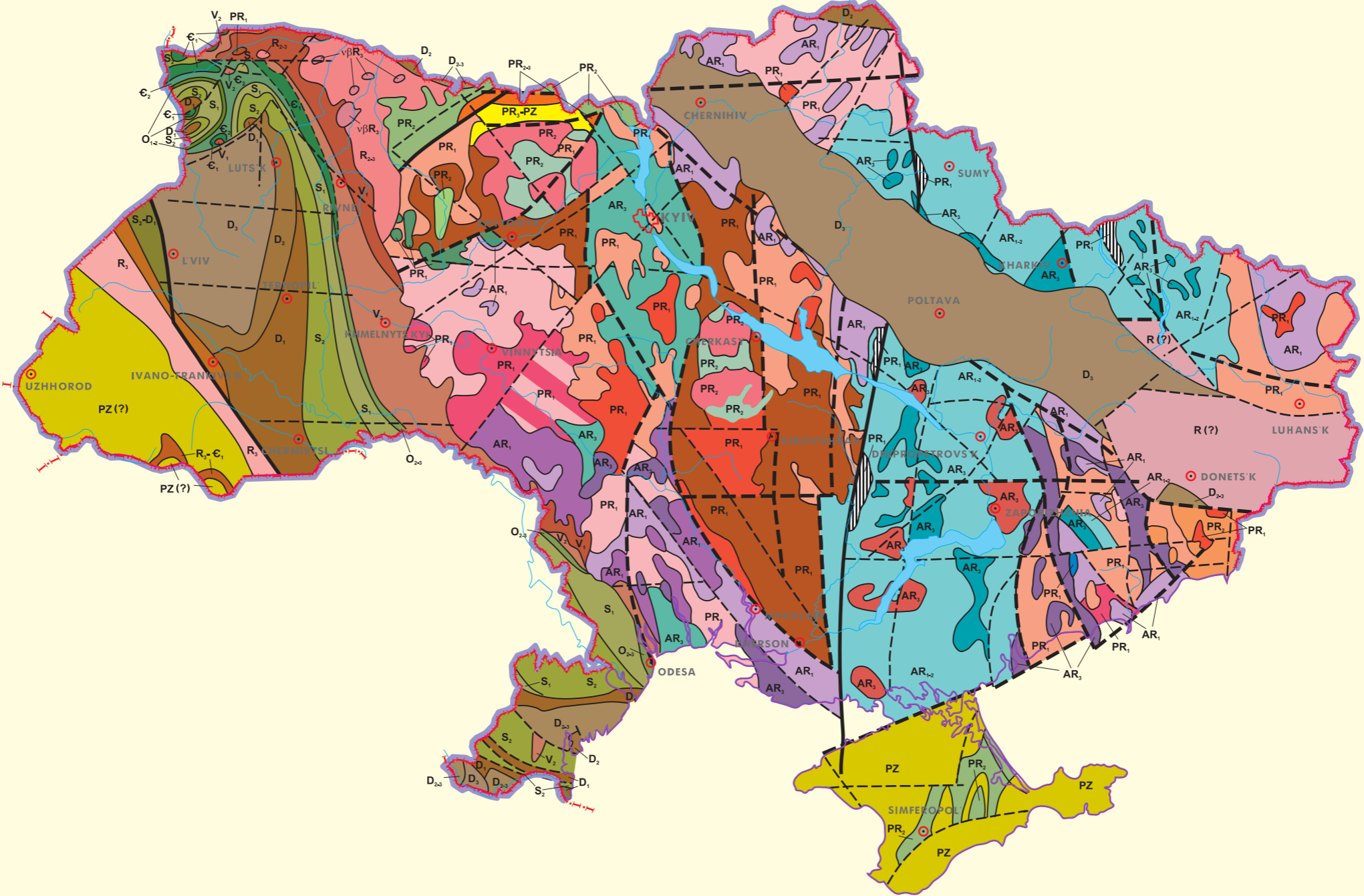
8. The Devonian strata in Ukraine occur generally at great depths. In the Dnipro-Donets' Depression, they contain oil and gas, potassic salt and bischoffite deposits.

Where the Devonian rocks reach the surface they contain copper in the slates (Dnister river area), or copper in the sandstones (southern Donbas).

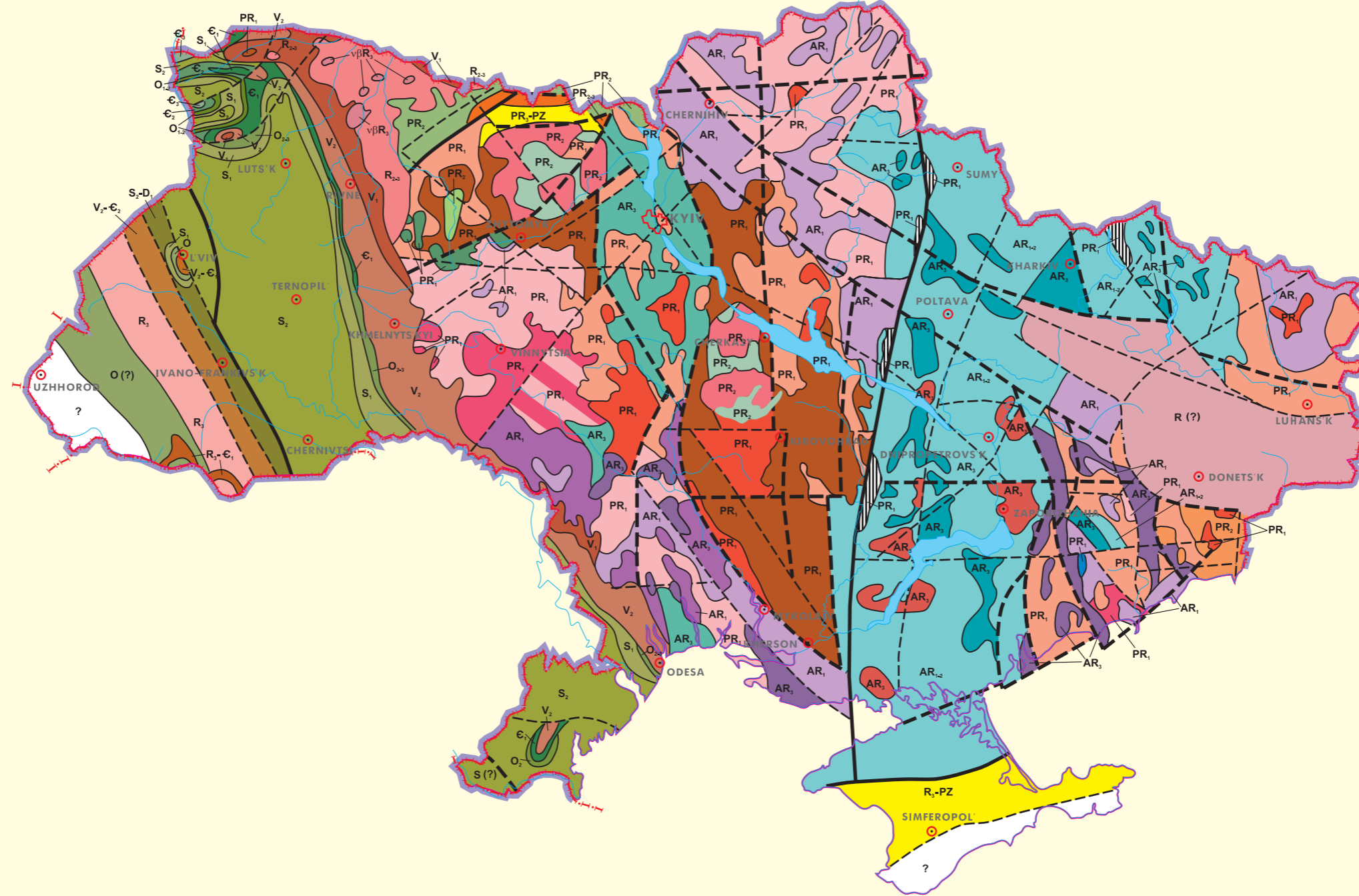
Minor hydrothermal showings of mercury, barite, lead, zinc and gold are known in the Devonian of southern Donbas and Dobruja. In the southern Donbas, the alluvial deposits of Middle Devonian filling the paleostreams on the Azov massif of the Ukrainian Shield contain stratiform uranium-thorium deposits.

The Devonian limestones and dolomites from the southern Donbas are used as metallurgical flux, building materials, gravel, raw material in the manufacturing of cement, and as facing stones. In the L'viv Depression there are gypsum, limestone and dolomites of Middle-Upper Devonian age.

PRE-CARBONIFEROUS (354.0 Ma)



PRE-DEVONIAN (417.0 Ma)



PRE-DEVONIAN (417.0 Ma)

The Pre-Devonian slice map shows the distribution of the Silurian marine terrigenous-carbonate strata deposited in the Dnister Foredeep. There is evidence also of a lateral variation of sediments, related to two structural-facies zones – the Kovel'-Khotyn shelf zone on the eastern side of the basin, and the L'viv-Kolomyia continental slope zone on the western side of the basin. The first zone comprises mainly carbonate sediments of genetically different origins – from the open-sea to near-shore and lagoonal facies. A Silurian section with excellent exposure in the Podolian Dnister region is considered to

be a reference Silurian section of international importance. It is subdivided into three series: the Yarus series (Wenlock-Lower Ludlow) of 80-120 m thickness, the Malynovets' series (Ludlow) of about 140 m thickness, and the Skalka series (Przhydolian) of about 170 m thickness. These series have been further subdivided into suites on the basis of composition and structural-textural features in the limestones.

The L'viv-Kolomyia structural-facies zone is represented by more of the deep-sea carbonate terrigenous sediments (Wenlock-Przhydolian), such as marl, limestone and abundant graptolite-bearing argillites. Their total thickness in the composite section attains 800 m. Fossil reefs are common

within the boundary zone between the deep sea and near-shore facies in Volyn'-Podillia.

After a long stage of tectonic stability, during the Upper Ordovician-Lower Silurian period, the sagging of the marginal trough resumed, resulting in the accumulation of graptolite-bearing shales (Rava-Rus'ka zone). Subsequent folding caused the formation of the foredeep structure and an associated frontal depression which became filled with red-colored molasse sediments of the Dnister series (Lower Devonian).

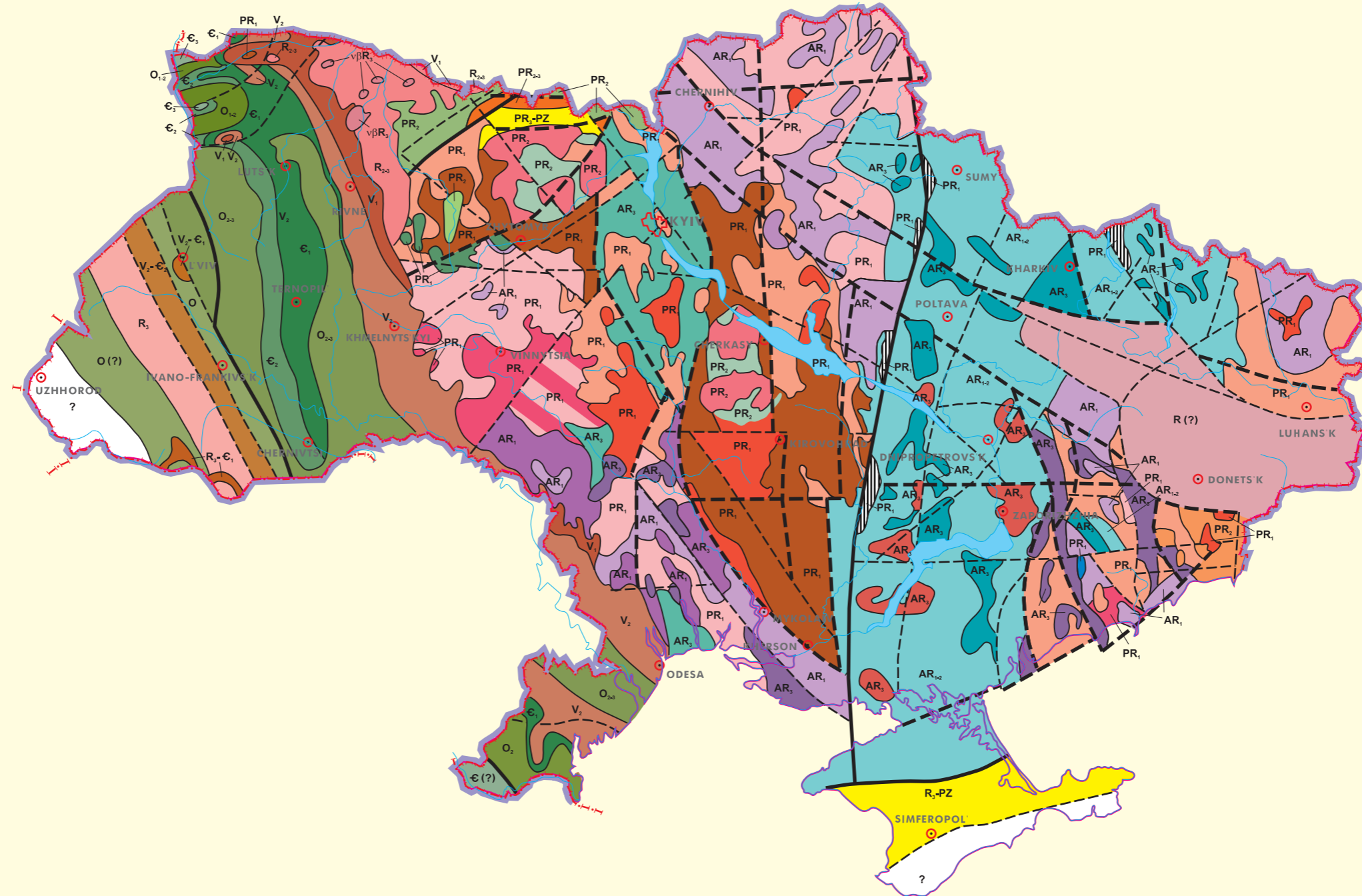
Subsequently, during the Caledonian orogeny, the graptolite shales were dislocated, a geosynclinal structure was for-

med, and the Rava-Rus'ka zone was joined to the East European Platform.

The Silurian, dominantly carbonate, rocks are common in the Volyn'-Podillia Plate. They are also found on the surface in the Dnister river area and in the valleys of the Zbruch and Smotrych rivers. These rocks are used as construction materials and in the manufacturing of cement. The Silurian limestones commonly have small occurrences of lead and zinc. The Dumaniv occurrence contains galena-sphalerite-pyrite-barite-fluorite assemblages.

Associated with the Silurian rocks is the Zbruch mineral water of the type "Naftusia" in the Khmel'nytskyi oblast'.

PRE-SILURIAN (443.0 Ma)



PRE-SILURIAN (443.0 Ma)

The Pre-Silurian slice map of the Ordovician period shows a new stage in the pericratonic development of the Dnister Foredeep. It is characterized by a change from a terrigenous sedimentation into a predominantly carbonate facies. Also, there was a migration of the deepest parts of the structure to the northwest, producing the Baltic syncline and the Polish section of the Baltic Sea coastal area, as well as the partial incorporation of the Fore-Dobruja area into the Dnister Foredeep structure.

Tectonic movement of the Earth's crust changed the geological structure of the Ordovician deposits and the longitudinal differentiation of the Foredeep by separating its Western and Eastern

parts by the Luts'k-Ternopil' longitudinal uplift. A long break in sedimentation took place in the Early and the Middle Ordovician. These changes were closely connected with Salairian orogeny within the neighboring mobile belt (the Kokhanivka zone).

A change in the structural plan of the Ordovician led to a change in the lateral facies of rocks into a western and an eastern limb of the Foredeep, separated by the Luts'k-Ternopil' Uplift. There is also an interruption in the sedimentary accumulation over much of the territory, which occurred in the Early and Middle Ordovician time. All of these changes are related to the Salairian orogeny which were also affecting the adjacent mobile belt (the Kokhanivka zone).

Within the marginal part of the Volyn'-Podillia Platform, there

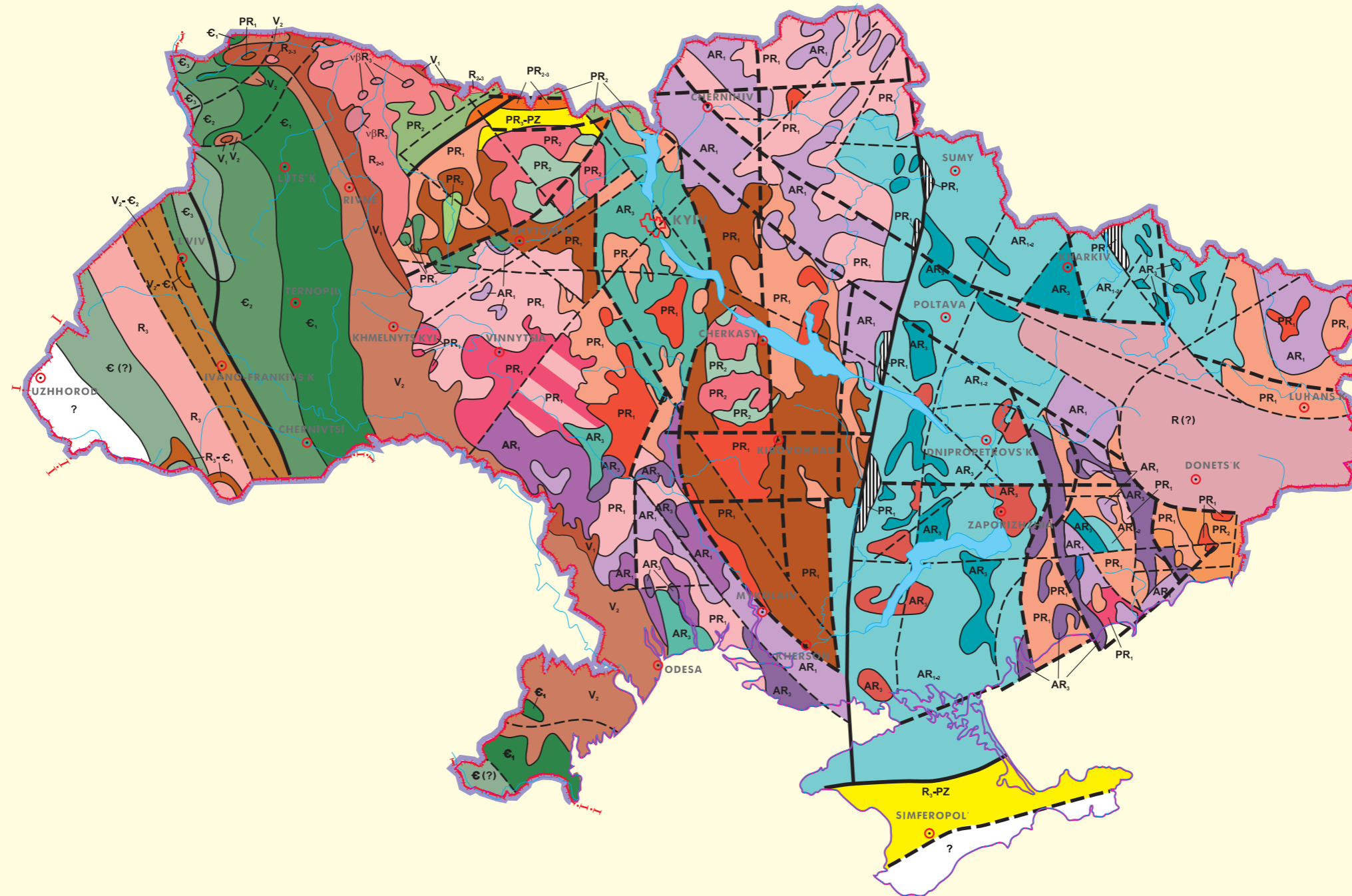
are two Ordovician series – the Molodivka and the Vyzhiv series. The Molodivka series (Upper Ordovician) covers the western and southwestern slopes of the Ukrainian Shield (in the eastern part of the Foredeep), transgressively overlaps the Cambrian and Vendian rocks with stratigraphic discontinuity, and is disconformably covered by the Silurian strata. The total thickness of the Molodivka series is in the order of 5-7 m. Within the Fore-Dobruja area, the Pleshiv suite (sandstones of about 25 m thickness) is considered to be the time-equivalent of the Molodivka series.

The Vyzhiv series (Lower-Middle Ordovician), measuring up to 50-60 m thickness, covers the Paleozoic Volynian Uplift and L'viv Trough which belong to the western part of the Foredeep

structure. This type of geological section is quite similar to the coeval Polish and Belarus analogs. The rocks of the Rava-Rus'ka zone differ substantially from the platformal carbonate sequence of the Foredeep. This zone, which has the shape of a trough, shows a progressive sagging during the Ordovician. Here, during the Early and Middle Ordovician, after a prolonged period of no sedimentation, a new accumulation of dark-gray argillites with thin layers of limestone occurred. The limestones are fossiliferous and contain graptolites, brachiopods and ostracods.

Polymetallic stratiform occurrences are known in the Ordovician sandstones of the Volyn'-Podillia plate (Starovyzhiv and Zarichchia).

PRE-ORDOVICIAN (495.0 Ma)



PRE-ORDOVICIAN (495.0 Ma)

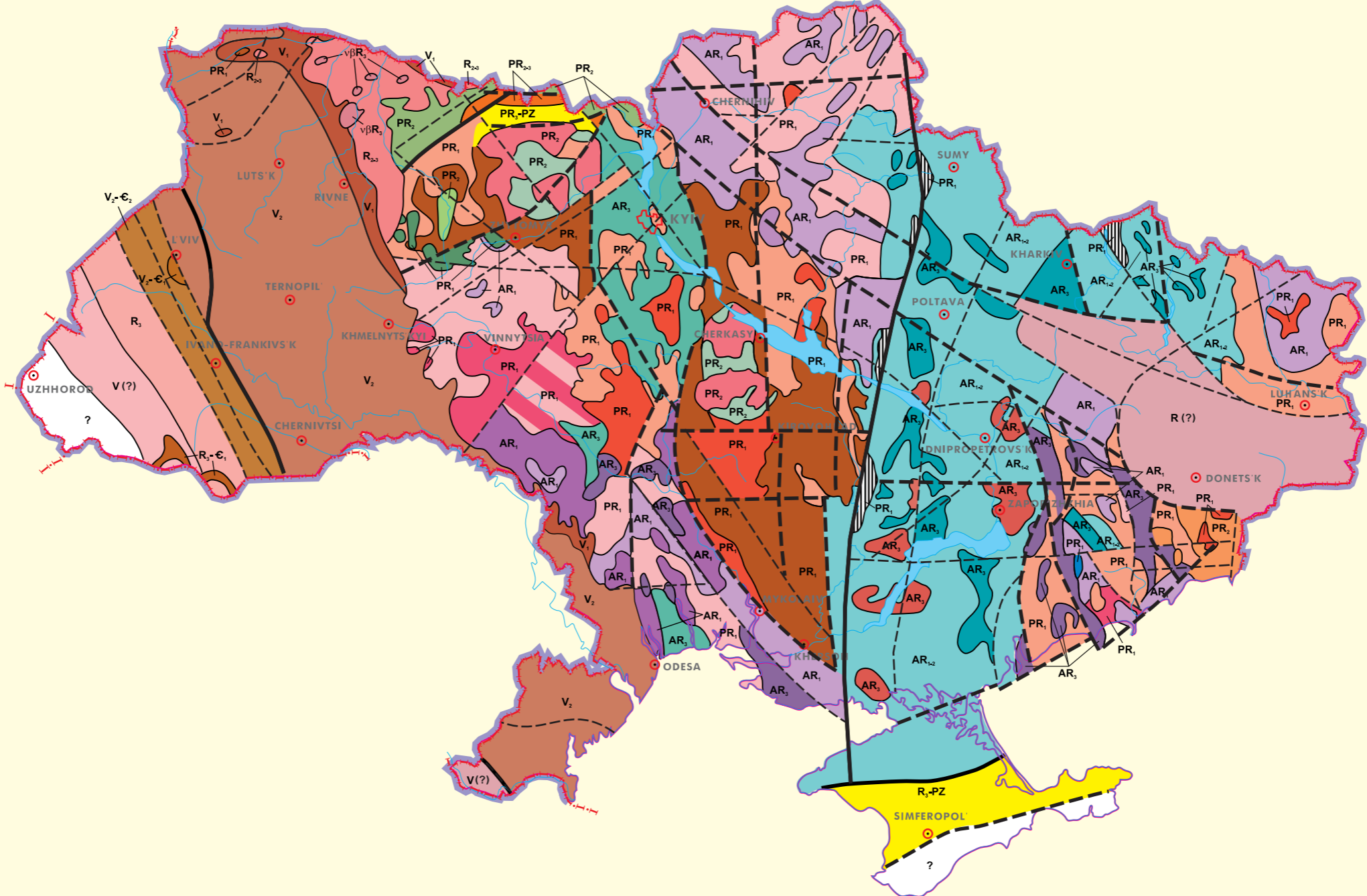
This Pre-Ordovician slice map of the Cambrian period shows further developments of the Dnister Pericratonic Foredeep. During the Cambrian period terrigenous rocks were deposited in this area, and they are represented by the Baltic (Lower Cambrian), Berezhkiv (Lower-Middle Cambrian), Smoliar and Krativ (Middle-Upper Cambrian) series. The Baltic series are as widely spread as the underlying Vendian rocks. Two distinctly different Baltic rock sections are known in Ukraine. The first one covers almost the entire Volyn'-Podillia Plate (with the exception of the Podillia Basement Uplift), and con-

sists of glauconite-quartz sandstones and grayish-green glauconite-bearing argillites (of the Baltic "blue clays" type) measuring in total thickness about 150 m. The second section, in the Podillia Uplift, instead contains gray and black massive argillites covered by red sandstones and siltstones. The total thickness of these deposits is less than 100 m. Towards the middle of the Lower Cambrian period a distinct change in the structural plan of the Foredeep occurred, as recorded in the Berezhkiv, Smoliar and Krativ series. Regions of maximum sinking in the Foredeep structure moved to the northwest and there was a shortening of the distance between the Volyn'-Podillia paleobasin and that of the East European

Platform. Thus, the Berezhkiv series consists of light gray quartz sandstones, and greenish-gray siltstones and argillites formed in different facies zones of a shallow sea. Maximum thickness of the series reaches 400 m in the deepest areas as at the Roztochchia zone. The Smoliar and Krativ series, developed in the Paleozoic Volhynian Uplift, comprise only terrigenous rocks – sandstone with beds of argillite and siltstone (the Kaplon'-Brody facies zone) measuring up to 20 m in thickness. Analogs of the Smoliar series have been intersected by diamond drilling in the Roztochchia zone of the Foredeep structure, but have been studied insufficiently.

Adjacent to the Foredeep structure there is a trough-like paleotectonic structure known as the marginal Fore-Halych trough. It was reworked by the Sairian (Late Baikalian) and Caledonian orogenies and filled with Cambrian clay-sand flysch rocks such as black argillites with common beds of light quartzite-like sandstone and siltstone. Here, the Vendian and Cambrian rocks are epigenetically altered and faulted, and form the basement of the Kokhanivka zone of the West European Platform. Polymetallic stratiform occurrences, which are present in the Ordovician sandstones of the Volyn'-Podillia plate, are also present in the underlying sandstones of the Lower Cambrian (Berezhkiv Series).

PRE-CAMBRIAN (545 Ma)



PRE-CAMBRIAN (545 Ma)

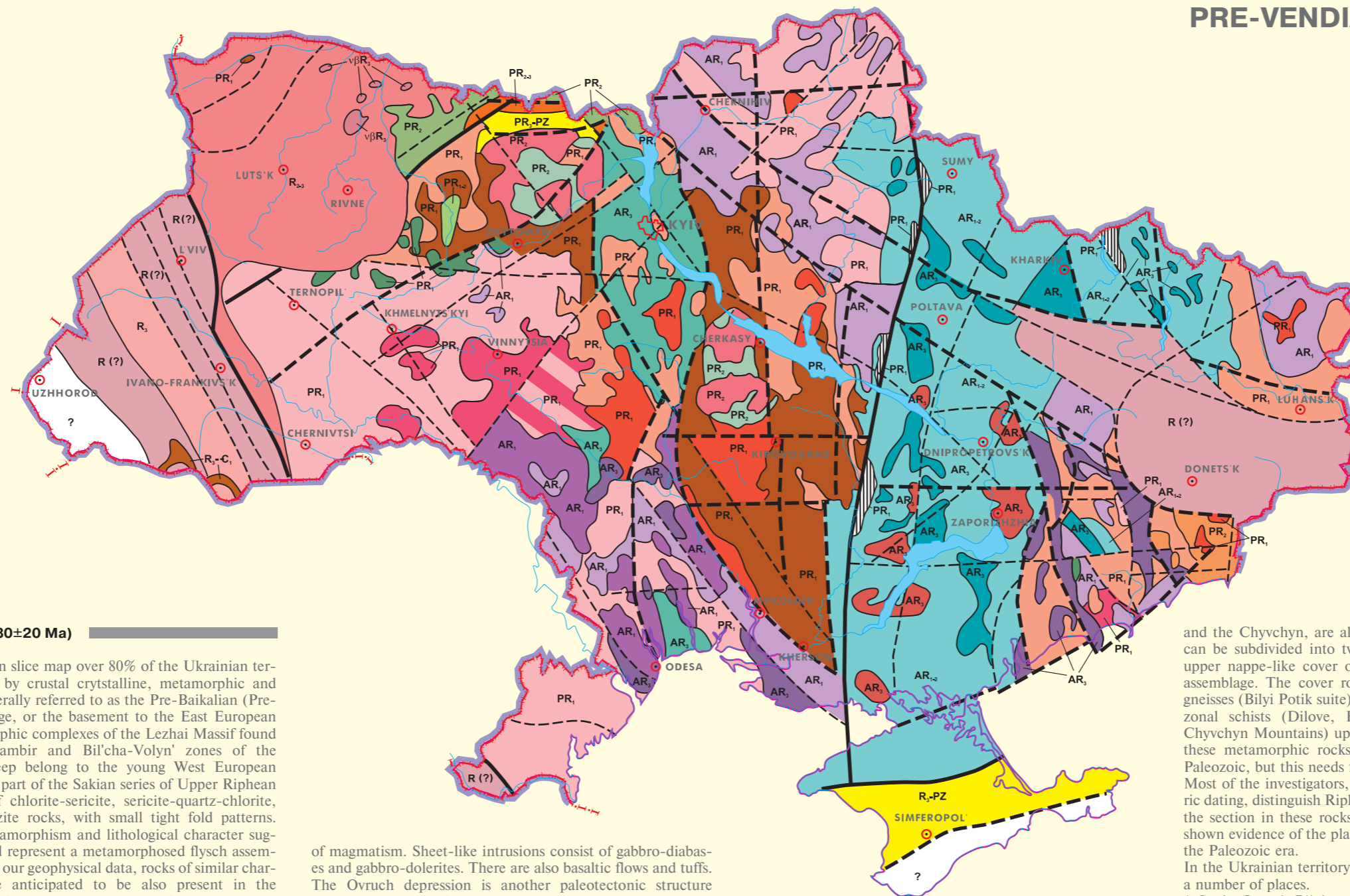
The Pre-Cambrian slice map of the Late Pre-Cambrian or Vendian period reflects plate stage development of the East European Platform. In Ukraine this development is exemplified by the Dnister Foredeep, a pericratonic structure that was superimposed on the Riphean trough formed earlier in the Platform. In the Upper Vendian time it was united with marginal Halych syncline and formed a zone of the volcanism and sedimentation – the Mohyliv-Podillia volcanic terrigenous series of about 170 m thickness, the terrigenous Kanylivka series (about 300 m) and the flysch sandy-clay rocks comprising black argillites, with intercalations of quartzite-like sandstones and siltstones (over 500 m thick). The upper part of the

last-mentioned section was intersected in diamond drill holes in the Kokhaniv-Rava Rus'ka zone. The Lower Vendian stage of development of the structural-formational complex could be described as intermediate between an aulacogen (Riphean) and a plate (Late Vendian). It includes glacial deposits of the Brody suite (50 m thick) and traps of thick Volhynian series (up to 500 m in thickness). This complex corresponds to the stage of development of the Riphean age Volyn'-Podillia Depression, and a gradual transformation of the structural plan into a sedimentary accumulation. Towards the end of the Volhynian time the sedimentary strata acquired a distinct northwestern orientation. The Vendian sequence in Ukraine is one of the most representative sections of Europe and Asia. It is well-exposed

within the Podillia-Dnister river area, has a well-developed lithologic differentiation, clear stratigraphic relationships between various subdivisions and no structural complexities. These features facilitate detailed studies of these rocks. This section of the Vendian rocks has a number of advantages in comparison to the Chinese and Australian analogs: the ease of accessibility, the completeness of profile, the absence of any long breaks in the sedimentation, the abundance and diversity of organic remains (such as Vendo-Ediacarian non-skeletal fauna, including the most ancient multicellular flora

– vendotenides, microfossils), and traces of fauna. Therefore, the Vendian section of Ukraine, which preceded the Cambrian period, can be taken as a good reference section for the Vendian rocks of the world. The upper Vendian has a number of useful mineral deposits – commercial fluorite deposits (the Bakhtyn deposit in Vinnytsia oblast'), and occurrences of base metals, phosphorite, barite and lithium. In addition, in the Volhynian series of Lower Vendian, there are traps (basaltic flows) and the associated occurrences of native copper that assay up to several per cent of copper. Associated with copper are minor but significant elements, including silver, gold and platinum group elements. Barite veins are common. Saponitic clays from basic tuffs, associated with basaltic rocks, are found in the Rivne oblast'.

PRE-VENDIAN (680±20 Ma)



PRE-VENDIAN (680±20 Ma)

On the Pre-Vendian slice map over 80% of the Ukrainian territory is underlain by crustal crystalline, metamorphic and intrusive rocks generally referred to as the Pre-Baikalian (Pre-Riphean) assemblage, or the basement to the East European Platform. Metamorphic complexes of the Lezhai Massif found at the base of Sambir and Bil'cha-Volyn' zones of the Forecarpathian Deep belong to the young West European Platform. They are part of the Sakian series of Upper Riphean age and consist of chlorite-sericite, sericite-quartz-chlorite, phyllite and quartzite rocks, with small tight fold patterns. Their grade of metamorphism and lithological character suggest that they could represent a metamorphosed flysch assemblage. According to our geophysical data, rocks of similar character and age are anticipated to be also present in the Roztochchia zone of the West European Platform.

The Pre-Vendian section marks the initial, pre-plate stages of formation of the sedimentary cover of the East European Platform. The cover rocks represent an accumulation of the Middle to Upper Riphean red-colored continental terrigenous sediments of the Polissia series, which fill the Volyn'-Polissia depression in the internal platform area. This depression is an integral part of the Riphean system of aulacogens and grabens of the platform, the roots of which (according to the geophysical data) are under the Carpathian Mountains. These roots trend at an angle to the Mountains and to the Halych mobile belt. The Polissia series are rhythmically banded rocks. Each rhythmic sequence starts with clayey rocks and ends up with minor sandstones and siltstones. Their thicknesses are in the order of 60 to 390 m. The total thickness of the series is about 900 m. At three different levels of the series, there is evidence

of magmatism. Sheet-like intrusions consist of gabbro-diabases and gabbro-dolerites. There are also basaltic flows and tuffs. The Ovruch depression is another paleotectonic structure where the oldest platform deposits are found. The lower part of the series, represented by the Zbran'kivtsi suite, is undoubtedly of Riphean age. This suite consists of quartz porphyries, porphyrites, phyllites and sandstones. Within the sediments there are Middle Riphean micro-phytofossils. Radiogenic dating of the quartz porphyries, however, gives ages ranging from 1340 to 1380 million years, which could be taken to indicate considerably older ages for these sediments than the Riphean. The total thickness of the Zbran'kivtsi suite is up to 380 m. The upper part of the Ovruch series, represented by the Tovkachi suite, consists of pink and raspberry-colored quartzite-sandstones with intercalations of pyrophyllitic mineralization. Its total thickness is over 1000 m. No good paleontological indicators are present to define its age. Considering that many of the investigators compare the Tovkachi suite to the upper part of the Bilokorovychi suite in the Bilokorovychi Depression of

Devonian to Carboniferous age, then it is possible that the Tovkachi suite is of Paleozoic age also.

The map also indicates the possible presence of Pre-Vendian rocks in the lowermost parts of the Dnipro-Donets' Depression. Although these rocks have not been actually found, the geophysical surveys over the southeastern part of the Depression have located a graben structure with specific rocks that are distinctly different from the overlying Paleozoic and the underlying basement rocks. These specific rocks are characterized by velocities of 5.7-6.0 km/sec which are of the same order as the velocities associated with the Riphean rocks in the East European Platform.

Two portions of the Marmarosh crystalline massif, the Rakhiv

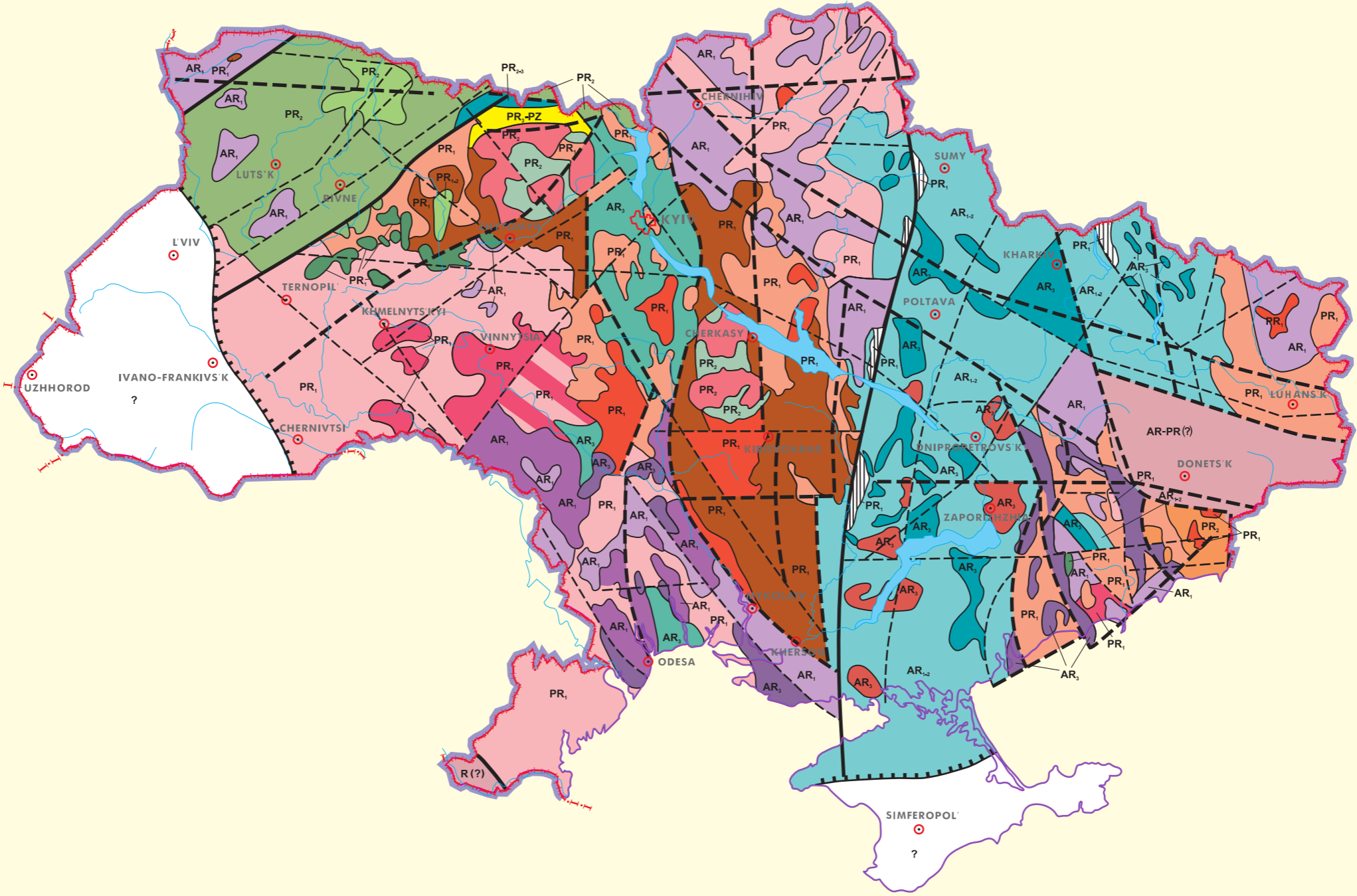
and the Chyvychn, are also indicated on the map. Each one can be subdivided into two different rock assemblages — an upper nappe-like cover overthrust on top of a flysch-like assemblage. The cover rocks consist of mesozonal schistose gneisses (Bilyi Potik suite) up to 1500 m in thickness, and epizonal schists (Dilove, Belebas and Mehur suites in the Chyvychn Mountains) up to 2500 m in thickness. The age of these metamorphic rocks is generally taken to be Pre-Late Paleozoic, but this needs further verification.

Most of the investigators, basing themselves on the radiometric dating, distinguish Riphean and Vendian-Cambrian parts of the section in these rocks. In this connection they also have shown evidence of the plant remains which are characteristic of the Paleozoic era.

In the Ukrainian territory, Riphean rocks reach the surface at a number of places.

1. In the Ovruch-Bilokorovychi system of grabens, the Riphean rocks occur as riftogenic effusive-terrigenous formations. The basal alluvial conglomerates and sandstones are known to contain small diamonds and elevated concentrations of gold. Stratigraphically higher up, in the effusive-sedimentary sequences there are hydrothermal occurrences of uranium, molybdenum and fluorite, and also pyrophyllitic schists and quartzites.
2. On the western slope of the Ukrainian Shield, the platform red sandstone of the Middle-Upper Riphean age has some near-shore marine placer-type ilmenite deposits.
3. In the Rakhiv massif of the Carpathians, the Riphean-Vendian metamorphosed underwater effusives of the Dilove and Belebas suites contain the Sauliak gold ore body, a uranium vein showing (Yavornyk), a stratiform lead-zinc deposit (Rakhiv), and many other copper, lead-zinc, barite, gold-pyrite and uranium occurrences.

PRE-RIPHEAN (1650±50 Ma)



PRE-RIPHEAN (1650±50 Ma)

Pre-Riphean formations, or Precambrian rocks, are exposed or covered by a thin sedimentary cover only within the Ukrainian Shield, and are subdivided into Archean and Proterozoic eras. The Shield has a central position in the southern part of the East European Platform.

The Pre-Riphean basement is comprised of metamorphic to ultrametamorphic, volcano-sedimentary, intrusive and metasomatic rocks of different ages. Their stratification is based on identifying successive tectonic-magmatic cycles represented by characteristic combinations of sedimentary-volcanic and plutonic formations or their metamorphosed analog formed under high P-T conditions in specific geodynamic environments.

Lower Archean (rocks older than 3.4 Ga) is represented by basic-granulites and amphibolite-gneiss complexes. These complexes are characterized by progressive amphibolite to granulite metamorphism and a wide distribution of granulite facies granitoid rocks. Lower Archean rocks are exposed on the Pre-Riphean slice map within the Podillia, western coast Azov Sea and Dnipro blocks and here and there in the rest of the Ukrainian Shield.

In the granulite facies terrains there was a high grade metamorphism of moderate pressures over extended periods. Under certain conditions, in the upper parts of this infrastructure, some granulite-diaphthorite-plagiogranite complexes were formed (diaphthorite is a lit par lit gneissic rock). Such complexes generally show amphibolite facies of metamorphism and are accompanied by granitic rocks formed by metamorphism.

The supracrustal rocks in the granulite facies of Archean blocks are represented by hypersthene gneisses, ranging in composition from basalt to rhyolite. These gneisses commonly have a vertical variation. In the lower section are the hypersthene gneisses (up to 3000 m thick), and in the upper parts they grade into kinzigites, or biotite-garnet gneisses. Originally these latter rocks were probably sandy-clayey deposits, or possibly some altered volcanics of dacite-rhyolite compositions. The supracrustal rocks do not have any sizeable areal distributions and occur generally as remnants in the granitoid rocks.

The plagiogranite-amphibolite-plagiogneissic complexes, generally known as gray gneisses, are the main country rocks in the greenstone belts in the Kursk-Dnipro megablock. The main components of the complexes are plutonic-metamorphic and supracrustal formations having mineral assemblages in the amphibolite facies of metamorphism. The supracrustal rocks occur as xenoliths and relics in the ultrametamorphic plagiogranitoids. On a regional scale both the metamorphic and the plutonic rocks have the same mineral fabric — parallel to the contacts. A full section of the plagiogranite-plagiogneiss complex has not been established but it is estimated to be in the order of about 4 km.

The early Archean tectono-magmatic cycle culminated at about 3.4 Ga.

The early stages of the Middle Archean are represented by the Kosiv greenstone belt in the western Azov block. Similar rocks

are also found in the Dnipro block. They are 3.31 to 3.29 Ga in age and as such can be regarded as the oldest known greenstone belts in this part of the Ukrainian Shield. This stage of the development terminated at about 3.2 Ga and is also characterized by ultrametamorphic plagiogranitoids.

The next stage of the late Archean tectono-magmatic cycle is dated at 3.15 to 2.90 Ga. It is well developed in the greenstones of the Dnipro block. This greenstone consists of volcanogenic, sedimentary volcanogenic and sedimentary deposits that have undergone greenschist to epidote-amphibolite facies of metamorphism. The greenstones here are lying unconformably over Lower Archean basement rocks of gray gneisses, and in places appear to be filling volcano-tectonic depressions between the granitoid and the gneissic plagiogranitoid dome-like bodies.

In the Dnipro block of the Ukrainian Shield this stage ended with the intrusion of tonalites and plagiogranites, followed by the discordant potassic granite plutons.

The following stage of the late Archean cycle is dated in the interval between 2.800 and 2.715 Ga. It consists of gneissic granulites which are in continuum with the supracrustal granulite sections of the Podillia and western Azov blocks, and the diaphthorite-granulite-amphibolite complexes of the Bila Tserkva block.

The gneissic granulites, occupying areas between the dome structures (in the interdome depressions), are of the high alumina type, and also have associated quartzites, calcic rocks, iron-bearing quartzites, and graphitic and biotite gneisses. In the gneissic granulite sections there are also basic and ultrabasic rocks, commonly as concordant sheets or sill-like bodies.

The amphibolite-diaphthorite complexes are present as slices in synclinal, isoclinal, and monoclinical folds of northwestern and submeridional orientations in the ultrametamorphic granitoids.

The structural matter complexes (SMC) of the Early Proterozoic tectono-magmatic cycle are most widely developed in the Volyn' and Kirovohrad blocks and in the Inhulets'-Kryvyi Rih juncture zone. In the general structure of the basement, the granitoid-metaterrogenic complexes of the Early Proterozoic form an independent structural cover. Their stratified sequences are commonly found lying unconformably over the granulite, diaphthorite-granulite-amphibolite and tonalite-greenstone basement. The Early Proterozoic section of the Volyn' and Kirovohrad blocks (Teteriv an Inhulo-Inhulets' series) consists of gneissic schist complexes that formed in the 2.46 to 2.36 Ga time interval. The supracrustal deposits are zonally metamorphosed under conditions of amphibolite to epidote-amphibolite facies. In the high temperature zones there are widely distributed ultrametamorphic transformations in various granites and migmatites. A typical supracrustal sequence of the Lower Proterozoic is found in the Kryvyi Rih belt of the Ukrainian Shield. The belt trends with some interruptions in a north-northeasterly direction along the Kryvyi Rih-Krupets deep-seated fault.

The Kryvyi Rih series formed during an interval from 2.23 to 1.80 Ga and are lying, with interruptions, on a greenstone basement. They consist of metaconglomerate-schist and jaspillite-chert-schist formations. Lying unconformably over these for-

mations and discontinuous, in places, is the cherty-carbonate-metasandstone formation (Hdantsiv suite) which is considered by many investigators as a tectonically emplaced plate, originally from a lower part of the section.

The early Proterozoic ultrametamorphic and intrusive complexes appear on the map over much of the territory of the southern part of the East European Platform.

Within the granulite blocks the ultrametamorphic rocks are represented by a complex of autochthonous rheomorphic granitoids. They have an areal distribution trending in a northwesterly direction, or form cores of some antiformal structures.

In the northwestern, central and eastern parts of the Ukrainian Shield there are many granitoid complexes that formed as a result of ultrametamorphic reworking of the early Proterozoic and partly Archean rocks. There is a notable close relationship between these granitoids and the antiformal structures. It is possible to distinguish between the autochthonous, para-autochthonous, alochthonous and metasomatic granitic complexes. The age of these granitoids ranges from 2.0 to 1.9 Ga.

Gabbro-dioritic intrusions are commonly associated with large tectonic zones and their intersection junctures. The intrusions are differentiated and range in age from 2.35 to 2.10 Ga. Not uncommonly they form cores of anticlinal or dome-like structures. Large intrusions include the Buky and Prutivka massifs, located on the northwestern part of the Ukrainian Shield.

The Middle Proterozoic is represented by a group of plutonic complexes, which in places are closely associated with stratified sedimentary-looking rocks. This group also contains leptite-gabbro-granodiorite (Osnyts'k), anorthosite-rapakivi-granite (Korosten') and syenite-granosyenite (Oktiabrs'ke and southern Kal'chuk) complexes. A leptite-gabbro-granodiorite complex is developed at the northwestern margin of the Ukrainian Shield and comprises felsic and basic volcanic rocks, and plutonic gabbro-diorite-granite rocks.

The ages of these rocks range from 1.95 to 2.03 Ga. The anorthosite-rapakivi-granites are represented in the Korosten' pluton, located in the northwestern part of the Ukrainian Shield, and in the Korsun'-Novomyrhorod pluton, located in the central part of the Ukrainian Shield. They include anorthosites, gabbro-anorthosites, gabbros, gabbro-norites and gabbro-diabases. The age of the rapakivi granites is 1.75 ± 0.10 Ga.

The syenite-granosyenite complexes are developed on the eastern side of the Azov block, including the Oktiabrs'ke, the Kal'chuk, and the Yelanchuk massifs. Within the complexes there are three groups of rocks — 1) basic and ultrabasic, 2) hybrid rocks, and 3) nepheline and alkaline syenites, granosyenites and subalkaline granites.

The Late Proterozoic stage is characterized by a reduced relief in the Shield and its slopes, the formation of local depressions, and local manifestations of alkaline and siliceous-alkaline metasomatism in the activated zones of the long-lasting deep-seated faults. The activated zones lasted for a long time, their ages ranging from 1.6 to 1.0 Ga.

The metasomatic rocks are known to occur in the marginal



Archean granites, Chmyrivka village, Kyiv oblast'

northwestern part of the Shield, both in the Sushchany-Perha tectono-magmatic northeasterly trending zone, and in the central Azov area, where they form a number of massifs of subalkaline to alkaline granites and metasomatites.

Hence, differences in the makeup, composition and age of these structural matter complexes (SMC) determine the character and evolution of the geological processes during the entire Pre-Riphean period of the East European Platform. It is possible to distinguish lateral and vertical types of SMC which form various stages of development of the Pre-Riphean basement: the Early Archean stage — the formation of granulites and "gray gneisses"; the Middle Archean — the formation of granite-greenstone structures; the Late Archean-Early Proterozoic — the transformation of the Early Archean structures; the Early-Middle Proterozoic — a stage of collision and mountain building, or orogenesis (this stage culminated the construction of the basement of the East European Platform as we see it today); and the Late Proterozoic — a stage of activation and rift genesis.

In the Pre-Riphean period of the Precambrian, all the phenomenal accumulations of iron occurred in such world-class deposits as the Kryvyi Rih, the Kremenchuk and the Bilozerka basins, with general resources of iron ore exceeding 100 Bt. The maximum annual production of iron ore in Ukraine was at about 125.5 mt.

The Archean granite-greenstone complexes contain nickel, chromite, molybdenite and gold deposits in the Dnipro region and Boh (Southern Buh) river area. There are also abundant high-quality graphite deposits (Southern Buh, Burtyn, Petrivka, Sachky regions) in the metamorphosed terrigenous-sedimentary-carbonaceous strata.

Associated with the Proterozoic granitoids there are widespread uranium and gold deposits. Later alkaline granitoids and zones of tectono-magmatism and tectono-metasomatism are characterized by rare metals, rare earth elements, and fluorite mineralization in the Volyn', Kirovohrad and Azov regions.

Ultramafic-carbonatite complexes contain rare metals-apatite deposits in the Chernihiv zone of the Azov region, and the ultramafic-mafic complexes have associated copper-nickel sulfide mineralization (Buky massif). In the Middle Proterozoic period there is a widely developed volcano-plutonic association (Korosten', Korsun'-Novomyrhorod) with gabbro-anorthosite-rapakivi granite plutonic complexes carrying huge resources of ilmenite-bearing gabbros, unique topaz-morion pegmatites, and iridescent labradorites.

There is a widespread development of colorful and decorative stones including granites, gabbros, labradorites, quartzites, jaspillites, marbles, dolomites and unakites (epidotized rocks).

The Ukrainian Shield is one of the best endowed Precambrian regions in the world in terms of mineragenic potential for the deposits of iron, graphite, ilmenite, uranium, rare metals and noble metals.

LITHOLOGICAL-FACIES MAPS

- Middle Eocene (Kyiv suite and its age analogs)
- Upper Cretaceous (Turonian-Santonian)
- Upper Cretaceous (Cenomanian)

The aim of the lithological-facies maps is to enhance understanding of how the paleogeographic, sedimentary, denudation, climatic, physico-chemical, and biological processes influenced the formation and areal distribution of mineral deposits.

In total, 26 lithological-facies and paleogeographic maps of Ukraine (from Mesozoic through Cenozoic stages) have been compiled by "Geoprohnoz", a State geological company. The maps provide a reconstruction of the paleogeographic environments (climate and physico-chemical characteristics of the basins, sedimentation and denudation processes) and thus establish some relationships in the formation and distribution of different mineral deposits. This Atlas includes only 3 of these maps which are characteristic of this stage of geological development. Two of these maps illustrate phosphorite formations and their localization.

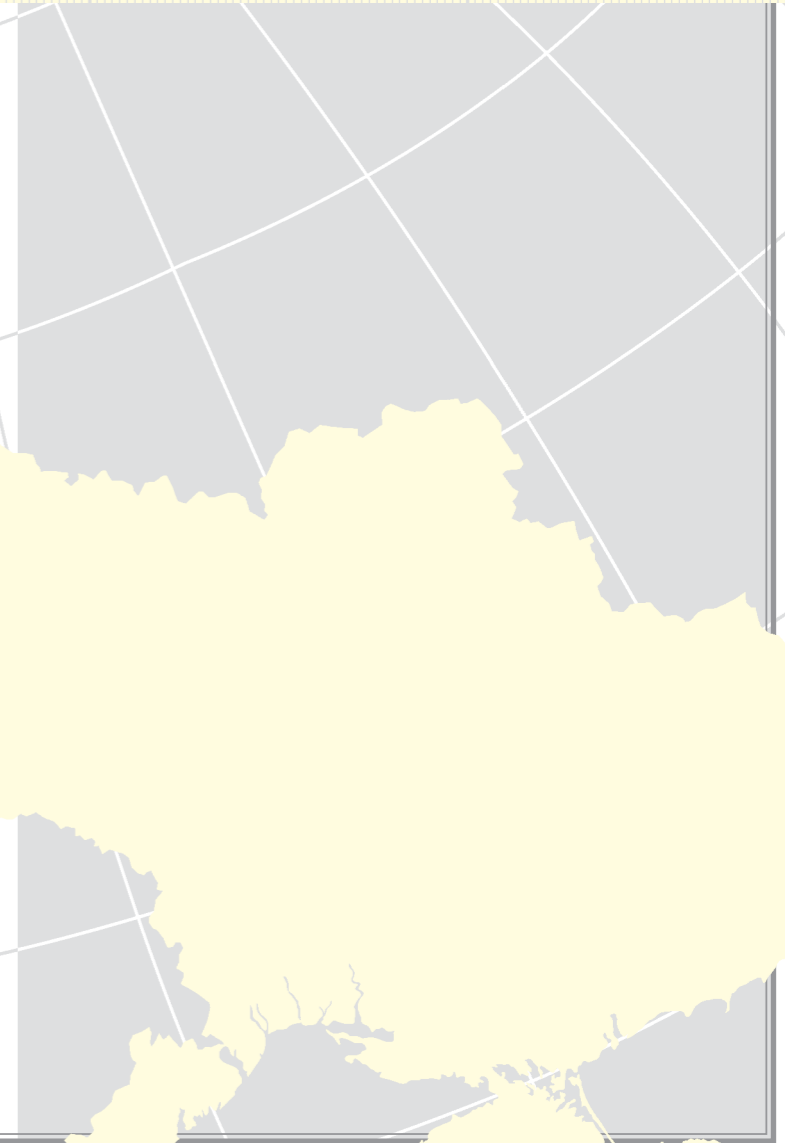
The formation of phosphorite deposits is connected to oceanic water upwellings. In this process, cold water currents, rising from deep oceanic environments, carry dissolved phosphorus, silicon, nitrogen and biogenic components. The geochemically active phosphorus, and other elements, are concentrated by precipitation on the marine shelves as a

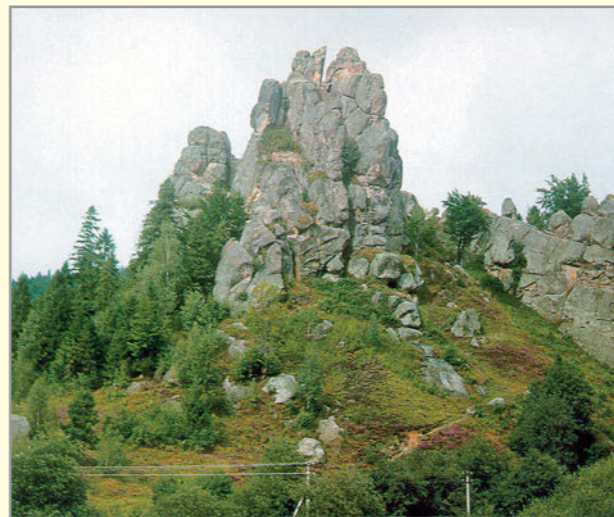
result of changes in the salt content in mixed waters, temperature, pH conditions, carbon dioxide content and other physico-chemical conditions of the mixed waters.

The distribution and magnitude of phosphorite-bearing areas are probably governed by the differences in the upwelling manifestation. In general, these are probably related to the tectonic mechanisms that started the water upwelling, chemistry of the cold waters, deep water currents and other features of the Thetys ocean of that time. More specifically, the upwelling is considered to be related to:

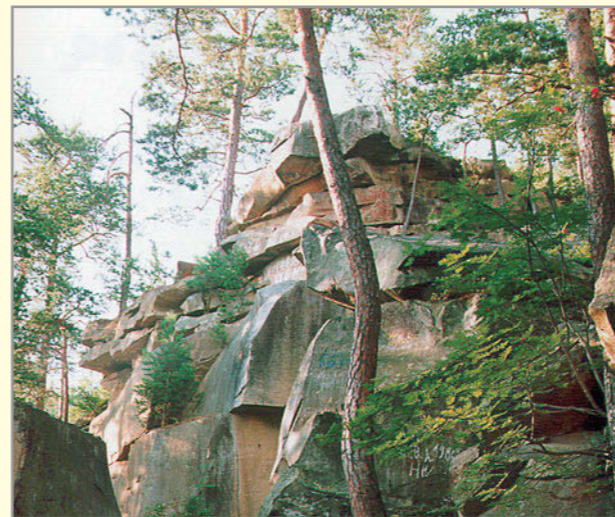
- the steady upwelling of deep waters, enriched by gaseous components derived through the faults associated with dome-like structures,
- the redistribution of mineralized waters by deep water currents over great distances,
- the appearance of favorable environments of redox conditions for the precipitation of elements.

These features are well tied in to the model of phosphatic accumulations on the Ukrainian territory. The current lithological-facies maps illustrate the conditions of formation of the phosphatic strata.

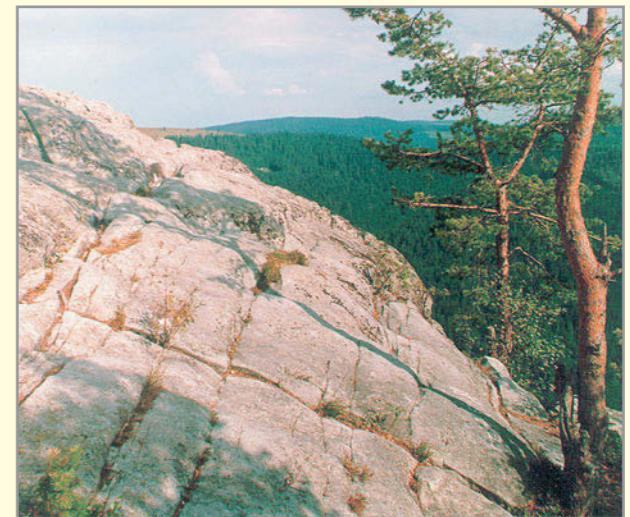




Paleogene rocks, Urych Rocks, L'viv oblast'



Paleogene rocks, Dovbush's Rocks, Ivano-Frankiv'sk oblast'



Paleogene rocks, Gorgan, Gorgany Mountains, Ivano-Frankiv'sk oblast'

MIDDLE EOCENE (37.0 - 49.0 Ma)
(Kyiv suite and its age analogs (37.0 - 45.0 Ma))

Bathymetric conditions of sedimentation in the Middle Eocene Kyiv basin were dominated either by deep or shallow shelf accumulations:

1. In the Carpathians, the deep-water shelf strata are represented by siltstone-argillite-sandstone and gritstone assemblages that are interpreted as a medium-rhythmic flysch pile. These rocks also carry agglutinated clusters, rarely calcareous, of foraminifera and mollusk fossils. In the Paleogene stratigraphic scheme of the Carpathians, a number of suites including the Vul'khivchuk, Drahiv, Velykobans'k, and Metiv are equivalent to the Kyivan section. The Metivian suite rocks include marbles with rare layers of micaceous argillites, siltstones and limestones and are widely distributed in the Marmarosh zone of the Carpathians. This suite measures 70-80 m in thickness.

2. The shallow-water shelf deposits of the Kyiv basin are found on the territories of Crimea, the Black Sea Lowland, the Dnipro-Donets' Depression and the sloping parts of the Ukrainian Shield. Carbonate formations, consisting mainly of carbonate rocks (light gray and white limestones with variable amounts of clay, light gray and greenish gray marls and limy clays), are abundant in Crimea and the Black Sea Lowland. The deepest areas are associated with relatively small depressions and basin-like structures in some parts of Crimea. To the north of the Crimean Mountains, in the Holitsyn and Syvash regions, there are widely developed limestones and light-colored massive marls measuring up to 120 m in thickness. Within

the Crimean flatlands there are two distinct lithological assemblages of carbonates, including gray sandy limestones and marls, and light gray limestones with intercalations of marls. The first assemblage is common in the northeastern flatlands, and consists of sandstones at the base, overlain by light gray and greenish gray limestones, with intercalations of marls. Its thickness is about 40 m. The second assemblage is represented in the Indol region and consists of light gray and greenish gray massive limestones with abundant fragmentary shell remains. It measures up to 35 m in thickness.

In the northern part of the Black Sea Lowland, the shallow-water shelf belt is also characterized by carbonate formations. In the lower part there are marls and clays of brownish gray color, and in the upper part there are greenish gray marls with rare layers of clays. This section is about 50 m in thickness. These rocks formed under relatively quiet conditions but a changing hydrodynamic regime.

A belt of shallow-water shelf facies is widely distributed in the Dnipro-Donets' Depression (in the southwestern, the central, and partially in the northeastern portions), in the Donets' Basin (its northwestern margin), and along the slopes of the Ukrainian Shield. Two series of rocks are distinguished there – the lower one consists of phosphoritic sandstones, and the upper one of marls. These constitute the most complete geological section of the Kyiv suite. In addition, the marls can be further subdivided into three units on the basis of the radiolarian intercalations. Each unit has a distinct micro-fauna, and is of a different thicknesses. The lithological composition of the intercalations apparently does not differ significantly

from the main mass, but it has a different mechanical composition and a carbonate content.

On the northwestern margin of the Donets' Basin, the conditions of sediment accumulation are close to those in the Dnipro-Donets' Depression. Here, the same two assemblages, as described above, are present – a lower phosphoritic sandstone (0.5-5 m thick) and an upper sandy marl (0-30 m). They contain very rich faunal assemblages.

In the Middle Eocene period, the Kyivan Sea covered much of the terrain in the central part of the Ukrainian Shield, close to the Dnipro-Donets' Depression. Here, mostly shallow-water formations, of the littoral and supra-littoral zones, are developed. The fact that at one time they were widespread is supported by their island-like distribution pattern in the northwestern, the northern and the southern Azov Sea portions of the Ukrainian Shield. Within these zones the marls change laterally into clay, glauconitic limey sandstone and sandstone facies. Within these facies, there are in places abundantly developed phosphorites of sand-size particles. They could be described as phosphorite sandstones and have potential economic interest. The phosphorites, present in the lower sections, are coarse grained and contain quartz, clays and carbonates. They are lying unconformably on the crystalline rocks, or chalky, marine or continental sediments of the Buchach suite. The thickness of the phosphoritic sandstones is of the order of 10 m, and in the Bovtysh Depression (a meteorite impact site) it is up to 40 m in thickness.

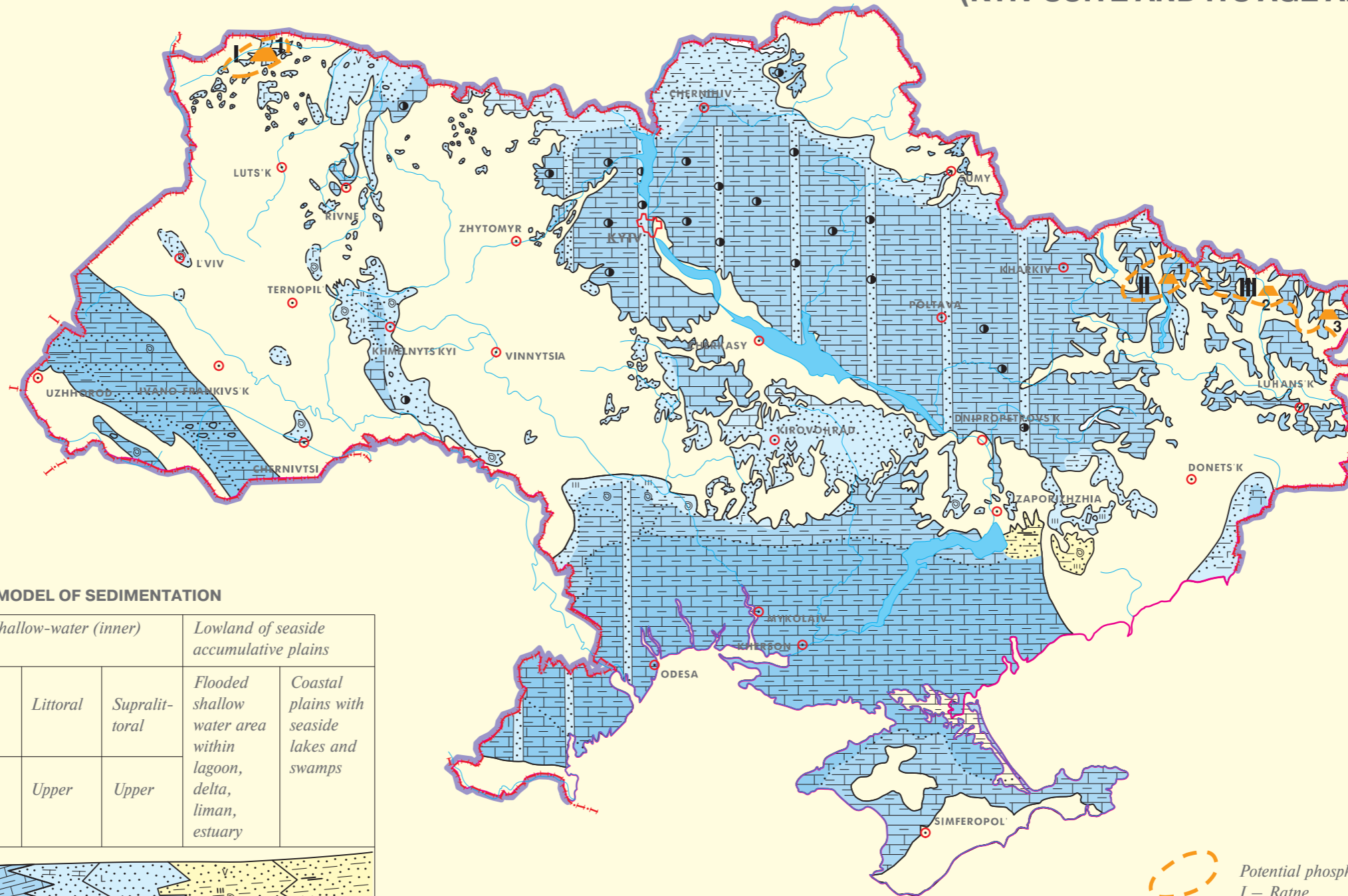
In the Azov Sea coastal section of the Ukrainian Shield, the littoral and supra-littoral zones are made up of calcareous and

sandy-clay formations, siliceous sandstones, sandstones with spicules and sponge remnants, spongiolites and limey clays. Alternation of clays and inequigranular clayey sands with pebbles is observed in places close to the Azov Sea coastal massif. On the uplifted portions of the Paleogene relief, there are either no deposits or they are represented by limestones and sandstones. Their total thickness does not exceed 25 m.

In the northeastern portion of Ukraine, between the Psiol, the Vorskla and the Merlo rivers (Okhtyrka, Lebedyn and Trostianets' regions) the sedimentary basin of the Kyivan Sea is filled mainly with sandy-clay rocks – such as clayey siltstones and glauconitic sandstones, siltstones, and glassy-looking sandstones (the Stebliv suite). They contain abundant remains of organisms with siliceous skeletons – such as radiolarians, diatoms and sponges, but there are practically no remains with calcareous skeletons. The thickness of the sedimentary pile is up to 134 m. Fine- to medium-grained clayey sandstones (4-5 m thick), and the patchy colored siltstones (8 m thick) contain fine-grained phosphoritic beds of various dimensions.

3. Various sediments accumulated in the lowlands near the sea coast, in the shallow-water lagoons, river flood plains, estuaries and deltas in the Kins'ka-Yaly trough and in the Orikhiv depression. Here, the sediments are represented mainly by carbonaceous terrigenous deposits – quartz sandstones, in places with layers and lenses of clay and brown coal, secondary kaolin, glauconite-quartz sandstone and variable grain-size quartz sandstones with layers of siltstone, more rarely clay, and rounded pebbles of quartz and quartz-feldspar. Their total thickness is up to 25 m.

MIDDLE EOCENE (KYIV SUITE AND ITS AGE ANALOGS)



LEGEND

FACIES AND LITHOGENETIC MODEL OF SEDIMENTATION

Open deep (outer) shelf		Open shallow-water (inner) shelf			Lowland of seaside accumulative plains	
Zone	Epibathyal	Moderate deep sea	Sublittoral	Littoral	Supralittoral	Flooded shallow water area within lagoon, delta, liman, estuary
	Lower	Upper	Lower and middle	Upper	Upper	
 Macrolithotypes						
Siltstone-argillite sandstone with gritstone beds	Marl-clay with fauna	Sand-clay-marl with phosphorites	Poorly sorted sand and sandstone	Limy sand	Terrigenous with volcanics and fauna	Carbonaceous terrigenous

Quartz-glaucanitic sand underlying marl-chalk phosphorite-bearing strata

Outline of the coeval deposits (facies)

Outline of contemporary distribution of the Middle Eocene deposits, Kyiv suite and its analogs

Absence of deposits

Potential phosphorite areas:
I – Ratne
II – Novyi Burluk
III – Troyits'ke-Markivka

Deposit:
1 – Ratne

Showings:
1 – Zahoruikiv-Baranivka
2 – Tanyushivka
3 – Pivnivka



Cretaceous deposits, Netishyn village, Khmel'nyts'kyi oblast'



Cretaceous deposits, Mizoch ridge, Mizoch, Rivne oblast'



Cretaceous deposits, Kremenets', Ternopil' oblast'

UPPER CRETACEOUS (65.0 - 100.0 Ma)
I (Turonian-Santonian (79.0 - 95.0 Ma))

In the Upper Cretaceous period, the Turonian-Santonian ages, a significant portion of Ukraine was under the sea. The sea basin was large and relatively deep, with calm hydrodynamics and decelerated sedimentation. It consisted of an open deep shelf and a sublittoral zone of an open shallow-water shelf.

On the territory of the present Carpathians in western Ukraine there was a sea basin of the geosynclinal type. Here, the sedimentation was slow and of the terrigenous-carbonate nature — carbonates and clayey-carbonates, sandstones, siltstones, and muddy-siltstones. The character of these rocks and the paleobiological remains (radiolaria, spicules of sponges, foraminifera, nanoplankton) indicate that this was a deep basin.

In Volyn'-Podillia there was an open sea basin where carbonate and in places clayey-carbonate muds with oysters and a variety of inocerams were deposited. Both the rocks and the fauna indicate that this was a relatively quiet hydrodynamic regime, and only rarely are there any indications of sea cur-

rents. In the western part of the Forecarpathian Depression, the accumulation of sediments included carbonate and clayey-carbonate muds with admixtures of sandy materials.

In the northwestern part of the Dnipro Donets' Depression, the Turonian-Santonian sediments are represented by clayey-carbonate muds with coccolitic and foraminifera remains. The types of foraminifera present indicate both cold and warm water assemblages, apparently indicating that the salty sea water temperature was changing. Towards the marginal parts of the Depression, and approaching the folded Donets' Basin, the clayey-carbonate sediments increase in thickness on account of the addition of a sandy component and fragments of mollusk shells.

In the Donbas, during the Turonian-Santonian time, sedimentation was accumulating under an open marine shelf environment. Here, the predominantly sandy accumulations of the Cenomanian age changed to clayey-carbonate and clayey-cherty accumulations in the Turonian-Santonian ages. The presence of the coccolitoforids, inocerams and sea urchins indicates that this was a normal salty sea water.

A good proportion of the Ukrainian Shield was also under a

shallow sea. Under conditions of frequent sea currents, some cherty-carbonate and carbonate-terrigenous accumulations were forming. Locally, there are rare layers of gritstone, opoka, and chalcidony.

A shallow sea also covered the western and southern parts of Ukraine, from the Volyn' and Podillia regions to the Crimean Mountains. The sea water was salty and well aerated. Most of the coastal region of the Black Sea and the Crimean Lowland was covered by carbonate and cherty-carbonate muds with minor admixtures of terrigenous materials. The Turonian-Santonian deposits are characterized by homogeneous faunal assemblages of inoceram-oyster groupings. The presence of *Crinoidea* and *Echinoderm* fossils indicates that this was a normal sea water environment.

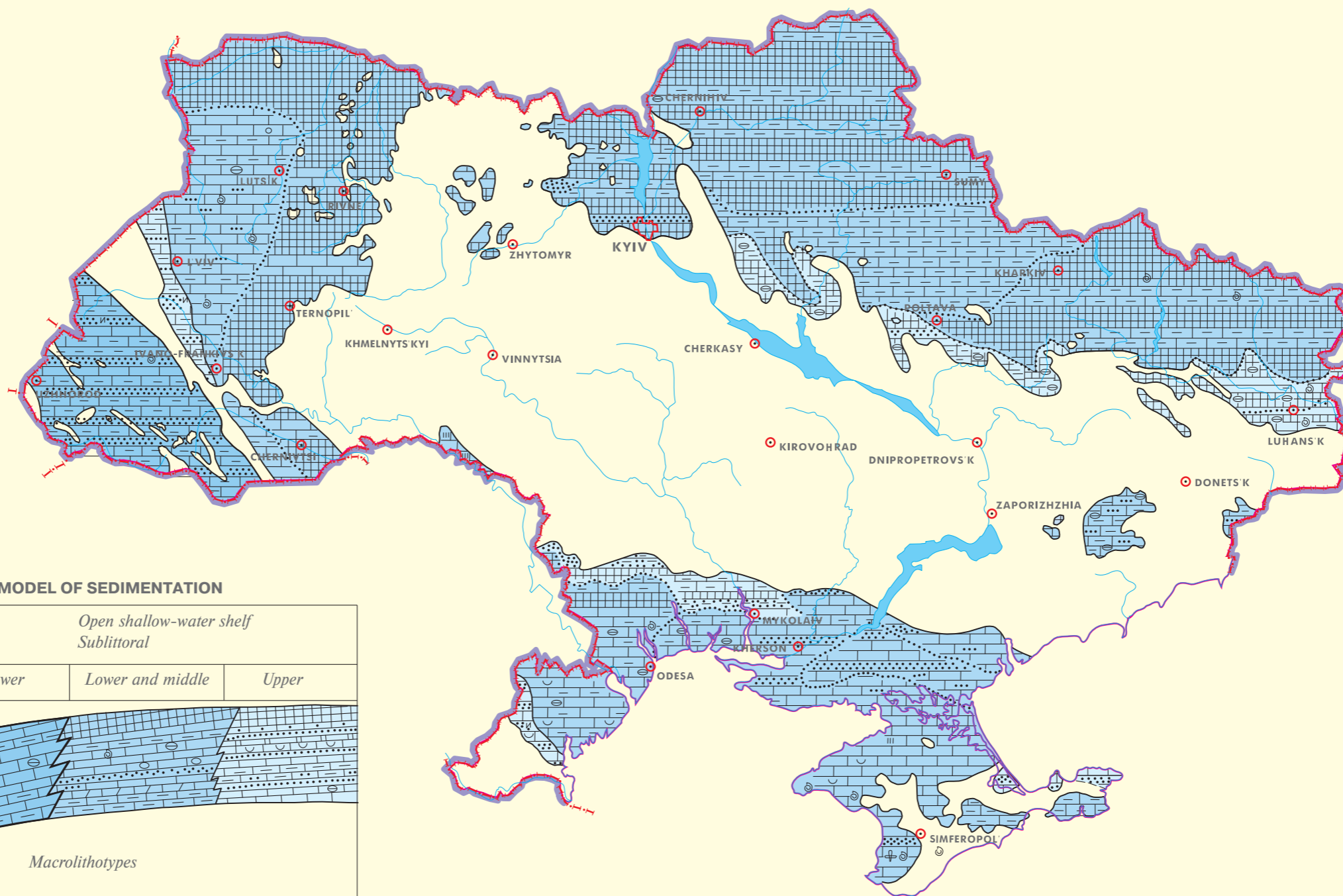
Relatively deep sea water covered southeastern Crimea in the Bilohir's'k paleotrough and the Kerch peninsula. Here, mainly clayey-carbonate sediments were deposited. Along the southern slope of the Ukrainian Shield some of the shallowest water deposits were accumulating carbonate and clayey-silty muds and sands. Meanwhile, chalk-like limestone with organic detritus and

glauconite, and limey sandstones were deposited in the Kiliia zone, an area between the Prut and Dnister rivers.

Land deposits. Although much of the Ukrainian territory was covered by sea during the Turonian-Santonian ages, there were a number of uplifted portions of the Ukrainian Shield that formed island-like land masses (the Vinnytsia, the Kirovohrad and the Lower Dnipro blocks, as well as the Near-Azov massif). Similar land masses existed in the Donbas, the Crimean Mountains, the Dobruja, and the Krukenychi area of the Forecarpathians.

The climate, during the Turonian-Santonian time, is characterized by increasingly warmer and drier conditions. This is supported by the dominance of the carbonate deposits and the appearance of warm climate plants. The appearance of the cold water foraminifera at various stages of the development of the Turonian-Santonian basin points to the inflow of cold arctic waters in the north. Thus, while the water temperature in the Crimean area was about 26°C, in the northern part of Ukraine it was only 15°C. These estimates are based on the isotopic studies of carbon and oxygen.

UPPER CRETACEOUS (TURONIAN-SANTONIAN)



LEGEND

FACIES AND LITHOGENETIC MODEL OF SEDIMENTATION

Open deep shelf Moderate deep-sea	Open shallow-water shelf Sublittoral		
	Lower	Lower and middle	Upper
<p style="text-align: center;"><i>Macrolithotypes</i></p>			
<i>Argillite-sandstone-marl with fauna</i>	<i>Limestone, marl, white chalk and chalk-like marl, with fauna</i>	<i>Chalk-like limestone and marl with minor content of chalk fragments, clayish limestone, dolomitized in places, with fauna</i>	<i>White chalk and chalk-like marl with admixtures of sandy and siliceous material, siliceous limestone, limestone, marl, rarely sandstone</i>

Outline of distribution of the Turonian-Santonian deposits

Outline of coeval deposits (facies)

Absence of deposits



Senomanian strata in the Dnister valley, Nahoriy village, Vinnytsia oblast'



Senomanian strata outcrop, Ustia village, Khmelnyts'kyi oblast'



Phosphorite concretions, Dnister area (On the left, view of a section)

UPPER CRETACEOUS (65.0 - 100.0 Ma) II (Cenomanian (95.0 - 100.0 Ma))

In the Upper Cretaceous period, the Cenomanian age, almost all the territory of Ukraine was under a warm-water sea of normal salinity. It was a shallow water platformal basin with some features of a geosyncline in the Crimea, the Carpathians and the Black Sea areas. Pieces of land, as separate islands, towered above the sea level. These were parts of the Ukrainian Shield, the Donets' ridge, the Crimean Mountains, the Dobruja and other smaller uplifted areas. Within the Dnipro-Donets' Depression there was also an influence from the cold boreal waters. The Lower Cenomanian strata are mainly terrigenous. On the boundary between the early and middle Cenomanian time interval a regression occurred, and it was marked by interruptions in the sedimentary cycles and the appearance of phosphorite deposits.

Carbonate sedimentations coincided with these interruptions and marked the beginning of the transgression in the second half of the Cenomanian age.

The Carpathian basin developed along the southwestern margin of the East European Platform. Here, carbonate and clayey-carbonate muds, as well as clayey silts with sand layers, were deposited under conditions of a moderate-to-deep water zone and a deep shelf environment. Judging by the remains of the inocerams, the marine waters had good aeration and normal salt content. A shallow epicontinental sea of the Volyn'-Podillia was separated from the Carpathian region by the Swietokrzyskie-Dobruja ridge. Within this epicontinental sea, deposition of sand, gravel and pebble sediments was produced by strong bottom current. At this time there was no large land mass in this area. To the east of the epicontinental sea, the Ukrainian Shield rose as large islands. In the southwest the epicontinental sea bordered on the geosynclinal Carpathian Sea. And in the north there were a few islands related to the Polissia ridge. As a result of such an environment very little terrigenous sedimentary material was added to this basin. The

deposits in this sea accumulated mainly as a result of weathering and erosion by flowing waters. Here are found triaxonidae fossils, or sponges with siliceous skeletons. The environment of slow moving waters and good aeration produced a rich faunal assemblage – mollusks, bulbous and flattened sponges with siliceous skeletons (*Triaxonidae*), oysters (*Amphidonta conica*), sea urchins and corals.

In the second half of the Cenomanian age, the Cenomanian sea basin was marked by its deepening and changing of sedimentation to a carbonate detrital mode. New groups of fauna, inocerams in particular, inhabited the sea. Their shells served as a rock-forming material for detrital limestones.

The shallowest part of the Cenomanian sea basin was situated in the Black Sea coastal depression, close to the dry land (the Ukrainian Shield). Sandy sediments were widely distributed here. Clayey-carbonate and siliceous sediments with significant amounts of silt and sand materials were formed between the present-day south Dnister, Buh and Dnipro rivers, in the Crimean Mountains, the Kerch peninsula and the Azov Sea coastal area, under conditions of the shallow-water shelf environment or the upper sublittoral zone.

Relatively deep-water conditions (or the middle sublittoral zone) were in existence in the Crimean Lowland, Tarkhankut peninsula and Karkinit trough. Carbonate and clayey-carbonate sediments accumulated in the basin with low hydrodynamic activity, while silty, sandy and cherty sediments were deposited in the nearby uplifted areas. Faunal assemblage was not rich and consisted mainly of inocerams. Within the Crimean flatlands there was some volcanic activity and this is recorded by the volcanogenic sedimentary intercalations in the carbonate and clayey-carbonate sediments.

At the same time, shallow sea sand and silt sediments were forming within the Dnipro-Donets' Depression.

The Upper Cenomanian is marked by intensified transgression and formation of carbonate-clay sediments containing abundant organic remains. Judging by the lithology and the variety of the

organic remains it contained (*Gavelinella cenomanika*, *Lingulogavelinella globosa*, *Gavelinella vesca*, *Brotzenella berthelini*, *Amphidonta*), the marine basin was characterized by normal salt content and a normal hydrodynamic regime.

In the Donbas area, mostly sand, clay and siliceous sediments were deposited in the shallow sea environment (upper sublittoral and littoral zones). These rocks indicate that the water was mobile, well aerated and represented a gaseous regime of the sea basin. The presence of small gastropods and lack of oysters point to an inflow of cold waters.

Dry land, encircling the sea, was characterized by a denudation landscape of weakly rugged topography in the Ukrainian Shield and the Donets' folded structure. An uplifted peneplain, 400-500 m above sea level, and a denudational plain were distinguished in the Crimean Mountains. Their intensity of erosion depended on the chemical and physical-mechanical characteristics of the strata, and also on the hypsometry of the terrain. The temperature of the sea water in the Cenomanian basin in Crimea was around 20°C. Results from studies of the Cenomanian marine fauna and microfauna suggest that there was a moderately warm climate in the Dnipro-Donets' Depression and the Donbas areas, and a subtropical climate in the Crimea and the coastal area of the Black Sea.

The paleogeographic and lithological-facies reconstructions allow a better understanding of the mineral potential, especially the hypergenic mineralization, in this period. They can be subdivided into two parts: the studies of separate systems of the sphere (such as paleogeology, its ancient relief, paleohydrosphere, ancient climate, living organisms), and the reconstruction of ancient landscapes and nature as a whole. The maps so constructed can then be used for various purposes in geo-ecological and hydrogeological investigations.

In summary, here are some of the more important conclusions about the Cenomanian age:

– The yellowish coarse-grained phosphorites are localized in the sublittoral environments of the Volyn'-Podillia, the margins of

the Dnipro-Donets' Depression and the Donbas. They are associated mainly with the Early and Late Cenomanian strata, and in the Cenomanian-Turonian conglomerates. Other than the Cenomanian, the coarse-grained phosphorites are found also in the Campanian period, where they were forming under quiet, sublittoral, shallow shelf environments of the Depression, the Donbas, and perhaps in the Volyn'-Podillia areas. Here, their concentration was enhanced by the reworking processes on the low relief bottom of the sea and by the structural-tectonic position as in the case of the Osykove deposit.

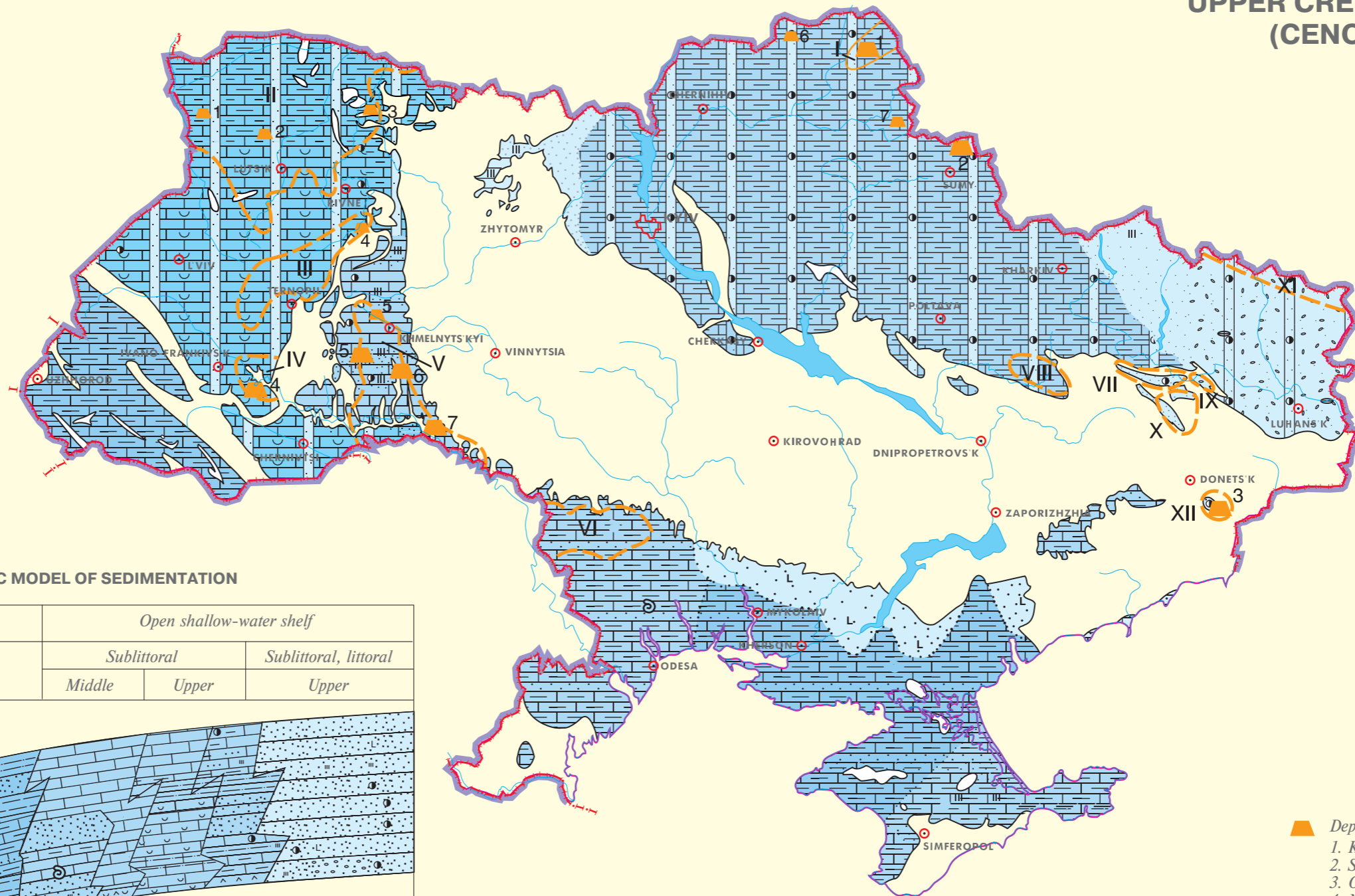
– The high carbonate strata occur in zones which are distant to the Turonian, Coniacian, Campanian, Maastrichtian and Donbas depositional basins. The siliceous carbonate rocks, used for cement-making, occur in the peripheral portions of these basins.

– The tripoli and opoka features of the sediments are associated with the sublittoral Upper Campanian strata, but less common in the Maastrichtian of the L'viv Depression, and in the margins of the Donbas. The globular cristobalite-bearing silicites from these areas are a good substitute for the semiprecious, highly prized silicagels and other cherty rocks imported from other countries into Ukraine. Besides the cristobalite-bearing silicites, there are also occurrences of opal and varieties of chalcedony. The latter is used as a semiprecious stone, and also in the chemical and electrical power industries.

– Concentrations of glauconite are associated with the Lower Cenomanian shallow water deposits in the Volyn'-Podillia, the Dnipro-Donets' Depression, the northwestern margin of the Donets' Basin, and also in the Maastrichtian of the northern Donbas. Glauconite mineral contains 3-13% potassium oxide. The glauconite-bearing rocks are used to make potash products.

– The distribution of the metallic mineralization in the Upper Cretaceous rocks has not been well investigated. There are known occurrences of zirconium and titanium close to the contact layer with the underlying Precambrian basement rocks. In the L'viv Depression, there are occurrences of celestite.

UPPER CRETACEOUS (CENOMANIAN)



LEGEND

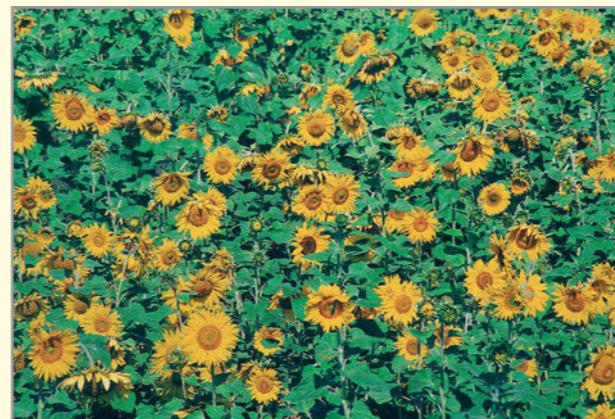
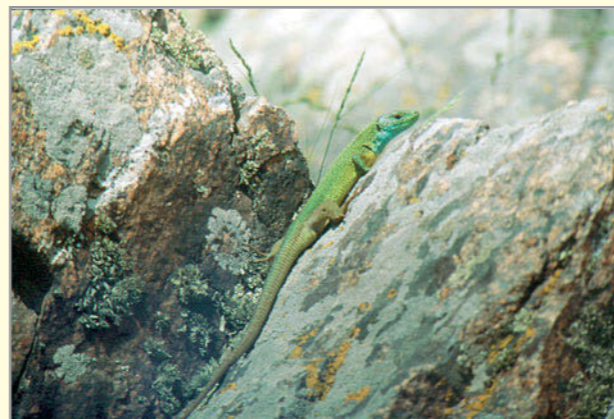
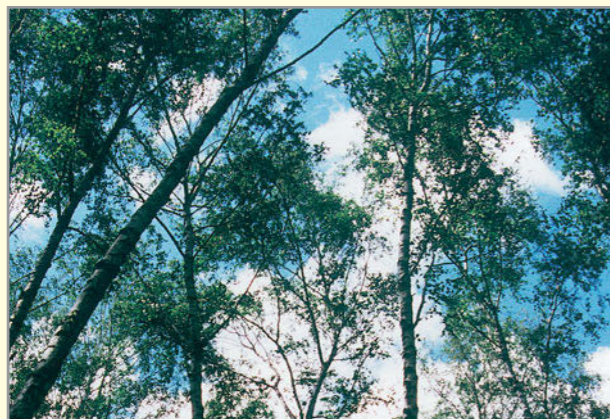
FACIES AND LITHOGENETIC MODEL OF SEDIMENTATION

Zone	Open deep shelf	Open shallow-water shelf		
	Moderate deep sea	Sublittoral		Sublittoral, littoral
		Middle	Upper	Upper
	<p style="text-align: center;">Macrolithotypes</p>			
	Silt-sandstone Argillite-marl	Clayish limestone and marl with beds of sandstone, limestone, marl with fauna and volcanic material	White chalk and chalk-like marl, organic-detrital limestone, marl and clay with increased content of sandy material	Sand and sandstone, with pronounced silicification and phosphorites

- Quartz-glaucanite sand underlying marl-chalk phosphorite-bearing strata
- Distribution of Cenomanian deposits
- Outline of coeval deposits (facies)
- Absence of deposits

- Phosphorite – potential areas:
 I – Seredyna-Buda
 II – Manevychi-Klevan'
 III – Zdolbuniv-Ternopil'
 IV – Semeniv
 V – Zhvan-Khmel'nyts'kyi
 VI – Northern Black Sea Lowland
 VII – Komyshevakha
 VIII – Oril'ka
 IX – Serebrianka
 X – Kramators'k and Kryva Luka
 XI – Troyits'ke-Markivka
 XII – Yalanchyk

- Deposits of phosphorites:
 1. Krolevets'
 2. Stets'kivka
 3. Osykove
 4. Nezvys'ko
 5. Kovalivka
 6. Dzhurzhyvka
 7. Zhvan
- Phosphorite showings:
 1. Liuboml'
 2. Byten'
 3. Oleksiyivka
 4. Bilohorodka
 5. Khot'kivtsi
 6. Vil'shanka
 7. Stakharshchyna

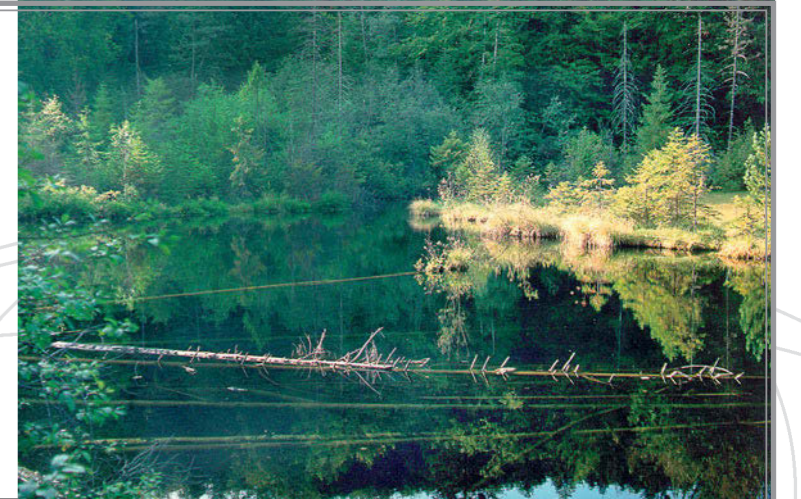


T H E G E O L O G Y A N D M I N E R A L D E P O S I T S O F U K R A I N E

section VI

ECOLOGICAL AND HYDROGEOLOGICAL MAPS

- Hydrogeological districts
- Surface geological processes
- Impact of surface geological processes
- Zones of ecological-geological risk
- Landscape and geochemical zoning
- Industrial waste load on geological environment
- Natural radioactivity
- Eco-geological situation





Sluch river "Switzerland", Sosnove village, Rivne oblast'



Kamianka river, Ivano-Frankivs'k oblast'



Waterfall on the Kamianka river, Ivano-Frankivs'k oblast'



Yaremchans'kyi Huk waterfall, Yaremcha, Ivano-Frankivs'k oblast'

HYDROGEOLOGICAL DISTRICTS

Modern zonation of Ukraine into hydrogeological districts is based on geological-structural and hydrogeological fundamentals.

The territory of Ukraine is divided into two hydrogeological provinces – the platform plains and the folded mountainous parts of the country. They have different rates of lateral and radial water exchange. Within these hydrogeological provinces there are smaller subprovinces which can be distinguished by the age of the underlying geological structures. In the folded mountainous province, two subprovinces are recognized: the East European subprovince, which coincides with the East

Carpathian Mountains, and the Scythian subprovince, which coincides with the Crimean Mountains.

Hydrogeological provinces and subprovinces are subdivided into eight artesian basins and four hydrogeological regions, which correspond to negative and positive geological structures respectively. Underground waters are found in the Quaternary, Neogene, Paleogene, Cretaceous, Jurassic, Triassic, Permian and Carboniferous rocks and also in the crystalline basement of the Ukrainian Shield.

The main water resources of Ukraine are accumulated in artesian basins which have the best potentially favorable conditions for the accumulation of underground waters. They commonly correspond to the Jurassic and Quaternary deposits.

In areas where there are clay deposits in the geological sections, there is a corresponding paucity of water resources.

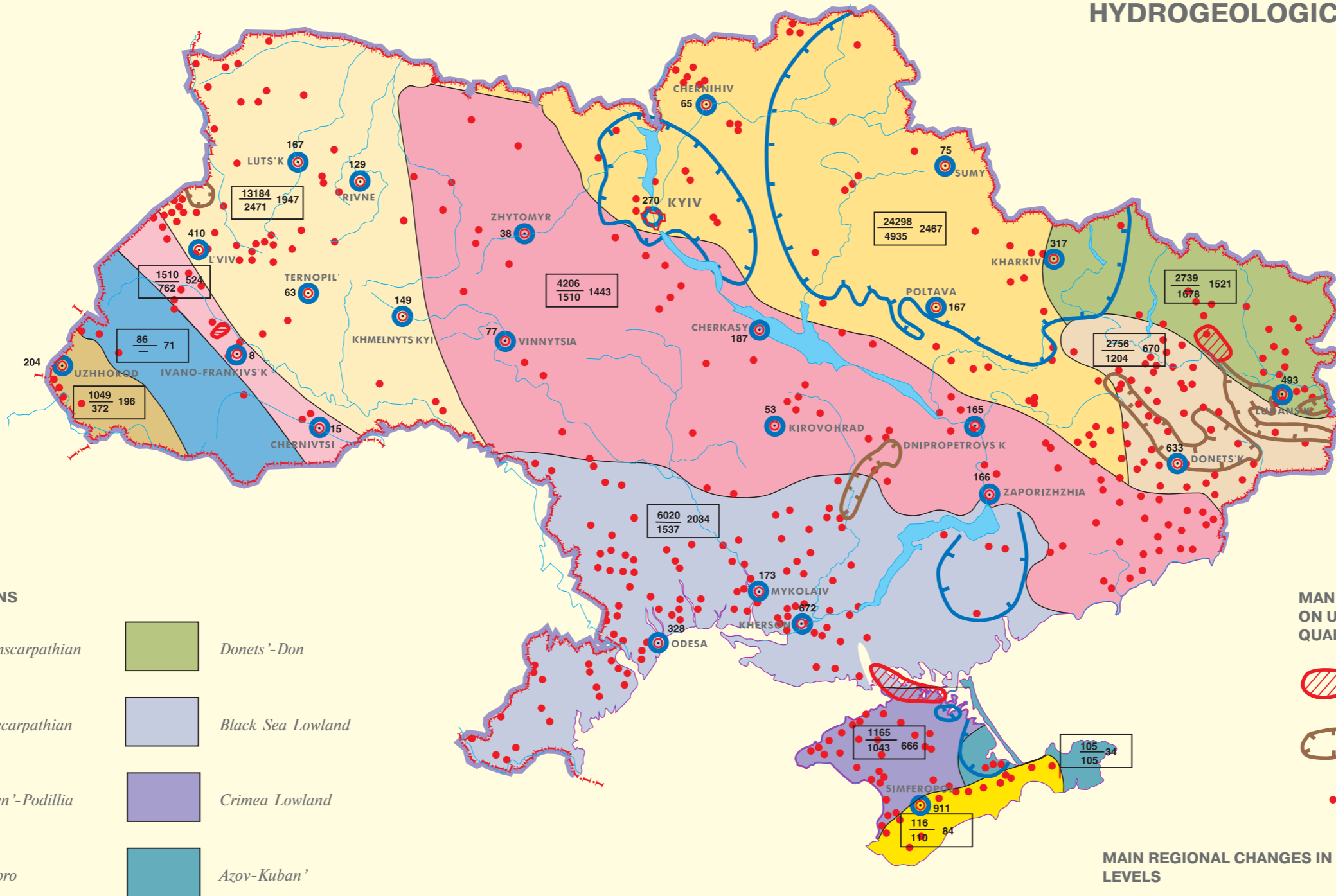
Currently, the total inferred underground resources of drinking water are estimated to be in the order of 57.4 million m³/day. The explored resources of the underground water amount to 15.7 million m³/day. The water usage amounts to 11.6 million m³/day, or about 16% of the usage of surface water sources. The predicted reserves of drinking water amount to about 45.8 million m³/day, or about 79% of the total inferred. An increase in the underground water consumption is advantageous for economic and social development and to some extent in the stabilization of the environmental situation in the country, especially after the Chornobyl' accident.

On the other hand, there are about 200 areas of local underground water pollution ("hot spots") in Ukraine. They are developed mainly in the unprotected groundwater aquifers. The polluted underground waters are estimated to be in the order of about 2.12 million m³/day, and the potentially polluted waters are about 0.41 million m³/day.

The regional monitoring system for the underground waters in Ukraine makes use of about 7000 boreholes. There are up to 10 different operating models of hydrogeological regions.

Pollution of the underground drinking water is commonly of a local character, being generally connected with the industrial regions where in the past there was little if any environmental monitoring.

HYDROGEOLOGICAL DISTRICTS



LEGEND

ARTESIAN BASINS

- | | | | |
|--|-----------------|--|-------------------|
| | Transcarpathian | | Donets'-Don |
| | Forecarpathian | | Black Sea Lowland |
| | Volyn'-Podillia | | Crimea Lowland |
| | Dnipro | | Azov-Kuban' |

HYDROGEOLOGICAL REGIONS

- | | | | |
|--|------------------|--|-------------------|
| | East Carpathian | | Donets' |
| | Ukrainian Shield | | Crimean Mountains |

MAN-MADE EFFECT ON UNDERGROUND WATER QUALITY RELATED TO

- Chemical industry
- Mining industry
- Agricultural influences (pesticides, nitrates)

MAIN REGIONAL CHANGES IN UNDERGROUND WATER LEVELS

- Regional depressions related to human activities (wells and mines)
- Boundaries of artesian basins and hydrogeological regions

$\frac{116}{105} \quad 20$ Predicted resources, exploitable reserves and average annual yield of underground water of artesian basins and hydrogeological regions, 1000s m³/day
 Numerator – predicted resources; denominator – exploitable reserves
 Number on the right – average annual yield

MONITORING OF UNDERGROUND WATER

173 Test site, giving number of test sites in a given region

Note: The hydrogeological divisions were made using geological-structural and hydrogeodynamic data. The outline of an artesian basin is controlled by certain porous strata in a hydrogeological region.



Ravines in Quaternary rocks, Kaidaky village, Dnipropetrovs'k oblast'



Quaternary rocks displaced towards the sea, Odesa



Blyzniata (the Twins), Adalary, Crimea



Smotrych river canyon, Kamianets'-Podil's'kyi, Khmelnyts'kyi oblast'

SURFACE GEOLOGICAL PROCESSES

Ukraine is a region of intricate geostructural and seismo-tectonic conditions conducive to a wide variety of development of hazardous surface geological processes (SGP) such as landslides, karst features, flooding, erosion, abrasion, etc. These processes have to be taken into account during construction of the engineering projects and could have a negative impact on the already existing industrial and residential complexes.

The long-term regional monitoring of geological environments has indicated that there can be a disequilibrium between the "water-rock" systems, which can lead to worsening of the hazardous SGP. This can occur in mining environments, industrial and urban areas, and land reclamation and hydro-technical projects. Such projects could cause a change in the water table, or surface waters, leading to new accumulations of water which could lead to hazardous SGP conditions. For this reason, the long-term forecasting and simulation of hazardous SGP in natural and man-made conditions, along with the

development of safety measures, are of great importance. Over 60% of the Ukrainian territory is subjected to some development of karst topography. Within this area, about 27% comprises open karst topography. The areas most affected by karst erosion include Volyn', Rivne and Ternopil' oblasts in the west, Donetsk and Luhans'k oblasts in the east, and Mykolaiv and Odesa oblasts in the south of the country. Landslides occur on about 50% of the farmed slopes, and are particularly common in the oblasts of Ivano-Frankivs'k, Chernivtsi, Odesa and Dnipropetrovs'k. Associated with about 70% of the drainage basins in the mountainous regions of Ivano-Frankivs'k, L'viv, Zakarpats'ka oblasts and Crimea, generally on the submontane slopes, are mudflows that affect 3-25% of the surface environment. Sagging or subsidence, commonly observed on the loess soils, affects up to 42% of their areal distribution. These fertile but delicate loess soils occupy 65% of the surface land mass of Ukraine. Intensive gully erosion affects 18% of the Ukrainian territory. Gully and sheet erosion are particularly widespread in the east (Donetsk and Luhans'k oblasts) and in the south (Odesa

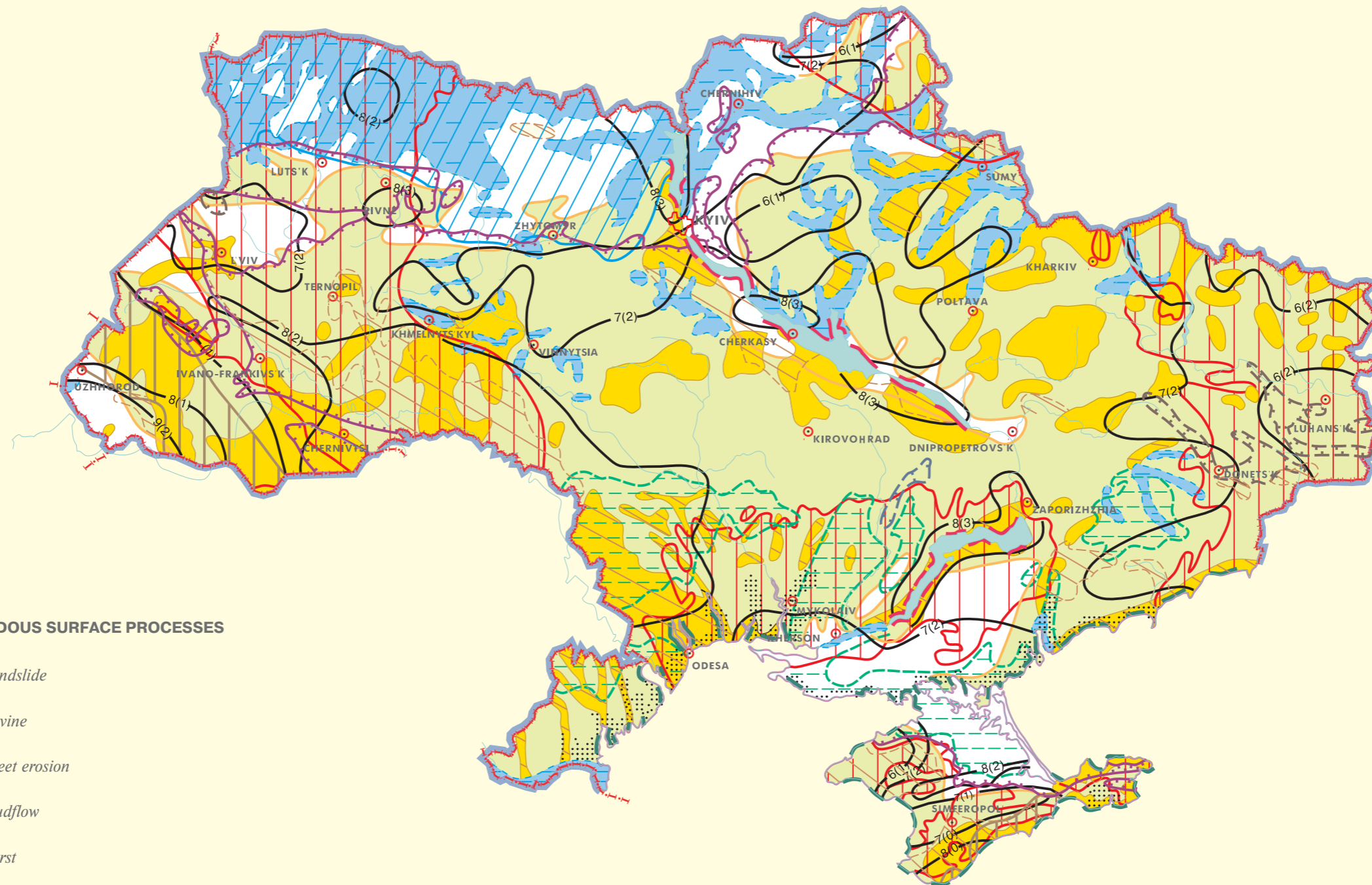
oblast') of the country. About 17% of Ukraine is affected by water-saturated grounds related to the natural high water table such as the marshy terrain of the Polissia area. Up to 80% of the irrigated land in southern Ukraine has been affected by water-logging. Up to 11-25% of the soils are affected to some degree by salinization. The most intense reworking of the shorelines is evident along the shores of the reservoirs making up the Dnipro river cascade. Over 3000 km of shoreline are thus affected. Along the shorelines of the Black and Azov Seas there is evidence of extensive erosion. In places, as near Odesa, it reaches up to 1 m/yr in some years. Coastal erosion results in the loss of lands highly valued both for their ecological significance and recreational uses. Within the steppe areas of Ukraine, the process of wind erosion is an important factor. Wind storms cause significant damage to agriculture in the area. All in all, the impact of man-made activities on the SGP is on the rise.

Between 1960 and 1995, the number of hazardous SGP events in Ukraine increased by several factors (3-5). They account for about 12 000 landslides, 5000 land subsidence incidences relat-

ing to karst topography conditions, and flooding of about one million hectares of loess and clay soils. There is a definite influence from the industrial complexes on the quality of water in the rivers in such mining areas as the Donbas and the Forecarpathians, and other industrial agglomerations, such as those in Crimea and along the Dnipro river. The impacts of industrial pollution along the Dnipro river are evident up to 50-100 km downstream from the source. Landslides related to man-made activities, evident in the Carpathian Mountains (Zakarpattia, L'viv, Chernivtsi, and Ivano-Frankivs'k oblasts), occur several times more frequently than natural ones.








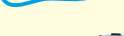

Hence, all SGP factors, both natural and man-made, have a tendency to change the physico-mechanical conditions of rocks/soils leading to instabilities of surface terrain. This then increases the cost of construction or limits its scope. Taking these conditions into consideration, it is important to have a good understanding of the surface geological processes, so that we can predict long-term changes in natural systems and, at the same time, protect nature.

SURFACE GEOLOGICAL PROCESSES





LEGEND


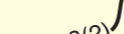
AREAS OF HAZARDOUS SURFACE PROCESSES

-  *Landslide*
-  *Ravine*
-  *Sheet erosion*
-  *Mudflow*
-  *Karst*
-  *Long-standing high ground water table (natural rise of underground water)*
-  *Marsh*
-  *Rise of ground water due to irrigation*
-  *Salinization of soil*



AREAS OF

-  *Sea coast and liman shore erosion*
-  *Reservoirs with shifting shorelines*

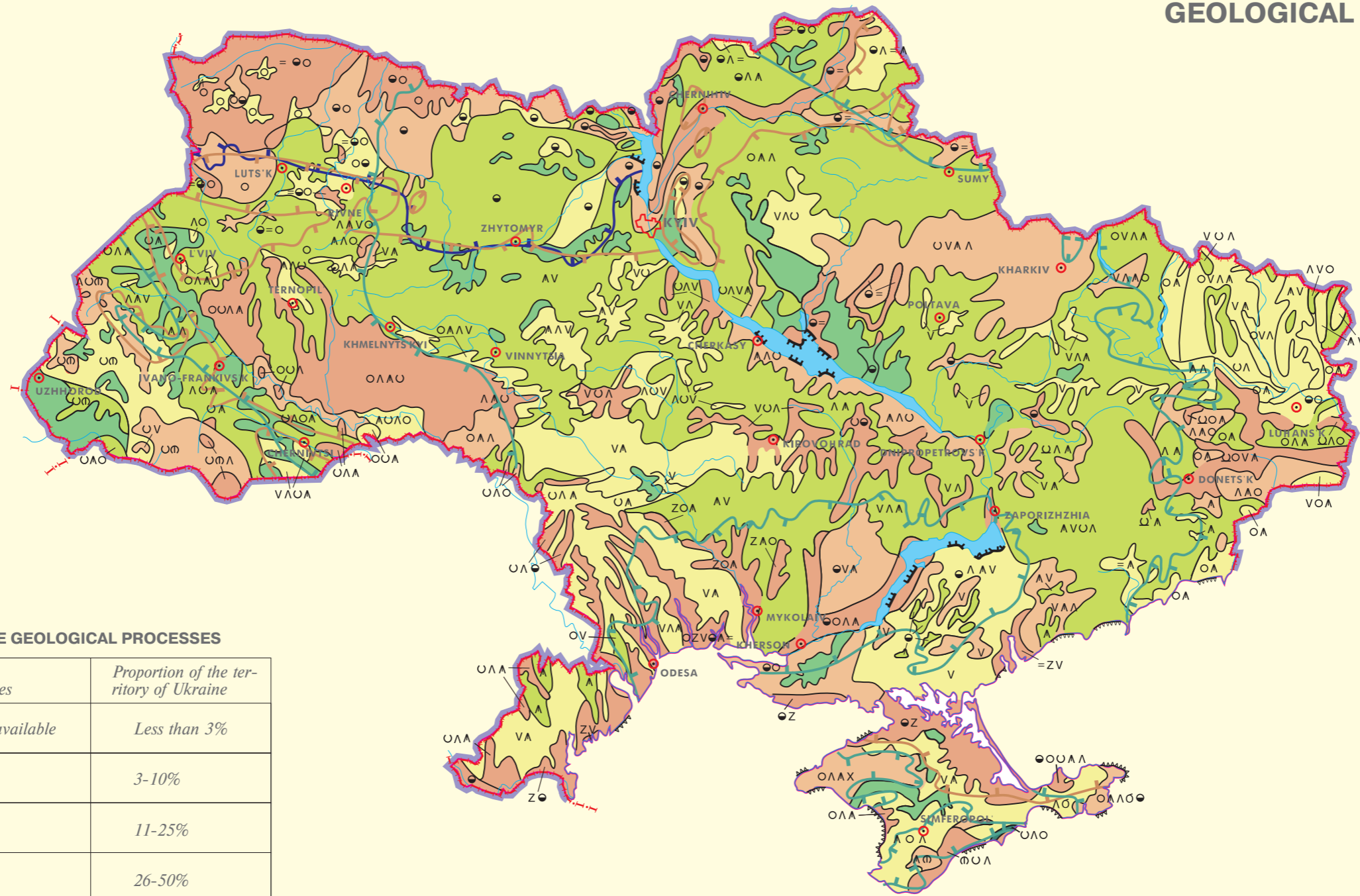
OTHER SYMBOLS

-  *Boundaries of loess deposits*
-  *Isoseismic line (technogenous increment, magnitude)*

AREAS OF ALTERED GEOLOGICAL ENVIRONMENT DUE TO

-  *Mining of iron deposits*
-  *Mining of coal deposits*

IMPACT OF SURFACE GEOLOGICAL PROCESSES



LEGEND

IMPACT OF SURFACE GEOLOGICAL PROCESSES

Rate of surface geological processes	Proportion of the territory of Ukraine
No data available	Less than 3%
Low	3-10%
Moderate	11-25%
High	26-50%
Very high	More than 50%

OUTLINES OF:



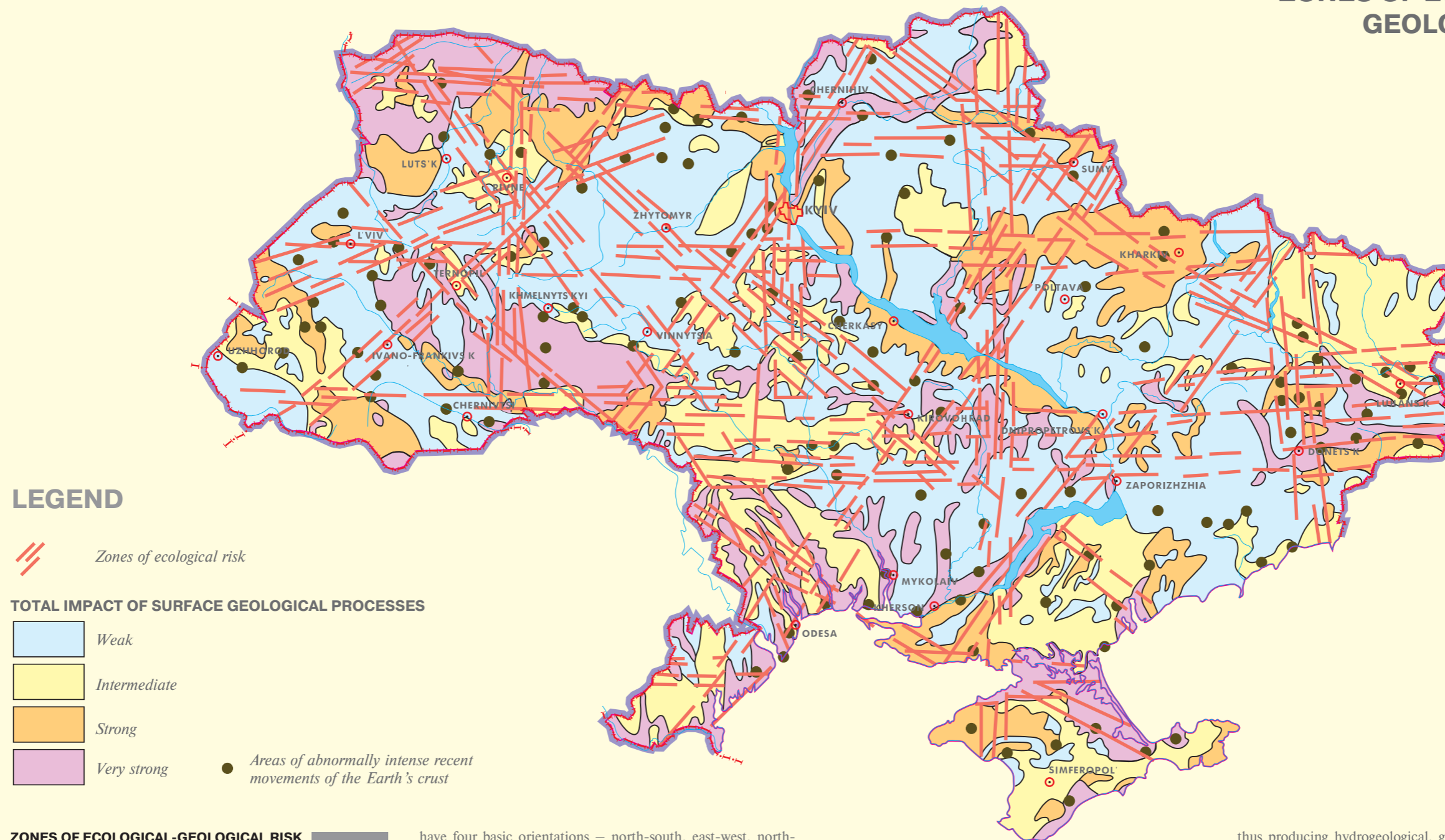
Long-standing high water table of stagnant underground water (natural rise of underground water within the Ukrainian Polissia region)

Areas with varying rate of surface geological processes


SURFACE GEOLOGICAL PROCESSES WITH THE HIGHEST RATE OF MANIFESTATION

- Landslide
- Subsidence
- ⊔ Subsidence and horizontal displacement of rocks over underground mining
- ^ Ravine erosion
- v Subsidence of loess deposits
- ~ Reservoirs with shifting shorelines
- ^ Sheet erosion
- Karst
- x Bottom erosion
- m Mudflow
- Rise of water
- = Marsh
- ~ Coastal erosion
- z Salinization
- v m ^ SGP formula (symbols are grouped in order of descending effect)

ZONES OF ECOLOGICAL- GEOLOGICAL RISK

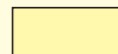


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 Zones of ecological risk


TOTAL IMPACT OF SURFACE GEOLOGICAL PROCESSES

 Weak

 Intermediate

 Strong

 Very strong

 Areas of abnormally intense recent movements of the Earth's crust

ZONES OF ECOLOGICAL-GEOLOGICAL RISK

There are three main aspects that have a bearing on the ecological-geological character of the terrain – the regional zones of the ecological-geological risk, the influence of the surface geological processes, and the seismic activity. The surface geological processes are related to both natural processes and human activities, and are described under another heading in this Atlas (see p. 100).

The regional zones of ecological-geological risk are tectonically unstable areas, manifested on the Earth's surface as linear parallel structures, which can be mapped by the remote sensing technique using satellite imagery. They form systems of trends crossing areas of different landscape, lithologies and tectonic features without causing any significant displacement of rocks or producing changes in their attitudes. These regional zones

have four basic orientations – north-south, east-west, north-easterly and northwesterly. The first two and the last two are practically at 90 degrees to each other. On the map they appear to form square grid patterns over most of the Ukrainian territory. Each cell of the grid is approximately of the same size and measures several hundred kilometers along the diagonal. Electric and magnetic surveys, special hydrogeological, engineering and geological investigations during diamond drilling for oil and gas showed that these linear structures are represented by numerous small faults or fractures of insignificant, if any movement. The host rocks commonly have the following characteristics – increased porosity and moisture content, electric conductivity, and decreased densities and rock strengths. Elsewhere in the world the linear zones have been interpreted as the so-called meso-fracture zones, and

those in Ukraine fall in the same category.

Many investigators consider the lineament zones as global shrinkage and stretch features of the Earth's crust. As such, they form weaknesses or channelways for the discharge of fluids deep in the Earth's crust, and similarly for the discharge of various fluids in the Phanerozoic cover rocks. That these fracture systems penetrate right through the cover is indicated by some of the diamond drilling results. In the near surface environment, the ground waters would have access to these channelways also. Such faults or fracture systems could be regarded as Neotectonic features. Most of the movements, however, are insignificant and did not play any role in Neotectonism, but the linear zones are capable of stimulating vertical migration of fluids,

thus producing hydrogeological, geothermal and geochemical anomalies. Imposition of new stresses on such environments could conceivably produce new movements and adjustments between various geological blocks in the Earth's crust.

The linear zones could possibly represent a manifestation of deeply positioned faults. Geophysical surveys have demonstrated that these faults can be traced down to 60-80 km depths. They appear to be zones of seismic activity, and their anomalous velocity gradients of recent movements in the Earth's crust commonly coincide with the lineament trends.

For these reasons, such linear zones are called "zones of ecological-geological risk". Their intersections, especially, are considered to be rather unfavorable sites for the location of major construction complexes and require thorough engineering and geological investigations.



Valley of the Dnister river near Nahoriany village, where the Liadova river flows into the Dnister (Khmel'nyts'kyi oblast')

LANDSCAPE AND GEOCHEMICAL ZONING

The degree of human influence on the environment can be evaluated only after extensive studies of both the natural and altered landscape-geochemical systems of any terrain. The altered systems could include any human activities that have an influence on the atmosphere, the hydrosphere, the biosphere and the lithosphere. This map illustrates the state of preservation of natural environments in various parts of Ukraine, and at the same time illustrates the natural climatic and landscape-geochemical zoning of the country.

In the process of intense development of industries as well as agriculture, some changes have been superimposed on the natural landscapes. They could be mechanical, hydraulic, hydrotechnical, or chemical in nature or any combination of these. This leads in many instances to the formation of new geochemical conditions of migration, concentration and redistribution of chemical elements and their involvement in the biological cycles of the ecological systems. As a result of continuously increasing human activities, landscapes undergo an ecological-geochemical overloading by highly toxic elements and their compounds accumulating in the soils, rocks, sediments under water, plants, and surface and ground waters. Various geochemical landscapes, characterized by various conditions of pollutant migrations, have different responses to these pollutants. Some have a tendency to accumulate the toxic substances, while others, in the process of lateral radial migration, tend to become "self-cleaning" or neutralizing. These complicated processes, in the end, determine the ecological condition of any given area or landscape. Thus, landscape-geochemical mapping allows one to evaluate, in present-day terms, some aspects of the quality of the human habitat and some risks to the health of human population living in the area.

The landscape-geochemical map shows the ecological-geochemical loading on the natural environment. In the process of compiling the data, various sources were used, that took into

account bio-climatic zonation, the conditions of mechanical, physical-chemical, biogenic, and technogenic migration of the chemical elements, the distribution of the geochemical aureoles, the anomalies of toxic elements and their compounds in the flowing waters (natural and man-made), the radionuclides in the soils, bottom sediments, surface and ground waters, the local and flood areas contaminated with man-made products such as tailings ponds, and the composition of the atmospheric pollutants, drainage waters and sewage waters of commercial agglomerations associated with the cities, industrial nodes and zones.

In compiling the map, soil was considered to be the main accumulator of pollutants, such as heavy metals, radionuclides and toxic organic compounds. The migration of elements in the "water-soil-plant" system was also taken into account. For a quantitative estimation of the heavy metal and radionuclide migration, a set of indices and coefficients was worked out, including biogenic absorption (accumulation), total soil pollution, intensities of lateral and vertical migration and water circulation, total discharge of pollutants into the air, etc.

Statistical analyses of the available data allowed the subdivision of larger areas into zones with various abilities for self-cleaning. The Carpathian and Crimean Mountains appear to be the best self-cleaning areas. This appears to be related to the rapid migration of pollutants in their waters and the high biogenic activity involving heavy metals and radionuclides. In the Carpathians the system of self-cleaning seems to be more efficient than in the Crimean Mountains. The landscapes of the Carpathian and the Crimean Mountains have a relatively light eco-geochemical loading in general, but this loading is known to progressively increase with proximity to the industrial centers. The areas capable of self-cleaning occur in the central part of Ukraine, in the forest-steppe and steppe zones underlain by the loess deposits and crystalline rocks. Here, there is both descending and ascending migration of chemical elements, as well as the removal of heavy metals and radionuclides by surface runoff from soils and by the movement of water in river

valleys and ravine bottoms. These areas in general are subjected to appreciable pollution with heavy metals (vanadium, copper, nickel, chromium, lead, and beryllium) and toxic substances released to the environment of large cities (Kyiv, Bila Tserkva, Kryvyi Rih, Nikopol', Dnipropetrovsk and others) and radionuclide fallout from the Chernobyl' disaster.

The western, southwestern and southern parts of the country have a low self-cleaning capacity, including the Volyn'-Podillia, the Dnister river area, and the northern part of the Crimean Lowlands. While these areas are characterized by surface runoff and soil erosion, the karst topography and fractured rocks facilitate the migration of pollutants into the ground waters. These landscapes receive pollutants from various industries located in cities, such as L'viv, Ivano-Frankivsk, Chernivtsi, Odesa and Kherson. In this part of the country there are also some hot spots of radionuclide fallout.

The landscapes where the accumulation of pollutants prevails are in the eastern, and to a lesser extent southern and north-eastern parts of Ukraine. These areas correspond more or less to the forest-steppe and steppe bioclimatic zones. The landscapes related to calcium and salt-bearing areas, commonly developed over carbonate rocks, are capable of accumulating pollutants, and chemical elements and their compounds in the soils. The areas are continuously loaded with eco-geochemical pollutants, related to the industrial activities in the Donbas and the Syvash, the industrial agglomerations of Chernihiv, Sumy, Shostka, Mariupol' and other large urban centers. Air pollutants include significant quantities of nitrogen, sulfur and salt acids. Soils contain a wide spectrum of toxic elements such as mercury, lead, cadmium, fluorine, zinc, chromium, arsenic, phosphorus and others.

Boggy areas of the northwestern Ukraine (Polissia), covering fluvioglacial deposits, can both accumulate pollutants and self-clean. These areas are heavily polluted with radionuclides from the Chernobyl' disaster. Both the radionuclides and the heavy metals are absorbed by humus and peat horizons, and are also

characterized by a strong migration capability as organo-mineral compounds in waters. This creates a serious threat of polluting both the surface waters and the groundwaters in the area. These waters are connected to the Dnipro river in Ukraine, a major water resource of the country. Other than these concerns, an additional eco-geochemical load is added from the manufacturing industries of Rivne, Zhytomyr and Kyiv.

Special formulas on the map illustrate the eco-geochemical load on the landscape in terms of associated chemical elements and their compounds emitted into the atmosphere and released into the effluent. The air pollutants are calculated on a basis of kilograms per person.

This type of map is the first one of its kind and covers the entire Ukrainian territory. The map offers a new approach in evaluating the geochemistry of surficial materials, and their capability to accumulate pollutants or their self-cleaning ability. It presents quantitative indicators and coefficients of migration of the heavy metals and radionuclides in the landscape, and provides coefficients of transfer between the landscape and the biota. This approach provides a new capability to map landscapes in different parameters, giving a good indication of the eco-geochemical load with the application of computer-based technology.

The map could serve as a basis for a regional appreciation of the risk of pollution of the biota by heavy metals, radionuclides and toxic organic compounds, depending on the landscape-geochemical conditions and intensity of the eco-geochemical load. The map could be also used in formulating protective programs for the environment, establishing causative and spatial relationships between the eco-geochemical environment and the health of the population, and planning rational and ecologically safe use of the area.

This map of the landscape and geochemical zoning establishes a baseline for ecological monitoring within Ukraine, for assessing pollution risks within separate areas and for working out recommendations on environmental protection and land use.

LANDSCAPE AND GEOCHEMICAL ZONING



LEGEND

GEOCHEMICAL LANDSCAPES OF DIFFERENT CAPABILITY FOR POLLUTANT MIGRATION AND ACCUMULATION

- Strong capability for self-purification
- Capable of self-purification
- Capability for accumulation is greater than for self-purification
- Weak capability for self-purification
- Capability for self-purification and accumulation is low

- Areas polluted by radionuclides (Cs-137, Sr-90)
- Areas with intense technogenic stress
- Zone boundaries

RESERVOIRS AND RIVERS WITH POLLUTED BOTTOM SEDIMENTS

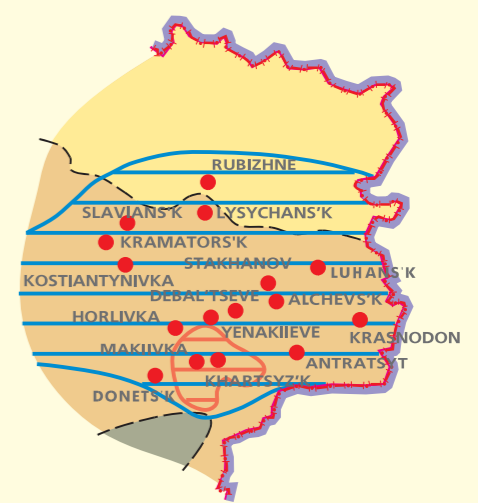
- With radionuclides
- With technogenic substances
- Cities with adverse environmental conditions

TOXIC ELEMENTS AND SUBSTANCES

$C_{7,1}Pb_{0,001}(Cl, SO_4, NH_4)$

$C_{7,1}Pb_{0,001}$ – toxic elements and substances in discharges into the air within cities, kg/capita per year
 (Cl, As, SO_4, NH_4) – toxic elements in waste water of industrial and urban agglomerations

DONBAS





Kamianka river, Ivano-Frankiv'sk oblast'



Geological site of basalt, Ivan's Valley, Berestovets' village, Rivne oblast'



Kremenchuk oil refinery



An array of natural gas pipelines crossing a river

INDUSTRIAL WASTE LOAD ON GEOLOGICAL ENVIRONMENT

Ukraine is a densely populated country with highly developed industrial and farming complexes. Industrial wastes have a strong influence on the ecological-geological environment, impairing living conditions and the economy of the country. The industrial waste load on the geological environment in Ukraine is 5 to 15 times heavier than in neighboring countries. Evaluations made by Ukrainian scientists from the Geological Survey of Ukraine (Derzhkomheolohiia), Ministry for Protection of the Natural Environment, and the Academy of Sciences of Ukraine, indicate that the total pollution (including solid, liquid and gas wastes) exceeds maxi-

mum allowable rates, and that measures taken to protect the soil and water of Ukraine are to date insufficient. All these factors contribute to both the observed and potential pollution of ground water, the principal and the most protected source of drinking water in Ukraine.

The main sources of environmental pollution within the country are factories, mining operations, mills, power plants, agricultural complexes and public utilities. They contribute wastes to dumps, active and covered garbage disposal areas, tailings or chemical ponds, filtering units, and surface water reservoirs, rivers and streams.

The map illustrates the degree of influence of various individual pollutants, in a bar chart form, for all administrative districts or oblasts of Ukraine. The bar chart is a ratio of the annual indi-

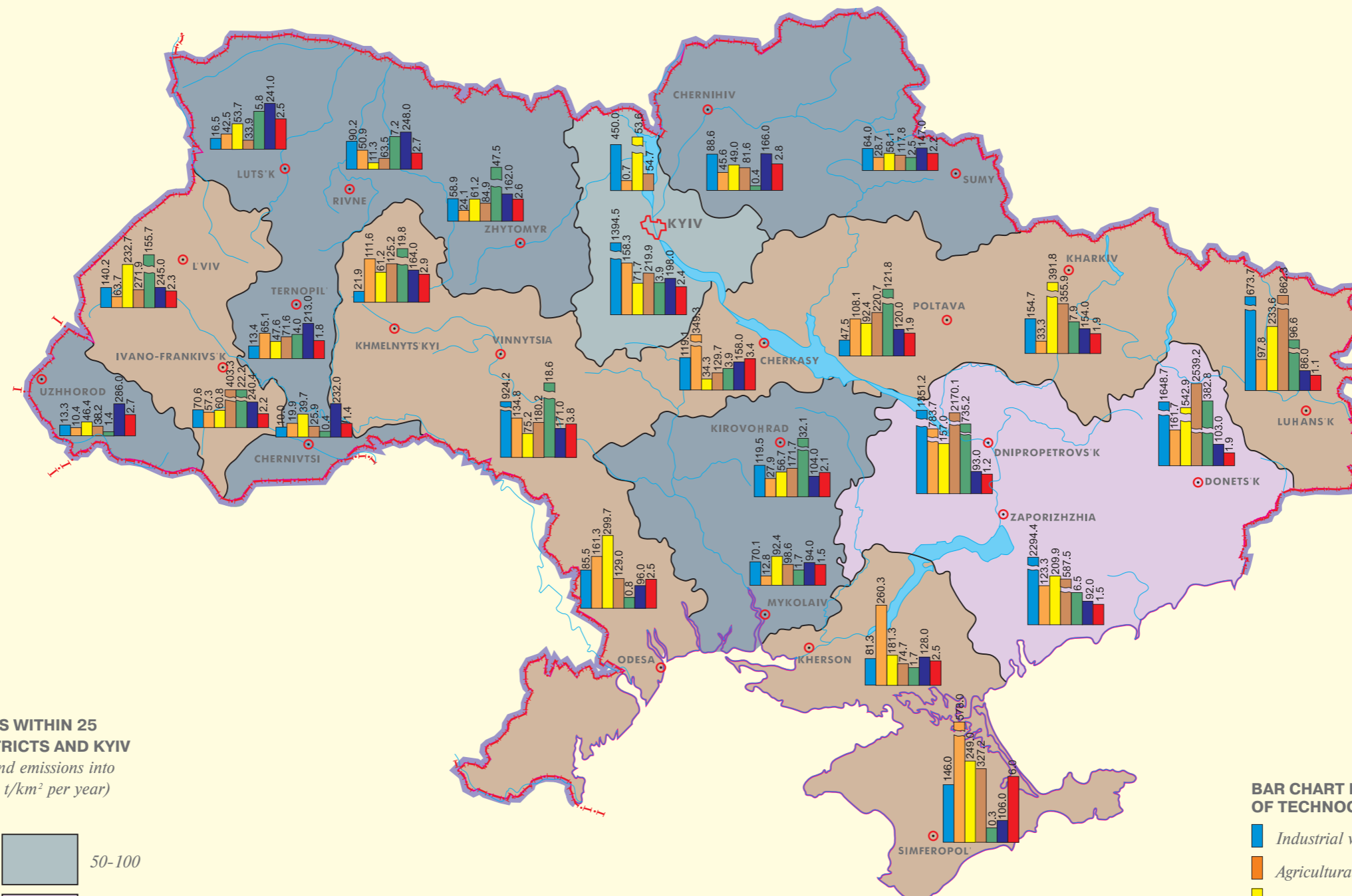
vidual pollutant to the area of the administrative district. Annually, there are 17 740 million m³ of liquid wastes, including 10 086 million m³ of industrial, 4146 million m³ of communal and 3510 million m³ of agricultural run-off, that is discharged into rivers, lakes and seas. In addition, there are 1.7 billion tons of solid wastes accumulated in stockpiles and dumps, 9 million tons of gases are emitted into the air, and 4.2 million tons of fertilizers and 46-89 000 tons of pesticides are applied to crops in Ukraine.

The Donets'k, Dnipropetrovs'k and Zaporizhzhia oblasts are subjected to maximum waste loads due to their highly developed mining, metallurgical, machine-building and chemical industries. The values of the pollutant stress range from 100 000 to 300 000 tons/km² per year in these areas. The agricultural

regions tend to have the lowest rates of pollution. The Kyiv industrial and urban agglomeration, with an area of about 1000 square kilometers, suffers from the highest pollution, which exceeds 1 000 000 tons/km² per year.

This type of map, covering the entire territory of Ukraine, is the first one of its kind. It gives an easy visual representation of the general degree of pollution in each district (oblast'), while the bar charts indicate the degree of contribution of each pollutant category in each district. The map forms a base for comparing the changes that occur within the country. These changes are reported to various government agencies on an annual basis. The data are then used in planning for the control and reduction of pollutants in various districts and for a wise use of natural resources.

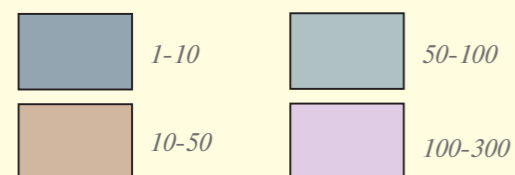
INDUSTRIAL WASTE LOAD ON GEOLOGICAL ENVIRONMENT



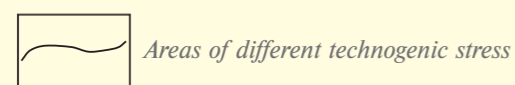
LEGEND

TECHNOGENIC STRESS WITHIN 25 ADMINISTRATIVE DISTRICTS AND KYIV

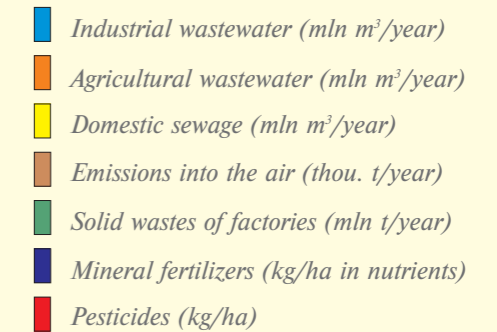
(liquid and solid wastes and emissions into the air, total in thousands t/km² per year)



OTHER SYMBOLS



BAR CHART FOR VARIOUS TYPES OF TECHNOGENIC LOAD





Proterozoic rapakivi granites, Novohrad-Volyns'kyi, Zhytomyr oblast'



Proterozoic granites, Hubkiv village, Rivne oblast'



Proterozoic granites, Korosten', Zhytomyr oblast'



Proterozoic granites in the canyon of the Hirs'kyi Tikych river, Buky village, Cherkasy oblast'

NATURAL RADIOACTIVITY

The nuclear power station disaster at Chernobyl' (1986) resulted in the contamination of 120 000 km² of Ukrainian territory with radionuclides (at levels exceeding 0.5 Ki/km²), thus aggravating the problem of natural radioactivity and its influence on human health.

The major areas of natural, but anomalous, elevated radioactivity are concentrated within the Ukrainian Shield. Less anomalous areas of natural radioactivity are found in the Donets' Basin and the Carpathians. In general, radioactivity is caused by thorium and uranium-bearing minerals in crystalline rocks, by uranium and radon gas in ground waters, and by radon in soil, water and air.

Natural radon emanations are observed in about 20% of the Ukrainian Shield territory. Such areas are characterized by numerous radio-geochemical anomalies with concentrations of radon of 100 eman and higher, and corresponding uranium and radium anomalies have values of 5×10^{-5} - 1×10^{-4} g/l and 1×10^{-11} - 5×10^{-11} g/l, respectively. In some places of Zhytomyr, Donets'k, Zaporizhzhia, Vinnytsia, Kirovohrad and Cherkasy oblasts, surveys revealed radon concentration of up to 900 eman and even 2000 eman. For these reasons the southern part of the Ukrainian Shield (100 000 km²) is the main natural uranium and radon-bearing field in Ukraine, not only in the rocks but also in the overlying soils and ground waters.

Natural radon and products of its decay account for about

three quarters of the annual irradiation dosage. The related irradiation thus produced by the radon gas concentration in the overlying soil and air is comparable to the fall-out irradiation from the Chernobyl' disaster.

People living in the uranium-mining areas are subjected to additional dosages of irradiation resulting from higher uranium concentration in the crystalline rocks of the area.

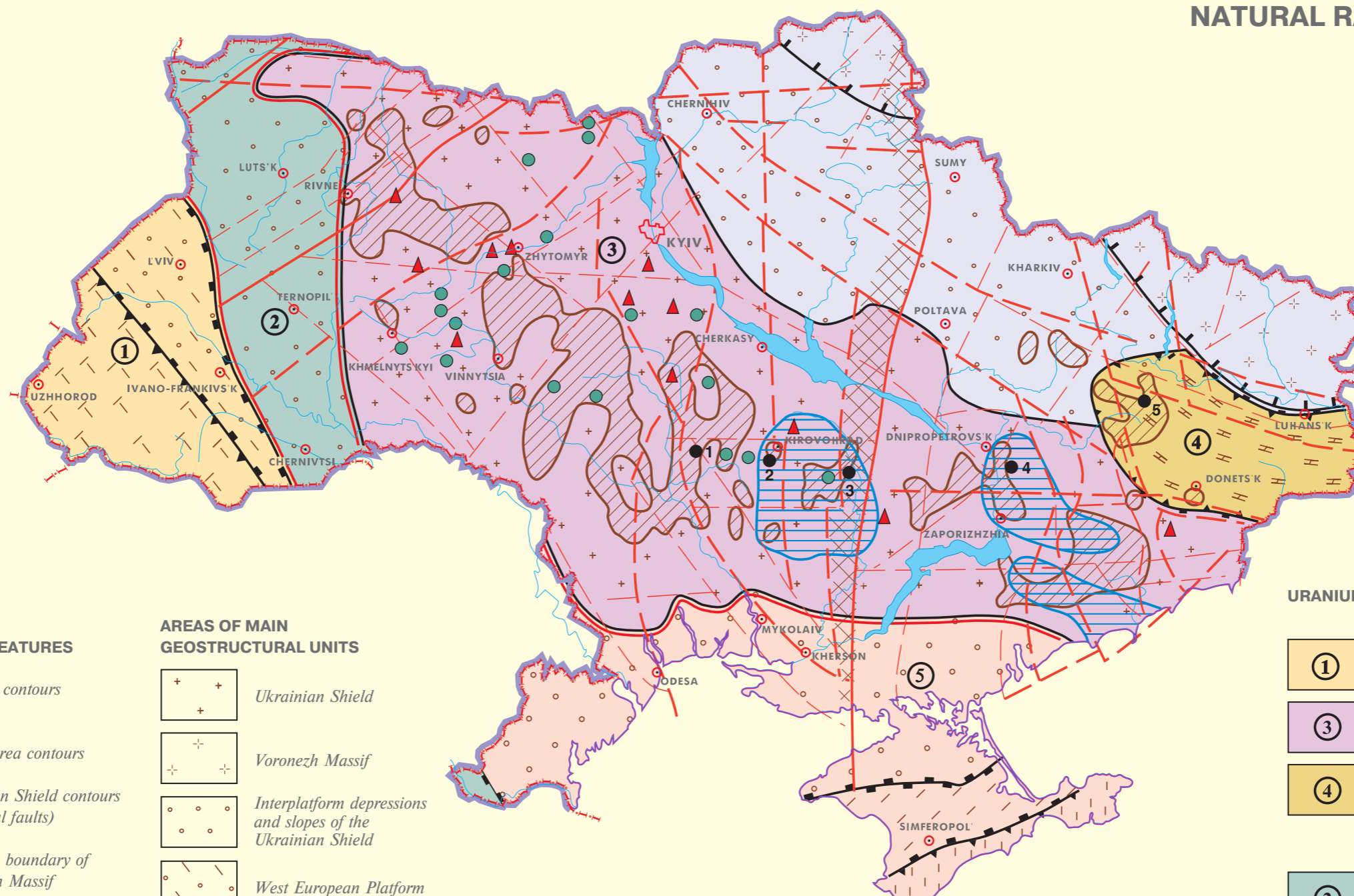
For these reasons, gathering of detailed data on natural radioactivity and further investigations into its impact on human health are urgent tasks, including the cumulative effects in areas contaminated with radionuclides from the Chernobyl' disaster.

In addition, these studies are of importance for mapping faults and other zones of activity, within which increased contents of

radioactive elements, heavy metals, fluorine, bromine, helium, etc. are observed in rocks and ground waters.

Elevated concentrations, particularly of radioactive chemical elements, both natural and as products of human activities, have a negative effect on the biogenic environment. In general it can be said that in the industrial zones there is a noticeable increase of diseases in the humans (general morbidity, kidney stones, etc.). These areas are also noted for their increase in the changes, brought about by human activities, on the surface geological phenomena. These include the accelerated development of karst and, with increased contamination of soils and surface waters and, as a result of strong exchanges between the surface waters and ground waters, the contamination of ground waters.

NATURAL RADIOACTIVITY



LEGEND

GEOSTRUCTURAL FEATURES

- Platform contours
- Folded area contours
- Ukrainian Shield contours (marginal faults)
- Southern boundary of Voronezh Massif
- Intermegablock suture zone
- Transregional faults
- Regional faults
- Other faults

AREAS OF MAIN GEOSTRUCTURAL UNITS

- Ukrainian Shield
- Voronezh Massif
- Interplatform depressions and slopes of the Ukrainian Shield
- West European Platform
- Folded areas of the Carpathians
- Scythian Plate
- Folded areas of the Crimean Mountains
- Donets' folded area

RADIOGEOCHEMICAL FEATURES

- Areas of abnormally high radon concentration in underground water (100 Em, 37 000 Bq/m³) soil and air
- Thorium anomalies in crystalline rocks
- Deposits of radon water
- Uranium deposits: 1. Vatutine; 2. Michuryn; 3. Zhovta Richka; 4. Sura; 5. Chervonyi Oskil

URANIUM PROVINCES

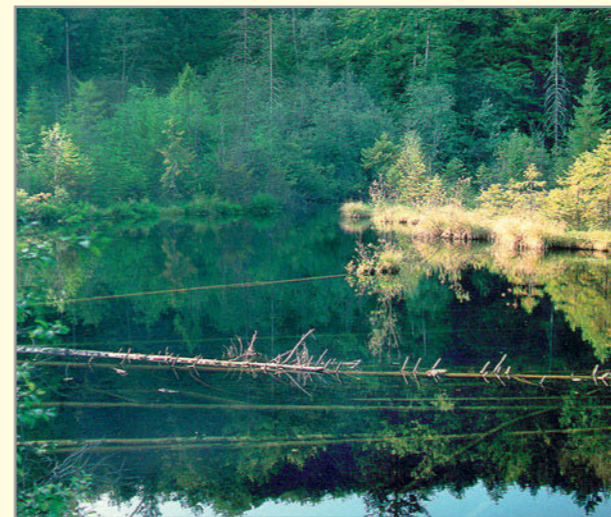
- REVEALED**
- 1 Carpathian
- 3 Ukrainian Shield
- 4 Donets'
- POTENTIAL**
- 2 Volyn'-Podillia
- 5 Crimean-Black Sea Lowland
- Dnipro-Donets' Depression and southern slopes of the Voronezh Massif
- Boundary and number of a province



Stolovi hory (Table Mountain), Western Crimea



Sluch river "Switzerland", near Hul's'k, Zhytomyr



Mountain Lake Morske Oko (Sea Eye), Kamianka village, L'viv oblast'



Slumped bank on the Tysva river, near Teresva, Zakarpattia oblast'

ECO-GEOLOGICAL SITUATION

Ecological-geological mapping involves a set of methods and technologies in the study of the ecological state of the geological environment and the changes produced by natural and man-made factors. The results of these studies are then presented on the ecological-geological maps.

The geological setting is the most important component of the natural environment. It includes soils, rocks, bottom sediments under lakes and rivers and ground waters. They are the most important elements of nature which interact with the atmosphere, hydrosphere, and biosphere and thus have a great influence on the living conditions of people. They also are the main repositories of such pollutants as radionuclides, heavy metals, toxic organic and other chemical compounds derived from liquid and solid wastes, debris and gaseous wastes blown by the wind. Mining activities in Ukraine are known to have caused, in places, irreversible harm to the geological natural environment. This, in turn, led to changes in the natural conditions which adversely affected human living conditions. Ukraine, like some other countries, has a high degree of industrial and agricultural development, energy use (especially atomic energy), and high population density. By comparison, however, the pollution rates, and the intensity of physical and chemical processes and energy exchange in Ukraine are from 5 to 15 times greater than in its neighboring countries. Finally, the disaster at the Chernobyl'

nuclear power station (1986) resulted in radioactive fallout over large portions of Ukraine, thus forming a new man-made radioactive geochemical province.

All of these factors contributed to the necessity for studying the state of the ecological-geological environment and recent changes in it throughout Ukraine.

During the compilation of the ecological-geological map of Ukraine, various data sources were utilized from different ministries and institutions. In particular, the following data were taken into account: 1) soil pollution with heavy metals and radionuclides such as Caesium-137 and Strontium-90 and their biogenic migration in the environment, 2) ground water pollution, 3) distribution of hazardous surface geological processes, and 4) accumulation of solid wastes. As a result, some new criteria for assessment of the environmental situation were worked out and applied, leading to a division of the country into regions of different man-made stress (hazardous, unfavorable and favorable).

The ecological-geological data on Ukraine allow the mapping of contour areas of the highest rates of environmental pollution, thus focusing on problem areas that require some immediate measures to improve the situation. At the same time, the map can be used for land-use planning, for the layout of large enterprises and cities, as well as for the protection of the environment and the wise use of natural resources.

Regions with highly unfavorable environments generally cover

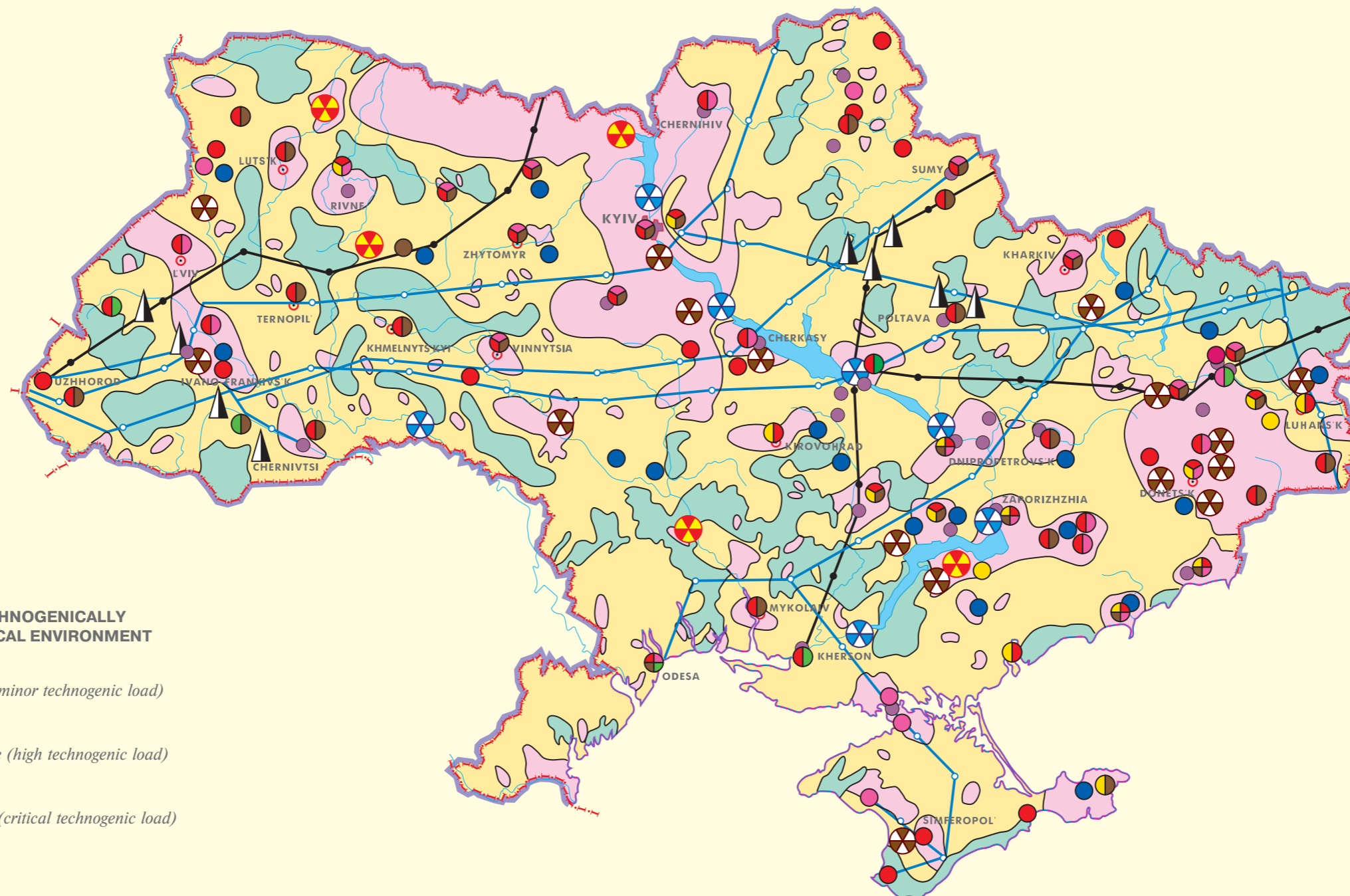
areas of intense urbanization, industrial cities, and commercial complexes and zones. Areas affected by the radioactive fallout are also included in this category. Mining areas in this category include the Donetsk, the Kryvyi Rih and the Forecarpathians. Here, the underground waters are unprotected and are commonly affected by pesticides, nitrates, toxic chemical elements and their compounds. Areas affected by surface dynamic processes (waterlogging, karst, landslides, subsidence) account for over 50% of these unfavorable environments. The contamination of soil with radionuclides such as Caesium-137 attain a range of 5-15 Ku/km², and in places exceeds 15 Ku/km². Air pollution from human activities is also high, frequently reaching 100 000 tons/km² per year.

Regions with unfavorable environment category occupy the largest portions of the Ukrainian territory and form a sort of background. Superimposed over this background are small areas of either intense pollution or of very little pollution. The unfavorable areas generally receive high rates of man-made pollutants, often from a single or a cluster of point sources and from intensive farming practices. They produce surface pollutants that are in the order of 20 000-95 000 tons/km² per year. The distribution of such pollution centers is generally 1-2 per 500 km². The underground waters here are not too well protected either. A negative contribution due to the surface geological processes amounts to 25-50% of the total category. Radionuclide contamination is generally less than 5 Ku/km².

Regions within a relatively favorable environment category have minor man-made pollutants. These are mainly agricultural lands and large forested areas, with small city-related industries. The underground waters are clean here. The effect of pollution resulting from surface geological processes amounts to less than 25%. Pollution from radionuclides is less than 1Ku/km². Lands within this category tend to occur more commonly in the western, south-central and northeastern parts of the Ukrainian territory. The map shows locations of the main man-made centers of activities that have a strong influence on the environment. These include industrial and power plants, and communication centers, and also places with an unfavorable ecological environment. The map also shows areas reaching critical levels of pollution. Furthermore, the map shows a mosaic-like pattern which is typical of the territories with complex geology and an uneven distribution of the man-made centers of activities.

This map is the first one of its kind in Ukraine, and its originality depends on the integral evaluation of both natural and human factors. The practical aspects of this map have two connotations – first, as an experience of applying new methods to map those parameters of the geological environment that have an influence on the ecology of our world, and second, as a basis that the map provides for the planning, distribution and development of Ukraine's productive forces in the future, as well as for the protection of the environment and the wise use of natural resources.

ECO-GEOLOGICAL SITUATION



LEGEND

ECOLOGY OF THE TECHNOGENICALLY DISTURBED GEOLOGICAL ENVIRONMENT

- Favorable (minor technogenic load)*
- Unfavorable (high technogenic load)*
- Hazardous (critical technogenic load)*

POLLUTION SOURCES EXERTING INFLUENCE ON THE GEOLOGICAL ENVIRONMENT

Plants and factories

- Metallurgical*
- Machine-building*
- Chemical*
- Oil-processing*
- Building materials*
- Mine*
- Oil and gas fields*
- Cluster of various enterprises (machine-building, metallurgical and building materials)*

POWER PLANTS

- Nuclear*
- Thermal*
- Hydroelectric*

PIPELINES

- Main gas pipelines*
- Main oil pipelines*

- Towns with unfavorable environmental situation*
- Boundaries between areas of different ecological-geological environment*



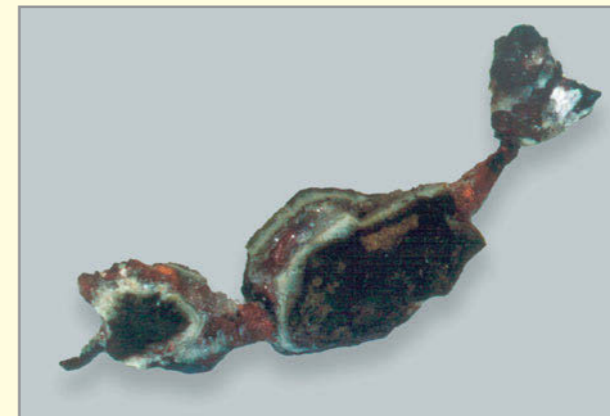
Blue topaz, Volyn' deposit, Zhytomyr oblast'



Yellow-green beryl, Volyn' deposit, Zhytomyr oblast'



Crystals of morion and feldspar, Volyn' deposit, Zhytomyr oblast'



Native copper, Volyn'



Banded jaspilite, Kryvyi Rih iron-ore basin



Oxidized carbonate manganese ore (black), Nikopol' basin



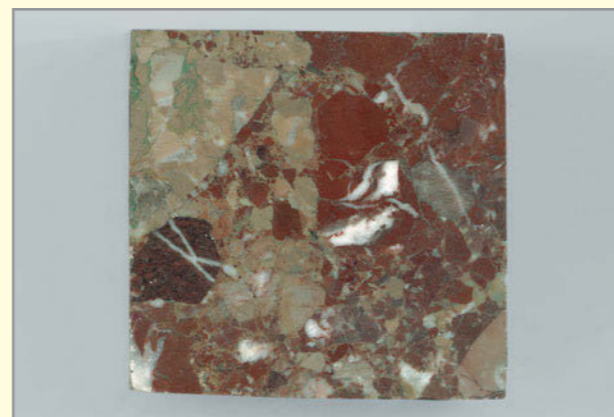
Cinnabar (red) with antimonite, Mykytivka deposit, Donetsk oblast'



Gibbsitic bauxite, Smila deposit, Ukrainian Shield



Potassic salt, Forecarpathia



Colored marble, Transcarpathia



Red granite facing stone, Ukrainian Shield



Iridescent labradorite, Holovyne deposit, Zhytomyr oblast'

T H E G E O L O G Y A N D M I N E R A L D E P O S I T S O F U K R A I N E



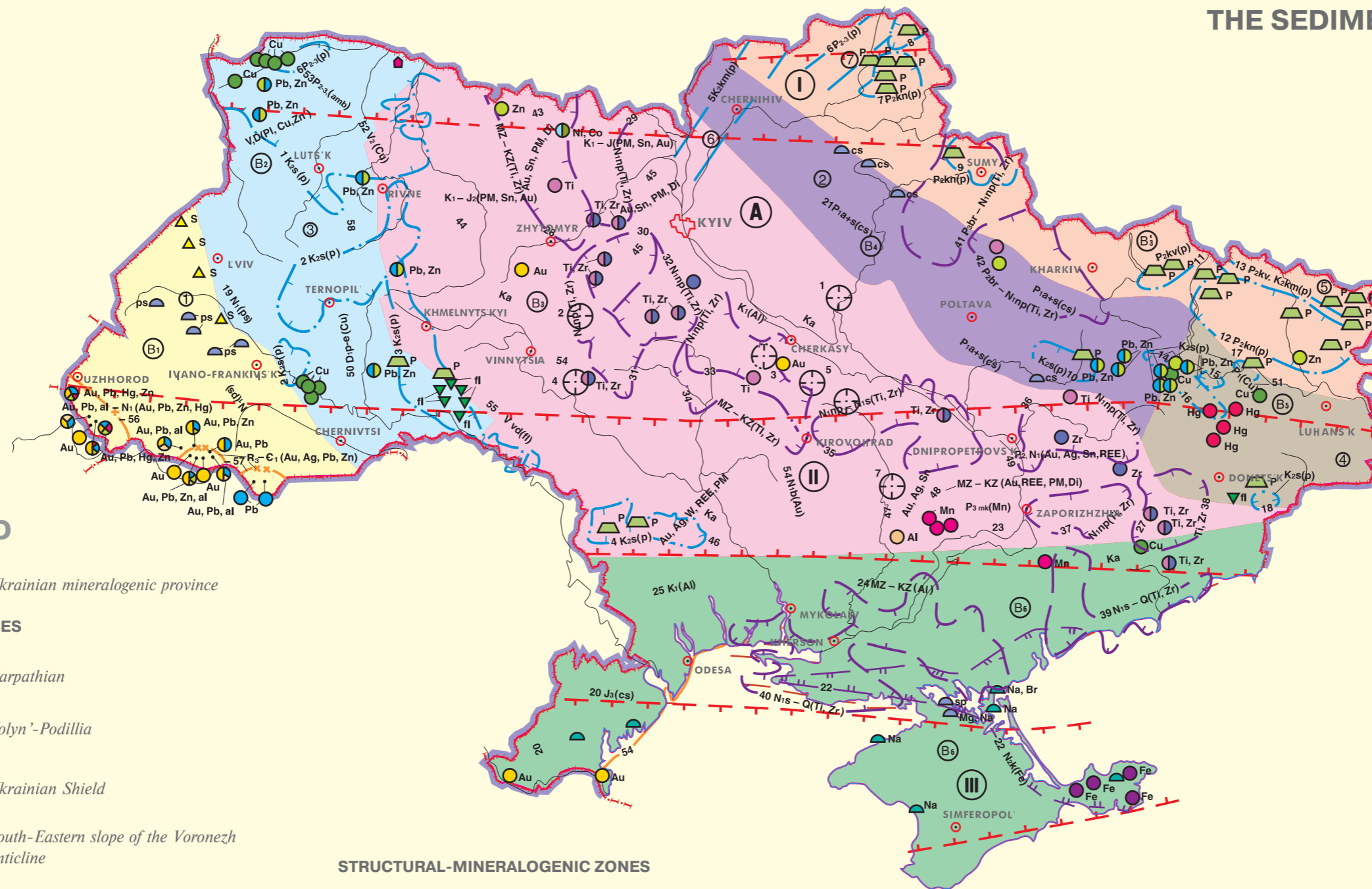
section VII

MINERALOGICAL MAPS

- Mineralogic zoning of the sedimentary cover
- Metallogenic provinces
- Fossil fuels – oil and gas
- Coal
- Ferrous metals (iron, manganese and chromite)
- Gold deposits
- Rare metals
- Titanium and zirconium placers and source deposits
- Diamonds
- Gems, semiprecious and decorative stones
- Geothermal power
- Mineral water sites
- Clay and kaolin
- Enterprises, industrial wastes and mining tailings
- Mineral deposits
- Mineral deposits currently in production
- Mining areas
- History of mining in Ukraine
- Unusual geological features



MINERALOGENIC ZONING OF THE SEDIMENTARY COVER



LEGEND

A Ukrainian mineralogical province

SUBPROVINCES

- B₁** Carpathian
- B₂** Volyn'-Podillia
- B₃** Ukrainian Shield
- B_{3'}** South-Eastern slope of the Voronezh anticline
- B₄** Prypiat'-Donets'
- B₅** Donets'
- B₆** Black Sea-Crimea-Azov
- K_a** Kaolin subprovince of the Ukrainian Shield

STRUCTURAL-MINERALOGENIC ZONES

- 1** Carpathian-Dnister
- 2** Dnipro-Donets' Depression (aulacogen)
- 3** Volyn'-Dnister
- 4** Central Donbas
- 5** Starobil's'k-Millerovo
- 6** Unuchky-Shchors
- 7** Seredyna-Buda

MEGAZONES OF FRACTURING

- I** North Ukrainian
- II** Central Ukrainian
- III** South Ukrainian

OTHER SYMBOLS

- Dislocations established by a number of different methods
- Impact structures (astroblemes): 1-Obolon', 2-Bilylivka, 3-Rotmistrivka, 4-Illintsi, 5-Bovtyshka, 6-Zelenyi Hai, 7-Ternivka

COMMERCIAL MINERALS

- Fe Iron
- Mn Manganese
- Ti Titanium
- Cu Copper
- Pb Lead
- Zn Zinc
- Al Aluminum
- Hg Mercury
- Zr Zirconium
- Au Gold
- al Alunite
- Ni Nickel
- Co Cobalt
- Amber Amber
- fl Fluorite
- P Phosphorite
- PS, CS Potash salt, common salt
- Na, Mg, Na, (Br) salts
- S Sulfur

METALLOGENIC PROVINCES

This map generalizes all the available metallogenic data of recent years, and shows not only metallogenic zones within Ukraine, but also some history of their development. The metallogenic analysis and divisions are based upon the most recent scientific concepts – the evolution and various stages of development of the Earth's crust, plate tectonics, the layering in the Earth's crust, the distribution of the geoblocks in the Earth's crust, structural-formational analysis and metallogenic zoning. The map illustrates the development of metallogenic epochs in time and space and in terms of the actual mineral deposits. In general, the metallogenic subprovinces correspond to tectonic zones. In Ukraine, large metallogenic divisions include the Dnipro-Donets', the Dnister River - Black Sea Lowland, the Carpathian-Crimean and the Ukrainian Shield metallogenic provinces. These provinces are further subdivided into subprovinces, structural-metallogenic zones, metallogenic zones and metalliferous regions. Various deposits are indicated on the map individually. The Ukrainian Shield was built up in three stages – the first stage was a protracted development of the Archean Craton. This was followed by the development of the Early Proterozoic mobile belts. And the final stage was associated with rifting. The first stage is characterized by the following structural-formational zones (SFZ) – high grade metamorphic enderbite-granulite rocks, lower grade amphibolite-gneissic rocks, and greenschist facies greenstone-granite assemblages. These rocks contain iron, gold, graphite, chromite, talc and magnesite deposits. The second stage was marked by the development of depressions, and tectono-thermally reworked suture zones between Archean cratons. This stage is marked by the development of iron, gold, uranium, titanium, lithium, vanadium, rare earth metals, apatite and gem stone deposits. During the last stage there were reactivations, especially along the structural-formational zones, which were commonly accompanied by rifting. Rare earth metals, tin,

STRUCTURAL METALLOGENIC ZONES THEIR AGES AND METALS

- I – Sushchany – Perha PR2-3/Be, Sn, REE, Zr, fl
- II – Korosten' PR2/Ti, ap, V, Sc, mor, to, be
- III – Bila Tserkva AR3/Fe, U
- IV – Holovaniv'sk AR-PR/Ni, Cr, Au, gf, Fe, Pt
- V – Korsun'-Novomyrhorod PR2/Ti, ap, Zr
- VI – Zvenyhorodka-Khmelivka PRI / U, Li, Ta, Nb, Au
- VII – Kirovohrad PRI / U, Au
- VIII – Western Inhulets' PRI/gf, Fe
- IX – Kryvyi Rih – Kremenchuk PRI/Fe, U, Sc, V, REE, Ge
- X – Verkhivtsi – Chortomlyk AR-PR1/Au, Fe, (Pt)
- XI – Sura AR-PR1/Au, Mo, t-mg
- XII – Kins'ka-Bilozerkka AR/Fe
- XIII – Orikhiv-Pavlohrad AR-PR1/Fe, Nb, REE
- XIV – Western Azov AR-PR1/Ta, Nb, ap, Fe, Au
- XV – Central Azov AR-PR/Fe, gf
- XVI – Vovcha PRI/Li, Ta, Nb
- XVII – Eastern Azov PR2/REE, Zr, Ta, Nb, fl, (dim)
- XVIII – Central P-T/ps, S, Pb, Zn
- XIX – Bakhmut-Nahol'na P-T/Hg, Sb, Au, Pb, Zn, Cu, cs
- XX – Prypiat'-Dnister PR3/Cu, fl (dim)
- XXI – L'viv-Ternopil' O-D/ (Pb, Cu)
- XXII – Forecarpathian N/S, ps, cs
- XXIII – Carpathian N/Hg
- XXIV – Transcarpathian N/Au, Pb, Zn, Ag, Hg, cs, ba
- XXV – Marmarosh PR2-PZ/Au
- XXVI – Crimean Mountain T-J/(Pb, Au)

tungsten, molybdenum, silver and pyrophyllite deposits are characteristic of this latter stage.

The Phanerozoic complexes unite two groups of the structural-formational zones – the platform assemblages and the folded belts. The first group is represented by a zone of passive continental margins and outside portions of the plates. The SFZ of the folded Alpine complex are the active margins of the continents and represent their collisions. Each one of these types of SFZ has its own metallogenic peculiarities. In terms of metallogeny, two SMZ groups are distinguished within Phanerozoic complexes. The platform cover contains manganese, titanium, zirconium, mercury, gold, silver, base metals, native copper, fluorite, potassic and rock salts, phosphorite and kaolin deposits. The folded systems have gold, silver, base metals, iron, mercury, alunite, barite, germanium, potassic and rock salts and sulfur deposits. Ukraine is characterized by some of the largest deposits of iron and manganese in the world. In addition there are large deposits of titanium, zirconium, graphite, kaolin, uranium, rare earth elements, lithium, sulfur and salts. Lesser deposits include gold, nickel, lead, zinc, chromite, apatite, gems and semiprecious stones, pyrophyllite and other minerals.

The Ukrainian Shield metallogenic province is rich in iron, graphite, titanium and uranium. Some new non-traditional deposits for this province (in Ukraine) have been discovered here. Thus in the granite-greenstone belts of the mid-Dnipro region (Sura and Verkhivtsi-Chortomlyk SFZ) gold has been discovered. Also, in the synclinal structures and in the epicratonic troughs filled by the Proterozoic volcanic-sedimentary formations, new fields of lithium pegmatites have been discovered in the Zvenyhorodka-Khmeliv SFZ and the Fedorivka metallogenic zone. Rare earth metal mineralization, associated with subalkaline and alkaline rocks, includes tantalum, niobium, beryllium, rare earth metals, zirconium, lead, molybdenum, lithium and fluorine. These deposits occur in the Sushchany-Perha and the Azov SFZ.

METALLOGENIC ZONES THEIR AGES AND METALS

- 1 – Ovruch PR2-PZ/pp, ap, (Au, dim)
- 2 – Krasnohirka-Zhytomyr PR1-2/Ni, Cu, Co, Pt, mu, (Au, Cs, Rb, gf, Nb, Ta)
- 3 – Kocheriv PR1/do, (Ta, Nb, Rb, Li, W, Sn, U, Au, fl)
- 4 – Khmel'nyts'kyi PR1-2/REE, gf, Mo, gr, (Zr, U, Cu)
- 5 – Northern-Podillia PR1-2/(REE, ap, Al)
- 6 – Kosnytsia-Voronkivs'ka AR/(Fe)
- 7 – Horodyshe-Smila PR2/Ti, ap, V, Sc, (Nb, Ta)
- 8 – Novomyrhorod PR2/Ti, ap, V, Sc
- 9 – Inhulets'-Kazanka PR1/(Pb, Zn, ap, gf, REE, Mo, Fe)
- 10 – Devladove AR-PR1/U, (Th, Ni, Mo)
- 11 – Fedorivka PR1/Li, Ta, Nb, (Rb, Cs, Sn)
- 12 – Haichur PR1/(REE, Nb, Ta, U, Au, ap)
- 13 – Chernihiv PR1/ap, Nb, Ta, REE, cor
- 14 – Soroky PR1/Ta, Nb, Au, Li, Rb, Cs, gf
- 15 – Oktiabrs'ke PR2/Ta, Nb, Zr, Al, REE
- 16 – Kal'mius PR2/REE, fl
- 17 – Slovians'k-Artemivs'k P-T/cs, (Pb, Zn)
- 18 – Bakhmut P/Cu, Pb, Zn, (Ag)
- 19 – Southern Donbas P-T/fl, (Pb, Zn, Ag, Au, REE)
- 20 – Lukiv-Ratne PR3/Cu, (Pb, Zn, Ag, dim)
- 21 – Podillia-Dnister PR3/fl, (Pb, Zn, Li, Ag, Au)
- 22 – Dubno-Horodok O-S/(Pb, Zn, Ag, Cu)
- 23 – Stanislav N1/S
- 24 – Sambir N1/ps

METALLIFEROUS REGIONS AND THEIR METALS

- 1 – Perha Be, Ta, Nb, REE, Zr, fl, Sn, di, (W, Pb, Zn, Ag, Au, Ti, ap, U, Th)
- 2 – Volyn' Ti, ap, V, Sc, Zr, mor, to, be
- 3 – Pobuz'ke Fe, Ni, Co, Cr, Au, (Cu, Pt, gf, Mo, U)
- 4 – Brats'ke-Oleksivka U, Th
- 5 – Novokostiantynivka U, Th

The Korosten' and Korsun'-Novomyrhorod structural-formational zones contain rapakivi-granites and gabbroic intrusions. They have associated titanium, apatite, vanadium, scandium mineralization, and pegmatites with topaz, beryl and morion. Unusual gold deposits have been discovered in the high grade gneissic-granulite complexes, volcano-plutonic belts, and in zones of tectonism in the Holovaniv'sk and Kirovohrad SFZ. The volcano-plutonic belts in the Volyn' subprovince have good potential for copper-nickel sulfide deposits associated with the pyroxenite-gabbro-norite and gabbro-dolerite-troctolite complexes. Diamond drilling has intersected widely disseminated and some massive sulfide (Cu-Ni-PGE) mineralization in these areas.

The Ukrainian Shield is known for its graphite deposits. There are no known analogs elsewhere in the world that have as much graphite as Ukraine. Some of the major deposits include – Burtyn, Petrove-Balakhivka, Khashchuvate-Zavallia and Sachkine-Troits'ke.

The Kryvbas structure (Kryvyi Rih-Kremenchuk SFZ) has been recently interpreted in a different way. The new model proposed a monoclinical structure for the iron deposits of the Kryvyi Rih, and a subductive-obductive pattern of development in the tectonic history of this area. Shear-zones here have talc horizons and appear to be the main ore-controlling structures that gave rise to these huge iron deposits.

The Dnipro-Donets' metallogenic province contains mercury, gold, base metals, copper and rock salt in Paleozoic carbonate-terrigenous, lagoonal, evaporite and red terrigenous formations. They are associated with the Central and the Bakhmut-Nahol'na SFZ.

The Dnister - Black Sea coastal province is characterized by the native copper found in the Vendian trap rocks (Lukiv-Ratne metallogenic zone), and fluorite in the continental terrigenous formations (the Podillia-Dnister River metallogenic zone) of the same age.

- 6 – Kirovohrad U, Au, (REE, Th, fl, ap, W)
- 7 – Pravoberezhnyi Fe, Ge, (gf, Au)
- 8 – Inhulets' U, Th
- 9 – Kryvyi Rih Fe, Ge, U, Sc, V, REE, gf, t, (Cu, Zr, Li, Mo, Au, W)
- 10 – Kremenchuk Fe, Ge, U, (Au)
- 11 – Verkhivtsi Au, Fe, (Cu, Ni, Co, Mo, U, t)
- 12 – Chortomlyk Au, Fe, (Cu, Ni, Co, Mo, U)
- 13 – Solone Au, Mo, Ni, Cu, Co, t-mg
- 14 – Bilozerkka Fe, (Au, Cu, Ni)
- 15 – Mykytivka-Kostiantynivka Hg, Sb, (As, Li)
- 16 – Nahol'na Au, Ag, Pb, Zn, (Li)
- 17 – Berehove-Bihan' Au, Ag, Pb, Zn, al, ba, (Cd, Cu, Hg, Ge)
- 18 – Soltovyna cs
- 19 – Rakhiv Au, Ag, (Pb, Zn, Cu, Ni, Co, Mn, U)
- 20 – Kerch Fe, (V)

ORE FIELDS

- 1 – Verby Mo, (Sn, fl)
- 2 – Buky Ni, Cu, Co, (Pt, Au)
- 3 – Burtyn gf
- 4 – Nehrebivka do
- 5 – Volodars'k-Volyns'kyi mor, to, be
- 6 – Fedorivka-Vydobor Ti, ap, V, Sc
- 7 – Chopovychi Ti, ap, V, Sc
- 8 – Khashchuvate-Zavallia gf, Au, (Mn, REE)
- 9 – Savran' Au
- 10 – Moldovka-Sekretarka Fe, Ni, Co, (Au, Pt, gf, Mo)
- 11 – Kapitanivka Ni, Co, Au, Cr, (Mo, Cu, Pt, U)
- 12 – Nosachiv Ti, ap, V, Sc
- 13 – Stankuvate Li, (Ta, Nb, Be, Cs, Au, gf)
- 14 – Klyntsi-Koneve Au, (U, Th)
- 15 – Petrove-Balakhivka gf, Fe, (Au, REE, Mo)
- 16 – Zhovta Richka Sc, V, REE, U, Fe, (Ge, Zr, Li, W)
- 17 – Vasynivka Fe

The Carpathian-Crimean metallogenic province contains gold, base metals, mercury, barite, alunites in the andesite-basalt, liparite-dacite and green schist formations (the Forecarpathian and the Marmarosh SFZ), along with sulfur, rock and potassic salt in terrigenous salt-bearing and sulfate-carbonate formations (the Forecarpathian and Transcarpathian SFZ), and iron in the ferrous sandy-clay formations (the Kerch iron region).

Of particular interest are the megazones of fracturing which have a transregional character. These linear zones measure up to tens of kilometers in width and hundreds to a thousand kilometers in length. The central megazone crosses the entire Ukrainian Shield, the southern parts of the Donbas and the Carpathian Mountains. Contained within this zone are some of the main gold deposits, rare earth metal deposits, uranium and fluorite deposits of the Ukrainian Shield, and the polymetallic gold and mercury deposits of the Carpathians and the Donbas. The northern megazone crosses the northwestern margin of the Ukrainian Shield, the northern part of the Volyn'-Podillia Depression, the northern part of the Dnipro-Donets' Depression and continues its trend toward the Voronezh Complex in Russia. Within this zone there are rare earth metal deposits, polymetallic silver deposits, fluorite deposits in the Ukrainian Shield, and concentrations of native copper in the traps of Volyn'.

Reserves of iron, manganese, titanium, graphite, zirconium, kaolin, sulfur and rock salt put Ukraine on a list of countries which are richest in these minerals. Moreover, new non-traditional metals for Ukraine have been also discovered and evaluated, including gold, base and rare earth metals, lithium, nickel, chromite, copper, fluorite, diamond and amber.

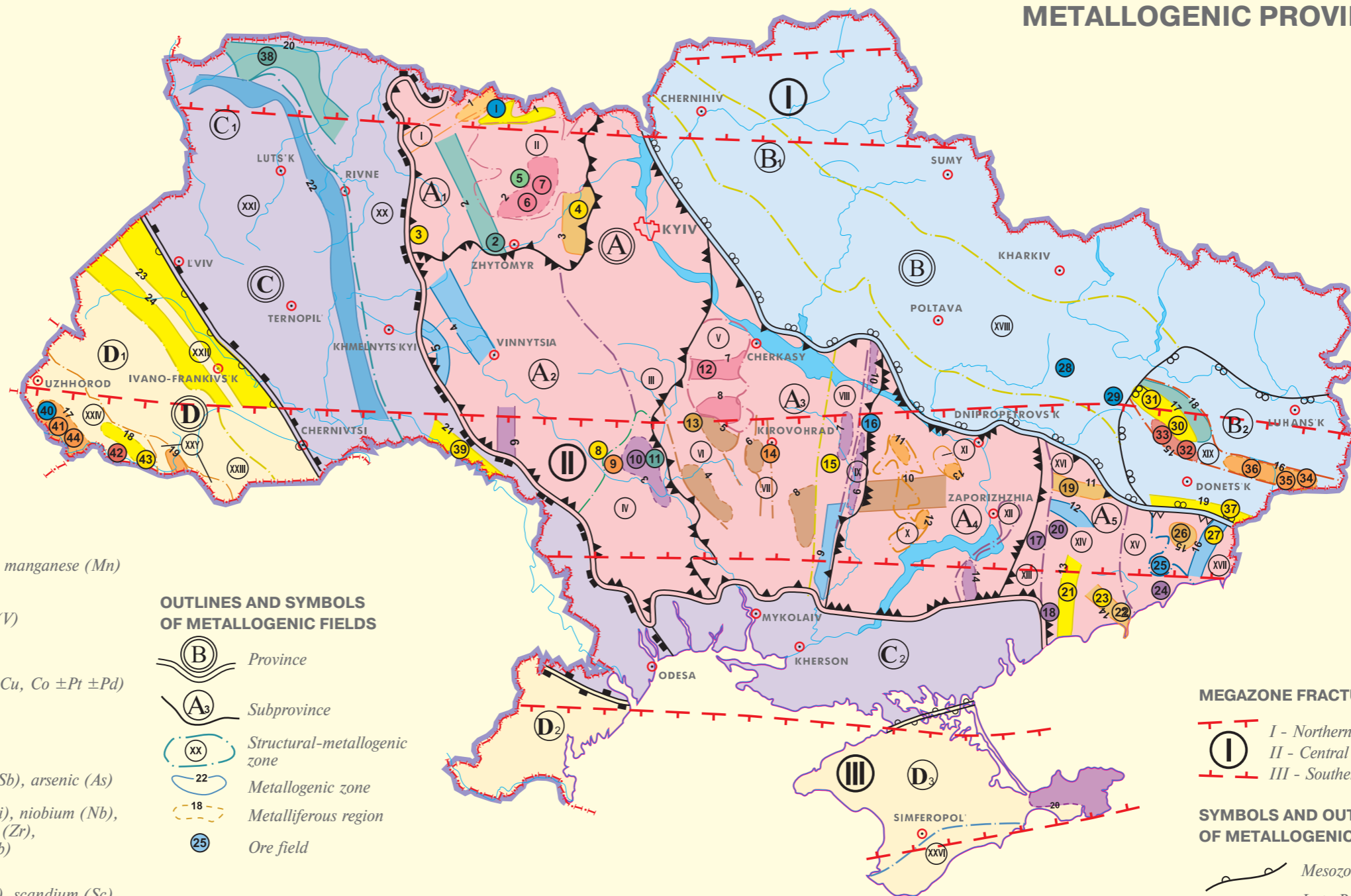
In summary, it can be said that a new level of metallogenic analysis has been achieved in Ukraine. The main relationships among the processes of mineralization, the types of ore-bearing environments and the importance of structures in the understanding of metallogenesis have been presented on this map.

- 18 – Korsak-Kuksunhur Fe, (gf, Sl, Au)
- 19 – Shevchenka-Fedorivka Li, Ta, Nb, (Rb, Cs, Sn)
- 20 – Hulaiipole Fe, (Au, U)
- 21 – Novopoltavka ap, Nb, Ta, REE
- 22 – Pivdenno-Sorochyne Nb, Ta, Au, Li, Rb, Cs
- 23 – Sachky-Troits'ke gf, (Au)
- 24 – Manhus Fe, gf, (Au)
- 25 – Southern Kal'chik REE, Zn, fl, Ti, V, ap
- 26 – Mazurivka Nb, Ta, Zr, Al, REE
- 27 – Petrovo-Hnutove fl, REE
- 28 – Biliaivka Pb, Zn, (cs)
- 29 – Novodmyrivka Pb, Zn, (cs)
- 30 – Artemivs'k cs, (Pb, Zn)
- 31 – Slovians'k cs, (Pb, Zn)
- 32 – Mykytivka Hg, Sb, (As, Li)
- 33 – Druzhkivka-Kostiantynivka Hg, Sb, (As, Li)
- 34 – Nahol'no-Tarasivka Au, Ag, Pb, Zn, (Li)
- 35 – Bobrykove Au, Ag
- 36 – Nyzhnii Nahol'chik Au, Ag, Pb, Zn, (Li)
- 37 – Pokrovka-Kyriivka fi, (REE, Pb, Zn)
- 38 – Otchyn-Ratne Cu, (Pb, Zn, dim)
- 39 – Bakhtyn fl, (Li, Pb, Zn, Ag, Au)
- 40 – Bihan' Pb, Zn, Au, Ag, al, ba, (Cd, Cu, Hg)
- 41 – Berehove Au, Ag, Pb, Zn, ba, Ge
- 42 – Vyshkovo Hg, Au, Ag, (Sb, Mo, ba)
- 43 – Soltovyna cs
- 44 – Kvasove Au, Ag, Pb, Zn

Note:












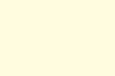

Chemical and other symbols show principal mineral deposits. Second-order mineral deposits are in parentheses.

METALLOGENIC PROVINCES



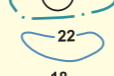

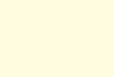
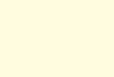


LEGEND





MINERALIZATION WITHIN METALLOGENIC UNITS

-  Iron (Fe), chromium (Cr), manganese (Mn)
-  Titanium (Ti), vanadium (V)
-  Copper (Cu), ±Zn ±Pb
-  Nickel-copper-cobalt (Ni, Cu, Co ±Pt ±Pd)
-  Lead (Pb), zinc (Zn)
-  Molybdenum (Mo)
-  Mercury (Hg), antimony (Sb), arsenic (As)
-  Beryllium (Be), lithium (Li), niobium (Nb), Tantalum (Ta), zirconium (Zr), Cesium (Cs), rubidium (Rb)
-  Rare earth elements (REE), scandium (Sc)
-  Uranium (U), thorium (Th)
-  Gold (Au), silver (Ag)
-  Apatite (ap), muscovite (mu), graphite (gf), talc-magnesite (t-mg), pyrophyllite (pp), kyanite (di), sillimanite (sl), dolomite (do), fluorite (fl), garnet (gr), corundum (cor), sulfur (S), barite (ba), alunite (al), common salt (cs), potassic salt (ps)
-  Morion (mor), topaz (to), beryl (be), diamond (dim)

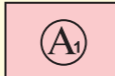

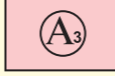
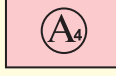
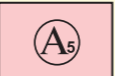

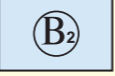




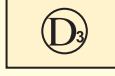
OUTLINES AND SYMBOLS OF METALLOGENIC FIELDS

-  Province
-  Subprovince
-  Structural-metallogenic zone
-  Metallogenic zone
-  Metalliferous region
-  Ore field


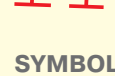

PROVINCES

-  Ukrainian Shield
-  Dnipro-Donets'
-  Dnister-Black Sea
-  Carpathian-Crimean






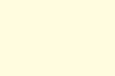


SUBPROVINCES

- | | | | | | | | | | | | |
|--|--|--|--|--|--|---|--|---|--|---|---|
|  Volyn' |  Podillia |  Kirovohrad |  Mid-Dnipro |  Azov |  Dnipro |  Donets' |  Volyn'-Dnister |  Black Sea |  Carpathian |  Dobruja |  Crimean |
|--|--|--|--|--|--|---|--|---|--|---|---|

MEGAZONE FRACTURING

-  I - Northern Ukrainian
-  II - Central Ukrainian
-  III - Southern Ukrainian

SYMBOLS AND OUTLINES OF METALLOGENIC EPOCHS

-  Mesozoic-Cenozoic
-  Late Paleozoic (Hercynian)
-  Early Paleozoic (Caledonian)
-  Late Proterozoic
-  Middle Proterozoic
-  Early-Middle Proterozoic
-  Archean-Early-Proterozoic
-  Archean



An oil well drilling rig, Dnipro-Donets' Depression



A mobile marine drilling platform in the Black Sea



An oil well pump, Dnipro-Donets' Depression



Natural gas station, Dnipro-Donets' Depression, Poltava oblast'

EASTERN REGION

- 1 – Talalaivka
- 2 – Mala Divytsia
- 3 – Pryluky
- 4 – Anastasivka
- 5 – Korzhi
- 6 – Leliaky
- 7 – Hnidyntsi

- 8 – Hlyns'k-Rozbyshivka
- 9 – Rudivka-
- Chervonozavods'ke
- 10 – Buhruvate
- 11 – Kachanivka
- 12 – Yablunivka
- 13 – Rybals'ke
- 14 – Kotel'va

- 15 – Komyshnia
- 16 – Opishnia
- 17 – Matviivka
- 18 – Yul'ivka
- 19 – Rozpashne
- 20 – Western
- Khrestyshche
- 21 – Melykhivka

- 22 – Shebelynka
- 23 – Abazivka
- 24 – Mashivka
- 25 – Medvedivka
- 26 – Yefremivka
- 27 – Reshetniakivka
- 28 – Matviyivka
- 29 – Bahate

- 30 – Lobachivka
 - 31 – Kondrashivka
- WESTERN REGION**
- 1 – Lokachi
 - 2 – Rudky
 - 3 – Bil'che-Volytsia
 - 4 – Uhry

- 5 – Boryslav
- 6 – Northern Dolyna
- 7 – Dolyna
- 8 – Strutyn'
- 9 – Bytkiv-Babche
- 10 – Rus'ki Komarivtsi
- 11 – Lopushne

SOUTHERN REGION

- 1 – Coastal Azov Sea
- 2 – Eastern Sarata
- 3 – Strilkove
- 4 – Dzhankoi
- 5 – Holitsyn
- 6 – Schmidt
- 7 – Zadornenka

- 8 – Tetianivka
- 9 – West Oktiabrs'ke
- 10 – Arkhanhel's'k
- 11 – Odesa
- 12 – Shtorm
- 13 – Northern Kazantyp
- 14 – Voikove
- 15 – Semenivka

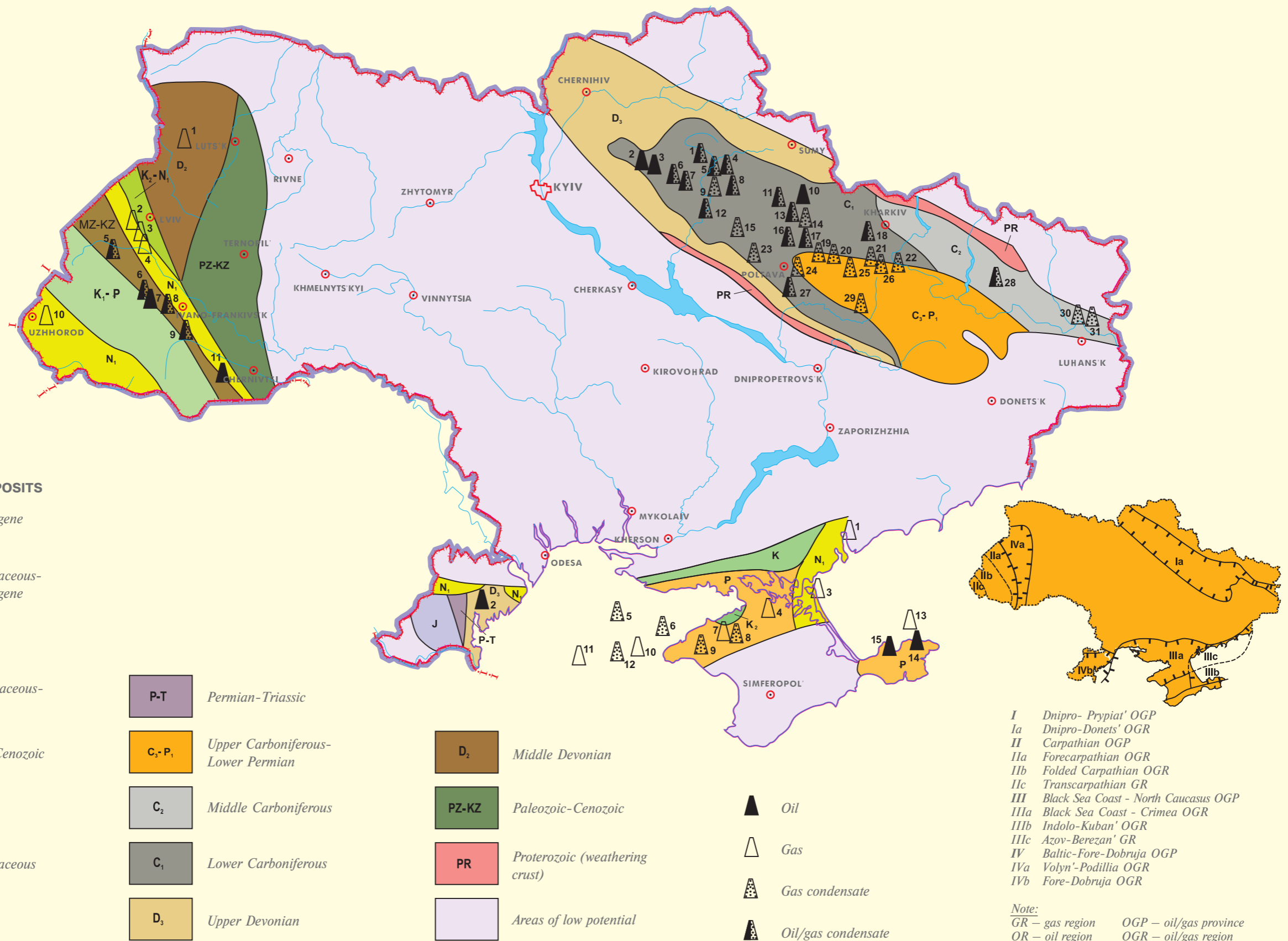
RECOVERABLE RESOURCES OF HYDROCARBONS

	Eastern oil/gas region		Western oil/gas region		Southern oil/gas region		of which, the sea shelf	
	Potential recoverable resources	% extracted as of January 1st, 2000	Potential recoverable resources	% extracted as of January 1st, 2000	Potential recoverable resources	% extracted as of January 1st, 2000	Potential recoverable resources	% extracted as of January 1st, 2000
Free gas (Bm ³)	4042.8	57	867.3	42	1525.0	5	1294.9	5
Dissolved gas (Bm ³)	81.9	48	171.7	40	22.9	–	22.0	–
Gas condensate (Mt)	243.0	54	9.8	56	123.4	3	100.0	2
Oil (Mt)	481.3	55	707.1	23	141.6	3	115.0	–

Note: Realization rate - ratio of total output to explored reserves in the original potential resources.

Free and dissolved gas, billion m³
Oil and gas condensate, Mt

FOSSIL FUELS – OIL AND GAS



FOSSIL FUELS – OIL AND GAS

A review of the knowledge on the oil industry indicates that Ukraine is one of the oldest regions in the world that practiced the extraction and use of natural oils from the ground. Here, from prehistoric times, man knew of the natural occurrences of oil and there is evidence of oil-well diggings and mining of this fluid substance. In 1864 oil-well drilling was carried out on the Kerch peninsula (Voskhod area), and in 1875 drilling for oil was also carried out in the Carpathians (Sloboda-Runhurska area).

In Ukraine, four oil and gas regions are recognized: the Dni-pro-Donets', the Carpathian, the Black Sea-Crimean and the Baltic-Fore-Dobruja regions. These regions can be further subdivided into smaller areas. Deposits of hydrocarbons are related to large geological structures or depressions in the ancient East European Platform, notably the young Scythian Plate, Alpine marginal downwarps and the folded areas. There are over 314 known deposits of oil and gas in Ukraine. Of these, 56 are significant deposits, and 258 fall into the small category. In the Dni-pro-Donets' region there are 187 deposits, in the Carpathian region there are 91 deposits, and in the Black Sea-Crimean region there are 36 deposits (of which 8 are in the Black Sea and 4 in the Azov Sea). Total production (from the earliest times to the present) from all of these regions has amounted to 347 Mt of oil with condensates, and 1711.2 B cubic meters of free and dissolved gases.

At this time the reserves (categories A+B+C) include 237 Mt

of oil and condensates, and 1230.6 M cubic meters of gas. Nearly 60% of the hydrocarbon resources are still not thoroughly explored.

The economy of the country limits the annual rate of production of oil and condensates to 3.8 Mt, and gas to about 18 B cubic meters.

The Dni-pro-Donets' and the Carpathian regions are the main areas in terms of production and reserves of oil and gas in Ukraine.

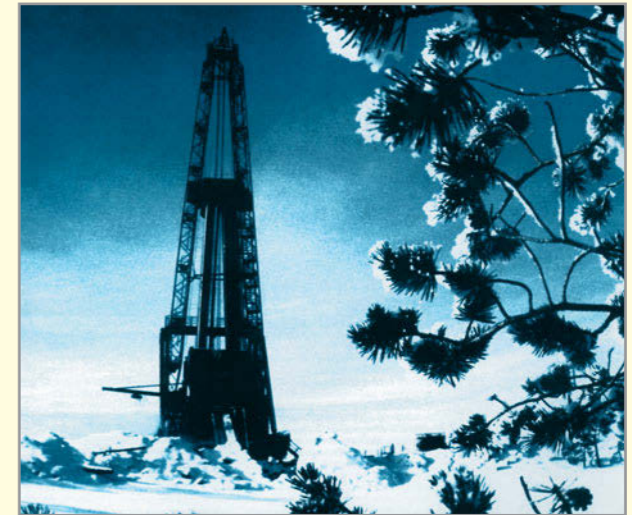
Oil and gas deposits are classified according their size as follows: small are less than 10 Mt of oil or 3 Bm³ of gas, medium are in the range of 10-30 Mt of oil or 3-9 Bm³ of gas, and large are >30 Mt of oil or >9 Bm³ of gas.

The Dni-pro-Donets' oil and gas region in eastern Ukraine is a relatively small area, but the volume of prospective sedimentary rocks is up to 0.7 M cubic kilometers. The prospective rocks occur down to 22 km. A complicated Precambrian basement structure together with Devonian and Permian salt deposits contributed to very different reservoir structures both morphologically and in terms of their sizes.

The main known resources of oil, condensates and gas are associated with the Lower Permian to the uppermost productive coal deposits, in structural traps in these rocks. Productive horizons occur in sandstones, siltstones and dolomites with porosities from 5-30%, and permeability up to 3.4 mkm². The deposits are multilayered, massive, generally with a single oil-gas-water contact, commonly with large reservoirs of gas-bearing strata (Shebelynka, Western Khrestyshche, Yefremivka,



Fixed marine platform on the Black Sea



Drilling derrick in winter

Hnidyntsi, Hlyns'k-Rozbyshivka deposits). Smaller deposits of hydrocarbons have sheet-like shapes and occur in association with the productive middle coal layers. Many discoveries of hydrocarbons in the lower coal beds indicate the possibilities of finding sizeable deposits here also. Reservoirs occur in granular rocks and in carbonates (Bahate deposit).

The Devonian productive complex is characterized by high prognostic evaluation. Gas flows have been obtained from the Hlyns'k, Rudenkivka and Horobtsi areas, and oil from the Buhruvate and Koziivka areas and others.

In the northwestern part of the northern border of the Dni-pro-Donets' Depression many drill holes intersected hydrocarbons in the Precambrian rocks (Khukhra, Yuliivka, Skvortsove, Cherneche and Ohul'tsi deposits).

Precambrian oil and gas complexes have been relatively little explored. Such deposits are allochthonous, and their productivity is connected to the potential of the sedimentary rocks in the Depression where there is a territorial and vertical differentiation in the distribution of hydrocarbons. The majority of the large and medium-sized deposits are associated with depressions and their slopes in the crystalline basement rocks. In the northwestern part of the Depression there are oil and gas deposits, whereas in the southeastern part there are gas condensates and gas deposits. Oil deposits occur down to 3.5-4 km depths, whereas gas deposits occur down to 6 km depths.

Gas, condensate and oil of different deposits in the area are variable in composition. The methane content in the gases of

oil deposits in the northwestern part of the Depression varies from 2.15 to 16.15%, and increases to 79.19% in the southeastern part of the Depression. In the gas-condensate deposits methane is the main gas and its content varies from 84 to 94%. Gases of the oil deposits contain up to 91.8% homologs of methane (Hnidyntsi deposit), whereas at the Shebelynka deposit they drop to 4.7%. According to the hydrocarbon composition this group of oil could be defined as methano-oily and oily-aromatic. Such oils contain from 28.5 (Hnidyntsi) to 817 cubic m/cubic m (Kharkivtsi) of dissolved gases.

The Forecarpathian oil and gas area covers the territory of Boryslav-Pokuttia, Sambir and Bil'che-Volytsia structural-tectonic zones of the Forecarpathian downwarp.

Oil, gas-condensates and gas deposits are associated with anticlinal folds, monoclinical blocks and their erosional remnants. Such deposits occur in the Jurassic, Cretaceous, Paleogene and Neogene rocks. Oil and gas deposits are associated with the Boryslav-Pokuttia and Bil'che-Volytsia zones. The absence of flysch deposits, reliable established horizons and the development of intense folding exclude the Sambir zones from the number of prospective regions.

In the Boryslav-Pokuttia zone there are regional oil and gas bearing Paleogene strata, and in other cases there are Upper Cretaceous structures that also contain oil and gas. The main reserves of oil and gas are concentrated in the Oligocene and Eocene rocks. Oil and gas deposits are associated with thick sandstones, as well as with thinner sandstone sheets distributed in the flysch sequences of sandstones, siltstones and argillites.

The main deposits include the Boryslav and the Oriv-Ulychne. The largest number of oil and gas occurrences (including the Dolyna, Bytkiv and other deposits) in the Boryslav-Pokuttia zone is associated with the menilite (carbonaceous schists) series of rocks of the Oligocene age.

In the Bil'che Volytsia zone the productive horizons are associated with the Upper Cretaceous terrigenous and the Upper Jurassic carbonate rocks, as well as with the sandy-clayey Miocene deposits.

Exploration drilling in the Pokuttia-Bukovynian Carpathians under the Forecarpathian downwarp discovered a post-Paleozoic platform, consisting of Mesozoic rocks. Productive horizons were discovered in the Cretaceous and Jurassic rocks, eventually leading to the discovery of the Lopushne oil deposit. This fact, together with the discovery of oil in the marginal downwarp of the Western Carpathians in the Cretaceous and Jurassic strata, as well as gas (at Rudky, Bil'che-Volytsia and Uhry) provide good reasons to think that there is a regional oil and gas province in the Mesozoic rocks of the Carpathians. In the Boryslav-Pokuttia zone there are oil and gas-condensate deposits, whereas in the Bil'che-Volytsia area gas deposits are common. As a general rule, the gas-condensate deposits are found under the oil deposits.

Oil deposits of the Boryslav-Pokuttia zone have a high paraffin and tar content, with minor quantities of asphalt and sulfur. The condensates are categorized as methano-oily. The gases associated with the oil deposits consist mainly of methane (57.43- 96.19%).

Gases associated with the gas-condensate deposits contain 85.4-95.7% methane.

The oil and gas region of the Folded Carpathians occupies structural zones of the Outer Carpathians. In the Skyba zone there are two producing deposits (Skhidnytsia and Bytkiv). The Skhidnytsia oil deposit is associated with relatively shallow Paleocene and Eocene sandstones. A significant number of small deposits are also found in the adjacent Polish territory.

The Transcarpathian gas province is situated within the Transcarpathian downwarp. Here, gently sloping brachyanticlinal structures, complicated by faulting, commonly permeated by salt and injected by volcanic rocks, have been formed during the final stages of the Alpine orogenesis.

Gas deposits are associated with various stratigraphic horizons of Paleogene and Neogene rocks. So far, a number of deposits have been discovered in this area (Solotvyna, Rus'ki-Komarivtsi, Koroleve and Staniv).

The Near Black Sea-Crimean gas and oil region occupies the western part of the Scythian plate and the southern part of the East European platform. Here the Karkinit-Northern Crimean downwarp structure is in contact with the southern slope of the Ukrainian Shield. It contains about 20 small deposits of gas and gas-condensates onshore (Zadorne, Hlibivka, Karlav, Dzhan'koi, Western Oktiabr's'ke, Tetianivka) and offshore in the northwestern part of the Black Sea shelf (Holitsyn, Southern Holitsyn, Schmidt, Shtorm, Arkhanhel's'k, Crimean, Odesa, Bezimenne).

Oil deposits of Lower Cretaceous age have been also discov-



Drilling derrick, Stryi, L'viv oblast'



An oil well operation on Leliaky oil deposit, Dnipro-Donets' Depression

ered at Oktiabr's'ke, Western Oktiabr's'ke and Tetianivka. Gas deposits under the Black Sea are associated with Paleocene rocks and occur in fractures and porous sandstones, siltstones, marbles and limestones.

The Indolo-Kuban' oil and gas region occupies the southern part of the Azov Sea and the Kerch peninsula and is associated with a downwarped crust.

Here the Neogene and Paleogene strata are oil and gas bearing. Several small deposits of gas (Northern Kerch, Fontan, Southern Syvash) and oil (Semenivka) have been discovered in these rocks.

The Azov-Berezan' gas region includes the Middle-Azov uplift and the Northern Azov-Yeysk downwarp, bordering in the north with the South-Ukrainian monocline. Here, a shortened sedimentary pile measures up to 2-5 km in thickness.

In the Central-Azov region several small gas deposits have been found. The main productive strata are part of the Maikop sedimentary sequence containing gas associated with anticlinal structures. Other small gas deposits are found in the Eocene, the Early Cretaceous and the Neogene rocks.

In the southern part of the region, 31 deposits of oil and gas have been found. Of these, 9 are oil, 6 are gas-condensates, and 16 are gas deposits. Twelve of these deposits are under the Black and Azov Seas. In terms of size, 5 of these deposits are medium-sized, and 26 are small.

Preliminary estimates of the hydrocarbon resources under the Black and Azov Seas are considered to be positive. The main oil and gas bearing strata are Cretaceous and Paleogene, found

at depths from 5 km to 500 m below the water. Considering the riftogenic nature and the size of the Black Sea depression, the sedimentary pile and its thermobaric history are taken to be very favorable for the deposition of gas in both the shelf and the continental slope environments.

The Volyn'-Podillia gas and oil region is connected to the L'viv downwarp, superimposed on the Paleozoic L'viv-Lublin downwarp. The oil and gas occurrences, bituminous rocks and droplets and fluid oil in fractures of carbonates are found in the Middle and Upper Devonian and the Lower Carboniferous rocks. Two gas deposits have been discovered in this region, the Velyki Mosty and the Lokachi deposits.

Exploration in the **Fore-Dobruja oil and gas region** started as a result of the discoveries of an oil deposit (Valeni) and a gas deposit (Ungheni) in Moldova. Initially only Neogene and Jurassic were explored, but later Paleozoic rocks were included also. Drilling in the eastern Sarata and Zhovtyi Yar areas intersected oil-bearing Middle Devonian strata.

Ukraine also has various non-traditional sources of hydrocarbons. These include hydrated and subhydrated gases, methane associated with coal beds and various minor by-products from thermal decomposition of coal and slates.

The presence of significant resources of oil and gas, numerous explored and producing wells, oil and gas refineries, industries related to the oil business and science and research centers offer opportunities for the formation of a major organization or a company that could become a domestic supplier of oil and gas in Ukraine.

COAL

Other than oil and gas, Ukraine possesses considerable deposits and reserves of various coals, including hard and brown coals, anthracite and bituminous shales. At present, some 94 areas have been investigated, yielding about 12.3 billion tons of coal reserves. In addition, potential reserves are estimated to carry about 4.6 billion tons of coal.

The main coal deposits are concentrated in the Donets' and L'viv-Volyn' Basins; brown coal deposits are in the Dnipro Basin. Their reserves and output as of 01.01.2000, were as follows:

Basin	Reserves (million t)	Annual output (million. t)
Donets' of which:	52 814.0	71.1
brown coal	16 669.9	31.9
anthracite	8287.7	16.6
L'viv-Volyn' of which:	1437.0	3.6
brown coal	933.1	-
Dnipro of which:	2186.7	1.4
open pit mining	532.2	1.3

Hard coal

The Donets' Basin or Donbas is a mature mine region of up to 50 000 km² containing about 330 coal beds, 180 of them being 0.45 m thick. Currently, 65 coal beds are mined. Coal

grade varies from brown to anthracite, being mostly of the medium-ash (7% to 15%), and medium-sulfur (1.5%-2.5%) type but some with higher sulfur contents (2.5% to 3.5%). The host rocks are Carboniferous strata. Mining started in the area over 100 years ago. The average depth of mining is about 665 m. Some mining is as deep as 1226 m. There are 228 mines operating at depths from 100 to 550 m, and 24 mines operating at 1000 m levels and deeper. Coal beds are known at depths of 1341 m. The L'viv-Volyn' Basin stretches along the Ukrainian-Polish border for more than 125 km, and is 50 to 60 km wide. Even though it covers about 10 000 km², the mining area is only 2000 km². Up to 80 coal beds are found in the Middle Carboniferous rocks in this area. Six of them are from 0.7 m to 1-2 m in thickness and are currently being mined. The coal layers are at depths of about 250 m in the east. In the west they are at greater depths of about 750 m, are thinner and less continuous. These coals vary in terms of the degree of metamorphism and quality, both vertically and areally. Their ash content varies from 9 to 28%. Some of these coals are used for the production of coke. There were up to 18 operating mines in this area at one time.

In the northwestern part of Dnipro-Donets' Depression, coal was found in the Serpukhovian strata (from 1 to 11 coal beds of 0.8–6.95 m thickness, at depths of 1138 to 1334 m) in the Vedył'si area. In its southwestern slope coal (from 1 to 19 coal beds of 1-4 m thickness) was found at depths of 830-1845 m (at Chervonopartyzans'k, Olyshivka, Isachkiv, Ostapivka, Bilotserkivtsi and others). These finds correspond to the limits of the oil-gas areas of the Dnipro-Donets' Depression Central Graben and their slopes. The coal content coefficient does not fall down, but actually rises towards the Dnipro-Donets' Depression Graben.

Brown Coal

The main brown coal deposits are concentrated in the Dnipro Basin. Other fields of less importance are found in the Dnipro-Donets' Depression, the Dnister river region, the Forecarpathian and the Transcarpathian depressions. Brown coal is mined only in the Dnipro Basin and in Transcarpathia. The Dnipro Basin, covering approximately 100 000 km², hosts about 200 deposits and occurrences. These deposits occur in the Paleogene strata which fill depressions in the underlying crystalline rocks. The most economic coal deposits occur, however, in the Middle Eocene in the Buchach suite. The Upper Paleogene and Miocene strata contain mainly thin layers of coal. The size of certain deposits, limited by the dimensions of the depressions, varies from several square kilometers to 50-60 square km. The thickness of the beds fluctuates from 1.2-2 to 18 m, and the beds occur at 10 to 150 m depths. This variety of coal has a medium-ash content (up to 20%), between 3.5 % and 4 % sulfur, 43-62% moisture, 61-72% light volatiles, up to 10.4% bitumens and about 23% tar.

Coal deposits within the Dnipro-Donets' Depression occur in the Paleogene-Neogene stratas. Brown coal beds with 1.2-50 m thickness are found at depths from 10 to 100 m. This kind of coal lends itself to processing for bitumen extraction and the production of mineral wax. The resources of the Novodmytrivka deposit are estimated at 390 million tons.

The brown coal deposits are also known in the Dnister river region, the Forecarpathian and the Transcarpathian areas, where 37 deposits and occurrences have been explored.

In the Upper Dnister region, 1 to 3 beds of coal are found at the 5-60 m depths; they occur in Lower Tortonian sediments and range in thickness from 0.5 to 1.5 m, sometimes reaching 3 m.

The Forecarpathian coal belt, some 15-30 km wide, contains a combination of beds up to 0.5 m thick at the depths of 5-30 m in the Upper Tortonian sediments. Coal beds in the Transcarpathian region occur in the Upper Pliocene sediments. The number of productive beds is from 2 to 8, their thickness ranges from 1.0-2.5 m. They are deposited at depths ranging from 5-50 to 200-250 m. This variety of coal has an ash content of 2-10.3 %, light volatiles range from 43-61 % and combustion heat 800-4800 kkal/kg.

Oil Shale

Oil shales are found in the Ukrainian Shield, the Volyn'-Podillia Plate, and the Carpathian and the Crimean Mountains. About 10 deposits and occurrences have been explored. Bovtyshka, the largest oil shale deposit, is located on the boundary between the Kirovohrad and Cherkasy districts. It is associated with a funnel-shaped depression in the Precambrian basement. The depression is 600 m deep and 20 km to 25 km wide and is taken to represent a meteorite impact site. Here, five commercial oil shale beds (2.5 m to 3.7 m thick) occur in Paleogene sediments. The combustion heat of the shale is 2000 to 3000 kcal/kg (dry fuel); ash and sulfur contents and tar yields vary from 63-65%, 0.8-3.5% and 10-18% respectively. This oil shale is used in the thermal power plants and chemical industry.

Bituminous shales are widely distributed in the Ukrainian Carpathians. They outcrop or are covered with a thin veneer of Quaternary sediments across an area of some 3000 km². Today, these high-ash (75%-92%) and low-organic (10%-20%) bituminous shales do not meet the requirements for a power plant fuel (tar yield being 1.5%-3.3%), but can be regarded as a potential fuel source in the future.

DEPOSITS

Hard coal

L'viv - Volyn' Basin

1. Buzhania
2. Novovolyn'
3. Mizhrichchia
4. Tiahliv
5. Velykomosty

Donets' Basin

6. Petrivka site
7. Bohdanivka mine
8. Novomoskovs'k site
9. Uspenka site
10. Tereshky site
11. Dobropillia mine
12. Western Donbas mine
13. Krasnoarmiis'k site
14. Selydove site
15. Myronivka site
16. Krasnodon mine
17. The mine named after Zasiad'ko
18. Yenakiieve mine
19. Southern Donbas site
20. Volodars'k site

Brown coal

Transcarpathian coal area

1. Uzhhorod
2. Bihan'
3. Velykyi-Rakovets'
4. Horbky

5. Rokosiv
6. Novoselivka

Forecarpathian coal area

7. Miliieve-Ispas

Dnister coal area

8. Rava Rys'ke
9. Brykiv
10. Nyshche
11. Zolochiv

Dnipro basin

12. Andrushivka
13. Makarove
14. Filiopil'
15. Tetiiv
16. Ryzhanivka
17. Kozats'ke
18. Balabanivka
19. Novosilky
20. Kaitanivka
21. Yurkivka
22. Zhuravka
23. Hlyns'k
24. Zolotarivka-Revivka
25. Bandurivka
26. Myronivka
27. Fastivka
28. Mokra Kalyhirka
29. Turiiia
30. Zlatopillia
31. Novo-Myrhorod
32. Motronivka-Trepivka

33. Morozivka
34. Semeniv-Oleksandriya
35. Hannivka
36. Krasnopillia
37. Sokolivka
38. Yelizavetivka
39. Novomykhailivka
40. Krynychuvate
41. Mykhailivka
42. Balakhivka
43. Verkhn'odniprovs'k
44. Shyroke
45. Synel'nykove
46. Veseli Terny
47. Apostolove
48. Sanzharivka
49. Horikhivka

Dnipro-Donets' coal area

50. Romny
51. Sula-Udaitsi
52. Novodmytrivka

Lower Dnister coal area

53. Bolhrad
54. Krynychne
55. Reni

Crimean coal area

56. Beshui

Oil shale

Carpathian shale area

1. Boryslav

2. Skhidnytsia
3. Verkhnie Syn'ovydne

Podillya shale area

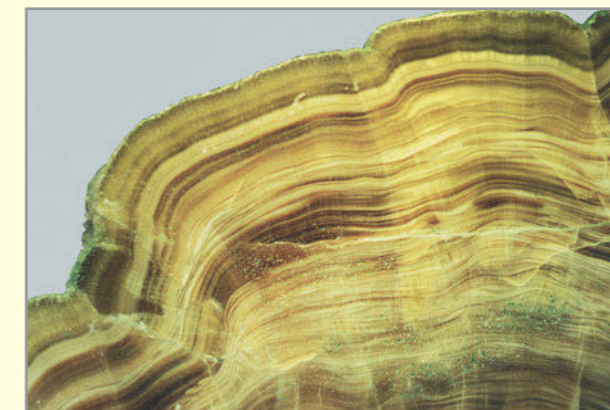
4. Novoselytsia

Dnipro basin

5. Bovtyshka

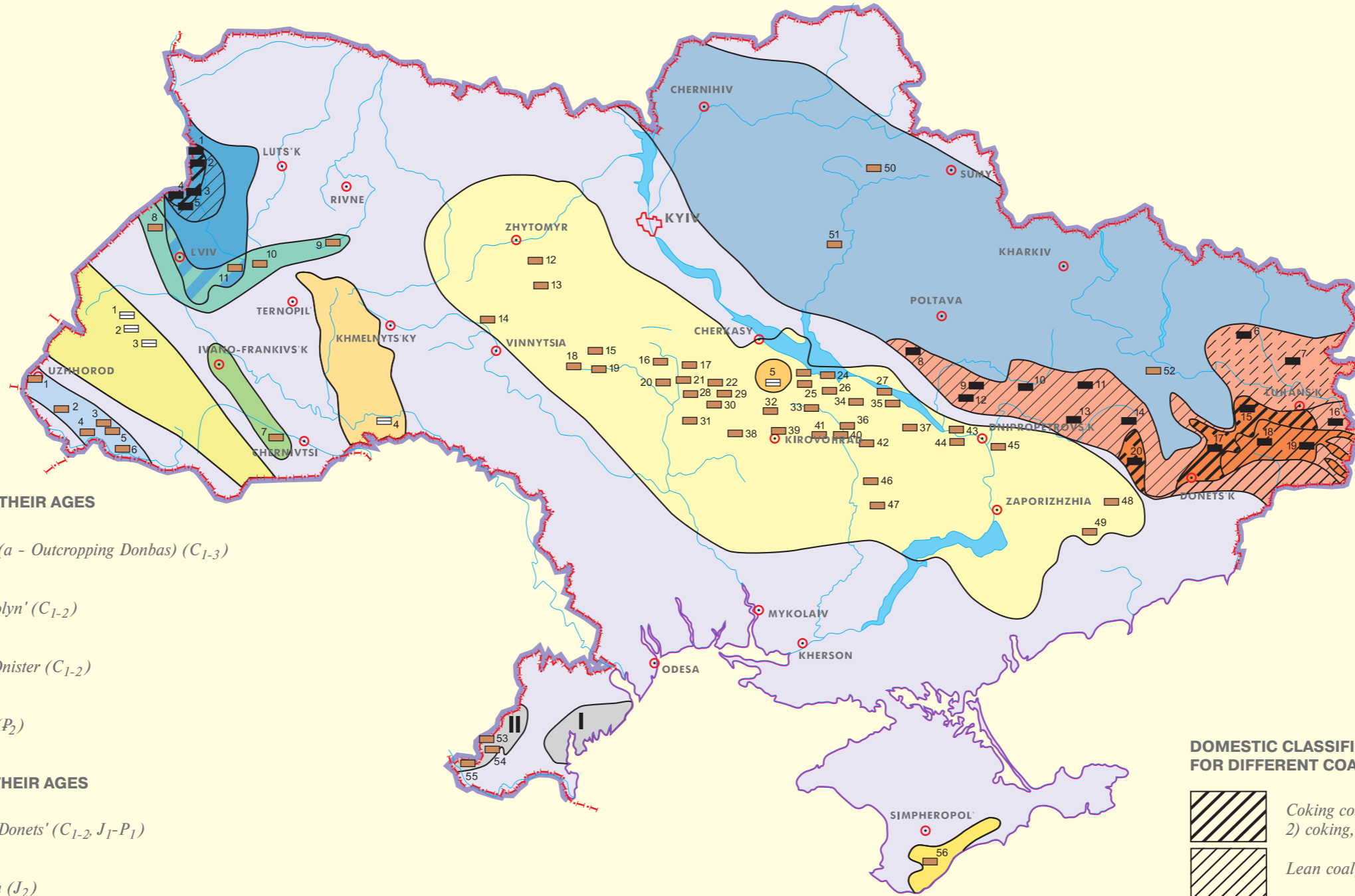


Cretaceous deposits, Donbas



Marble onyx, Dnister region

COAL



LEGEND

COAL BASINS AND THEIR AGES

- Donets' (a - Outcropping Donbas) (C₁₋₃)*
- L'viv-Volyn' (C₁₋₂)*
- Lower Dnister (C₁₋₂)*
- Dnipro (P₂)*

COAL AREAS AND THEIR AGES

- Dnipro-Donets' (C₁₋₂, J₁-P₁)*
- Crimean (J₂)*
- Forecarpathian (N₁)*
- Transcarpathian (N₁₋₂)*
- Upper Dnister Region (N₂)*
- Lower Dnister (N₂)*

OIL SHALE AREAS AND THEIR AGES

- Bovtyshka (P₁)*
- Carpathian (P₃)*
- Podillia (N₁)*

FUEL MINERALS

- | | |
|-------------------|----------------------|
| Deposits | Coal showings |
| <i>Hard coal</i> | <i>Coal showings</i> |
| <i>Brown coal</i> | <i>Coal showings</i> |
| <i>Oil shale</i> | |

DOMESTIC CLASSIFICATION FOR DIFFERENT COAL TYPES

- Coking coal: 1) fat - high tar content, 2) coking, 3) lean, 4) baking*
- Lean coal, semi-anthracite, anthracite*
- Long-flame and gas coal*
- Coal transitional between brown and long-flame*
- Boundaries of the basins and areas*

Note:
Only some deposits are shown in the Donets' basin.

FERROUS METALS
(Iron, Manganese and Chromite)

Ukraine has a highly developed ferrous metallurgy industry on account of its huge iron and manganese deposits. They have been mined since the end of the 19th century by both underground and open pit methods. The capacities of these mines range anywhere from 0.5 to 40 Mt of ore annually. Nowadays, iron and manganese concentrates, crushed iron-rich ore, iron agglomerates and pellets are produced in the country.

Ukraine is the fifth largest producer of iron ore in the world after China, Brazil, Russia and Australia, but holds the first place in the mining of manganese (32% of the world's production).

Iron deposits. As of 1995, the total explored reserves of iron ore amounted to 32 Bt, and the proven reserves stood at 28 Bt or 6% of the world reserves. Relatively low-grade iron ores, commonly composed of jaspillites and magnetite quartzites and carrying from 25.8% to 35.1% iron, are the dominant ore types. Rich ores generally grade from 50.6% to 62% iron and constitute about 7% of the explored iron reserves in Ukraine.

Within the deposits which are either mined or are ready for mining there are 17.8 Bt of reserves (58% of the total), and there are additional reserves which are being investigated that amount to 12.8 Bt (36%). The potential reserves that need further exploration are in the order of 30 Bt. In total there are 48 iron ore bodies, 25 of which are mined.

The **Kryvyi Rih Iron Basin** (or Kryvbas) is of Proterozoic age, and is located in the south-central part of the country in the Ukrainian Shield. It trends in a north-northeasterly direction, measures from 2 to 7 km in width and is more than 100 km in length. In addition, there are two outlying regions – the Kremenchuk and the Bilozerka. The Kryvbas is one of the largest in the world. Lithologically, it is comprised of jaspillites, banded cherts, sandy chert-carbonates, conglomerate-sandstones, and meta-andesite-basalts. Within the Basin, the most productive is the Saksahan

suite which measures up to 1500 m in total thickness. It consists of banded magnetite quartzites, with some members merging together in places or thinning out altogether. The ore bodies have sheet-like, lens-like and stockwork configurations.

The banded iron-bearing quartzites contain 30-45% iron, include non-oxidized (magnetite, specular hematite-magnetite, silicate-magnetite), and oxidized assemblages (martite, specular hematite-martite, goethite-hydrogoethite-martite). Areally the oxidized ores occur down to about 100 m depth, but locally oxidation occurs down to 2000-2500 m and even deeper. The rich iron layers can be from 10 to 100 m thick, and there are about 25 such members. They consist of magnetite, martite, hematite-martite and goethite-martite assemblages that on average have about 56% Fe, 0.02% P, and 0.16% S. Of these, the martite and hematite-martite are the most common. Low grade ores are commonly represented by magnetite-bearing quartzites. High grade ores are mined underground down to the levels of 850-1200 m. Lower grade ores are mined mainly in open pits up to 300 m in depth.

In the Kryvbas area there are up to 21 Bt of ore reserves. The complex has an annual production capacity of 190 Mt of iron ore that can yield about 70 Mt of pig iron. The surface mineralization is oxidized and enriched; at greater depths there are mainly magnetite-bearing ores.

The **Kremenchuk region** (Poltava oblast') is situated on the eastern side of the Dnipro river and represents a northern outlier of the Kryvyi Rih Iron Basin. It has a belt-like configuration measuring 1 to 3 km in width and 45 km in length. It contains about 4.1 Bt of iron ore reserves in total. Here the Saksahan suite is 1200-1300 m thick. Ores are rich, containing on average 58.5% iron. The magnetite quartzites have about 32.8% iron, and the comingtonite-magnetite quartzites have about 27.4% iron. The Poltava concentrating plant crushes about 34 Mt of ore per year. The **Bilozerka region** (Zaporizhzhia oblast') has a belt-like configuration some 5 to 20 km in width and 65 km in length and is

comprised of metamorphosed sedimentary and volcanic rocks. Banded iron-bearing quartzite bodies range from 60 to 250 m in thickness, are up to several kilometers in length, and extend up to 1500 m in plunge. The ore bodies are up to 100 m thick. Explored ore reserves, carrying on average about 60.6% iron, amount to about 0.7 Bt, of which 40% are rich ores of martite type. The Zaporizhzhia plant produces close to 3 Mt of direct smelting ore. The **Azov Iron Basin** is located in the Zaporizhzhia and the Donets'k oblasts, on the southeastern part of the Ukrainian Shield. It occupies an area of about 360 square kilometers. The iron ore deposits are associated with the Lower Proterozoic and Archean iron-cherty formations. The ore bodies are in brachyanticlinal structures and in narrow graben-like synclines. In total they amount to about 3.5 Bt. Concentrates from these ores yield 69-72% iron. These ores are not mined at this time.

The **Kerch Iron Basin** is located on the Kerch Peninsula in the Autonomous Republic of Crimea. The iron deposits are associated with troughs and depressions 1.5-13 km wide and 6-40 km long. The iron-bearing horizon is associated with the Kimmeridgian marine strata of the Lower Pliocene age. It consists of sub-horizontal beds of brown iron-bearing sandy clays. They measure from 0.5 to 2 m in thickness along the margins and up to 25-40 m in the central parts of the troughs. The main types of mineralization include brown hydrous iron chlorite, ferri-montmorillonite, hydrous goethite, and greenish-brown leptochochlorite. The brown mineralization resulted by oxidation of the greenish-brown underlying layer. Oolitic textures are common in these layers. In total there are about 1.8 Bt of mineralization including 560 Mt grading about 37.5% iron. At one time these deposits were mined by open pit operations. They are not mined at this time.

There are also some small iron deposits towards the central part of the Buh river.

Manganese Deposits. After South Africa, Ukraine has the second largest manganese reserves in the world. Ukraine possesses 2.5 Bt of ore, with an average grade of 23.1% Mn. Its main reserves are

concentrated in the Nikopol' basin within the Dnipropetrovs'k and the Zaporizhzhia oblasts (the Nikopol' and the Velykyi Tokmak manganese deposits). In the Nikopol' area, a 25 km wide band of manganese-bearing beds is traced for about 250 km. The beds (2 m thick on average) are hosted by sandy-silty-clayey sediments of the Lower Oligocene age. There are three types of ores – carbonate (average 19.8% Mn), oxide (27.8% Mn), and oxide-carbonate (24.4% Mn).

Data on the main Mn ore deposits are shown below.

Deposit	Reserves (million t)	Annual output (million t)	Mn content (%)
Nikopol'	704.8	4.98	23
Velykyi Tokmak	1578.5	-	25.8

The mineralogy of the ores comprises pyrolusite, psilomelane, manganite, quartz, and clay minerals. Carbonate ores include rhodochrosite, manganocalcite, calcite, quartz and clay minerals. The Nikopol' deposit is mined by both underground and open pit methods. The Velykyi Tokmak deposit is not mined at this time. Ukraine contributes 32% of the total manganese world production. Significant quantities of manganese are exported to Russia and western Europe.

Chromite deposits and occurrences are found in Ukraine in ultrabasic rock massifs (middle Boh (Southern Buh) river region). They are associated with small dunite-harzburgite bodies. Most of the mineralization is disseminated, but there are also some of the massive type. The ore bodies form a series of closely spaced steeply dipping lenses, 2-4 m thick, and carrying up to 29% chromium trioxide. In terms of the reserves, their size is not large, but they could satisfy some of the local demands. The chromite mineralization also carries anomalous quantities of the platinumoid group of elements, gold, nickel and cobalt.

IRON DEPOSITS

- 1 – Hrushkivka
- 2 – Moldovka

KREMENCHUK IRON-ORE BASIN

- 3 – Kremenchuk
- 4 – Bilanivka
- 5 – Yerystivka
- 6 – Lavrykivka
- 7 – Horyshni-Plavyni

KRYVYI RIH IRON-ORE BASIN

- 8 – Popel'naste
- 9 – Artemivs'k
- 10 – Zakhidne (Western)
- 11 – Zhovta Richka
- 12 – Hannivka
- 13 – Petrivs'ke
- 14 – Pervomais'k – N1 mine
- 15 – Pervomais'k – N2 mine
- 16 – Pervomais'ke
- 17 – Ordzhonikidze mine

- 18 – Hvardiia mine
- 19 – Lenin mine
- 20 – Zhovtneva mine
- 21 – Sukha Balka Raion
- 22 – Velyka Hleiuvatka
- 23 – Bat'kivshchyna mine
- 24 – Saksahan mine
- 25 – Kirove Raion
- 26 – Valiavky
- 27 – "Hihant-Hlyboka" (Deep Giant) mine
- 28 – Valiava "Pivnichna" (Northern) mine
- 29 – Novokryvoriz'ke
- 30 – Shymanivs'ke
- 31 – Dilianka (locality) №6
- 32 – Skeliuvatka locality
- 33 – Skeliuvatka-Mahnetytove
- 34 – Inhulets'
- 35 – Inhulets' Raion

BILOZERKA IRON-ORE BASIN

- 36 – Northern Bilozerka
- 37 – Southern Bilozerka
- 38 – Pereverziv

AZOV IRON-ORE REGION

- 39 – Vasynivka
- 40 – Huliaipole
- 41 – Kuksunhur
- 42 – Mariupol'

KERCH IRON-ORE BASIN

- 43 – Akmanai locality
- 44 – Kyiats'k locality
- 45 – Sim Kolodiaziv (Seven Wells) locality
- 46 – Novoselivka
- 47 – Zamors'k-Pisochna locality
- 48 – Chehene-Salyn locality
- 49 – Katerlez'k basin
- 50 – Baksyn
- 51 – Komysh-Burun basin
- 52 – Eltihen-Ortel'
- 53 – Kyz-Aul basin

MANGANESE DEPOSITS

- 1 – Khashchuvate

NEAR-DNIPRO BASIN

- 2 – Fedorivka
- Nikopol':**
- 3 – Chortomyk-Oleksivka locality
- 4 – Pokrovs'ka locality
- 5 – North-Western locality
- 6 – Chkalove locality
- 7 – Sulik locality
- 8 – Komintern-Marivka locality
- 9 – Hrushevs'ko-Basanska locality

Velykyi Tokmak:

- 10 – Northern locality
- 11 – Central locality
- 12 – Southern locality

CHROMIUM DEPOSIT

- 1 – Kapitanivka





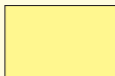

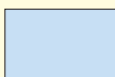



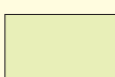

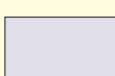
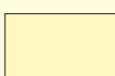
Banded-iron formation (BIF), jaspilite variety, Kryvyi Rih iron-ore basin



FERROUS METALS






LEGEND

STRUCTURAL DIVISION




- | | | | |
|---|--|---|--|
|  | <i>Mesozoic-Cenozoic cover of the Ukrainian Shield</i> |  | <i>Cretaceous-Paleogene Central Crimea Uplift</i> |
|  | <i>Volyn'-Odesa Monocline</i> |  | <i>Cretaceous-Paleogene Al'ma Depression</i> |
|  | <i>Paleozoic deeps (1 - Lviv, 2 - Dobruja Foredeep)</i> |  | <i>Mesozoic Dnipro-Donets' Depression: northern flank (1), southern flank (2)</i> |
|  | <i>Paleozoic Volyn' Uplift</i> |  | <i>Voronezh Anticline (southern slope)</i> |
|  | <i>Southern Ukraine Monocline</i> |  | <i>Folded Structures of the Ukrainian Carpathians (1), the Donbas (2), the Northern Dobruja (3), the Crimean Mountains (4)</i> |
|  | <i>Late-Cretaceous-Paleogene Karkinit-Northern Crimea Deep</i> |  | <i>Alpine troughs: Carpathian Foredeep (1), Indolo-Kuban' (2), Inner Transcarpathian (3)</i> |

-  *iron ore basins and regions*
-  *manganese ore basin*


IRON DEPOSITS

-  *high-grade ores (50.6-62% FeO)*
-  *low-grade ores (25.8-35.1% FeO)*
-  *high-grade and low-grade ores (30-45% FeO)*




MANGANESE DEPOSITS

-  *oxides (27.8% MnO)*
-  *carbonates (19.8% MnO)*
-  *carbonates and oxides (24.4% MnO)*

CHROMITE DEPOSITS

-  *low-grade chromite*

IRON AND MANGANESE ORE RESERVES (Mt)

-  *large – over 300 (Fe) and 30 (Mn)*
-  *medium – 125 to 300 (Fe) and 10 to 30 (Mn)*
-  *small – less than 125 (Fe) and 10 (Mn)*

GOLD DEPOSITS

Gold in Ukraine has been mined since prehistoric times. Such mining sites have been found in the Donbas area and in the Transcarpathian region. At present a total of 240 occurrences and a few deposits are known. On the basis of these data three gold regions are recognized: the Ukrainian Shield, the Carpathians and the Donbas. Among these regions, the better studied deposits are in the Carpathians (Transcarpathian structural metallogenic zone), specifically in the Berehove-Bihan' mineralized region.

The Muzhiievo deposit in the Carpathians has been explored and is currently being mined. Gold mineralization occurs in the volcanogenic-sedimentary rocks, andesite-rhyolite flows of Miocene-Pliocene age forming a caldera structure. In the upper part of the ore body gold mineralization has a simple mineralogical assemblage with gold as the main mineral, but at depth it gradually passes into the gold-polymetallic type. Of the total, about 30% of gold is in the simple and 70% is in the polymetallic mineralization. The gold content varies from 1 to 150 g/t, the average is 7-8 g/t.

The Berehove gold deposit is adjacent to the Muzhiievo deposit. It is mainly polymetallic in nature and is essentially analogous to the polymetallic part at Muzhiievo. It has considerable size in both vertical and horizontal directions (more than 1 km).

The ore body consists of three parallel zones with submeridional orientation with veinlet-disseminated sulfide mineralization.

To the east of the Muzhiievo deposit is the Rakhiv gold region with the Sauliak gold deposit. This deposit is associated with the Riphean-Lower Paleozoic age Marmarosh Massif comprised of metamorphosed rocks. Gold in quartz-carbonate minerals of the ore body is easily concentrated.

The total resources of gold in the Carpathian province represent about one quarter of all the gold resources in Ukraine. Favorable formations in the Carpathians for gold exploration amount to about 1000 square kilometers.

An ancient gold-bearing province in Ukraine is the Ukrainian Shield. By comparison to the other highly productive Precambrian Shields (Canadian, Western Australian, South African, Indian) the Ukrainian Shield emerges as another potentially gold-bearing area. This is supported particularly by recent work. Several different gold associations have been established typical of Precambrian rocks. These include – gold-quartz veins, gold-sulfide-quartz, gold-skarn, gold-uranium and gold-iron formation associations.

Gold is found in the granite-greenstone Archean formations of the Dnipro river area, and constitutes a structural-metallogenic zone. Here, in the complex synclinal structures (Verkhivtseve, Sura, Chortomyk, Sofiivka, Bilozerka and others) a wide variety of volcanic rocks is represented from ultramafic to felsic, typical of greenstone belts. These rocks are schistose and metamorphosed, and have been subjected to various intense metasomatic changes, such as propylitization, listvenitization (quartz-carbonate), silicification, beresitization (quartz-sericite) and sulfidation. Gold is associated with such alteration zones and occurs in mineralized zones, in quartz, carbonate and quartz-carbonate veins, and in iron formations. Examples of gold mineralization of this type include the Serhiivka, Balka Zolota, Balka Shyroka and Pivdenne deposits and a number of other gold occurrences. The Serhiivka and Balka Zolota deposits are located on the southern side of the Sura granite-greenstone complex and are controlled by the plagioliparite, plagioclase-bearing rhyolite volcanic rocks. The gold-bearing veins are concentrated mainly in the contact zones, and have a subparallel orientation to the contact.

The Balka Shyroka gold deposit is located in the eastern part of the Chortomyk granite-greenstone complex. Here, packages of interbedded iron formation and basic and felsic volcanic rocks are mineralized and are associated with the listvenite-beresite alteration. The mineralized zones are tabular and have subvertical attitudes.

Somewhat later gold deposits are found in the Lower

Proterozoic mobile belts and suture zone depressions (Kirovohrad, West-Inhulets', Kryvyi Rih and Kremenchuk), and are related to the linear tectono-metasomatic zones (Tal'ne, Pervomais'k-Trakhtemyriv, Zvenyhorodka-Hannivka, Kirovohrad) commonly found around complex plutons and granite massifs. These zones are commonly marked by alkaline metasomatism, skarn formation, the development of abundant mica and silicification. The ore bodies consist of mineralized zones and quartz veins. Here, gold is mainly native and is associated with native bismuth, pyrite, pyrrotite, arsenopyrite, galena, and less commonly chalcopyrite.

In the Kirovohrad metallogenic zone there are two gold deposits located close to each other – the Klyntsi and Yuriivka. They are related to the eastern contact of the Novoukraiins'kyi granitic massif. The gold mineralization is in the biotite, biotite-amphibolite and cordierite gneisses. The mineralized zones are also strongly silicified and have steep attitudes. Gold is not evenly distributed in these mineralized zones which can be described as the low sulfide content type.

In the Tal'ne metallogenic zone, there is the Savran' gold area that contains the Mais'k gold deposit. It is associated with the gneisses, migmatites and amphibolites which have undergone intense hydrothermal-metasomatic alteration such as silicification and biotitization. Gold is mainly native and tends to be more common in the altered rocks which have an overall steep attitude. On the basis of these deposits, the Ukrainian Shield could become a significant producer of gold in the near future. The potential gold resources on the Ukrainian Shield are considered to be relatively large and represent about 65% of the total for the country. Gold-bearing areas with potential for new discoveries are estimated to be in the order of 5000 square kilometers in the Ukrainian Shield.

The Donets' Basin (Donbas) is another gold-bearing terrain in Ukraine. In the Nahol'na region there are a number of gold-silver deposits (Bobyrykiv and Hostrobuhor) and gold-silver-polymetallic deposits (Zhuravs'k). Their geological position, age and type of

mineralization, and the mineralogical particulars of these deposits are all similar to the deposits found in the black shales or slates of the Muruntau gold deposit in Uzbekistan. In the Nahol'na region, the best studied is the Bobrykiv gold deposit. It is associated with the southern flank of the Bobrykiv brachy-anticline, which consists of sandy-clayey strata of Carboniferous age. The gold-sulfide mineralization is localized along a tectonic zone, and includes both vein and veinlet-disseminated types.

The total resource of the Donets' Basin region represents about 10% of the total resource of the country. Favorable area for gold exploration amounts to several hundred square kilometers.

The most productive gold-bearing zones in Ukraine at this time are associated with the transregional long-living (Late Archean–Cenozoic) megazones of fracturing having east-west orientations. The Central Ukrainian megazone transects the entire Ukrainian Shield, the southern parts of the Donbas area and the Carpathian Mountains. Associated with this megazone are some of the main deposits of gold-rare metals and uranium and the gold-polymetallic and mercury deposits of the Carpathians and the Donbas areas.

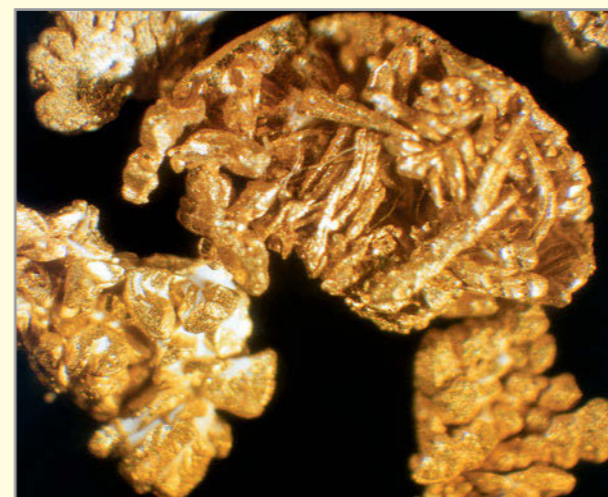
The Northern Ukrainian megazone crosses the northwestern marginal part of the Ukrainian Shield, the northern part of the Volyn'-Podillia plate, and continues into Poland and into the Voronezh Massif in Russia. This megazone coincides with the rare metal, silver-polymetallic and fluorite mineralization in the Ukrainian Shield, native copper in the traps of Volyn', rare metal and gold mineralization in the Voronezh Massif and the silver-polymetallic deposits in Silesia in Poland.

The gold deposits of Ukraine can be subdivided into four major epochs of deposition – Late Archean-Early Proterozoic (2450-2900 Ma), Middle Proterozoic (1650-1720 Ma), Permo-Triassic (220-300 Ma) and Neogene (15 Ma).

As a result of the exploration work done in recent years in Ukraine, there is evidence of a good potential for gold deposits in the country. Further development of this potential is necessary before the country becomes a major producer of this noble metal.



Gold bricks recently extracted from the Klyntsi (Ukrainian Shield) and Muzhiievo (Transcarpathia) deposits



Placed native dendritic gold from the Muzhiievo deposit, Transcarpathia (x70)



Native granular gold from Berehove deposit, Transcarpathia (x150)

METALLOGENIC ZONES

1. Vyhorlat-Huta
2. Sushchany-Perha
3. Kirove-Kocheriv
4. Dnister

5. Tal'ne
6. Pervomais'k-Trakhtemyriv
7. Zvenyhorodka-Hannivka
8. Kirovohrad

9. Verkhivtseve-Sura-Chortomyk
10. Kins'ka-Bilozerka
11. Central Donbas
12. Nahol'chyk

GOLD-BEARING REGIONS

1. Berehove-Bihan'
2. Rakhiv
3. Sura
4. Chortomyk
5. Nahol'na

GOLD ORE-BEARING*, GOLD-BEARING FIELDS:

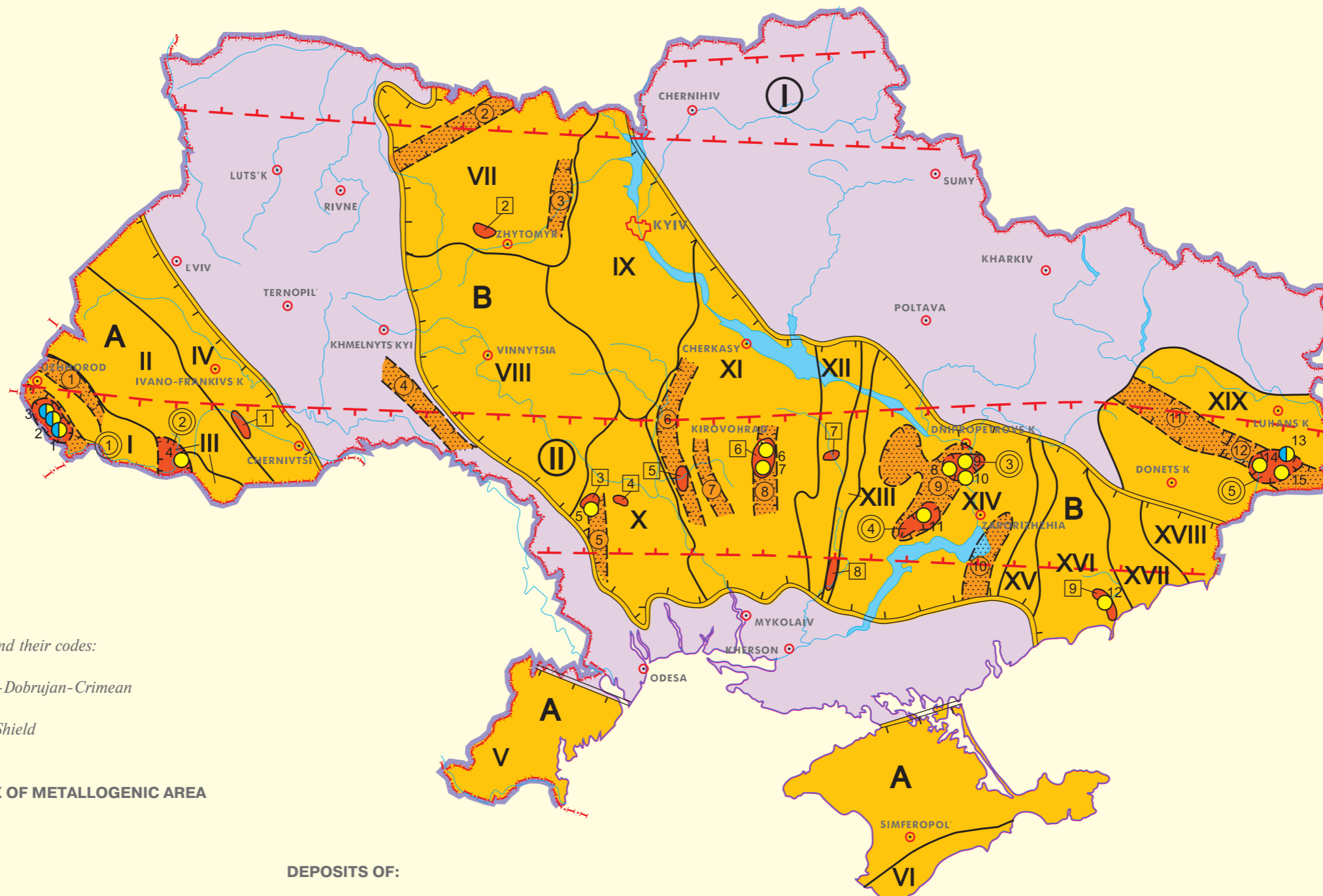
1. Yabluniv
2. Buky
3. Savran'*
4. Kapitanivka
5. Mikhailivka
6. Klyntsi-Konev*
7. Petrove-Balakhivka
8. Murakhivka
9. Soroky

DEPOSITS:

1. Muzhiievo
2. Berehovo
3. Bihan'
4. Sauliak
5. Mais'k
6. Klyntsi
7. Yuriivka

8. Serhiivka
9. Balka Zolota
10. Pivdenne(Southern)
11. Balka Shyroka
12. Surozh
13. Zhuravs'ke
14. Hostroyi Buhor
15. Bobrykiv

GOLD DEPOSITS



LEGEND

- Provinces and their codes:**
- A** Carpathian-Dobrujan-Crimean
 - B** Ukrainian Shield

BOUNDARY AND INDEX OF METALLOGENIC AREA

- A** Province
- XI** Structural-metallogenic zone (SMZ)
- 3** Metallogenic zone (MZ)
- 5** Gold-bearing region
- 1** Gold ore-bearing and gold-bearing fields

DEPOSITS OF:

- Gold
- Gold-polymetallic

Megazones of fracturing:

- I** North-Ukrainian
- II** Central-Ukrainian

STRUCTURAL-METALLOGENIC ZONES

- | | | | |
|---------------------|------------------------|-------------------------------|------------------------|
| I – Transcarpathian | VI – Crimean Mountains | XI – Kirovohrad | XV – Orikhiv-Pavlohrad |
| II – Carpathian | VII – Volyn' | XII – Western-Inhulets' | XVI – Western Azov |
| III – Marmarosh | VIII – Podillia | XIII – Kriviyi Rih-Kremenchuk | XVII – Cental Azov |
| IV – Forecarpathian | IX – Bila Tserkva | XIV – Dnipro | XVIII – Eastern Azov |
| V – Dobruja | X – Holovaniv | | XIX – Donets' Basin |

RARE METALS

As a mining country, Ukraine is well endowed with rare metals and rare earth elements. In spite of this, these resources have not been fully used.

The majority of rare metal deposits and showings are within the Ukrainian Shield, which could be regarded as a large rare metal province. There are 22 rare metal bearing complexes, formed during the Early Proterozoic period in the mobile belts, and during the Late Proterozoic as superimposed zones of tectono-magmatic and tectono-metasomatic activities. Within such zones there is granitoid and alkaline magmatism, abundant pegmatites and evidence of metasomatism. Rare metal mineralization is associated with granites and syenites, commonly replaced by pegmatites and alkaline metasomatic materials. Some of these mineralized complexes are highly weathered and have associated placer deposits. Up to the present several rare metal deposits have been explored – including the Perha beryllium deposit, the Zhovta Richka uranium-vanadium-scandium deposit, the Novopoltavka apatite-rare earths-niobium deposit, and the Mazur zirconium-niobium deposit.

At this time the Azov fluorite-zirconium-rare earths deposit is undergoing further investigations. Some exploration work has been also carried out on the lithium prospects – including Polokhivka, Stankuvatka and Shevchenko deposits. All exploration work indicates so far that these may be major

deposits. In addition, a number of occurrences of tantalum, niobium, yttrium and related elements, lead, molybdenum and tungsten have been outlined.

The ores of the black and base metals (iron in quartzites, ilmenite in gabbros, manganese, nickel and cinnabar) also carry elevated values of vanadium, gallium, germanium, scandium, hafnium, bismuth and antimony. Tailings also carry a variety of rare metals – Sc, V, Ga, Ge, Ta, Nb, REE, Zr.

Among the well known deposits, of special interest are the largest and unique deposits, which could become a major source of rare minerals in Europe and perhaps in the world. These include the unique deposits of beryllium at Perha, and the zirconium-rare earths at Azov.

The Perha beryllium deposit is located in the northern part of Ukraine, and is considered to be a new type of deposit of high quality beryllium associated with alkaline feldspathic metasomatism. The main beryllium mineral is gentgelvite, which was considered earlier as a very rare mineral species. This deposit has been well explored, including a systematic geochemical evaluation for zirconium, rare earths, niobium, tantalum, lead and fluorite. Other significant elements in the deposit include Ta, Nb, REE, Zr, F, Li, Mo, Sn, W, Au, Ag, Zn, and Cd.

The Azov zirconium-rare earths deposit is associated with alkaline syenites and is one of the largest in Europe. Mineralization is associated with taxitic olivine-amphibole alkaline-feldspar syenites. Ore minerals include zircon, orthite, britolite, bastnezite and

fluorite. The group of rare earth elements is variable and includes cerium, lanthanum, neodymium, erbium, samarium, lutecium and yttrium. At present there is some final exploration and evaluation work being carried out on this deposit.

The Polokhivka, Stankuvatka and Shevchenko lithium deposits are associated with petalite-spodumene pegmatites and also carry some Nb, Ta and Cs. They are characterized especially by high concentrations of lithium and other elements, and close spatial association with iron and uranium mining areas. Iron-free lithium concentrates are used in the manufacturing of ceramics and glass products. Abundance of high quality clays and silica in Ukraine, combined with the lithium raw materials and availability of electric energy offers new opportunities for the development of ceramic and glass industries in the country. The estimated resources of lithium ores and the geological-economic evaluations of these deposits indicate that they may be profitable at current prices. The Mazur deposit consists of zirconium-niobium-tantalum mineralization in nepheline syenites (mariupolites). This is a highly prospective deposit. The Novopoltavka deposit consists of phosphorus-rare earth elements-rare metals mineralization in carbonatites. Apatite (ap) is the main mineral and the rare earth elements, niobium and tantalum, could be retrieved as valuable by-products.

Uranium-bearing albitites and aegirinites occur in the Kryvyi Rih-Kremenchuk zone. This area produces not only iron and

uranium but also vanadium-scandium minerals (Zhovti Vody) which are concentrated in aegirine-acmite rocks. The method of extraction of scandium from these ores has been worked out and the ores are being mined now.

Ukraine has large placer deposits of titanium-zirconium. They include continental, near-shore marine and beach sands. At this time production is coming from the Malyshev deposit. In the past this deposit was the main source of zircon concentrates for the entire former Soviet Union. In addition to zircon, this deposit supplies ilmenite, rutile, sillimanite and graphite by-products. There is a series of placer deposits along the northern and the southeastern slopes of the Ukrainian Shield, and along the northeastern edge of the Dniipro-Donets' Depression.

A strong development of the mining sector, metallurgical, chemical and machine-producing industries in the country creates favourable conditions for the utilization of rare metals. These metals form the base for the development of new alloys, which could be useful in high quality technologies.

The rare metal mineralogical potential resources of Ukraine are some of the largest in Europe and could conceivably satisfy the needs of most of the countries in Europe. Ukraine is interested in further developing a mutually satisfactory cooperative effort in evaluating these deposits as well as developing efficient methods of concentration of minerals and extraction of rare metals, and marketing these products.

METALLOGENIC ZONES AND MINERALIZATION AGE

(PR – Proterozoic, PZ – Paleozoic)

- 1 – Sushchany-Perha (Be, Nb, Ta, REE/ PR_{2,3})
- 2 – Kocheriv (Ta, Nb, Rb, Li/ PR₁)
- 3 – Podillia (fl, Li, Be, Nb, REE/ PR₁₋₃)
- 4 – Khmil'nyk (REE, Zr/ PR₁)
- 5 – Holovanivsk (REE, U, Sc/ PR₁)
- 6 – Zvenyhorodka (REE, U/PR₁)
- 7 – Lypnizhka (Li, Ta, Nb/ PR₁)
- 8 – Khmel'ove (Li, Ta, Nb, Be/ PR₁)
- 9 – Novoukrainka (REE, U/ PR₁)
- 10 – Kirovohrad (REE, U/ PR₁)
- 11 – NorthTersianka (Nb, Ta, REE/ PR₂)
- 12 – Fedorivka (Li, Ta, Rb, Cs/ PR₁)
- 13 – Haichur (REE, U, Nb, Ta/ PR₁)
- 14 – Chernihivka (Nb, Ta, REE, ap/ PR₁)
- 15 – Soroky (Ta, Nb, Li, Rb, Cs/ PR₁)
- 16 – Oktiabr (Nb, Ta, REE, Zr/ PR₂)
- 17 – Kal'mius (REE, fl/ PR₂)
- 18 – South-Donbas (Be, REE, fl/ PZ)

DEPOSITS* AND MINERALIZED FIELDS

- 1 – Perha * (Be, Ta, Nb, REE)
- 2 – Novohrad-Volynskiy (Nb, Ta, Rb, Cs)
- 3 – Volodarsk-Volynskiy * (Be, Li, Sc)
- 4 – Lyznyky (Be, Rb, Li)

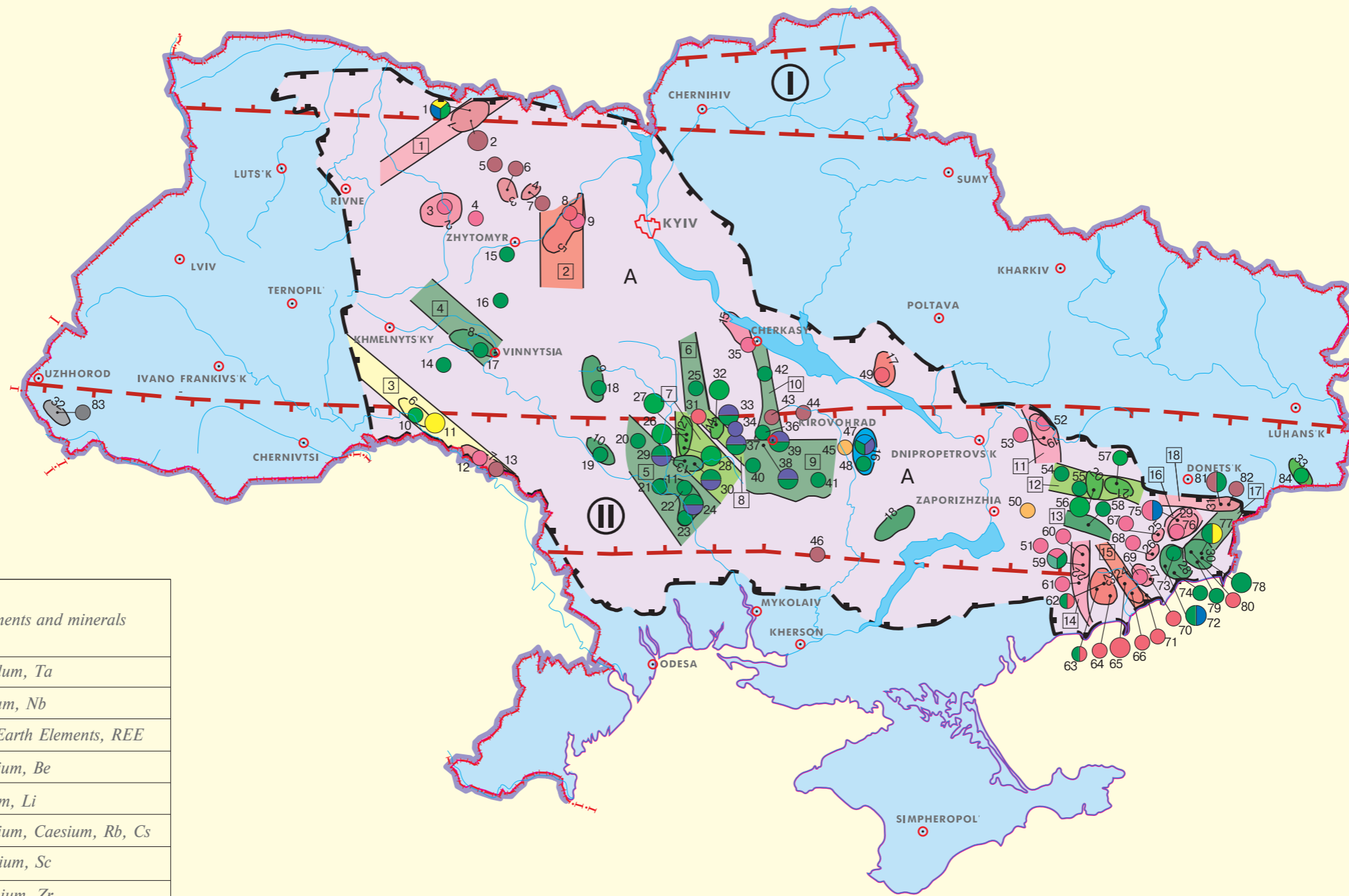
- 5 – Korostyshiv (Ta, Nb, Rb, Li)
- 6 – Bakhtyn-Stavchynsi * (fl, Li)
- 7 – Kamianka-Soroky (Be, Nb, REE)
- 8 – Mykolaivka-Holoskiv (REE, Zr)
- 9 – Chapaivka (REE)
- 10 – Solomyivka (REE)
- 11 – Korabel'ne * (REE, U)
- 12 – Stankuvatka * (Li, Ta, Nb, Be)
- 13 – Lozuvatka (REE)
- 14 – Polokhivka * (Li, Ta, Nb)
- 15 – Rus'ka Poliana (Nb, Ta, REE)
- 16 – Zhovta Richka * (Sc, U, REE, Zr, Li)
- 17 – Komendantivka (Ta, Nb, Li)
- 18 – Tok (REE)
- 19 – Malotersianka (Nb, Ta, REE)
- 20 – Shevchenko * (Li, Ta, Nb)
- 21 – Fedorivka (Li, Ta, Rb, Cs)
- 22 – Novopoltavka * (Nb, REE, ap)
- 23 – Yelyseivka (REE, Ta, Nb)
- 24 – South-Soroky * (Ta, Nb, Li, Rb, Cs)
- 25 – Katerynivka (Nb, Ta, REE, Li)
- 26 – Kamiana Mohyla (Nb, Ta, Li)
- 27 – Staryi Dub (Nb, Ta, REE)
- 28 – South-Kal'chyk (REE, Zr, fl)
- 29 – Mazurivka * (Nb, Ta, Zr)
- 30 – Petrove-Hnutiv * (REE, fl)
- 31 – Pokrovka-Kyriivka (Be, REE, Nb, fl)
- 32 – Bihan' * (Ge)
- 33 – Nahol'chyk (Li)

DEPOSITS*, SHOWINGS

- 1 – Yastrubets'ke (REE, Zr, fl)
- 2 – Perha * (Be)
- 3 – Novohrad-Volynskiy (Nb, Ta, Rb, Cs)
- 4 – Luhovsk'ke (Nb, REE, Ta)
- 5 – Omelianivka (Be, Ta, Nb)
- 6 – Volodarsk-Volynskiy * (Be, Li, Nb)
- 7 – Lyznyky (Be, Li, Rb)
- 8 – Raivka (Ta, Nb)
- 9 – Tovstiv (Nb, Rb)
- 10 – Stavchany (Li, fl)
- 11 – Bakhtyn * (fl)
- 12 – Soroky (Nb, Be)
- 13 – Kamianka (Be, Nb, Ta)
- 14 – Rovy (REE, Zr)
- 15 – Hnylopiat' (REE)
- 16 – Postolivka (REE)
- 17 – Maidan-Holoskiv (REE, Zr)
- 18 – Chapaivka (REE)
- 19 – Solomyivka (REE)
- 20 – Holovanivsk (REE)
- 21 – Pervomaysk (REE)
- 22 – Korabel'ne (REE)
- 23 – Kostiantynivka (REE)
- 24 – Yuzhnoukrainsk'k * (REE, U)
- 25 – Mykhailivka (REE)
- 26 – Stankuvatka * (Li, Ta, Nb)
- 27 – Lypnizhka * (Li, Ta, Nb)
- 28 – Nadiia * (Li, Ta, Nb)
- 29 – Lozuvatka * (REE, U, Th)
- 30 – Kalynivka * (REE, U, Th)
- 31 – Mostove (Ta, Be)
- 32 – Polokhivka * (Li, Ta, Nb)
- 33 – Novokostiantynivka * (U, REE)
- 34 – Ulianivka (U, REE)
- 35 – Rus'ka Poliana (Nb)
- 36 – Osykvatka (REE, Zr, fl)
- 37 – Dokuchaieve * (U, REE)
- 38 – Severynivka * (U, REE, Zr)
- 39 – Lelektivka * (U, REE)
- 40 – Trudoliubivka (REE, U)
- 41 – Dolynsk'ke (REE)
- 42 – Tymoshivka (REE, U)
- 43 – Zelenyi Hai (Be)
- 44 – Znamianka (Be, REE, U)
- 45 – Olexandrivka-Mariivka (Rb, Cs)
- 46 – Novoukrainka (Be, Ta, Nb)
- 47 – Zhovti Vody * (Sc, U, REE)
- 48 – North Hannivka (REE, Zr)
- 49 – Komendantivka (REE, Nb, Li)
- 50 – Kyrpotyne (Cs, Rb)
- 51 – Scherbakivka (Nb, Ta)
- 52 – Malotersianka (Nb, Ta, Zr, REE)
- 53 – Novopavlohrad (Nb, Ta, REE)
- 54 – Chaplyne (REE)
- 55 – Oleksiivka (REE)
- 56 – Shevchenkove * (Li)

- 57 – Fedorivka (Li)
- 58 – Malynivka (REE, U)
- 59 – Novopoltavka * (Nb, REE, ap)
- 60 – Ulianivka (Nb, Ta)
- 61 – Behim-Chokrak (Nb, REE, ap)
- 62 – Andriivka (REE, Ta, Nb)
- 63 – Yelyseivka (REE, Ta, Nb)
- 64 – Oleksiivka (Ta, Nb)
- 65 – Kruta Balka * (Ta, Nb, Li)
- 66 – Blakytyni Skeli (Ta, Nb)
- 67 – Katerynivka (Ta, Nb)
- 68 – Kamiana Mohyla (Ta, Nb)
- 69 – Starodubivka (Ta, Nb)
- 70 – Starodubivka placer deposits (Ta, Nb)
- 71 – Komyshevka (Ta, Nb)
- 72 – Azov * (REE, Zr, Nb)
- 73 – Mohyla Seredynivka (REE, Zr, Nb)
- 74 – Mohyla Storozheva (REE, Zr, Nb)
- 75 – Mazurivka * (Nb, Zr)
- 76 – Kalynove-Shevchenko (Nb, Ta, Zr)
- 77 – Petrove-Hnutiv * (REE, fl)
- 78 – Pyshechivka * (REE)
- 79 – Pavlopil'-Druzhba (REE)
- 80 – Kal'mius placer deposits (Ta, Nb)
- 81 – Pokrovka-Kyriivka * (Be, REE)
- 82 – Kumachove (Be, REE, Nb)
- 83 – Bihan' * (Ge)
- 84 – Krokodyl (Crocodile) (Li)

RARE METALS



LEGEND

Deposits	Showings	Elements and minerals
●	●	Tantalum, Ta
●	●	Niobium, Nb
●	●	Rare Earth Elements, REE
●	●	Beryllium, Be
●	●	Lithium, Li
	●	Rubidium, Caesium, Rb, Cs
●		Scandium, Sc
●	●	Zirconium, Zr
●		Germanium, Ge
●		Uranium, U
●		Fluorite, fl
●		Apatite, ap

2 - deposit number
 Note: Color of metallogenic zones and field areas corresponds to main mineral deposits.

BOUNDARY AND INDEX OF METALLOGENIC AREA

Rare earth metal province – Ukrainian Shield

Metallogenic zone

Mineralized field

Megazones of Fracturing (Linear features from satellite imagery)

North Ukrainian

Central Ukrainian



Marble onyx, Transcarpathia



Sandstone with zircon, rutile, ilmenite, Malyshivka deposit, Dnipro zone



Dacitic tuff, Transcarpathia



Agate

TITANIUM AND ZIRCONIUM PLACERS AND SOURCE DEPOSITS

The East European province of heavy mineral placers (HMP) are found in Ukraine and extend into Belarus and Russia. They are associated with areas of Paleogene and Neogene sediments. In this province the most promising is the Ukrainian sub-province of HMP, whose zones, areas, fields, deposits and occurrences are identified (see p. 131).

Several varieties of HMP are recognized, including 1 – marine coastal, 2 – continental redeposited, 3 – residual, as well as 4 – contemporary sea beach and 5 – shallow shelf deposits. The first three types are commonly buried at 10-100 m depths. The marine coastal HMP are related to clay and sand accumulations of Oligocene and Miocene age. These HMP occur in the

ALLUVIAL REGION

- 1 – Volyn'
- 2 – Skvyra
- 3 – Bila Tserkva
- 4 – Zelenyi Yar
- 5 – Novomyrhorod
- 6 – Pravoberezhnyi
- 7 – Livoberezhnyi
- 8 – Huliaipole
- 9 – Mokri Yaly
- 10 – Tokmak
- 11 – Kakhovka
- 12 – Sumy
- 13 – Kharkiv

ALLUVIAL FIELDS

- 1 – Luhy
- 2 – Lytvynivka
- 3 – Irsha
- 4 – Kocheriv
- 5 – Koziivka
- 6 – Marianivka
- 7 – Holubiatyn
- 8 – Vasyl'kiv
- 9 – Tarasivka

Dnipro, the Azov-Black Sea coastal and the Kharkiv-Sumy zones. The first one is the most productive. Forming an arc 50 to 100 km wide and 700 km in length along the northeastern slope of the Ukrainian Shield, it contains the main commercial titanium and zirconium deposits such as Vovchans'ke, Voskresnivka, Pivdenne, Tarasivka and Malyshivka. The Vil'nohirs'k state mining and metallurgical plant is mining the last-named deposit. It is one of the world's largest integrated enterprises for mining, extracting and processing ores containing rare metal minerals. The enterprise manufactures over 40 production related items, such as rutile, ilmenite, zircon and kyanite-sillimanite concentrates; zirconium dioxide; yttrium stabilized zirconium dioxide; zirconium oxychloride, zirconium carbonate, fianite, silicon tetrachloride, hafnium dioxide, electrolytic hafnium powder and quartz sands used in the production of metal-

- 10 – Tarashcha
- 11 – Stebliv
- 12 – Makariv
- 13 – Morozivka
- 14 – Zelenyi Yar
- 15 – Horodyshche-Smila
- 16 – Novomyrhorod
- 17 – Bil'shevys
- 18 – Near-Dnipro
- 19 – Voskresnivka
- 20 – Vovcha
- 21 – Komyshevakhka
- 22 – Ternuvate
- 23 – Uspenivka
- 24 – Pavlivka
- 25 – Tokmak
- 26 – Berdians'k (Azov Sea Shelf Zone)
- 27 – Ochakiv-Dzharylhach (Black Sea Shelf Zone)
- 28 – Vylkove (Black Sea Shelf Zone)
- 29 – Lebedyn
- 30 – Khotin'
- 31 – Krasnyi Kut
- 32 – Bohodukhiv
- 33 – Merchyk
- 34 – Nova Vodolaha

lurgical moulds. The Vilnohirs'k enterprise was granted the Golden Globe International Trophy in 1996. HMP horizons containing appreciable quantities of ilmenite, leucoxene, rutile, zircon, kyanite, staurolite and sillimanite ($n \cdot 10 \text{ kg/m}^3$ of commercial heavy minerals) occur in the upper parts of the geological sections and are about 10 m thick. Ilmenite is highly altered, contains up to 68% TiO_2 and is easily concentrated.

Ukraine has 11 titanium-zirconium deposits, about 280 major occurrences and 1400 minor occurrences. Continental HMP of redeposited (alluvial, deluvial and proluvial) and residual heavy minerals were accumulated in the Mesozoic and Cenozoic times in the northwestern part of the Ukrainian Shield. Leucoxene content is rather low, and ilmenite is the main commercial mineral in the alluvial placers, containing

DEPOSITS

Zirconium-rare earth deposits

- 1 – Yastrub
- 2 – Mazurivka
- 3 – Azov

Phosphorus-vanadium-titanium deposits

- 4 – Stremyhorod
- 5 – Fedorivka
- 6 – Vydvor
- 7 – Kropyvnia
- 8 – Poromivka
- 9 – Yurivka
- 10 – Nosachiv
- 11 – Mariupol'
- 12 – Pokrovka-Kyriivka

ALLUVIAL TITANIUM-ZIRCONIUM DEPOSITS

- 1 – Irshans'k group (Irshans'k*, Verkhnyi Irshans'k*, Lemna*, Mezhirichka*, Livoberezhne, Ushyts'ke, Ushomyr, Zlobych, Valky-Hatskivka, Trostianets', Paromivka, Stavyshche, Pravoberezhne, Krasnorichka, Torchyn)
- 2 – Zelenyi Yar

49-54% TiO_2 . Mineral grains are of variable sizes and are irregularly distributed. Their contents vary from 70 kg/m^3 to 80 kg/m^3 .

Residual HMP in 10-15 m thick weathering crusts of gabbro and anorthosite massifs contain from 30 kg/m^3 to 130 kg/m^3 of weakly altered ilmenite.

Contemporary sea beach and shallow shelf HMP, containing ilmenite, rutile, leucoxene, zircon and less commonly monazite, columbite and cassiterite are of minor importance due to their relatively small dimensions.

Ukraine produces about 20% of the total world production of titanium and zirconium.

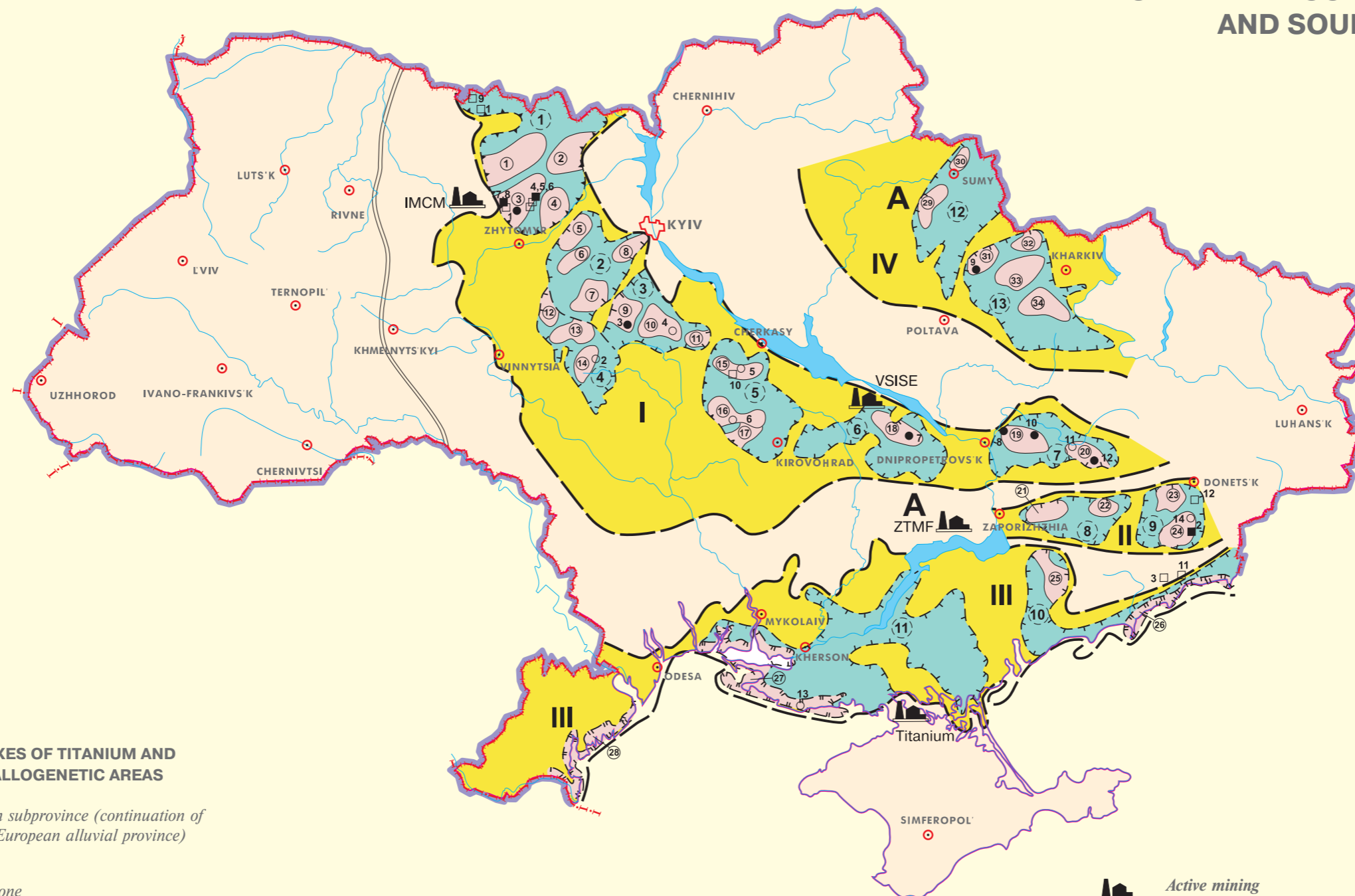
Ukraine supplies titanium-zirconium concentrates to various countries in the former Soviet Union, and also exports to other countries in the world.

- 3 – Tarasivka
- 4 – Tarashcha
- 5 – Horodyshche-Smila group (sites – Tsvitkove, Voronivka, Vovkivka, Kalynivka)
- 6 – Novomyrhorod group (Byrzulove, Valuivka, Likarivka, Kanizh, Ochertianka, Andriivka)
- 7 – Malyshivka*
- 8 – Pivdenne
- 9 – Krasnyi Kut
- 10 – Voskresnivka
- 11 – Novomykolaivka
- 12 – Vovcha
- 13 – Dzharylhach
- 14 – Mokri Yaly group (areas – Tatarka, Manuil, Zlatoustivka)

Note: Underlined – deposits with proven reserves

* Producing deposits

TITANIUM AND ZIRCONIUM PLACERS AND SOURCE DEPOSITS



LEGEND

LIMITS AND INDEXES OF TITANIUM AND ZIRCONIUM METALLOGENETIC AREAS

- Ukrainian subprovince (continuation of the East European alluvial province)*
- Alluvial zone*
- I – Dnipro*
- II – Azov*
- III – Azov-Black Sea*
- IV – Kharkiv-Sumy*
- Alluvial region*
- Alluvial field*

AREAS OF ALLUVIAL DEPOSITS

- continental (alluvial, deluvial, eluvial, proluvial)*
- Coastal deposits**
- buried*
- surface*

PLACER DEPOSITS

- 1 ● *proven reserves*
- 6 ○ *estimated reserves*

SOURCE DEPOSITS

- 2 ■ *proven reserves*
- 8 □ *estimated reserves*

Active mining and processing plants

IMCM *Irshans'k Mining and Concentrating Mill*

VSISE *Vil'nohirs'k State Integrated Iron and Steel Enterprise*

ZTMF *Zaporizhzhia Titanium-Magnesium Factory*

Titanium *Crimea Production Association "Titanium"*



Kimberlite, Azov area



Diamonds faceted at Vinnytsia faceting factory "Crystal"



Diamond faceted at Vinnytsia faceting factory "Crystal"



Diamond faceted at Vinnytsia faceting factory "Crystal"

DIAMONDS

The first recorded find of a diamond in Ukraine was in 1949 in the alluvial sediments of the Bazavluk river. This diamond was 2 mm in size and weighed 1.2 mg. Since then, investigations by various geological organizations and scientific institutions have demonstrated that the territory of Ukraine has great potential for discovering deposits of diamonds. Over a hundred locations with diamonds are known at this time, in addition to numerous aureoles in unconsolidated sediments with associated diagnostic minerals (pyrope, picro-ilmenite, chromian spinels, chromian diopside). These locations are found in different age sediments in the Ukrainian Shield, the Volyn'-Podillia plate, the Donbas, and the shorelines of the Black and Azov Seas. The diamonds occur mainly as single crystals or fragments, which together with the associated diagnostic minerals commonly form aureoles in placer deposits. Such aureoles are known in the central portion of the Dnister river and the southern part of the Buh river, in the northwestern part of the Ukrainian Shield (Bilokorovychi depression) and in the central part of the Donbas (Yenakiieve area). Significant quantities of diamonds are found in placer deposits of titanium-zirconium of the Neogene age such as Samotkan' (Malyshiv), Vovchans'ke, Zelenyi Yar, Tarasivka and other deposits. They carry up to 1-2 carats of diamonds per ton of sand. Studies of the diamonds and their associated diagnostic minerals allowed to typify the known aureoles, establish their genetic associations and point to possible locations of their origin.

Amongst the various diamonds studied, according to their morphology and physical attributes, some diamonds are either identical or close to the diamonds associated with kimberlites, lamproites, impactites and metamorphic rocks of the Kazakhstan type. The most commonly found diamonds are of the kimberlite type. They occur in conglomerates of the Bilokorovychi suite of the Upper Proterozoic age, in the sandy deposits of the Polissia Riphean series and the Valdai Vendian suite, in the alluvial deposits of the Quaternary age located in the northwestern part of the Ukrainian Shield; in the sandy deposits of the Poltava series and the Baltic suite, and the Quaternary alluvium of the southwestern part of the Shield; in the sandy deposits of the Poltava series and the Sarmatian layer and in the Quaternary alluvium of the central part of the Shield; in the Quaternary conglomerates in the eastern part of the southeastern Shield and in the sandstones of Lower and Upper Carboniferous, and in the Quaternary alluvium of the central part of the Donbas (Yenakiieve area); in the alluvial sediments of the lower and middle part of the Dnister river, and in the beach sands of the northern shorelines of the Black and Azov Seas. The diamonds of the kimberlitic type are dominantly colorless crystals with octahedral forms, but some rhombodecahedrons, cubes and twinned crystals are encountered also. Most of them are small in size, generally less than 0.5 mm. Some crystals, however, measure up to 3.0-3.5 mm in diameter, and weigh 20-40 mg. The largest diamond crystals have been found in the conglomerates of the Bilokorovychi suite and in the allu-

vium of the Syniukha and Dnister rivers. High concentration of diamonds of the kimberlite type have been established in the titanium-zirconium placers as in the Samotkan' and Zelenyi Yar deposits, but the size of these diamonds is generally less than 0.5 mm.

Taking into account the areal distribution of the diamond finds and the aureoles of the associated diagnostic minerals of the kimberlite type, and also particular geological structures and the history of their development on the Ukrainian territory, the following favorable areas for the primary diamondiferous kimberlite bodies are outlined: 1) the central part of the Prypiat' swelling-Volyn' area (known to contain Kukhotskovo'lsk, Preskal'sk and Serkhiv eruptive diamond-bearing kimberlite facies of the Devonian age); 2) the northwestern part of the Ukrainian Shield (Novohrad-Volyn's'kyi and Shepetivka areas); 3) the southwestern part of the Ukrainian Shield (Berdychiv-Vinnytsia, Skvyra and Dnister areas); 4) the central part of the Ukrainian Shield (Kirivohrad area) where there are two occurrences of micaceous kimberlites dated at 1.8 Ga; the southeastern part of the Ukrainian Shield (Azov area), where four kimberlite pipes and two micaceous Devonian kimberlites are known.

Diamonds of the lamproite type in the aureoles are tentatively outlined, since they are not that much different from those of the kimberlite type. Thus the lamproitic diamonds are encountered in the Samotkan' and Zelenyi Yar titanium-zirconium placer deposits. Lamproites are known to occur in the central part of the Ukrainian Shield (1.4 Ga dykes near the city of

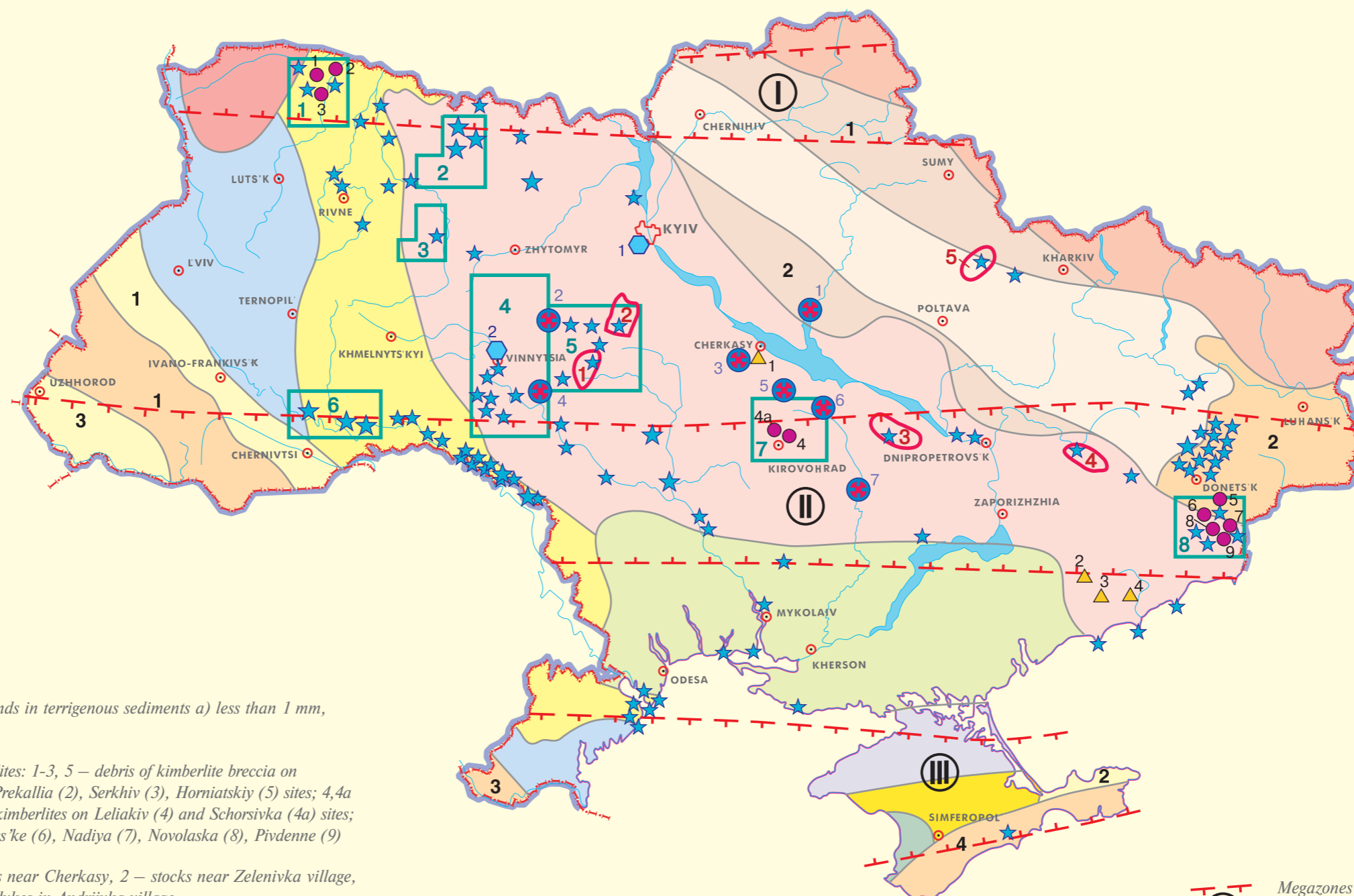
Cherkasy) and in the western part of the southeastern area of the Shield (a pipe known as Mriya, and dykes and stockworks in the vicinity of the Kolarivka, Zelenivka and Andriivka villages). There are possibilities of finding lamproites in other parts of the Ukrainian Shield also.

Diamonds of the type associated with the metamorphic rocks are also distinguished tentatively by analogy to those in Kazakhstan. They are mostly present in the Samotkan', Zelenyi Yar and other titanium-zircon placers. Their presence in the basement rocks is inferred.

Diamonds of the impactite type are found in the Neogenic titanium-zirconium placers such as Samotkan', Zelenyi Yar, Tarasivka and Vovchans'ke deposits. Impactites are known to occur in the Western (Bilyivka), Illintsi, Bovtyshka, Rotmistrivka, Zelenyi Hai, Obolon', and Ternivka astroblemes (meteorite impact sites). Impactites from these astroblemes are known to carry diamonds, and the Bilyivka astrobleme contains such diamonds in abundance in the impactite.

There are two major diamond-cutting concerns in Ukraine: "Esmerald" in Kyiv and "Crystal" in Vinnytsia. These two plants produce high quality finished products that account for about 5% of the world production. They produce some very complicated imaginative diamond shapes. Most of the diamonds worked are less than one carat. These facilities also manufacture all kinds of equipment for cutting and polishing diamonds, and from these facilities emerge diamond-cutting masters with high qualifications.

DIAMONDS



LEGEND

- a b Occurrences of diamonds in terrigenous sediments a) less than 1 mm, b) 1-3.5 mm
- ★ ★ Occurrences of kimberlites: 1-3, 5 – debris of kimberlite breccia on Kukhits'ka Volia (1), Prekallia (2), Serkhiv (3), Horniatskiy (5) sites; 4, 4a – dykes of micaceous kimberlites on Leliakiv (4) and Schorsivka (4a) sites; Kimberlite pipes: Petrivs'ke (6), Nadiya (7), Novolaska (8), Pivdenne (9)
- ▲ 1 Lamproites: 1 – dykes near Cherkasy, 2 – stocks near Zelenivka village, 3 – Mriya pipe, 4 – dykes in Andriivka village
- 1 Potential exploration areas for kimberlite, lamproite and diamond deposits
 - 1 – Volyn'
 - 2 – Novohrad-Volyns'kyi
 - 3 – Shepetivka
 - 4 – Berdychiv-Vinnytsia
 - 5 – Skvyra
 - 6 – Dniester
 - 7 – Kirovohrad
 - 8 – Azov

- 7 Explosive ring structures (astroblemes, meteorite craters)
 - 1 – Obolon', 2 – Bilylivka, 3 – Rotmistrivka, 4 – Illintsi, 5 – Bovtyshka, 6 – Zelenyi Hai, 7 – Ternivka
- 2 Diamond-bearing titanium-zirconium placers
 - 1 – Zelenyi Yar, 2 – Tarasivka, 3 – Malyshev (Samotkan'), 4 – Vovchans'ke, 5 – Krasnokuts'k

- I Megazones of fracturing
 - I - North-Ukrainian
 - II - Central-Ukrainian
 - III - South-Ukrainian
- 1 Diamond cutting plants
 - 1 – "Esmerald" in Kyiv
 - 2 – "Crystal" in Vinnytsia

Note: For structural divisions see map Ferrous Metals, p. 125.

GEMS, SEMIPRECIOUS AND DECORATIVE STONES

Ukraine has considerable resources of different gem and semi-precious stones such as topaz, beryl, morion, rock crystal, amethyst, amber, jasper, rhodonite, obsidian, agate, opal and garnet. There is an abundance of top-quality granite, gabbro, labradorite and marble deposits. Of the 155 explored facing stone deposits, carrying in total about 500 million m³ reserves, 79 are being mined now producing 0.3 million m³ of stones per year. These deposits are concentrated mainly within the Ukrainian Shield. Colored marble was found in Transcarpathia and the Donets' Basin. Different types of limestone of facing stone quality are also known in Crimea.

The recently completed reevaluation of gem and facing stone resources of Ukraine resulted in a more precise definition of 5 regions and 19 areas of high potential. They are outlined as follows:

I. The northwestern region is located in the Volyn'-Podillia Block of the Ukrainian Shield and has known deposits of beryl, topaz, rock crystal, morion, amethyst, labradorite, graphic pegmatite, agate, opal and amber.

II. The Transcarpathian region includes Rakhiv and Chyvchyn crystalline massifs and is known for its garnet, jasper, opal, rhodonite, obsidian, alunite and marble deposits and occurrences.

III. The Middle Buh region contains ruby, garnet, jasper and

colored chalcedony.

IV. The Azov Region occupies the southeastern edge of the Ukrainian Shield and is known for its emerald, ruby, leucosapphire, beryl, topaz, garnet, amethyst, opal, mariupolite and graphic pegmatite deposits and occurrences.

V. The South Crimean Mountain region is particularly known for its marble onyx, and also has gagate, amethyst, jasper and colored chalcedony.

In terms of the multitude of deposits of various gems and semi-precious quality stones, their colors, the size of these deposits, and their near surface occurrences in Ukraine, there are no other analogs in the rest of Europe.

Facing stones of gabbro, labradorite and granite of different

colors produced in Ukraine are in great demand abroad. They are exported to the CIS countries, Italy, Germany, Japan, Greece and others.

The gem stones of the Volyn' district are hosted in a pegmatite body. This area is considered to be the most promising for the top-quality topaz (red colors), beryl (citrine and blue colors), morion, smoky quartz and rock crystal. In addition, this area ranks as the second in Europe, in terms of the reserves of high-grade amber.

Other areas worthy of note include the occurrences of jaspilite and tiger's eye (Kryvyi Rih), unakite (Dnipro Region), iridescent labradorite (Volyn'), marble onyx (Dnister river region) and rhodonite and obsidian (Carpathians).



Amber items from Polissia, the State Treasure House collection



Agate, Crimean Mountains



Iridescent labradorite, Volyn'



Amethyst, Rafalivka, Rivne oblast'

DEPOSITS AND SHOWINGS

- | | | | | | |
|-----------------------|---------------------|-------------------|---------------------------|-----------------------|---------------------|
| 1 – Dubrovytsia | 24 – Adamivka* | 47 – Tryhiria * | 71 – Ivanivtsi | 95 – Buzynivka | 118 – Yantseve* |
| 2 – Perebrody | 25 – Synii Kamin* | 48 – Kornyn* | 72 – Voronivka | 96 – Sil'tse* | 119 – Hostryi Buhor |
| 3 – Zolote | 26 – Symony* | 49 – L'viv | 73 – Horodyshe | 97 – Muzhiiwo | 120 – Central |
| 4 – Vil'ne* | 27 – Rikhty | 50 – L'viv I | 74 – Radvanka* | 98 – Rokosiv | Nahol'chyk |
| 5 – Klesiv* | 28 – Malyn | 51 – Yaziv | 75 – Kirovs'ke* | 99 – Kovanka* | 121 – Nahol'no- |
| 6 – Yasnohirka* | 29 – Myrnians'ke* | 52 – Zhuravnenka* | 76 – Kremintsi | 100 – Velyka Kamianka | Tarasivka |
| 7 – Osmalyne* | 30 – Torchyn* | 53 – Raiky* | 77 – Krychove | 101 – Beretians'ke | 122 – Bohdanivka |
| 8 – Mezhyrichka* | 31 – Kamiany Brid * | 54 – Hlukhivtsi | 78 – Kryvche | 102 – Hlimeia | 123 – Volnovakha |
| 9 – Didkovychi * | 32 – Slipchytisi * | 55 – Zhezheliv* | 79 – Mushkutyntsi | 103 – Prybuis'ke | 124 – Dons'ke |
| 10 – Vas'kovychi | 33 – Fedorivka* | 56 – Rozdil | 80 – Vynohradne | 104 – Trebushany | 125 – Katerynivka |
| 11 – Bekhy * | 34 – Barashi | 57 – Zastinka | 81 – Karpivka | (Dilove)* | 126 – Strilka |
| 12 – Nahoriany * | 35 – Korets' | 58 – Tereblianka | 82 – Rakhny-Pol'ovi | 105 – Dovhi Runy | 127 – Drahuny |
| 13 – Kuryanivka * | 36 – Mohyliany | 59 – Budaniv | 83 – Stari Babany* | 106 – Preluky | 128 – Kruta Balka |
| 14 – Tserkovne | 37 – Volyn'* | 60 – Podorozhnie | 84 – Uman' (Horodets'ke)* | 107 – Krasnopillia | 129 – Yelyseivka |
| 15 – Kovalivka * | 38 – Lyznyk* | 61 – Talalaivka | 85 – Tans'ke* | 108 – Kapitanyivka | 130 – Bielins'ke |
| 16 – Dobryn' * | 39 – Holovyne* | 62 – Andrushivka | 86 – Likarivske* | 109 – Sofivka | 131 – Baherovo |
| 17 – Yampil * | 40 – Stari and Novi | 63 – Bohuslav* | 87 – Voinivka* | 110 – Kostiantynivka | 132 – Biuk-Yankoi |
| 18 – Ivano-Dolyns'k * | Petrivtsi | 64 – Dovhalivka | 88 – Kapustyn* | 111 – Ocheretne | (Mramorne) |
| 19 – Hulianka | 41 – Bystryivka* | 65 – Novopskov | 89 – Krups'ke* | 112 – Novodanylivka* | 133 – Karadah |
| 20 – Omelianivka* | 42 – Nehrebivka* | 66 – Kamianytsia | 90 – Horikhivka* | 113 – Dibrova | 134 – Beshuis'ke |
| 21 – Shchorsivka* | 43 – Slobidka* | 67 – Trostianets | 91 – Kudashivka* | 114 – Kryvyi Rih | 135 – Haspra |
| 22 – Kamiana Pich* | 44 – Horods'ke | 68 – Demkovtsi* | 92 – Novomykolaivka | 115 – Trykraty* | 136 – Pokostivka* |
| 23 – Rudnia | 45 – Korostyshiv* | 69 – Kalusyk* | 93 – Volos'ke | 116 – Inhulets | |
| Shliakhova | 46 – Hrabivka* | 70 – Tyvriv* | 94 – Novopavlivka* | 117 – Tok* | |

Reserves and production of facing stones in Ukraine, 01.01.2000

Deposit	Type of stone	Reserves (thou. m ³)	Annual out (thou. m ³)
Granitoid			
Kapustyno	Red granite	3 545.6	22
Horikhivka	Red granite	49 735	2
Tok	Red granite	14 116	11.4
Kornyn	Red-gray granite	5 501	-
Didkovychi	Pink-gray granite	4 504	-
Kudashivka	Gray granite	11 268	-
Bohuslav	Light-gray granite	6 249	1
Pokostivka	Light-gray granodiorite	2 858	4.9
Gabbroide			
Holovyne	Iridescent labradorite, black	12 424	2.2
Vas'kovychi	Light-gray labradorite	410	-
Slipchytisi	Gabbro and black labradorite	11 954	21.8

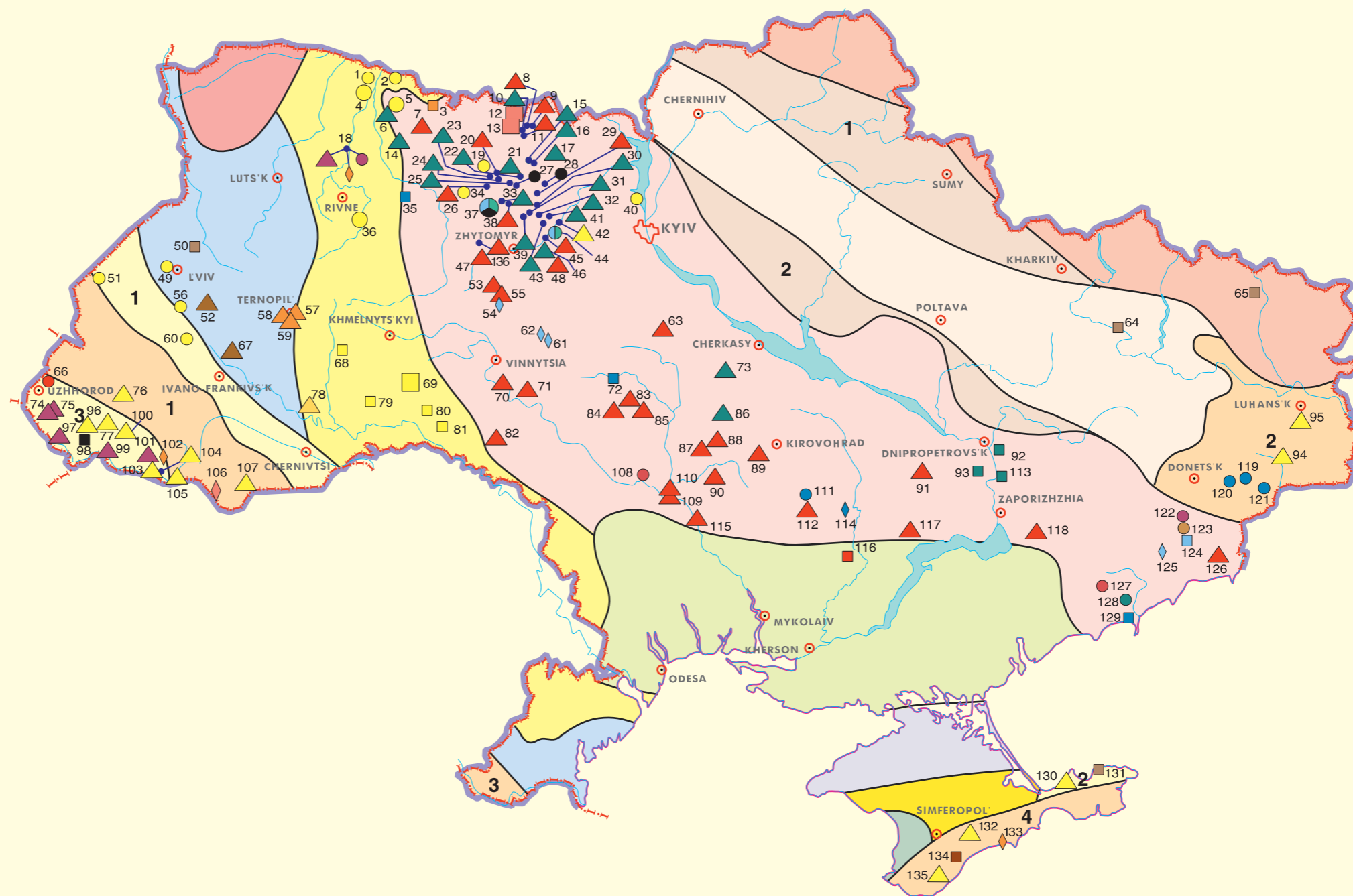
* Mined deposits

GEMS, SEMIPRECIOUS AND DECORATIVE STONES

LEGEND

Deposits	Showings	
		Gem stones
	●	<i>emerald</i>
	●	<i>ruby, sapphire</i>
●	●	<i>beryl</i>
●	●	<i>topaz</i>
	●	<i>garnet</i>
	●	<i>amethyst</i>
●	●	<i>morion</i>
	●	<i>rock crystal (quartz)</i>
	●	<i>zircon</i>
●	●	<i>amber</i>
		Semiprecious industrial stones
	◆	<i>opal</i>
	◆	<i>agate</i>
◆	◆	<i>rhodonite</i>
	◆	<i>tiger's, cat's eye</i>
		Industrial stones
	■	<i>mosaic quartzite</i>
■	■	<i>marble onyx</i>
	■	<i>unakite (epidotized)</i>
	■	<i>opaline wood</i>
	■	<i>gagate (silic. coal)</i>
	■	<i>obsidian</i>
	■	<i>graphic pegmatite</i>
	■	<i>jaspelite</i>
	■	<i>mariupolite, sodalite</i>
■	■	<i>pyrophyllite</i>
		Decorative stones
▲		<i>granite and granitoid</i>
▲		<i>gabbro, labradorite</i>
▲		<i>tuff, andesite, basalt</i>
▲		<i>marble etc.</i>
▲		<i>gypsum</i>
▲		<i>sandstone</i>
▲		<i>travertine</i>

● Complex deposits and showings



Note: For structural divisions see map Ferrous Metals, p. 125.



"Falcon's eye", a variety of colored chert, Kryvyi Rih iron-ore basin



Carnelian onyx (sardonyx), Karadah, Crimea



Amethyst, Volyn'



Amber, Polissia

GEOTHERMAL POWER

Natural heat from the Earth, or geothermal energy, is not new, but it is a non-traditional, accessible and possibly a good source of energy in Ukraine. There are two main kinds of geothermal energy: hydrothermal (thermal waters, vapor-water mixtures, overheated vapors) and natural heat of the rocks, brought to the surface by conductivity from the deeper levels in the Earth.

Hydrothermal power

The usefulness of thermal water as a heat source is determined mainly by its temperature, filtration properties, chemical composition, corrosiveness and the salt content.

Comprehensive studies of the geological, hydrothermal and thermal conditions within Ukraine showed that Crimea, the southern part of Kherson oblast' and Transcarpathia possess enough thermal water for commercial usage.

Criteria for commercial usage of thermal water are as follows:

- water temperature in situ should be not lower than 70°C
- not deeper than 3000 m for the Crimean lowland and 2000m for Transcarpathia
- mineral content of thermal waters should be less than 35 g/l
- minimum well yield of 2-3 liters/sec (170-250 m³/day)
- estimated cost of the hydrothermal power must be approximately the same as that of coal power
- potential areas must host two aquifers which can be operated simultaneously.

The major sources of hydrothermal power that satisfy the above criteria are mainly in Crimea.

Thermal water resources are estimated as follows:

Regions	Estimated resources of thermal water: reserves, 1000 m ³ /day hydrothermal power, million Gcal/year		
	Flowing	Pumped	Artificially pressurized in situ
Total in Ukraine	$\frac{23}{0.6}$	$\frac{137}{2.14}$	$\frac{27166}{453}$
Crimea	$\frac{23}{0.6}$	$\frac{125}{2}$	$\frac{27166}{453}$
Transcarpathia	—	$\frac{12}{0.14}$	—

Utilization of thermal waters is complicated by the following:

- the problem of a safe waste water discharge into the environment
- the problem of reusing discharge waters by subsurface injection
- the high risk of drilling holes having low water yields.

In spite of these potential problems, hydrothermal waters are among the most promising alternative power sources in the future. Elsewhere in the world hydrothermal plants supply enough energy to satisfy some of the commercial/industrial requirements.

Natural heat from rocks

Worldwide experience in the use of heat from geothermal steam and hydrothermal springs, and various geological and geophysical studies and technical and economic estimations show that it is possible to use the natural heat of rocks. Nevertheless, due to the unfavorable distribution of rocks with high enough temperature, and lack of efficient technology for heat extraction, geothermal energy is not used widely today. It should be noted that the power industry can use efficiently only 4% of the estimated conductive geothermal energy.

Investigations into heat flows throughout Ukraine revealed a strong dependence of their rates upon the tectonic environment. At this time, maximum heat flows are observed within the Mesozoic and Cenozoic tectonic formations and/or where the warming up of the upper Earth's crust of the same age occurred. Estimated resources of the conductive geothermal energy within the upper 10 km of the Earth's crust in Ukraine are as follows:

Geothermal power

Location	Geothermal power	
	Joules	Comparison fuel*, c.f.
Crust-upper 10 km	6.9×10^{22}	2.38×10^{12}
Platform areas	1.9×10^{22}	0.66×10^{12}
Geosyncline areas	5.0×10^{22}	1.72×10^{12}
Crust-upper 3 km	3.3×10^{22}	1.12×10^{12}
Platform areas	0.95×10^{22}	0.32×10^{12}
Geosyncline areas	2.35×10^{22}	0.8×10^{12}

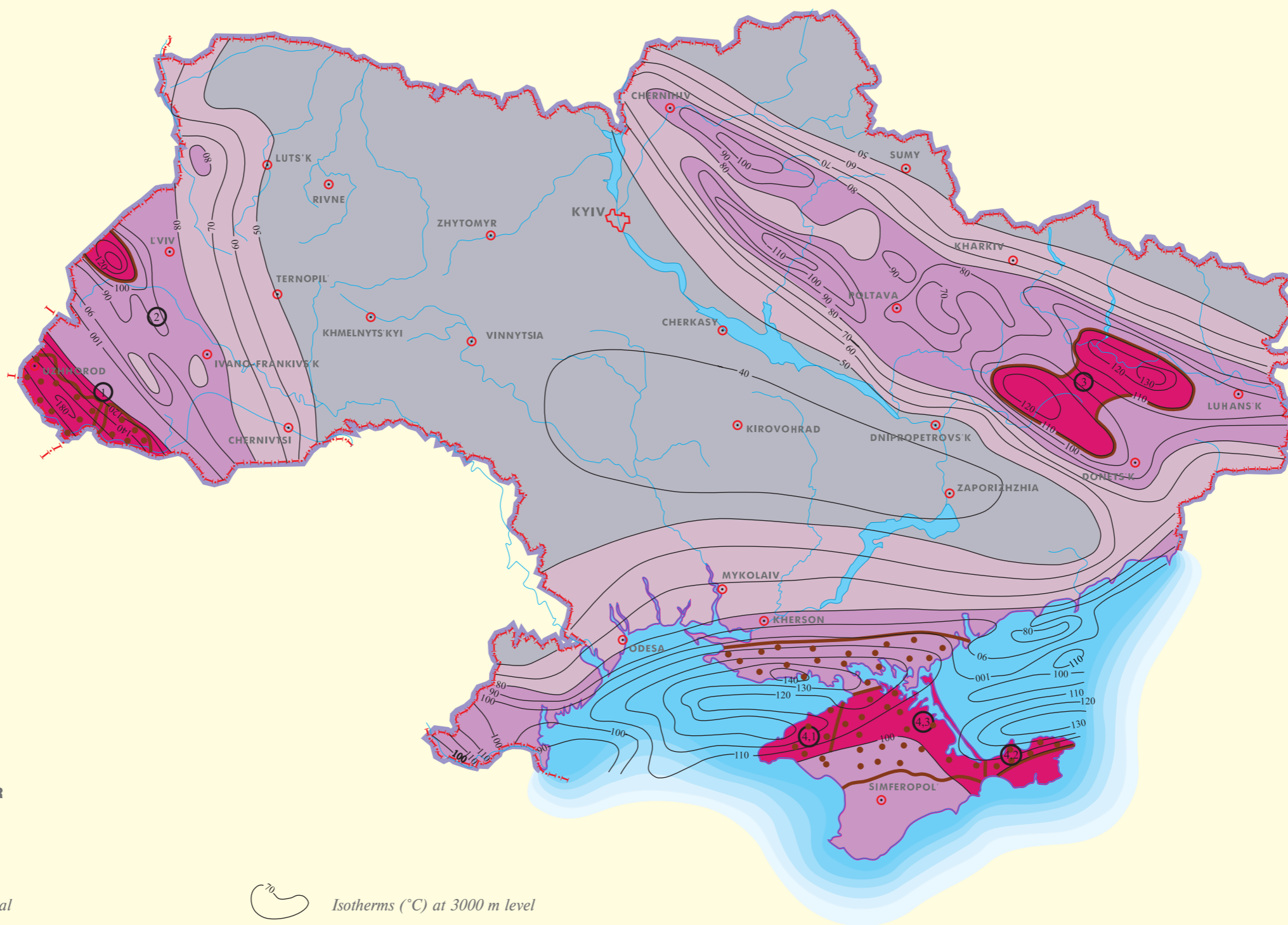
In terms of conductive geothermal power, the Ukrainian territory is subdivided into high-yield, average and low-yield potential areas. The most promising ones are located in the Transcarpathian Deep, northwestern part of the Carpathian Foredeep, Fore-Dobruja Deep, Crimean flatlands, Kerch peninsula, Donets' folded structure and adjoining parts of the Dnipro-Donets' Depression. Within these areas, resources of conductive geothermal power are estimated at 1.52×10^{20} Joules, comparable to 5170 Mt of oil equivalent.

Geothermal power resources of highly potential areas

Regions	Geothermal power	
	$\times 10^{20}$ J	$\times 10^9$ tons c.f.*
1. Transcarpathia	0.32	1.11
2. Carpathian Foredeep	0.16	0.56
3. Folded Donets'k Basin	0.3	1.02
4. Crimea	0.74	2.48
4.1. Tarkhankut peninsula	0.27	0.92
4.2. Kerch peninsula	0.24	0.8
4.3. Steppe Crimea	0.23	0.76
Total	1.52	5.17

* Comparison fuel (c.f) – total amount of oil or gas in 1 ton of oil or 1000 m³ of gas

GEOTHERMAL POWER



LEGEND

POTENTIAL REGIONS FOR GEOTHERMAL POWER

- High potential*
- Moderate potential*
- Some Potential*
- Low potential*

- Isotherms (°C) at 3000 m level*
- Areas with estimated resources of thermal water*
- Areas with potential for geothermal power*

MINERAL WATER SOURCES

Ukraine has abundant mineral water resources. Mineral waters occur commonly in the country and there is quite a large variation in their composition. Based on the hydrogeochemical properties of the water, the country can be divided into five provinces as follows:

- 1) Carbonic waters
- 2) Nitric, nitro-methanic and methanic waters
- 3) Radon-bearing oxy-nitric waters
- 4) Hydrosulfatic waters
- 5) Organo-hydrochemical waters ("Naftusia")

1) The carbonic water province (50-60 km wide) is related to the Transcarpathian artesian basin. The gas in the water is mainly carbon dioxide (98-100%). Its concentration at 800-1000 m depths reaches 3-15 g/l. In the vicinity of a number of villages (Poliana, Soymy, Chornoholova and others) there are emissions of dry carbon dioxide gas.

The composition of underground waters varies from hydrocarbonic calcic to sodium chloride bearing, from sweet to saline. Some waters have other microcomponents, such as iron, arsenic and boron. Such waters are considered to be beneficial for health and commonly have elevated temperatures. Within this province there are carbonic waters of commercial types; "Narzan", "Borjomi", "Essentuki", sodic carbonic waters of the type "Krynica" and "Usol's'ka", saline waters of the type "Kelechyn's'ka", and arsenic-bearing carbonic waters of the type "Syn'ohors'ka" and "La Burbul".

Another carbonic water province is found in the Azov-Kuban' artesian basin such as the Kerch area in Crimea.

2) The nitric, nitro-methanic and methanic waters form the largest province in Ukraine. These waters are found in all artesian basins in the platformal and folded formations, and in the hydrogeological region of the Crimean Mountains. Here the waters can be hydro-carbonate-sulfatic, sulfatic to saline, commonly with no other components. The mineral content ranges from a few grams per liter to salty compositions. Locally, however, there are waters with elevated bromine, iodine, silica, and organic matter.

Waters with no specific components are the most common in this province and include such areas as the Forecarpathians, Volyn'-Podillia, Dnipro, Donets'-Don, Black Sea Lowland, Crimean Lowland, Azov-Kuban' artesian basins, and the folded regions of the Donbas and Crimea. These waters include the following types: "Moskovs'ka", "Zvenyhorods'ka", "Chernivets'ka", "Uchums'ka", "Krains'ka", "Myrhorods'ka", "Yizhevs'ka" and "Kuyalnyts'ka".

Waters with specific components include iron, arsenic, silica, and various organic matter. Iron-bearing waters are found in the Donbas, the Forecarpathian and the Volyn'-Podillia artesian basins. A commercial source of this type of water has been established only in one place, in the vicinity of the town of Sloviianohirs'k (Donets'k oblast'). The composition of the waters here is similar to the "Polustriv" type. Arsenic-bearing waters of "La Burbul" type are found in the Black Sea artesian basin near the city of Berdians'k. Siliceous waters are found in the Forecarpathian, the Volyn'-Podillia, the Dnipro, and the Donets'-Don artesian basins. These waters are commercially produced in the Khmel'nytskyi and Kharkiv regions. Occurrences of bromian, iodine and iodine-bromian waters are found in all artesian basins, and also in the hydrogeological region of the Crimean Mountains. One commercial operation exists near the city of Berdiansk.

3) Radon-bearing oxy-nitric waters tend to occur in the hydrogeological formations of the Ukrainian Shield. These waters are chemically different from the ones described above, and their mineral content varies from fractions of a gram to 5-8 g/l. It is typical for this area that both the mineral and the fresh water reservoirs are located in the same places and approximately at the same depths.

4) Sulfatic waters are found only in the Forecarpathian artesian basin, where they are associated with the gypsum-anhydrite rocks of the Neogene age. In composition they are similar to the waters of the "Matsesta" type. Occurrences of this type of water have been noted in other artesian and hydrogeological regions.

5) Waters with elevated organic content are represented by the type "Naftusia". Such waters are commercially used in the "Truskavets'" resort establishment and in the Zbruch river area.

There are other similar sources of water along the valley of the Zbruch river. Other sources of water of the "Naftusia" type are also known in the region of Kharkiv and in the Carpathian folded area (Skhodnyts'ke).

In Ukraine, the discharge of mineral waters is in the order of 60 000 cubic meters per day. Currently the total consumption is about 5300 cubic meters per day.

Further development of the mineral water resources can be considered both in terms of the already known and developed areas, which have potential for increased productivity, and in terms of developing new formations which are practically unexplored. Looking at the developed areas, it appears that in many cases they are operating at about half their capacity. In terms of potential areas for further exploration for mineral waters, it appears that every administrative area has some good prospects. Their compositional types have not been always determined. In particular there is good potential for finding commercial mineral water sources of the carbonic type in the Kerch peninsula of Crimean, sulfatic waters in the Poltava, Kharkiv, Odesa, Kherson, Zaporizhzhia, Zakarpattia and L'viv oblasts and Crimea, ferrous mineral waters in the Zakarpattia, L'viv and Donets'k oblasts, mineral waters with elevated organic materials in the Zakarpattia, Khmel'nytskyi, Kyiv, Cherkasy, Kirovohrad, Kharkiv and probably other oblasts that are known to contain carbonaceous materials in the geological columns, siliceous mineral waters in the Zakarpattia, Khmel'nytskyi, Kharkiv and Sumy oblasts, iodine-brome mineral waters in the Zakarpattia, L'viv, Volyn', Chernihiv, Poltava, Kharkiv, Luhansk, Donets'k, Zaporizhzhia, Kherson oblasts and the Autonomous Republic of Crimea.

These are some of the indicators of the potential for different mineral waters in the formations that have been examined to some extent. Considerably more work is required to evaluate the potential in the rest of the country.

Other than this, there is also the question of the influence of industrial pollutants on the mineral waters. The study of mineral water, as an element of the geological environment, could be an important factor which determines the current economic development of various regions in Ukraine.



Table Mountains (Stolovi hory), Western Crimea



Falcon's Stone (Sokolynyi Kamin') mountain, Khmel'nyts'kyi oblast'

MINERAL WATER SOURCES

1 – Mena	14 – Velykyi Liubin'	27 – Truskavets'	40 – Nova Poliana	53 – Murovani Kurylivtsi	66 – Kryvyi Rih	79 – Zaliznyi Port
2 – Stepan'	15 – Berezhivka	28 – Moshny	41 – Kelechyn	54 – Novomoskovs'k	67 – Yuhoka	80 – Kyrlylivka-2
3 – Zhuravychi	16 – Teofipol'	29 – Lyman	42 – Makivka	55 – Oleksandriia	68 – Novoselivka	81 – Kyrlylivka-1
4 – Zhobryn	17 – Drabiv	30 – Skhidnytsia	43 – Tsarychanka	56 – Kudlynka	69 – Velykyi Anadol'	82 – Odesa-1
5 – Korets'	18 – Myrhorod	31 – Pidialyns'ke	44 – Western Slovians'k	57 – Zoloty Kolodiaz'	70 – Andriivka	83 – Odesa-2
6 – Verkhne Syn'ovydne	19 – Bila Tserkva	32 – Morshyn	45 – Slovians'k	58 – Znamianka	71 – Novoazovs'k	84 – Karolino-Buhaz
7 – Brovary	20 – Novopskov	33 – Zbruch	46 – Sosnovyi	59 – Shalanky	72 – Lazurne	85 – Serhiivka
8 – Shepetivka	21 – Zaichykyivka	34 – Novi Sanzhary	47 – Poliana	60 – Brusnytsia	73 – Berdians'k-2	86 – Northern Syvash
9 – Korbutivka	22 – Myronivka	35 – Novyi Zbruch	48 – Soimy	61 – Solonyi Lyman	74 – Berdians'k-1	87 – Chokrak Lake
10 – Polonne	23 – Naftusia	36 – Sloviianohirs'k	49 – Zvenyhorodka	62 – Berehove	75 – Kobleve	88 – Yevpatoriia-1
11 – Denyshi	24 – Volochys'k	37 – Demydivka	50 – Syniak	63 – Tysa	76 – Ochakiv	89 – Yevpatoriia-2
12 – Koncha-Zaspa	25 – Khmil'nyk	38 – Uzhhorod	51 – Holubnye	64 – Hirs'ka Tysa	77 – Kuial'nyk	90 – Saky
13 – Vlasivka	26 – Konopkivka	39 – Ploske	52 – Luhans'k	65 – Budenets'	78 – Chornomors'ke	91 – Feodosiia

MINERAL WATER SITES



LEGEND

MINERAL WATER PROVINCES

- Carbon dioxide-bearing water in regions of young magmatism
- Nitric, nitric-methane and methane-bearing water of artesian basins
- Oxy-nitric radon-bearing water of the Ukrainian Shield
- Hydrosulfide-bearing water of the Carpathian Foredeep

Exploitable reserves of mineral water

4368.8
662.4

 potential measured reserves, m³ per day
 actual annual consumption, m³ per day

OTHER SYMBOLS

- Under-exploitation
- Not exploited
- Boundaries of mineral water provinces

TYPES OF MINERAL WATER

- carbonic
- hydrosulfidic
- siliceous, iron-bearing
- bromine, iodine-bromine, boron-bearing
- radon-bearing
- with increased content of organic substances ("Naftusia" type)
- with no specific constituents and properties

HEALTH RESORTS OF UKRAINE BASED ON DIFFERENT TYPES OF MINERAL WATER

- | | |
|--|--|
| <ul style="list-style-type: none"> Carbonic 1. Poliana 2. Shalanky 3. Hirs'ka Tysa 4. Soimy | <ul style="list-style-type: none"> Bromine, iodine-bromine, boron-bearing 12. Berdians'k |
| <ul style="list-style-type: none"> Hydrosulfidic 5. Syniak 6. Liubin' Velykyi 7. Cherche | <ul style="list-style-type: none"> Radon 13. Khmil'nyk 14. Bila Tserkva |
| <ul style="list-style-type: none"> Siliceous, iron-bearing 8. Soimy 9. Slovianohirs'k 10. Bereziv'ske mineral waters 11. Rai Olenivka | <ul style="list-style-type: none"> With increased content of organic substances ("Naftusia" type) 15. Truskavets' 16. Sataniv |
| | <ul style="list-style-type: none"> Unclassified (no specific properties) 17. Myrhorod 18. Feodosiia 19. Morshyn |

CLAY AND KAOLIN

Ukraine has huge resources of kaolin and clays. In terms of their resources, variety and quality they are some of the best in the world.

Kaolin. The largest resources of kaolin occur on the Ukrainian Shield and along its slopes over an area some 950 km long and up to 350 km wide. There are both primary (in situ) kaolin deposits such as those directly related to the weathering of crystalline Precambrian basement rocks, and secondary ones which have been eroded and redistributed. The thickness of the primary kaolin deposits varies from 1.4 m to 120 m (commonly ranging from 10 to 40 m), and the secondary deposits vary from 5 to 8 m in thickness.

In total there are about 200 kaolin deposits, of which 34 have been explored and 21 are mined. A general resource estimate of kaolin deposits is in the order of 4.5 Bt, and the explored resources amount to about 450 Mt.

The largest mining and kaolin enrichment plants are Prosiana, Hlukhivtsi and Turbiv. In the early 1990s annual kaolin production was close to 3 Mt, of which 2 Mt were put through an enrichment process producing over 1 Mt of kaolin concentrate. Various businesses in Ukraine consume 25% of the concentrated kaolin, and the rest is exported. Some of the better varieties

of concentrated kaolin are used in the production of porcelain and faience (pottery), and also paper, rubber and in drilling solutions. Kaolin from secondary deposits is used in the production of fire-resistant materials, and faience and construction-related ceramics. Alkaline kaolin is a complex raw material that is used in the production of kaolin from feldspars, which is a source of high quality concentrates used in the production of fine ceramics and china-faience articles and wares.

A general prognosticated and explored potential of kaolin in Ukraine could totally satisfy the needs of the European market, for example.

Data as of 01.01.2001, for the main deposits in Ukraine, are shown below.

Deposit	Reserves (thou. t)	Annual output (thou. t)	Kaolin content (%)
Prosiana	69 548	378	45-72
Volodymyriv	11 048	226	82
Velyki Hadomtsi	83 050	-	60
Hlukhivtsi	55 563	176	55-60

Bentonite clays are widely distributed over the Ukrainian Shield, the Dniro-Donets' Depression, Transcarpathia and Crimea. The main mineable resources are, however, practi-

cally in one large deposit (Cherkasy oblast'), where the bentonite clays occur in several layers from 0.5 to 15 m thick in the near surface environment. A particular feature of these bentonite clays is their high deflocculation, a very useful characteristic in their applications. At this time bentonite clays are used as form-producing ceramic raw materials, as an ingredient in drilling muds, and also as natural catalysts and adsorbents in oil refining, in metallurgical, food and paper production and in farming. Bentonite clays are used as adsorbents in the production of butter, foods and sugar. They are used also as a mineral matrix of some biochemical composites. Bentonite clays are utilized in preparations used to deactivate or clean up surfaces and in the removal of toxic substances.

Fire-resistant and refractory clays are widely distributed on the Ukrainian territory. The main deposits occur in the Donbas and the Ukrainian Shield. Layers of such clays measure from 0.3 to 63.5 m in thickness and occur near the surface, in places down to 60 m depths.

The fire-resistant clays can withstand high temperatures (up to about 1580°C), have high plasticity, coherence and a wide range of baking temperatures. Such clays are used mainly in the metallurgical, machine-building, tool-manufacturing and ceramic industries. There are 20 deposits of such clays with explored reserves over 550 Mt; and 10 deposits are being mined at this

time. They are used in various branches of ceramic industry.

Saponite clays are of particular interest in connection with their unique features. Recently one saponite deposit (Varvariv) with a reserve of about 30 Mt was explored. It is located in the north-western part of the Ukrainian Shield on its slope. The saponite clays are found at depths of 10-20 m, and the thickness of the layers range from 20 to 50 m. Saponite clays differ from other clays in terms of their elevated magnesium and potash content, high indications of specific swelling, colloidal and cation exchange capacity. In terms of these features, the saponite clays can be effectively utilized in farming: as a mineral supplement for animals, as a preservative for green fodder, as a complex ameliorator of soils and in recultivation of ground polluted by radionuclides. Research is being carried out on the use of saponite clays in the treatment of certain cancers.

In summary, Ukraine has the largest mineral resource potential for kaolin and other high quality clays in Europe. Further effective realization of this potential requires the introduction of current methods of technological enrichment of some of the clays, the certification of the quality of production, and the expansion of the uses of clay products.

Clays and kaolin, which are so abundant in Ukraine, will play an important role in the development of local industry, farming, biology and medicine.



Hlukhivtsi unreclaimed open pits after kaolin mining



Reconstruction of Trypillian clay pottery (4000-2500 BC)



Reconstruction of clay pottery from the Trypillian period



An example of current open-pit mining of kaolin, Hlukhivtsi

CLAY

Deposits

1. Hlibivs'ke
2. Chudivka
3. Os'maky
4. Mykhailivs'ke (Krasnopillia)
- 4* Krasnopillia (Mykhailivs'ke)
5. Varvariv
6. Burtyn
7. Opishnia
8. Berezhany
9. Yevsuh
10. Cherkasy (near Zvenyhorodka)
11. Novobokiv
12. Overiany
13. Ivantsivi
14. Mukachiv
15. Lavkins'ke

16. Horbky
17. Pyzhiv
18. Nyzhnoshepits
19. Mykolaivka
20. Matros
21. Rai-Oleksandrivka
22. Nykyforivka
23. Popasnia
24. Chasiv Yar
25. Artemivs'k
26. Kurdiuvivka
27. Shestakivka
28. Piatykhaitky
29. Saksahan'
30. Pervozvanivka
31. Devladove
32. Novoperivka
33. Kuteinykove

34. Zatyshne
35. Polohy
36. Kurtseve
37. Kudryne

Enlargement of area 1

38. Novokrasnodarka
39. Nova Shveitsariia (Near open pit)
40. Nove Rais'ke
41. Nova Shveitsariia (Southern)
42. Zakhidno-Dons'ke (Western-Don)
43. Vesele (Novooleksiivka)
44. Andriivka
45. Oktiabrs'ke
46. Pivdenno-Oktiabrs'ke

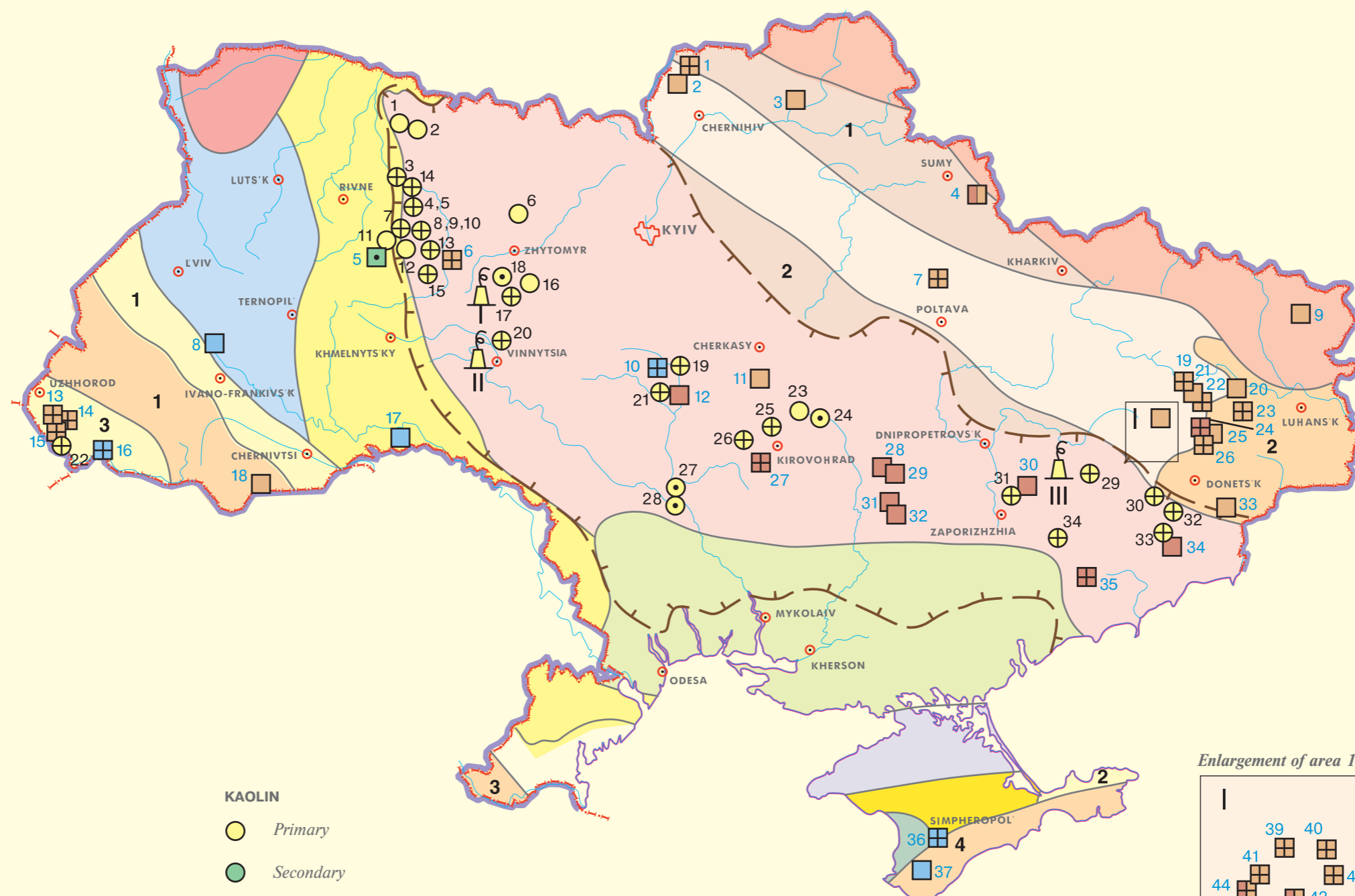
KAOLIN

Deposits

1. Klesiv-1
2. Ostki
3. Derman'
4. Dibrivs'k
5. Dubrivs'k
6. Potiivka-2
7. Kupyn
8. Maidan-Vyla (Khmelivka)
9. Maidan-Vyla (Northern block)
10. Maidan-Vyla (Novaky)
11. Staryi Lis ravine (1 & 2 sites)
12. Sudymont
13. Burtyn
14. Shadaviv
15. Polonne
16. Velyki Hadomtsi

17. Hlukhivtsi
18. Zhezheliv
19. Murzyn
20. Turbiv
21. Novoselytsia
22. Berehove
23. Verboloziv (Bandurivka)
24. Verboloziv
25. Kirovohrad
26. Oboznivka
27. Chausove
28. Kinets'pil'
29. Prosiana
30. Volodymyrivka
31. Biliaivka
32. Bohorodys'ke
33. Katerynivka
34. Polohy

CLAY AND KAOLIN



LEGEND

CLAY

- Fire-resistant clay
- Refractory clay
- Bentonite clay
- Saponite clay

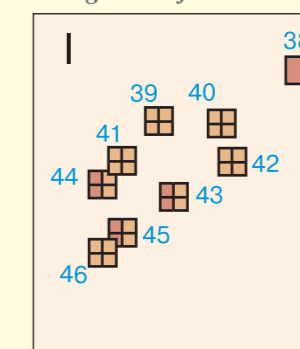
- Deposits – developed
- Deposits – prepared for development
- Deposits – not developed

KAOLIN

- Primary
- Secondary
- Alkaline
- Outlines of the kaolin province in the Ukrainian Shield
- Deposits – developed
- Deposits – prepared for development
- Deposits – not developed

- Kaolin plants
- I - Hlukhivtsi
- II - Turbiv
- III - Prosiiana

Enlargement of area 1



Note: For structural divisions, see map Ferrous Metals, p. 125.



Coal waste piles, Donbas



Columnar jointing in Ivano-Dolyns'k basalts, Rivne oblast'



Potassic salt, Forecarpathia



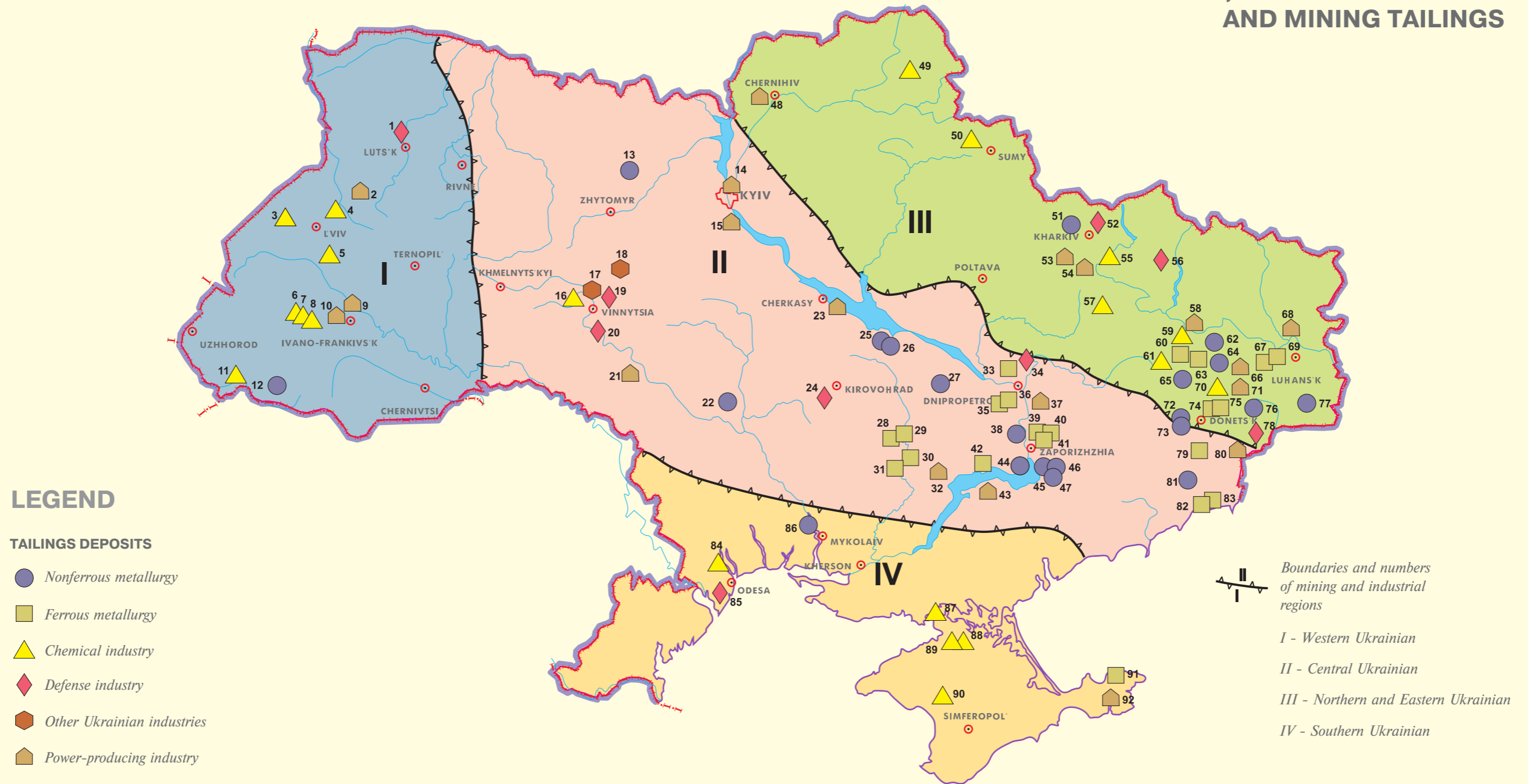
Crystals of sulfur and celestite, Forecarpathia

ENTERPRISES, INDUSTRIAL WASTES AND MINING TAILING

- | | | | |
|---|---|---|--|
| 1 – Luts'k foundry and machine plant | 25 – Pure metals plant, in the city of Svitlovods'k | 47 – "Ukr mashmetremont" in the city of Zaporizhzhia | 72 – Industrial association "Donets'kvorkol'ormet" |
| 2 – Dobrotvir power plant, L'viv oblast' | 26 – Svitlovods'k hard alloy works | 48 – Chernihiv central heating and power plant | 73 – "Vorkol'ormet" scientific research institute, in the city of Donets'k |
| 3 – Yavoriv mining and chemical association "Sirka" | 27 – Upper Dnipro mining and metallurgical plant | 49 – Shostka industrial association "Svema" | 74 – Yenakiyev metallurgical plant, Donets'k oblast' |
| 4 – L'viv chemical plant | 28 – New Kryvyi Rih mining and concentrating plant | 50 – Sumy industrial association "Khimprom" | 75 – Makiivka metallurgical plant, Donets'k oblast' |
| 5 – Rozdil mining and chemical industrial association "Sirka" | 29 – OJSC "Pivden' iron mining and concentrating plant" | 51 – Industrial association "Kharkivvorkol'ormet", in the city of Kharkiv | 76 – Torez hard alloy plant |
| 6 – Concern "Chlorvinil" producing potassium fertilizers | 30 – Kryvyi Rih metallurgical plant "Kryvorizhstal" | 52 – Kharkiv ball bearing factory | 77 – Sverdlovs'k hard alloy plant |
| 7 – Magnesium-producing plant "Chlorvinil" | 31 – OJSC "Inhulets' mining and concentrating plant" | 53 – Kharkiv power plant-2 | 78 – Amvrosiivka foundry and machine plant |
| 8 – Factory producing plant protection chemicals | 32 – Kryvyi Rih power plant, in the city of Zelenodol's'k | 54 – Zmiyiv power plant, in the town of Komsomolets' | 79 – Donets'k metallurgical plant |
| 9 – Burshtyn power plant, Ivano-Frankivs'k oblast' | 33 – "Dnipro" metallurgical plant, in the city of Dniprodzerzhyns'k | 55 – Kharkiv autogenous machinery plant | 80 – Starobesheve power plant, in the town of Novyi Svit |
| 10 – Kalush central heating and power plant, Ivano-Frankivs'k oblast' | 34 – Dnipro Region chemical plant, Dniprodzerzhyns'k | 56 – Kupians'k ball bearing factory | 81 – Donets'k chemical and metallurgical plant, in the town of Dons'ke |
| 11 – OJSC "Zatysyans'kyi chemical plant" | 35 – Petrovs'kyi metallurgical plant, Dnipropetrovs'k | 57 – Pervomais'k industrial association "Khimprom" | 82 – Mariupol' metallurgical plant "Azovstal'" |
| 12 – Transcarpathian metallurgical plant, in the city of Vyshkiv | 36 – Dnipropetrovs'k metallurgical plant | 58 – Slovians'k power plant, Donets'k oblast' | 83 – Mariupol' metallurgical plant "Illich" |
| 13 – Irshans'k mining and concentrating plant | 37 – Dnipropetrovs'k power plant | 59 – Slovians'k industrial association "Khimprom" | 84 – Odesa superphosphate factory |
| 14 – Darnytsia central heating and power plant | 38 – Zaporizhzhia titanium and magnesium plant | 60 – Kramators'k metallurgical plant | 85 – Odesa earth-moving machine factory |
| 15 – Trypillia power plant, in the city of Ukrainka | 39 – Zaporizhzhia metallurgical plant "Zaporizhstal" | 61 – Kostiantynivka chemical plant | 86 – Mykolaiv alumina plant |
| 16 – Vinnytsia industrial association "Khimprom" | 40 – Zaporizhzhia electromechanical plant "Dniprospestal" | 62 – Artemivs'k non-ferrous metals plant | 87 – Crimean titanium dioxide plant |
| 17 – Turbiv kaolin plant | 41 – Zaporizhzhia ferro-alloy plant | 63 – Kostiantynivka metallurgical plant | 88 – Krasnoperekop bromine plant |
| 18 – Hlukhivtsi kaolin plant | 42 – Nikopol' ferro-alloy plant | 64 – Mykytivka mercury plant | 89 – Crimean soda plant |
| 19 – Turbiv machine plant | 43 – Zaporizhzhia nuclear power plant, in the city of Enerhodar | 65 – Kostiantynivka plant "Ukrzinc" | 90 – Saky chemical plant |
| 20 – Vinnytsia ball bearing factory | 44 – OJSC "Zaporizhzhia aluminum plant" | 66 – Myronivka power plant, in the city of Debal'tseve | 91 – Kerch metallurgical plant |
| 21 – Ladyzhyn power plant, Vinnytsia oblast' | 45 – Dnipro plant, in the city of Zaporizhzhia | 67 – Komunars'k metallurgical plant, Luhans'k oblast' | 92 – Komysheburun central heating and power plant, in the city of Kerch |
| 22 – OJSC "Buh Area ferronickel plant" | 46 – Scientific-research institute of titanium, in the city of Zaporizhzhia | 68 – Luhans'k power plant, in the city of Shchastia | |
| 23 – Cherkasy power plant | | 69 – Stakhanov ferro-alloy plant, in the city of Alchevs'k | |
| 24 – Kirovohrad foundry and machine plant | | 70 – Horlivka industrial association "Stirol" | |
| | | 71 – Vuhlehirs'k power plant, the city of Debal'tseve | |

Note: OJSC – Open Joint Share-Holding Company

ENTERPRISES, INDUSTRIAL WASTES AND MINING TAILINGS



LEGEND

TAILINGS DEPOSITS

- Nonferrous metallurgy
- Ferrous metallurgy
- ▲ Chemical industry
- ◆ Defense industry
- ⬡ Other Ukrainian industries
- Power-producing industry

ENTERPRISES, INDUSTRIAL WASTES AND MINING TAILINGS

In Ukraine, the problems of the build-up of industrial wastes and their possible utilization are on the list of top priorities, in terms of both ecology and economy. From previous years of operations, some 500 plants in Ukraine produced an estimated 25 billion tons of solid wastes. Currently, 1.8 billion tons are being added to this figure annually. The total area occupied by tailings ponds is in the order of 50 000 hectares. The rate of waste recovery in Ukraine

amounts to only about 12%, as compared to 60-80% in other countries with highly developed economies. The state geological company "Geoprognoz" performs systematic investigations on waste materials of different plants and factories in Ukraine. Sampling and study of tailings ponds at 50 plants showed that 28 of them contain wastes with rare, noble and base metals and non-metallic minerals of significant concentrations. In some cases, the mineral content is of the same order of magnitude as in the remaining mineral deposits. Seven of the tailings ponds studied can be mined right now, and the other 21 tailings ponds need some concentration procedures.

At present, non-metallic components of waste materials are widely used as building materials, chemical reagents for the purification of sewage waters, fertilizers, etc. Ukraine contains areas of industrial waste materials with the potential economic value of serving as new sources of metals and other raw materials. As a result of reprocessing of some of the investigated tailings deposits, the following elements can be concentrated and recovered: scandium, gallium, yttrium, tantalum, niobium,

mercury and cesium. They would satisfy the country's demands for several tens of years. Similarly, lead, zinc, copper, vanadium, zirconium, gold, silver and lithium, recovered from tailings, could satisfy 10% to 25% of the country's annual requirements. Utilization of metals from tailings could potentially result in substantial profits and would be in harmony with the resolution of some of the environmental problems. Studies of waste materials from ore processing indicate that there is a potential for profitable recovery of various valuable metals in Ukraine.

MINERAL DEPOSITS

Ukraine has an abundant raw mineral base. In total, there are about 20 000 deposits and occurrences. Over 8000 of these deposits, representing about 94 different types of mineralization, may have economic significance. In terms of current prices of various commodities, the explored deposits have a value of about a 7-7.5 trillion dollars.

Many of the deposits are located in areas with good access to infrastructure. By 1998, 3349* deposits that have been explored supply over 2000 mining and processing operations in the coun-

try. In the best years, Ukrainian mining enterprises produced 23-25% of the gross national product and satisfied about 80% of the national mineral requirements. The export of minerals made a contribution to the flow of foreign currency into the country. Ukraine is not only self-sufficient in many raw mineral commodities and their manufactured products, but exports them as well. These are: iron, manganese, titanium, zirconium, uranium, mercury, graphite, kaolin, native sulfur, bentonite and fire-resistant clays, salt, fluorite, alkaline salts and facing stones. At this time, in spite of the presence of numerous oil and gas deposits in Ukraine, the current production satisfies only about

20% of the national requirements of natural gas and about 10% of oil. The Dnipro-Donets' Depression is considered to be one of the best oil and gas regions of Ukraine. The oil and gas deposits are associated with lithological and structural traps in carbonate rocks of different ages, particularly Devonian, and include some of the underlying Precambrian rocks. Prospective oil and gas regions in the Carpathians include the autochthonous structural complexes. In the southern part of Ukraine the obducted zones of the Fore-Dobrujan Depression, and the thick Paleozoic carbonate strata of the western Black Sea region need further exploration for oil and gas. Here recent investigations under the Black

and Azov Seas have indicated the presence of both oil and gas. Recently the Ukrainian Geological Survey has obtained very encouraging results in prospecting and exploring for deposits of gold, molybdenum, copper, nickel sulfides, zinc, lead, rare earth elements, and rare metals. These results made it possible for the State Geological Committee to develop plans to provide the country with its own resources of base, rare and noble metals.

At this time, Ukraine is lacking in such metals as copper, lead, zinc, nickel, molybdenum, tin, beryllium, lithium, tantalum, niobium, rare earth, gold, silver and platinum.

LIST OF MINERAL DEPOSITS

1, 2 – Novhorod-Sivers'kyi	38 – Klyns'ko-Krasnoznamenka	78 – Opishnia	119 – Kovalivka	160 – Poliana	201 – Chornohuzy	241 – Volodymyrivka	279 – Lazurne
3 – Ratne	39 – Tymofeievka	79 – Chutove	120 – Dolyna	161 – Soimy	202 – Obozrivka	242 – Amvrosiivka	280 – Kuial'nyk
4 – Papirnia	40 – Nemyriv	80 – Sementsi	121 – Terebovlia	162 – Bytkiv-Babychi	203 – Kapustyno	243 – Kryvyi Rih	281 – Kyrylivka
5 – Rozlioty	41 – Kupin	81 – Matviivka	122 – Haidamaky	163 – Pasichna	204 – Semenivka-Oleksandrivka	244 – Kostiantynivka	282 – Odesa
6 – Yastrubets'ke	42 – Maidan-Volia	82 – Vyshneve	123 – Murzyntsi	164 – Kryvche	205 – Balakhivka	245 – Kryvyi Rih (Saksahan river)	283 – Eastern Sarata
7, 8 – Klesiv	43 – Burtyn	83 – Staryi Sambir	124 – Smila	165 – Humentsi	206 – Malyshiv	246 – Olenivka	284 – Bilhorod-Dnistrovs'kyi
9 – Ovruch	44 – Korostyshiv	84, 85 – Rozvadiv	125 – Mala Komyshevata	166 – Dzhurzhyvka	207 – Shyroke	247 – Novotroits'ke	285 – Serhiyivka
10 – Yasnohirka	45 – Hnidyntsi	86 – Rozdil	126 – Raihorodok	167 – Stari Babany	208 – Pervozyanivka	248 – Olenivka	286 – Strilkove
11 – Ivanchyk	46 – Buhruvate	87 – Bila Tserkva	127 – Hryniava	168 – Yurkove	209 – Piatykhatky	249 – Styla	287 – Dzhankoy
12 – Stets'kivka	47 – Svydnytsia	88 – Myronivka	128 – Budanivka	169 – Nemyriv	210 – Karnaukhivka	250 – Karakuba	288 – Zadorne
13 – Stepanyk	48 – Yaziv	89 – Abazivka	129 – Balabanivka	170 – Tans'ke	211 – Avdiivka	251 – Osykove	289 – Novosil's'ke
14 – Lokachi	49 – Sudymont	90 – Rozpashne	130 – Novozbruch	171 – Kaitanivka	212 – Novopavlivka	252 – Balka Mokra	290 – Kolodiazne
15 – Omelianivka	50 – Tryhiria	91 – Khmil'nyk	131 – Bohorodchany	172 – Yelyzavetka	213 – Horbok	253 – Trykraty	291 – Bielins'ke
16 – Stremyhorod (Phosphorite)	51 – Danyshi	92 – Bohuslav	132 – Kalush-Holyn'	173 – Znamianka	214 – Lopushna	254 – Novodanylivka	292 – Eastern Baherove
17 – Romny	52 – Yablunivka	93 – Mashivka	133 – Velyka Kuzhelivka	174 – Myronivka	215 – Brusenky	255 – Vysokopillia	293 – Vasylivka
18 – Talalaivka	53 – Kharkivtsi	94 – Western Khrestyshche	134 – Tyvriv	175 – Novooleksandrivka	216 – Zavallia	256 – Tok	294 – Krasnyi Partyzan
19 – Synii Kamin'	54 – Kozhyivka	95 – Medvedivka	135 – Novosilka	176 – Hannivka	217 – Dereniukha	257 – Polohy (fire clay)	295 – Holitsyn
20 – Stremyhorod (Titanium)	55 – Burtyn	96 – Melykhivka	136 – Bahate	177 – Novomyrhorod	218 – Kapitanivka	258 – Huliaypole	296 – Yevpatoriia
21 – Rudnia Shliakhova	56 – Polons'ke	97 – Shebelynka	137 – Novodmytriivka	178 – Kirovohrad	219 – Nadija	259 – Novotroits'ke (dolomite)	297 – Feodosiia
22 – Zdolbuniv	57 – Andrushivka	98 – Lyman	138 – Sloviianohirs'k	179 – Morozivka	220 – Pervozyanivka	260 – Northern Shevchenko	298 – Semenivka
23 – Fedorivka	58 – Sula-Udaytsi	99 – Starobil's'k	139 – Yamy	180 – Verkhniodniprovs'k	221 – Petrivka	261 – Pokrovs'ke-Kyryivka	299 – Ivanivka
24 – Kamiany Brid	59 – Yul'ivka	100 – Boryslav (ozokerite wax)	140 – Husarivka	181 – Kramators'k	222 – Sukhyi Khutir	262 – Orikhivka (sand)	300 – Saky
25 – Volyn'	60 – Berezivka	101 – Boryslav (oil)	141 – Sloviianka	182 – Chasiv Yar	223 – Kudashivka	263 – Orikhivka (coal)	301 – Chervone
26 – Holovyne	61 – Kotel'va	102 – Stebnyk	142 – Novyi Karfahen	183 – Luhans'k	224 – Pravda	264 – Polohy (secondary kaolin)	302 – Bakhchysaray
27 – Slipchytsi	62 – Kornyn	103 – Morshyn	143 – Bilohorivka	184 – Chasiv Yar	225 – Pavlivka	265 – Polohy (sand)	303 – Psylerakhivs'ke
28 – Leliaky	63 – Myrhorod	104 – Zastinna	144 – Nyrky	185 – Nove Rais'ke	226 – Synel'nykove	266 – Zatyshne	304 – Kadakiv
29 – Chervonozavods'ke	64 – Komyschnia	105 – Zbruch	145 – Bantysheve	186 – Novoandriivka	227 – Novomykhailivka	267 – Kalinino-Shevchenko	305 – Hosfort Mountain
30 – Anastasivka	65 – Zakhidni Solokhy	106 – Turbiv	146 – Artemivs'k	187 – Vesele	228 – Kovach	268 – Novopoltavka	306 – Chehene-Salyn
31 – Rava-Rus'ka	66 – Berezivka	107 – Tetiiv	147 – Mykhailivka	188 – Oktiabrs'ke	229 – Sokyryntsi	269 – Balka Bila	307 – Kamysch-Burun
32 – Kryvytsia	67 – Semyrenky	108 – Cherkasy	148 – Kramators'k	189 – Mykytivka	230 – Solotvyn	270 – Velykyi Tokmak	308 – Kyiat
33 – Dubrivka	68 – Novoselivka	109 – Reshetniakivka	149 – Artemivs'k	190 – Bihan'	231 – Solotvyn	271 – Novopoltavka	309 – Sim Kolodiaziv (Seven Wells)
34 – Slobidka	69 – Novoposkov	110 – Berestoven'ka	150 – Ploske	191 – Syniak	232 – Hirs'ka-Tysa	272 – Balka Velyki Tabory	310 – Kyz-Aul basin
35 – Nehrebivka	70 – Velyki Hadomtsi	111 – Yefremivka	151 – Nova Poliana	192 – Holubynne	233 – Trebushany (Dilove)	273 – Mariupol'	311 – Pokostivka
36 – Hlyns'k-Rozbyshivka	71 – Pishchany	112 – Shebelynka	152 – Humentsi	193 – Kudryntsi	234 – Kuz'myne	274 – Troits'ke	312 – Katerlez'k basin
37 – Southern Panasivka	72 – Zaluzhany	113 – Yefremivka	153 – Kaliusyk	194 – Zhvan	235 – Preluky	275 – Hryhorivka	
	73 – Voloshcha	114 – Izium	154 – Zvenyhorodka	195 – Berehove	236 – Sofiyivka	276 – Pivdenne-Bilozerka	
	74 – Velyki Hlybovychi	115 – Truskavets'	155 – Kozats'ke	196 – Berehove	237 – Devladove	277 – Kuksunhur	
	75 – Hlukhivtsi	116 – Podorozhnie	156 – Zhuravka	197 – Muzhiievo	238 – Biliaivka	278 – Azov Sea Coastal	
	76 – Makarivka	117 – Konopkivka	157 – Bandurivka	198 – Muzhiievo	239 – Prosiana		
	77 – Zhezheliv	118 – Barbukhy	158 – Uzhorod	199 – Il'nytsia	240 – Yantsiv		
			159 – Rus'ki Komarivtsi				

Note: Deposits currently in production are shown on the map p. 147.

MINERAL DEPOSITS



LEGEND

HYDROCARBONS

- ▲ Oil
- ▲ Gas
- ▲ Oil and gas

COALS

- Brown coal

FERROUS METALS

- Iron
- Manganese

NON-FERROUS AND RARE METALS

- Nickel
- Aluminum
- Lead and zinc
- Mercury
- Titanium
- Rare metals
- Gold

NON-METALLIC MINERALS

- ▼ Sulfur
- ▲ Apatite
- ▲ Phosphorite
- ▲ Common salt
- ▲ Potassium salt
- Chalk for soda production

NON-METALLIC MINERALS FOR METALLURGY

- Quartzite
- Fire clay
- Dolomite
- Flux limestone
- ▲ Molding sand (foundry sand)
- Feldspar
- Talc and magnesite

MINERALS FOR CEMENT INDUSTRY

- Limestone
- Chalk
- Marl
- Clay
- Opoka

MINERALS FOR GLASS, PORCELAIN AND FAIENCE INDUSTRIES

- ▲ Quartz sand
- ◆ Feldspar
- Primary kaolin
- Secondary kaolin

SEMI-PRECIOUS AND GEM STONES

- Amber
- Rhodonite
- Marble onyx
- Quartz, topaz, beryl

DECORATIVE STONES

- Granite
- Gabbro
- Labradorite
- Marble, dolomite
- Travertine
- Sandstone
- Tuff

URANIUM DEPOSITS

1. Vatutine
2. Michuryn
3. Zhovta Richka
4. Siveryniv
5. Pervomais'k

MINERALS FOR DIFFERENT INDUSTRIES

- Ozokerite
- ◆ Graphite
- ◆ Zeolite
- ◆ Gypsum
- Bentonite
- Mineral paints
- Saponite
- Basalt

UNDERGROUND WATER

- Mineral
- Thermal

Note: For structural divisions, see map Ferrous Metals, p. 125.

**MINERAL DEPOSITS
CURRENTLY IN PRODUCTION**

This map shows the location of about 200 mineral deposits currently in production in Ukraine. These include oil, gas and coal, ferrous metals (iron, manganese), base and rare

metals, and also non-metallic deposits (graphite, zeolites, native sulfur, common and potassic salts, high quality heat-resistant flux raw materials, foundry raw materials, decorative stones, and glass and cement raw materials). These ore deposits represent a relatively small proportion of the total deposits mined in Ukraine.

In general, the concept of qualifying the deposits into "main", "basic", "priority" or other types is a very relative exercise, since the absence of any one type of deposit in the mineral-raw materials base in one or another branch can create constraints for the economy of the country as a whole. It is another matter that some of the deposits (such as clay for the making of

bricks and tiles, or sand for the building industries) are widespread and hence their supplies to the appropriate manufacturers are not a problem. Such deposits could be described as "local" or ubiquitous. Others, shown on this map as the main useful mineral deposits, could be described as having a national significance.

LIST OF MAIN ORE DEPOSITS CURRENTLY IN PRODUCTION

HYDROCARBONS

- Oil**
31 Buhruvate
38 Koziyivka
57 Staryi Sambir
85 Dolyna
194 Semenivka
Gas
24 Krasnoznamenka
32 Svydnytsia
42 Kotel'va
45 Berezivka
48 Zaluzhzhia
53 Chutove
54 Sementsi
60 Abazivka
61 Rozpashne
64 Mashivka
65 Western Khrestyshche
66 Medvedivka
67 Melekhy
68 Shebelynka
81 Yefremivka
89 Hryniava
92 Bohorodchany
95 Bahaten'ke
135 Chornohuzy
150 Sotolvyn
181 Strilkove
182 Dzhankoy
192 Holitsyn
193 Zadorne
Oil and gas
7 Talalaivka
16 Leliaky
17 Anastasivka
22 Hlyns'k-Rozbyshivka
23 Southern Panasivka
25 Tymofiivka
30 Hnidyntsi
36 Yablunivka
37 Kharkivtsi
52 Opishnia
55 Matviivka

- 72 Boryslav
111 Bytkiv-Babychi
112 Pasichna
Brown coal
40 Andrushivka
108 Bandurivka
118 Myronivka
119 Morozivka
133 Il'nytsia
138 Semenivna-Oleksandrivka

FERROUS METALS

- Iron**
175 Southern Bilozerka
Manganese
172 Velykyi Tokmak

NON-FERROUS
AND RARE METALS

- Nickel (laterite)**
145 Kapitanivka
Titanium
139 Malyshev
Gold
131 Muzhiievo

NON-METALLIC
MINERALS

- Sulfur**
26 Nemyriv
33 Yaziv
83 Podorozhnie
Potassium salt
73 Stebnyk
93 Kalush-Holyn'
Common salt
79 Yefremivka
100 Artemivs'k
149 Sotolvyn
Chalk for chemical industry
88 Raihorodka
99 Bilohorivka

NON-METALLIC MINERALS
FOR METALLURGY

- Quartzite**
4 Ovruch
Fire clay
87 Murzyntsi
121 Chasiv Yar
124 Novyi Rais'k
125 Novoandriivka
126 Vesele
127 Oktiabr's'ke
137 Oboznivka
140 Piatykhatky
170 Polohy
Dolomite
97 Yamy

- 160 Olenivka
161 Styla
Flux limestone
158 Olenivka
159 Novotroits'ke
162 Karakuba
168 Novotroits'ke (dolomite)
185 Eastern Baherove
186 Krasnyi Partyzan
190 Psylerskiv's'ke
191 Kadakiv
Foundry sand
56 Vyshnevka
98 Husarivka
123 Chasiv Yar
167 Orikhivka
171 Polohy

PORCELAIN
AND FAIENCE INDUSTRIES

- Quartz sand**
1 Papirnia
46 Novoselivka
49 Velyki Hlibovychi
141 Avdiivka
Feldspar
173 Balka Velyki Tabory
Primary kaolin

- 20 Dubrovytsia
27 Kupin
28 Maidan-Volia
29 Burtyn
34 Sudymont
50 Hlukhivtsi
77 Turbiv
132 Berehove
153 Prosiana
Secondary kaolin
155 Volodymyrivka
169 Polohy

MINERALS
FOR CEMENT INDUSTRY

- Limestone**
106 Humentsi
174 Hryhorivka
Chalk
10 Zdolbuniv
102 Kramators'k
80 Shebelynka
Marl
156 Amvrosvivka
189 Bakhchysaray
Clay
19 Kryvytsia
114 Humentsi
120 Kramators'k
Opoka
18 Rava-Rus'ka
146 Pervozvanivka
163 Balka Mokra

FACING STONES

- Garnet**
2 Klesiv
6 Yemelivka
43 Kornyn
51 Zhezheliv
63 Bohuslav
94 Tyvrviv
115 Stari Babany
116 Tans'ke

- 136 Kapustyno
147 Kudashivka
154 Yantseve
164 Trykraty
165 Novodanylivka
166 Tokove
Gabbro
9 Rudnia Shliakhova
12 Kamiani Brid
21 Slobidka
Labradorite
8 Synii Kamin'
11 Fedorivka
14 Holovyne
15 Slipchytsi
Marble, dolomite
134 Velyka Kamianka
152 Trebushany (Didove)
184 Bielins'ke
Travertine
113 Kryvche
Sandstone
75 Zastinka
86 Terebovlia
90 Budaniv

SEMIPRECIOUS
AND GEM STONES

- Amber**
3 Klesiv
Topaz
13 Volyn'

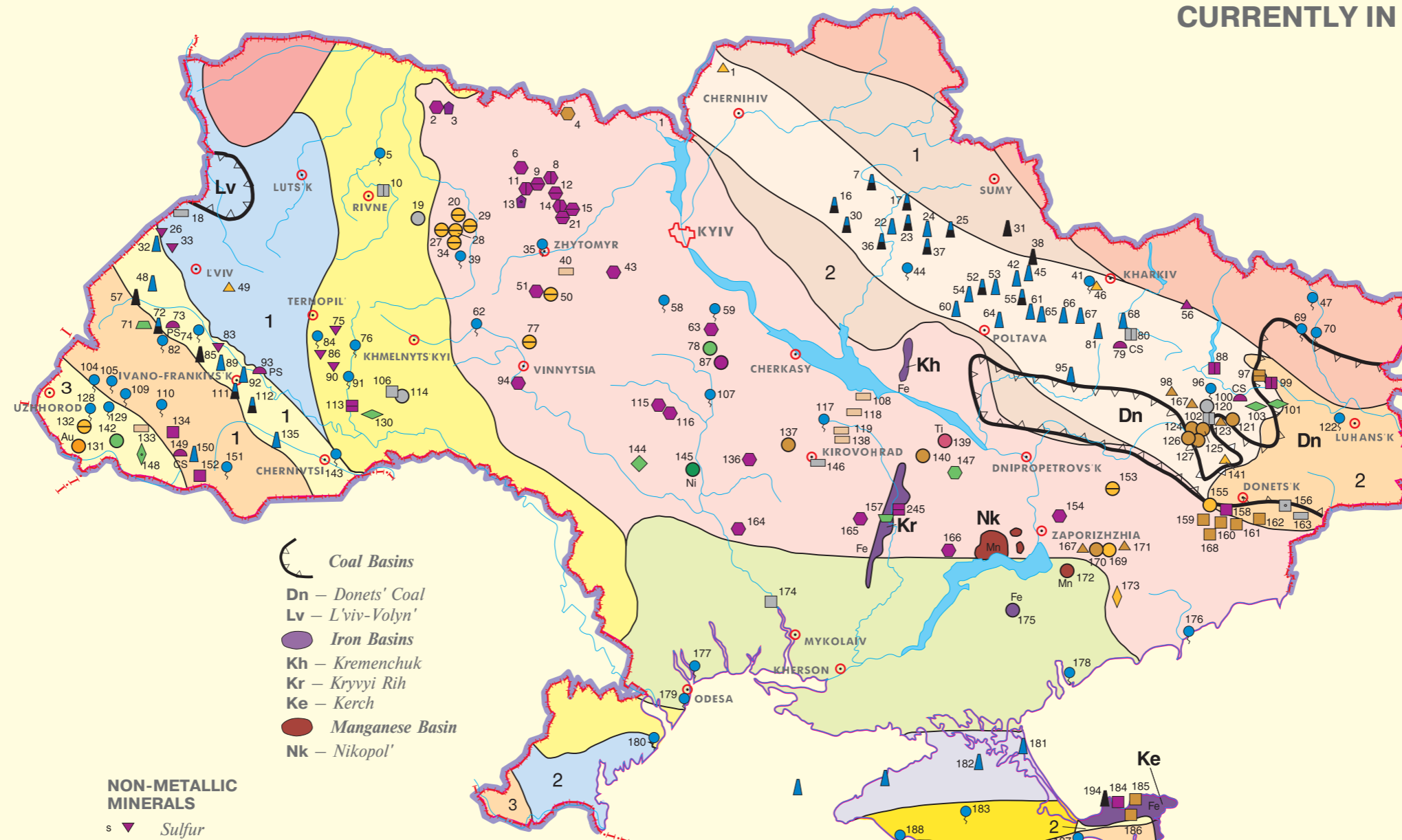
MINERALS FOR
VARIOUS INDUSTRIES

- Ozokerite (mineral wax)**
71 Boryslav
Graphite
144 Zavallia
Zeolite
148 Sokyrnytsia
Gypsum
101 Mykhailivka
103 Artemivs'k

- 130 Kudryntsi
Bentonite
78 Cherkasy
142 Horbky
Mineral plant
157 Kryvyi Rih (Saksahan river)
UNDERGROUND WATER

- Mineral water**
5 Stepanyk
35 Danyshi
39 Polons'ke
41 Berezivka
44 Myrhorod
47 Novopskov
58 Bila Tserkva
59 Myronivka
62 Khmil'nyk
69 Lyman
70 Starobil's'k
74 Morshyn
76 Zbruch
82 Truskavets'
84 Konopkivka
91 Novozbruch
96 Sloviianohirs'k
104 Ploske
105 Nova Poliana
107 Zvenyhorodka
109 Poliana
110 Soimy
117 Znamianka
122 Luhans'k
128 Syniak
129 Holubyn
143 Brusnytsia
151 Hirs'ka-Tysa
176 Lazurne
177 Kuial'nyk
178 Kyrylivka
179 Odesa
180 Serhiyivka
183 Kolodiazne
187 Feodosiia
188 Yevpatoriia

MINERAL DEPOSITS CURRENTLY IN PRODUCTION



LEGEND

HYDROCARBONS

- ▲ Oil
- ▲ Gas
- ▲ Oil and gas

COALS

- Brown coal

FERROUS METALS

- Iron
- Manganese

NON-FERROUS AND RARE METALS

- Nickel
- Titanium
- Gold

NON-METALLIC MINERALS

- ▼ Sulfur
- PS Potassium salt
- CS Common salt
- Chalk for soda production

NON-METALLIC MINERALS FOR METALLURGY

- Quartzite
- Fire clay
- Dolomite
- Flux limestone
- ▲ Molding sand (foundry sand)

MINERALS FOR CEMENT INDUSTRY

- Limestone
- Chalk
- Marl
- Clay
- Opoka

MINERALS FOR GLASS, PORCELAIN AND FAIENCE INDUSTRIES

- ▲ Quartz sand
- ◆ Feldspar
- Primary kaolin
- Secondary kaolin

SEMIPRECIOUS AND GEM STONES

- Amber
- Quartz, topaz, beryl

DECORATIVE STONES

- Granite
- Gabbro
- Labradorite
- Marble, dolomite
- Travertine
- ▼ Sandstone
- ◆ Tuff

MINERALS FOR DIFFERENT INDUSTRIES

- Ozokerite (wax)
- ◆ Graphite
- ◆ Zeolite
- ◆ Gypsum
- Bentonite
- Mineral paints
- Basalt

UNDERGROUND WATER

- Mineral

- ☞ Coal Basins
- Dn – Donets' Coal
- Lv – L'viv-Volyn'
- Iron Basins
- Kh – Kremenchuk
- Kr – Kryvyi Rih
- Ke – Kerch
- Manganese Basin
- Nk – Nikopol'

Note: For structural divisions, see map Ferrous Metals, p. 125.

MINING AREAS

Ukraine's mineral resources are abundant and diversified. Mining for various minerals has been carried out over the centuries. Industrial mining began to develop rapidly in Ukraine during the tsarist regime at the end of 19th century. Later, during the Soviet regime, mining in Ukraine achieved peak production levels, especially in such commodities as coal, iron and manganese.

Central Ukraine has abundant accumulations of ferrous metals, such as iron and manganese and is also noted for its deposits of

nepheline syenite, rare and noble metals, fluorite, graphite and other mineral commodities.

In Northeastern region (notably, the Donbas) there are major deposits of coal, oil and gas in combination with large accumulations of common and potassium salts, mercury deposits, and flux limestone, raw materials for the cement industry, etc. Major production centers include cities in the Donets'k, Luhans'k and Dnipropetrovs'k oblasts and the southern part of Kharkiv oblast'. Proximity of both the energy sources and raw materials resulted in the development of major industries in this area.

Mineral deposits in Western Ukraine, from the Carpathian Moun-

tains to the city of L'viv, include gas, oil, common and potassium salts, coal, sulfur, gold and others. Their development during the Austro-Hungarian regime and subsequent periods resulted in a mature mining and chemical industry region in Ukraine.

The Southern part of Ukraine is less rich in minerals by comparison to the eastern and western areas of the country. It is noted, however, for a number of districts with various commodities – such as the Kerch iron basin, the Northern Crimea oil/gas province, deposits of rock salt and brines, mineral and thermal water, flux and building limestone and other minerals. Chemical industries have been developed in this area.

The map illustrates the distribution of various deposits and some of the major industrial complexes in Ukraine. At this time, Ukraine has 19 industrial complexes, 161 underground operating mines, 20 large open pit operations, and about 4660 medium- to small-size open pit operations. All the major ones are shown on the map.

Ukraine's geographic position, combined with a well-developed infrastructure (railway and paved road systems, a major waterway in the middle of the country, sea ports, electric power lines, and a network of oil and natural gas lines), and an abundance of known mineral deposits, puts Ukraine in a favorable position in Europe.



Solotvyn salt stock, Zakarpattia oblast'



Ivano-Dolyns'k open pit in basaltic rocks, Rivne oblast'



An open-pit of Hlukhivtsi kaolin factory



Open pit mining of Pokostiv granite, Zhytomyr oblast'

MINING AREAS

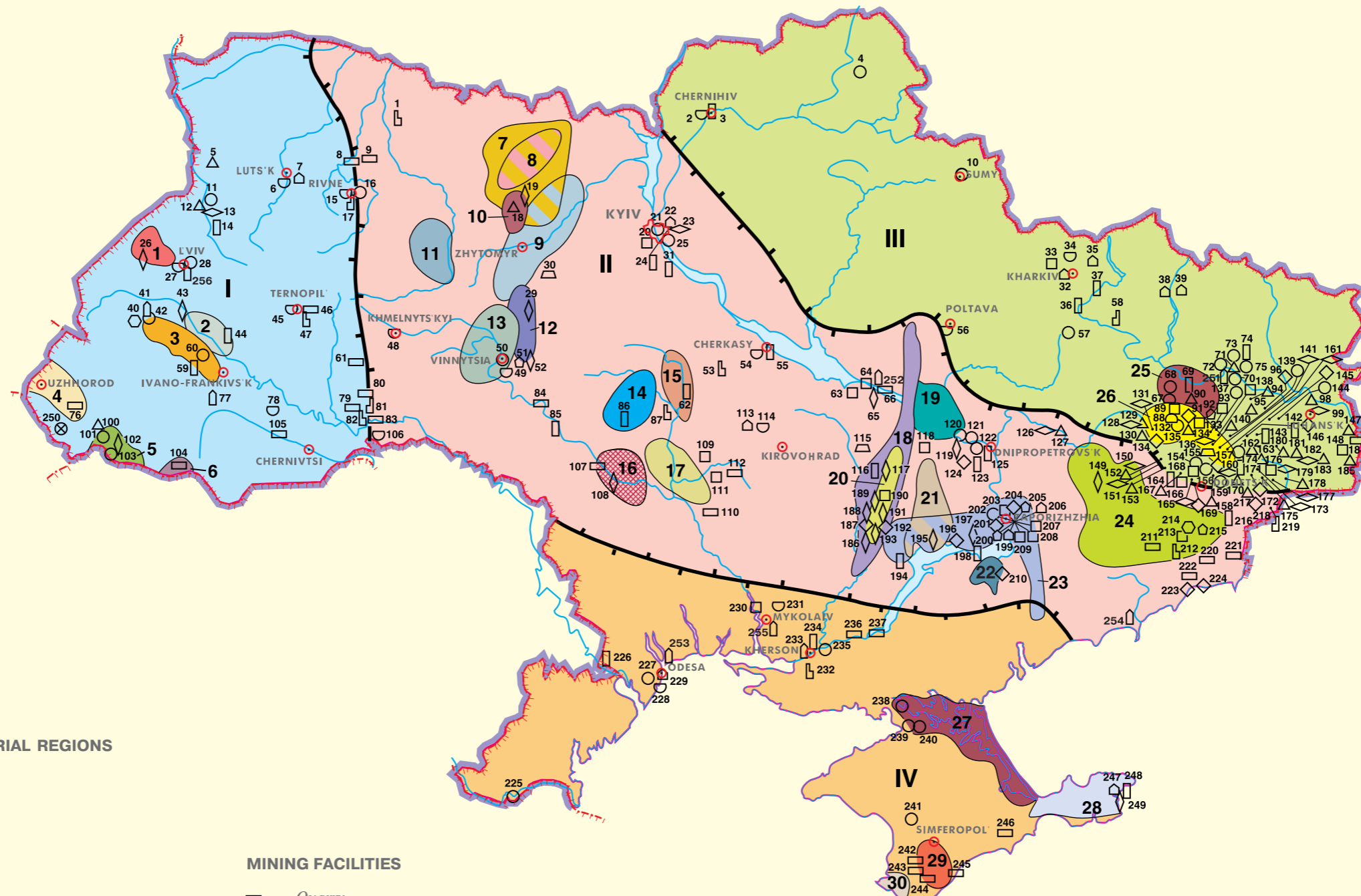
- 1 – Yavoriv sulfur
- 2 – Rozdil sulfur
- 3 – Stebnyk-Kalush salt
- 4 – Uzhhorod mining area of building materials
- 5 – Vyshkiv mercury and zeolite
- 6 – Solotvyn rock salt
- 7 – Irshans'k titanium and apatite
- 8 – Korosten' building materials

- 9 – Korostyshiv-Zhytomyr building materials
- 10 – Volodars'k-Volyns'kyi piezoquartz
- 11 – Burtyn kaolin and graphite
- 12 – Hlukhivtsi kaolin
- 13 – Vinnytsia building materials
- 14 – Uman' building materials
- 15 – Kirovohrad kaolin
- 16 – Zavallia graphite

- 17 – Buh river nickel
- 18 – Kryvyi Rih-Kremenchuk iron basin
- 19 – Samotkan' titanium
- 20 – Kryvyi Rih iron
- 21 – Kudashivka-Apostolove building materials
- 22 – Bilozerka iron
- 23 – Tokmak manganese
- 24 – Prosiyanivka-Volodymyrivs'ke kaolin and flux

- limestone
- 25 – Slovians'k salt
- 26 – Mykytivka mercury and bentonite, kaolin and flux limestone
- 27 – Crimean area raw materials for the chemical industry
- 28 – Kerch iron
- 29 – Simferopol' building materials
- 30 – Sevastopol' flux and dimension limestone

MINING AREAS



LEGEND

MINING AND INDUSTRIAL REGIONS

- I** Western
- II** Central
- III** Northeastern
- IV** Southern
- Boundaries of mining and industrial regions
- Boundaries of mining areas

MINING FACILITIES

- Quarry
- Mining and concentrating plants (graphite, kaolin, sulfur)
- Mines
- Gold-polymetallic mine
- Coal open pit
- Coal concentrating plants
- Mining administration

PROCESSING FACILITIES

- Ferrous metallurgy plants
- Non-ferrous metallurgy plants
- Oil refineries
- Plants of refractories, flux and molding materials
- Power plants
- Machine-building plants
- Sugar plants
- Chemical plants
- Cement plants
- Crushed stone factories
- Molding, ceramic, glass plants

PLANTS, MINES, ASSOCIATIONS, REFINERIES AND INSTITUTES

- 1 – Klesiv crushed stone plants
2 – “Chernihivtsukor” association
3 – Chernihiv central heating and power plant
4 – Shostka association “Svema”
5 – Novovolyns’k mines
6 – “Luts’ktsukor” association
7 – Luts’k foundry and machine plant
8 – Berestovets’ building materials quarry
9 – Ivan-Dolyns’k building materials quarry
10 – Sumy industrial association “Khimprom”
11 – Sokal’ chemical fibre plant
12 – “Ukrzakhidvuhillia” industrial association
13 – Chervonohrad coal concentrating plant
14 – Dobrotvir power plant
15 – Shpakiv sugar plant
16 – Rivne industrial association “Azot”
17 – Zdolbuniv cement and slate plant
18 – Piezoelectric quartz mines
19 – Irshans’k mining and concentrating plant
20 – “Iskra” plant, Kyiv
21 – Chemical plant, Kyiv
22 – Brovary aluminum metalworks plant
23 – Powder metallurgy plant, Brovary
24 – Darnytsia central heating and power plant
25 – “Khimvolokno” industrial association
26 – Yavoriv mining and chemical association “Sirka”
27 – “L’vivtsukor” association
28 – L’viv chemical plant
29 – Hlukhivtsi mining and concentrating plant
30 – Andrushivka coal mines
31 – Trypillia power plant
32 – Kharkiv autogenous machinery plant
33 – “Kharkivtsement” industrial association
34 – “Kharkivtsukor” association
35 – Kharkiv ball bearing factory
36 – Zmiyiv power plant
37 – Kharkiv power plant
38 – Kupians’k foundry plant
39 – Kupians’k ball bearing factory
40 – Boryslav ozokerite mining administration
41 – Drohobych oil refinery
42 – Stebnyk potassium plant
43 – Rozdil mining and chemical association “Sirka”
44 – Burshtyn power plant
45 – “Ternopil’ tsukor” association
46 – Ternopil’ stone quarry
47 – Ternopil’ cement plant
48 – “Khmel’nyts’ktsukor” association
49 – “Vinnytsiatsukor” association
50 – Vinnytsia industrial association “Khimprom”
51 – Vinnytsia plant producing refractories and fluxes
52 – Turbiv kaolin plant
53 – Khlystunivka crushed stone plant
54 – “Cherkasytsukor” association
55 – Cherkasy central heating and power plant
56 – “Poltavatsukor” association
57 – Pervomais’ke industrial association “Khimprom”
58 – Balakliia cement and slate plant
59 – Kalush central heating and power plant
60 – “Chlorovinil” industrial association
61 – Zakupne quarry administration
62 – Yurkivka central heating and power plant
63 – Svitlovods’k non-ferrous metals plant
64 – Pure metals plant, Svitlovodsk
65 – OJSC “Poltava mining and concentrating plant”
66 – Mala Kokhnyvka clay quarry
67 – Slovians’k ceramic factory
68 – “Khimprom” industrial association
69 – Slovians’k power plant
70 – OJSC “Lysychans’k soda plant”
71 – “Lysychans’kvuhillia” industrial association
72 – Rubizhne chemical plant
73 – Rubizhne industrial association “Barvnyk”
74 – Severodonets’k central heating and power plant
75 – Severodonets’k industrial association “Azot”
76 – Mukacheve crushed and dimension stone quarry
77 – Nadvirna oil refinery
78 – Horodenka sugar plant
79 – Kamianets’-Podil’s’kyi building construction plant
80 – Nihun quarry administration
81 – Kamianets’-Podil’s’kyi facing and building materials plant
82 – Kamianets’-Podil’s’kyi building construction plant
83 – Smotrych dimension stone quarry
84 – Samchyntsi granite quarry
85 – Ladyzhyn power plant
86 – Uman’ central heating and power plant
87 – Tal’ne crushed stone plant
88 – Druzhkivka china factory
89 – Druzhkivka non-ferrous metallurgy works
90 – “Kramators’kvuhillia” coal association
91 – Druzhkivka hardware plant
92 – CJSC “Chasiv Yar plant of refractories”
93 – Artemivs’k non-ferrous metals plant
94 – “Pervomays’kvuhillia” coal association
95 – “Stakhanovvuhillia” coal association
96 – Stakhanov ferro-alloy plant
97 – Luhans’k power
98 – “Luhans’kvuhillia” coal association
99 – “Luhans’kvuhlezbahachennia” coal concentrating association
100 – “Il’nyts’ka” mine no.10
101 – OJSC “Zatysnians’kyi chemical plant”
102 – Khust limestone quarry
103 – Transcarpathian experimental metallurgical plant
104 – Rakhiv marble factory
105 – Chernivtsi limestone quarry
106 – Kel’menitsi sugar plant
107 – Haivoron building construction plant
108 – Zavallia graphite quarry
109 – OJSC “Buh area ferronickel plant”
110 – Pervomais’k granite quarry
111 – Novoukrainka crushed stone quarry
112 – Kapustyno stone quarry
113 – Kirovohrad foundry and machine plant
114 – “Kirovohradtsukor” association
115 – Balakhivka brown coal quarry
116 – Central heating and power plant
117 – Mining and concentrating plant “Skhid”
118 – Dniprodzerzhyns’k metallurgical plant
119 – Dniprodzerzhyns’k iron mining and concentrating plant
120 – Dniprodzerzhyns’k industrial association “Azot”
121 – Dnipro area chemical plant
122 – Dniprodzerzhyns’k coke and chemical plant
123 – Dniprodzerzhyns’k metallurgical plant
124 – Dnipro area power plant
125 – Pavlohrad power plant
126 – “Pavlohradvuhillia” coal concentrating plant
127 – “Pavlohradvuhillia” industrial association
128 – “Krasnoarmiys’ka” mining and concentrating plant
129 – “Krasnoarmiys’ka” mine
130 – “Dobropil’vuhillia” industrial association
131 – “Oktiabr’s’k” coal concentrating plant
132 – Kostiantynivka chemical plant
133 – Kostiantynivka metallurgical plant
134 – “Pivden’koks” coke industrial association
135 – “Dzerzhins’kvuhillia” coal association
136 – “Dzerzhins’k” coal concentrating factory
137 – Horlivka industrial association “Stirol”
138 – Mykytivka mercury mining and processing plant
139 – Horlivka chemical plant
140 – “Artemvuhillia” coal association
141 – “Izotivs’ka” coal concentrating plant
142 – Myronivka power plant
143 – Vuhlehirs’k power plant
144 – Alchevs’k metallurgical plant
145 – Alchevs’k coke and chemical plant
146 – Lutuhyne roller plant
147 – “Krasnodonvuhillia” coal association
148 – Krasnodon stone and crushed stone quarry
149 – “Proskanakaolin” industrial association
150 – “Ukraina” coal concentrating plant
151 – “Komsomol’s’k” coal concentrating plant
152 – “Chervonoarmiys’kvuhillia” coal association
153 – “Selydovvuhillia” coal association
154 – Avdiivka coke and chemical plant
155 – Yasynuvata metallurgical plant
156 – Yasynuvata coke and chemical plant
157 – Makiivka metallurgical plant
158 – “Makiivvuhillia” coal association
159 – Makiivka coke and chemical plant
160 – “Radians’ka” coal concentrating plant
161 – Yenakiieve coal concentrating plant
162 – Yenakiieve coke and chemical plant
163 – “Shakhtars’kvuhillia” coal association
164 – Kurakhivka power plant
165 – “Chumakivs’ka” coal concentrating plant
166 – “Vtorkoliormet” research institute
167 – “Donets’kvuhillya” coal association
168 – “Donets’kvorkoliormet” industrial association
169 – Donets’k metallurgical plant
170 – Khartsyz’k mining administration
171 – Zuivka power plant
172 – Khartsyz’k steel works
173 – “Shakhtars’ka” coal concentrating plant
174 – “Shakhtars’ka” mine
175 – Torez mines
176 – Torez hard alloys plant
177 – Torez coal concentrating plant
178 – “Torezantratsyt” coal association
179 – “Snizhnians’ka” coal concentrating plant
180 – “Donbasantratsyt” coal association
181 – “Anratsyt” coal association
182 – “Anratsyvtvuhlezbahachennia” coal concentrating association
183 – “Roven’kyantratsyt” coal association
184 – Sverdlovs’k plant of superhard materials
185 – “Sverdlovs’kanratsyt” coal association
186 – OJSC “Inhulets’ iron mining and concentrating plant”
187 – “Kryvbasruda” iron association
188 – Kryvyi Rih iron mining and concentrating plant
189 – OJSC “Northern iron mining and concentrating plant”
190 – Kryvyi Rih central heating and power plant
191 – OJSC “Central iron mining and concentrating plant”
192 – “Mittal Steel” plant
193 – OJSC “Southern iron mining and concentrating plant”
194 – Kryvyi Rih power plant
195 – Ordzhonikidze iron and manganese mining and concentrating plant
196 – Nikopol’ ferro-alloy plant
197 – Marhanets’ mining and concentrating plant
198 – Zaporizhzhia power plant
199 – “Ukravtometremont” (car-and-truck repair enterprise)
200 – Zaporizhzhia refractories plant
201 – Zaporizhzhia titanium and magnesium plant
202 – Zaporizhzhia coke and chemical plant
203 – “Dniprospeksstal” steel works
204 – Zaporizhzhia ferro-alloy plant
205 – Zaporizhzhia plant of abrasive materials
206 – “Komunar” automobile plant
207 – Dnipro aluminum plant
208 – “Zaporizhstal” steel works
209 – Titanium Research Institute
210 – CJSC “Zaporizhzhia iron plant”
211 – Krasna Poliana limestone quarry
212 – Khibodariivka crushed stone plant
213 – Donets’k chemical and metallurgical plant
214 – Novotroits’ke dolomite mines administration
215 – Dokuchaievs’k flux and dolomite plant
216 – Starobesheve power plant
217 – “Metalist” mine
218 – Amvrosiivka foundry and machine plant
219 – Amvrosiivka cement plant
220 – Karans’ke granite quarry (near Hranitne)
221 – Tel’manove granite quarry
222 – Kal’chyk dimension and crushed stone quarry
223 – Mariupol’ metallurgical plant
224 – “Azovstal” steel works
225 – Izmail pulp and board mill plant
226 – Moldova power plant
227 – Odesa superphosphate plant
228 – “Odesatsukor” association
229 – Odesa machinery plant
230 – Mykolaiv alumina plant
231 – Zasilia sugar plant
232 – Kherson building prefabrication plant
233 – Kherson oil refinery plant
234 – Kherson enterprise of heating network
235 – Kherson pulp and paper plant
236 – Tiahynka crushed stone quarry
237 – Burhunka crushed stone quarry
238 – Crimean plant of titanium dioxide
239 – Crimean bromine plant
240 – Crimean soda plant
241 – Saky chemical plant
242 – Al’ma limestone quarry
243 – Bakhchysarai crushed stone quarry
244 – Hlybokyi Yar crushed stone quarry
245 – Sharkhynka crushed and stone quarry
246 – Aharmysh flux, crushed and dimension stone quarry
247 – Kerch machine-building plant
248 – Komysh-Burun central heating and power plant
249 – Komysh-Burun iron plant
250 – Muzhiievo gold-polymetallic mine (opened 19.03.99)
251 – Lysychans’k oil refinery
252 – Kremenchuk oil refinery
253 – Odesa oil refinery
254 – Berdians’k oil refinery
255 – Mykolaiv oil refinery
256 – L’viv oil refinery

HISTORY OF MINING IN UKRAINE

From the most ancient times, rocks are associated with the appearance, the development and the activities of humans. All cultures of ancient civilizations reflect their philosophical, esthetic, and religious thinking that rocks were symbols of eternity, beauty and belief. Significantly enough, we divide various epochs in the human development into the stone, the bronze and the iron ages.

Evidence of human presence from ancient times on the Ukrainian territory are finds of stelae-statues, sculptures, various work tools of chert, stone containers, battle axes and hammers, and maces, possibly as symbols of power and authority.

In the early and middle ages in Ukraine, workshops or sites for the making of stone tools and artifacts have been discovered, where local sources of rocks, such as quartzites, sandstones,

pyrophyllites, limestones and granites, were utilized. Later, the ancient stone workers and carvers developed high levels of craftsmanship to use rocks as raw material for construction, architectural decor, sarcophagi, various adornments and cult items.

The map of mining history illustrates the sites of stone working, and the main stages of metallic and ceramic development, the discovery and exploration of the ancient mining regions in Ukraine.

MINING SITES OF OLD RUS' -UKRAINE

During the times of Rus' (IX-XIII centuries), there is evidence that there was an organized, administered and directed, regionally specialized system of mining of minerals and distribution of their various products over much of the present-day territory of Ukraine.

The main branches of use of the mined minerals/rocks in this period were for construction, farming and domestic needs.

Reconstructed according to the archeological data, the mining of raw materials is estimated to be in the order of hundreds, thousands or hundreds of thousands of tons depending on the type of materials mined and their usage. The construction of churches and other buildings out of rocks and bricks according to the new Byzantine technologies required an organization for the mining and transport of large quantities of clays, kaolin, lime, sand, marble, gravel and various rock types. For this purpose, glacial boulders and deposits were utilized, and the mining of sandstones and granites was carried out. Mining of pyrophyllite was used as materials along sutures in the construction and as covers, and also in the production of highly artistic bas-relief carvings and parapets. The mode of life in old Rus' and its neighbors was saturated with the necessary instruments and artifacts made from pyrophyllite schists. These included millstones, foundry forms, spinning utensils, and ornaments such as

crosses, beads and figurines. Such products spread along various trade routes throughout Rus' and into other parts of Europe and Asia. Evidently this raw material-based industry in the Ovruch ridge was organized by the Kyivan rulers who controlled that area. The extent of production and the technological particularities of this industry, which have no known analogs, support an entirely reasonable hypothesis about the goods-money equivalency of the spinning utensils and other items in the Euro-Asiatic world of the middle ages, produced from the pyrophyllite schists in Rus'-Ukraine.

Numerous mining sites of the bog iron deposits attest to the highly developed iron metallurgy of old Rus'.

There were also specialized enterprises in the mining, cutting and transport of tuffaceous rocks, sandstones, chalk, limestones, minerals used for coloring, rock salt, semiprecious stones and amber.

HISTORY OF DISCOVERY OF IMPORTANT MINING, OIL AND COAL-BEARING BASINS, REGIONS AND ORE DEPOSITS OF UKRAINE

Time of discovery	Name of basins, regions, ore deposits and brief historical notes
Donets' coal basin	
IV-III millennium B.C.	Largest prehistoric source of chert in eastern Europe (vicinities of Amvrosiivka, Slovians'k and Artemivs'k). Mercury deposit (Mykytivka), one of the largest in the world, supplied cinnabar – used by prehistoric man in ritual paints and powders.
III-II millennium B.C.	There is evidence that coal was used by the bronze age people for fuel.
II millennium B.C.	Burial sites of nomadic tribes around Tor (Slovians'k) and Bakhmut salty lakes.
1721	H. Kapustin discovered coal at some cossack towns in the Donbas area.
1722	Initial small coal operations in the vicinity of the town of Bakhmut, and in the valley of Bilen'ka river.
1795	"Dahmara" – first full-scale coal mine.
1796	Beginnings of systematic coal mining.
1827	Ye. Kovalevskyi started systematic geological studies.
1859	First production of cast iron at the Bakhmut mine.
1862	Discovery of copper and evidence of ancient mining and smelting in III-II millennium B.C. near the city of Bakhmut, at Klyntsi and Marianivka villages.
1869	Establishment of an iron industry by the Welsh industrialist J. Hughes.
24.01.1872	Establishment of the "Donets' Metallurgical Factory" – to begin regular production of cast iron.
1911	At the International Exhibition in Turin (Italy), the geological map of the Donets' Coal Basin was awarded a gold medal.
Kryvyi Rih iron ore basin	
1787	Academician V. Zuiev published the first known reference on the Kryvyi Rih iron deposits.
1803	First exploration work in the basin by V. Pylenko.
1881	Saksahan mine opened, controlled by the French enterprise: "The Society of Kryvyi Rih Iron ores" under the direction of O. Pol.
1892	Opening of the first cast iron foundry in the basin.

Time of discovery	Name of basins, regions, ore deposits and brief historical notes
Nikopol' (South-Ukrainian) manganese basin	
1874	The discovery of the basin by H. Feodosii.
1886	The beginning of exploration and mining of manganese ores.
Boryslav oil-producing region	
XIII century	The earliest information about "rock oil" in the Halych principality of Rus'.
XVI century	Historical documents on the use of oil as a medical substance, and as a lubricant for wheels.
XVII century	Historical reference to surface showings of one of the oldest oil-producing fields (Nahuievychi).
1792	The first oil well production near Nahuievychi.
1820s	The development and production of oil from the Boryslav region.
1855	First extraction of ozokerite (wax) in Boryslav.
1859	The establishment of the first oil refinery in Drohobych.
1920	The discovery of natural gas deposits at Dashava in the Carpathian area, while drilling for salt deposits.
1948	The Dashava natural gas supplied by pipeline to Kyiv.
1992	By 1992, a total of 100 Mt of oil was produced in the Carpathian region.
Dnipro-Donets' oil and gas region	
1937	The Institute of Geological Sciences established the presence of oil. Subsequently, the region became the largest oil and gas producing area in Ukraine.
1946	The discovery of a gigantic natural gas deposit at Shebelynka.
Berehove-Bihan' gold region	
XII century	Historical reference to the mining of gold in this region.
19.03.1999	The discovery of first gold (polymetallic) ore body in Ukraine (Muzhiievo).
28.09.1999	First gold brick (5.7 kg) poured from the Muzhiievo deposit.

TRYPILLIAN CULTURE

The Trypillian culture (named after the original findings near the village of Trypillia, near Kyiv) is part of the highly developed agrarian society living in the Balkan-Danube region in prehistoric times. In the period between IV and mid-III millennium B.C. the Trypillians occupied a large territory of forest-steppe, from the Prut river in the southwest to the Dnipro river in the east, and in the middle of the III millennium B.C. they also occupied the steppes north of the Black Sea between the Dnister and the Danube rivers.

The Trypillian civilization is best known in the world for its ornamented, highly artistic clay dishes and sculptures. This was a period of a high level of material and spiritual culture and social order. There is evidence of cultural-economic contacts with ethnically related populations of the area, and with closely related but sometimes remote tribes. Trade or bartering

was occurring, first of all, on account of the development of natural resources such as chert, chert-like substances and salt. In the Dnipro river area there are known adits in cherts in the Studenytsi area; adits, pits and workplaces in the region of Bukivna; worked deposits and workplaces in Ozhev; and specialized settlements involved in chert mining and production of chert artifacts in Polyvanyi Yar and in Bodaky in the Horyn' area. In western Volyn', a distinct clean chert was mined from the Turonian layer. Other known areas of chert mining are found in Nezvys'ko, Malynivtsi, and Hrynychuky on the Dnister river. Significant quantities of items manufactured from these cherts were apparently exported.

Deposits of local copper mineralization in the territory of the Trypillian culture are found in the vicinity of the city of Zalishchyky in the Ternopil' oblast', in Horodenka and Chernelytsia in the Ivano-Frankivsk' oblast', and also in the area of Velyki Myds'k in the Rivne oblast'.



Statuette of a woman. Eneolithic, Trypillian culture, IV millennium B.C., Volodymyrivka village, Kirovohrad oblast'



Statuette of a woman from Trypillian period, IV millennium B.C., Volodymyrivka village, Kirovohrad oblast'



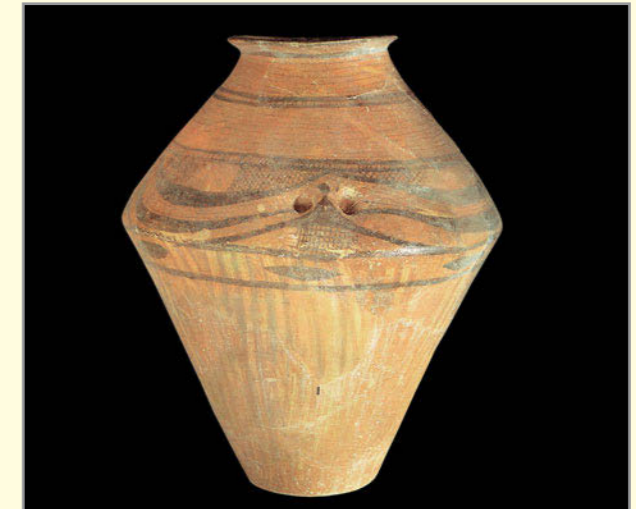
Cups and a lid for a vessel, Konovka village, Chernivtsi oblast'



Decorated vessel for grain preservation, Konovka village, Chernivtsi oblast'



Female and male statuettes, Maidanets'ke village, Cherkasy oblast'



Ornamented ceramic vessel, Maidanets'ke village, Cherkasy oblast'

ANTHROPOMORPHIC STELAE FROM THE COPPER AGE

Stone monuments or stelae with human (anthropomorphic) images found in Ukraine date back to the copper-bronze age about 5000 years ago. These monuments are found in Crimea and the steppes of Ukraine. They are made from tabular masses of rock commonly the size of a man's height. They are fairly accurate creations that present images of that early society. In terms of the flowing lines, proportionality, and composition, these stelae of Ukraine can be compared to such outstanding examples of primeval art of Europe as the cave paintings of Western Europe, the mesolithic statues of the Lower Danube and the petroglyphs of Karelia and Lake Onega areas.

In terms of iconography, these stelae are distinctly different from rock sculptures of later times such as those of the Cimmerians, Scythians, ancient Slavs and nomads of the steppes.

The stelae-obelisks of the Cimmerians from the IX-VII cen-

turies B.C., portray images of warriors in full military regalia. The stone statues of the Scythians, who replaced the Cimmerians in the steppes of Ukraine, are more realistic and better made than the older ones of the Cimmerians.

The sculptures of the Slavic peoples date from the III-IV centuries B.C. These sculptures represent idols, particularly the four-faced human statues from the Dnister river and the Forecarpathian region. A well-known idol has been found in the Zbruch river. On a four-sided pillar of rock there are sculptures depicting human activities and cosmological concepts of the ancient Slavs. The sites of the temples where these idols originally stood have been located also.

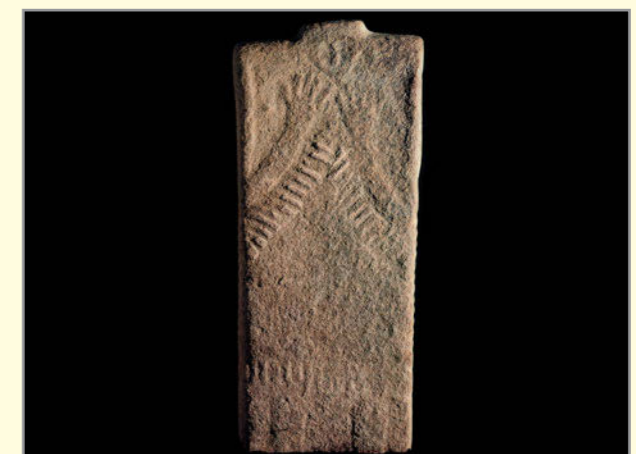
Among the ancient stone sculptures of Ukraine, the most common ones are the so-called stone women from the nomadic turkic tribe of Polovtsians. It is estimated that there are about 700 such sculptures. If we add over 300 examples of the stone stelae from the Copper age, and about the same number of statues from the other ancient epochs, then Ukraine has over a thousand ancient stone sculptures.

The first anthropomorphic sculpture of the eneolithic period

in Ukraine was discovered in the village of Natalivka in 1883. Today there are over 300 such finds, and with time more discoveries will be made. Among these of world renown are the stelae from the Kernosivka, Bilohrudivka, and Kazankivka areas.

Stelae from the northern part of the Black Sea area belong to the period of residence in the steppes of Ukraine of tribes belonging to the Kemi-Obyn pit culture from the Copper age. This pit culture occupied the terrain from the Taman' peninsula east of Crimea to the lower Dnipro and southern Buh rivers.

The Copper age rock stelae from the III millennium B.C. are noted for their workmanship, their original methods of portraying realistic images and abundance of information about the world of that time. Such sculptures are found mainly in the southern part of Ukraine. Similar sculptures are also found in Bulgaria, Romania, Moldova, and in the Northern Caucasus. Such stelae in Ukraine are made from a number of rock types — granites, sandstones, limestones and others. Most of the stelae measure from 0.5 to 2 m in height, but some are bigger.



Anthropomorphic stela, Bilohrudivka-I near Uman', Cherkasy oblast'

SCYTHIAN KURHANS (BURIAL MOUNDS)

On the Ukrainian territory there are hundreds of kurhans but only several tens of these have been systematically excavated for archeological studies. The term "kurhan" is derived from a turkic language. Kurhan is an earth mound (in Ukrainian, mohyla) and represents one or more burial sites. A kurhan may be surrounded by a moat, or by a circle laid out of rocks. A mound may be covered by plates of rocks. The oldest kurhans are present in the steppe zone of the northern Black Sea area and are dated from IV millennium B.C. A continuum of kurhans have been erected from that period until the middle ages (first half of XIII century).

The kurhan style of burial is associated with the nomadic steppe peoples. On top of a kurhan there are commonly anthropomorphic stone stelae, or a massive monumental sculpture which had a sacramental significance.

Some of the largest and richest kurhans are Scythian, and they are commonly known as the "tsar kurhans". The largest ones are up to 21 m in height, and up to 120 m in diameter. Among the Scythian kurhans the best known are the Oleksandropil', the Kul'-Oba, the Chortomyk, the Perederii and the Tovsta. The

Oleksandropil' kurhan, located in the Dnipropetrovs'k area, is of the tsar type, dates from the III century B.C. and contained close to 700 golden objects, including golden adornments in the horse bridles. The Kul'-Oba kurhan, located to the southwest of the city of Kerch in Crimea, is also a tsar type, and dates from the end of the IV century B.C. It contained numerous golden objects – a pectoral with endings in the form of Scythians on horseback, bracelets, military items inlaid with gold, and a golden chalice with an image of Medusa of Gorgon and the head of a Scythian. A female sarcophagus made of cedar in the same kurhan contained a diadem made of electrum, golden pendants for the temples, a golden pectoral and a golden necklace with amphora-like pendants. This kurhan also contained a golden cup with scenes of Scythian life, a silver cup with images of birds catching fishes. The Perederii mound is found near the village of Zrubne in the Donets'k oblast'. This kurhan belonged to a Scythian nobleman and is dated from the IV century B.C. It contained a golden helmet with pressed, carved and engraved scenes of fighting between Scythian youths and mature Scythian warriors. The Tovsta mound, one of the richest tsar-type kurhans, is located near the city of Ordzhonikidze in the Dnipropetrovs'k oblast'. It is

dated from the second half of the IV century B.C. This kurhan contained a three-layer golden pectoral depicting worshipping scenes from Scythian life, colored enamel plant ornaments, scenes of wild animals hunting, fantastic animals and other scenes. The Chortomyk tsar-type kurhan, dated from the IV century B.C., is located on the right bank of the Dnipro river, near the village of Chkalove, some 30 km to the northeast of the city of Nikopol' in the Dnipropetrovs'k area. It contained over a hundred golden items such as a golden sword sheath, with the handle of the sword inlaid in gold, a golden necklace with figurines of lions hanging from it, and a silver amphora with a golden frieze illustrating scenes of Scythians taming horses.

Although some of the golden items were possibly imported, the majority of them were made by the Scythians themselves in a Scythian style. The source of the gold used in the manufacturing of these numerous golden items is not certain, but there is at least one area in the Donbas region where mining for gold dates from the Scythian period. Placer gold in southern Ukraine is another possible source. Rocks for the building of the stelae are locally derived but in many cases have been transported considerable distances to the kurhan sites.



A golden pectoral from the Scythian tsar burial mound, Tovsta Mohyla, middle IV century B.C., Dnipropetrovs'k oblast'



A golden Scythian helmet from the Perederii burial mound, IV century B.C., Donets'k oblast'



A golden ornament from the Scythian burial mound Perepiatykha, end of VII – beginnings of VI century B.C., Kyiv oblast'



A golden ring from the Scythian burial mound, Sokolova mound, I century A.D., Mykolaiv oblast'



Golden sword and sheath from a Scythian burial mound, IV century B.C., Velyka Bilozirka village, Zaporizhzhia oblast'

MAIN HISTORICAL-ARCHITECTURAL AND HISTORICAL-CULTURAL CENTERS

1. **The National Museum of the History of Ukraine in Kyiv** contains archeological finds of the Scythian period. The museum stands on the X century site of pottery and rock workshops. An old foundation of a church built in 989-996 A.D. is constructed from local rocks. In 1240, during the invasion of the Tatar-Mongol hordes, this church was totally burned down, together with the last defenders of the city of Kyiv.

2. **The St. Sophia historical-cultural site in Kyiv.** At the center stands the St. Sophia Cathedral built in 1037 A.D. at the old battle grounds where Yaroslav the Wise defeated the Polovtsians. Local rocks were used in the construction of the cathedral.

3. **The Kyiv Caves (Kievo-Pechers'kyi) Monastery** (now a state historical-cultural preserve) was founded in 1015 by two monks. The area contains many ancient churches and is noted for its man-made caves of Neogene sandstones. The caves are at 5 to 10 m depth below the surface, up to 2 m in height, 1.5 m in width, and up to 500 m in length. In 1941 one of its most beautiful churches, the Uspenskyi Cathedral, was destroyed. Recently it was reconstructed and consecrated in 2000. Local rocks were used in its original construction.

4. **The National Museum of Historical Treasures** is a branch of the National Museum of the History of Ukraine in Kyiv. It contains over 130 000 display items, including many of the Scythian masterpieces from the VI century B.C. to the III century A.D., ancient Rus' artifacts from the VI to the XI

centuries A.D., jewellery of the Ukrainian craftsmen from the XVI century to the present, and a large collection of ancient coins.










5. **Khersones-Tavrian Historical-Architectural Preserve.** Founded in 1888, it contains examples of architecture dating to the V century B.C. created by hellenic immigrants from Asia Minor. Rocks used in the construction of the city of Khersones (Korsun', Kherson) were locally quarried limestones of the Neogene age. A marble-like local limestone was also used as a construction rock and in sculptures. Other marbles in the area of the Black Sea were also utilized. In addition Crimean jaspers were used in the construction.












Banded pyrophyllite, Zhytomyr oblast'

LEGEND














ANCIENT MINING SITES OF ROCKS AND MINERALS (VIII-II millennium B.C.)

-  Site of extensive mining of chert
-  Mining site of chert in the Stone-Bronze ages:
1- Horodok, 2- Polovtsi, 3- Novyi Mlyn, 4-6- Bukivna, 7-Studenytisia, 8-Izium, 9- Shyroke
-  Workplace in rocks from the Neolithic-Bronze ages
-  **Bakhmut region:**
-  Rock salt extraction
-  Copper-bearing sandstones
-  **Mykytivka region:**
-  Mercury deposits
-  **Nahol'nyi Ridge:** Scythian-Alanian regions of gold mining and burial sites of the "metallurgists"




MAIN MINING CAMPS, OIL AND GAS BASINS AND REGIONS (earliest information / time of discovery / beginning of mining)

-  Donets' coal basin (III-II millennium B.C. / 1721 / 1796)
-  Kryvyi Rih iron basin (1787/1803/1881)
-  Nikopol' manganese basin (1874/1874/1886)
-  Boryslav oil and gas region (XIII century / XVI century / 1792)
-  Dnipro-Donets' oil and gas region (? / 1937/ 1937)
-  Berehove-Bihan' gold region (XII century / 1948 / 1999)
-  Oil deposits
-  Gas deposits
-  **Stone stelae (IV-III millennium B.C.)**
Anthropomorphic stelae of the Copper age


MINING SITES OF THE OLD RUS'-UKRAINE (VII-XIV centuries A.D.)

-  Pyrophyllite mining in the Ovruch Ridge area in the middle ages
-  Pyrophyllite and quartzite mining near the villages of Nahoriany, Cherevky, Rudnia-Frankivka
-  Jewelry workshops (crosses, figurines, beads) from pyrophyllite near the city of Ovruch and villages Prybytky and Noryns'k
-  **Pyrophyllite manufacturing centers (bas-relief, decorative architectural details, millstones, metal pouring forms, spindles)**
-  Kyiv and Chernihiv
-  Vicinities of the villages of Nahoriany, Khlupliany, Prybytky, Horodets', Pokaliv, Skrebelychi, Noryns'k, Korenivka, Velyka Khaicha, Koptivshchyna
-  Area of mining of tuffaceous rocks and possible production of millstones from these rocks near the village of Luhova on the Sybok river, Vinnytsia oblast'
-  Area of mining of limestones and probable production of spindles, Volyn' region, from VII-X centuries
-  Probable areas of mining of limestones and chalk, in the Volyn' region, from X-XII centuries
-  Probable mining sites of rock salt in the Carpathian region, from X-XIII centuries
-  Probable mining sites of sandstone, from X-XIII centuries
-  Amber deposits and workshops in Kyiv
-  Archeologically researched mining sites of bog iron deposits and iron smelters

SITES OF TRYPILLIAN CULTURE WITH CERAMIC FINDS AND COPPER ITEMS

- | | | |
|---|---|---|
| <p> 4 Early stage (end of V millennium – middle IV millennium B.C.)</p> <p>1 – Maidanets'ke
2 – Luka-Vrublivets'ka
3 – Bernashivka
4 – Lenkivtsi
5 – Sabatynivka
6 – Oleksandrivka</p> <p> 13 Middle stage (middle of IV millennium – end of IV millennium B. C.)</p> <p>7 – Trypillia
8 – Veremia
9 – Veselyi Kut
10 – Krasnostav
11 – Nezvys'ko
12 – Zalishchyky
13 – Horodnytsia II
14 – Molodove (temple of Polyvaniv Yar)
15 – Volodymyrivka</p> | <p> 28 First half of the late stage (end of IV millennium – beginning of III millennium B. C.)</p> <p>16 – Yevmynka
17 – Domantivka
18 – Lukashi
19 – Khalepia (Kolomiishchyna I)
20 – Troianiv
21 – Talianky
22 – Dobrovody
23 – Sushkivka
24 – Kosenivka (Stari Babany)
25 – Maidanets'ke
26 – Krutoborodyntsi
27 – Bil'che Zolote
28 – Koshylivtsi (temple of Oboz)
29 – Velyka Slobidka (temple of Khreshchate)
30 – Zhvanets'-Shchovb
31 – Shchepentsi
32 – Konovka (temple of Putsyt)</p> | <p> 33 Late stage (first half of III millennium B.C.)</p> <p>33 – Holyshiv
34 – Lystvyn
35 – Horods'ke
36 – Sofiivka I
37 – Chervonyi Khutir
38 – Sandryky
39 – Kasperivtsi
40 – Tsviklivtsi
41 – Zhvanets (temple Lysa Hora)
42 – Pechera
43 – Hard
44 – Puhach
45 – Slobidka-Romanivka
46 – Usatove
47 – Maiaky
48 – Nerushai
49 – Bolhrad</p> |
|---|---|---|

SCYTHIAN KURHANS WITH ITEMS OF METAL, ROCK, AND SEMIPRECIOUS STONES (VII-IV centuries B.C.)

- | | | | | |
|---|---|--|--|---|
| <p> 4 Burial mounds of Scythian tsars and aristocracy</p> <p>1 – Perepiatykha
2 – Mel'hunivka</p> | <p>3 – Perederii Mound
4 – Bashmachka
5 – Krasnyi Kut
6 – Oleksandropil'
7 – Chortomlyk</p> | <p>8 – Tovsta Mound
9 – Haimanova Mound
10 – Khomyrna Mound
11 – Baby
12 – Rozkopana Mound</p> | <p>13 – Hostra Mound
14 – Tsymbalova Mound
15 – Chmyreva Mound
16 – Solokha
17 – Berdians'ke</p> | <p>18 – Kozel
19 – Melitopol'
20 – Ohuz
21 – Kul'-Oba
22 – Zoloto</p> |
|---|---|--|--|---|

HISTORY OF MINING IN UKRAINE



LEGEND

 Main historical-architectural and historical-cultural sites

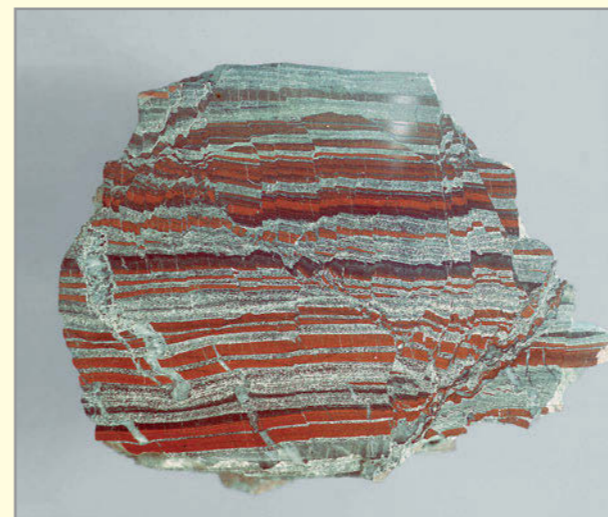
- 1 – National Museum of the History of Ukraine
- 2 – St. Sophia historical-cultural site in Kyiv
- 3 – Kyiv Caves (Kievo-Pechers'kyi) Monastery Historical-Cultural Preserve in Kyiv
- 4 – National Museum of Historical Treasures
- 5 – Khersones-Tavrian Historical-Architectural Preserve



Leznyky granite, Ukrainian Shield



Banded quartzite, Ovruch ridge



Red-banded jaspilite, Kryvyi Rih iron ore basin



Kerchenite in brown iron ore, Kerch iron ore basin

GEOLOGICAL SITES AND UNUSUAL FEATURES

Ukraine has an abundance of unusual geological sites and some unique mineral deposits. This is probably related to the geological-structural position of the territory, where a variety of different age geostructures come together and where the Earth's crust is noted for its unusually lengthy and geodynamic activities, as well as to the presence of penetrating transregional mineral-concentrating structures.

UKRAINIAN SHIELD

The Ukrainian Shield area is one of the most productive mineralized Precambrian formations in the world. It contains deposits of iron, manganese, uranium, rare metals, gold, graphite and kaolin. Certain types of deposits are unusual and have been identified here for the first time. These include the rare metal and uranium deposits found in alkaline metasomatites and gold deposits in tectono-metasomatic zones.

KRYVYI RIH IRON ORE BASIN (KRIB)

This basin is one of the largest in the world. Here, the general resources of iron ore are estimated to be over 40 Bt. Of these, 20 Bt are proven, out of which 1.6 Bt are high grade ores. High grade ores have, on the average, 56.4% Fe, and the low grade ores have 20-46% Fe. The latter ores are upgraded

by milling and concentration. Currently in operation are 12 high grade mines, and 5 low grade mines.

The deepest mines are at the 1500 m levels. Jaspilites are the primary ores mined in the KRIB. They are best described as a banded iron formation (BIF). This BIF formed over a relatively short period, from 2.4 to 2.2 Ga. It is estimated that about 90% of the world's iron ore resources are in the BIF.

These iron deposits are composed predominantly of three elements – iron, silicon and oxygen, and mineralogically they are comprised of oxides of iron and quartz.

Recent thermodynamic reconstructions have demonstrated that the KRIB is a product of the chemical reactions of a global system involving a combination of "hydrosphere-atmosphere-stratosphere", and occurred during the transition from a reducing to an oxidizing state. Thus, prior to 2.4 Ga, the surface of the Earth was controlled by reduced forms of polyvalent elements, mainly by sulphides, ammonium nitrates and oxides of carbon. After 2.2 Ga, the Earth entered into an era of oxygen when most surface geochemical processes were controlled by free oxygen. Hence, the character of geochemical processes changed from gray to red weathering surfaces. It is possible that, in this transition period, the Earth's biosphere also evolved as a result of change from molecular-protein matter to nucleic-protein forms.

KERCH IRON ORE BASIN (KIB)

KIB is a unique reservoir of phosphorus minerals. Iron phosphates include kerchenite and vivianite and their oxidized products – a, b and g kerchenites, oxykerchenites, bosporite, pitzite, azovskite; phosphates of iron and calcium – anapaite and its derivatives – mitiridatite, fuscherrchite, boritskite, kamish-burunite; magnesio-iron phosphates – enterolite, calcium-iron phosphate – neomeselite, phosphate of calcium – kurskite. Many of the above-mentioned phosphates are found only in this region and are named after various locales in Crimea.

SOUTH UKRAINIAN (NIKOPOL') MANGANESE BASIN

This basin stretches in a sublatitudinal direction along the southern part of the Ukrainian Shield for some 250 km and is 25-50 km wide. It contains Lower Oligocene terrigenous-marine quartz-glaucanite sandy-clayey manganese-bearing layers with nearly horizontal attitudes. These layers measure from a few centimeters to 4.5 m in thickness (avg. 2 m) with the manganese mineralization occurring in concretions and lenses representing up to 50% of the clayey siltstone host rocks. The ore horizon is generally from 10 to 110 m from the surface. Three types of ores are recognized – oxides (avg. 28.6% Mn), oxide-carbonates (avg. 25% Mn) and carbonates (avg. 20.7% Mn). Mn-carbonate ores represent close to 78.5% of the total reserves, and the Mn-oxide ores about 15%.

The origin of the Mn ores and the source of Mn is still under discussion. Its source could be endogenic, or related to weathering, or related to the Black Sea paleobasin.

The Nikopol' basin is one of the largest Mn deposits in the world and, in terms of production, it has first place in the world. In 1991 it produced 6.6 Mt of Mn mineral concentrates.

IRSHANS'K TITANIUM REGION

This region in the Ukrainian Shield is the largest source of titanium in Europe. Ukraine produced over 90% of the total titanium output in the former Soviet Union. Titanium mineralization occurs in the ilmenite-zircon placers, and in ilmenite-bearing gabbros.

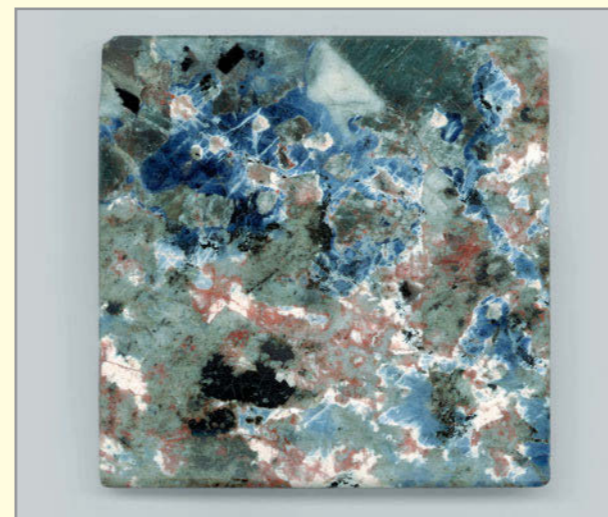
A significant apatite-ilmenite deposit (Stremyhorod) was discovered in 1976-1980. It is associated with stock-like zoned gabbro-troctolite intrusive rocks, which are part of a gabbro-anorthositic massif related to the Korosten' rapakivi-granite pluton of the Middle Proterozoic age. The ore body is oval in plan (2.3x1 km) and funnel shaped in section, and has been investigated by drilling down to 1200 m depth. It grades 6.9-8.2% TiO₂, 2.8-4.5% P₂O₅ and has significant quantities of scandium and vanadium. This ore is amenable to high concentration. There are plans to mine the Stremyhorod deposit by an open pit down to the 300 m level, and below that by an underground method.



Crimson-red granite, Ukrainian Shield



Uranium-bearing albitite, Kirovohrad uranium ore region



Mariupolite, Azov region



Nepheline syenite, Azov region

KIROVOHRAD URANIUM REGION (KUR)

There are two currently operating uranium mines (Inhul and Smolyn) in this region. Both are of the metasomatic type and are considered to be unique not only in Europe but the world.

KUR is marked by a major anticlinorium with two different granitoid complexes in its axial position. The southern complex consists of anatectic potassic granites (close to 2 Ga) and the northern complex is represented by rapakivi granites and anorthosites (1.7-1.8 Ga). Flanks of the anticlinorium are comprised of Lower Proterozoic gneisses and migmatites with relatively small bodies of granites. In the east and in the west the anticlinorium is faulted. The uranium deposits are related to post-granite sodium metasomatism superimposed on the granite and metamorphic country rocks and is associated with faulting during the Early Proterozoic period. The deposits are located where the faults have local complications and are marked by major bodies of albitites in granites, migmatites and gneisses. The uranium mineralization is superimposed on the albitites that have been cataclastically deformed, producing fine disseminations, veinlets, intergranular matrix, and as cement to the cataclastic albitites. The deposits tend to be toward the interior of the albitite zones, commonly are concordant with these zones, and have plate-like, lensey and pillar-like stockwork shapes from a few meters to tens of meters in width, and from tens to a few hundred meters in length. Uranium minerals in the ore bodies include – uraninite, nasturan, brannerite, coffinite, hydrous oxides, uranium silicates, and sooty pitchblende.

At a currently produced value of about US\$25/kg of U_3O_8 , the

uranium resources at KUR are estimated to last for a few decades in satisfying the demands for the atomic power stations in Ukraine. There is geological potential for finding additional reserves of uranium at KUR.

AZOV RARE EARTH ELEMENT (REE) AND RARE METALS DEPOSITS

The deposit is located on the south side of the Donets'k region, about 25 km from the port city of Mariupol'. This is the biggest deposit in Ukraine (or Europe) containing on average 1.6% REEs and 1.5% ZrO_2 , and can be compared to the REE deposits of Baiun'-Obo (Kyrgyzstan) or the Mountain Pass deposits (USA), but is more complex than these deposits. The main mass of the zircon-britolite-orthite ores is associated with the taxitic and pegmatoid melanocratic alkaline syenites in the layered Volodars'k pluton that has a lopolith-like shape. The pluton was emplaced during the tectonomagmatic event of the Late Proterozoic age (1820-1750 Ma). A thick weathering surface over the deposit produced a kaolinite-hydrous mica zone up to 35 m in thickness with economic contents of zirconium and REEs.

Pegmatitic syenites also carry REE mineralization. They consist of anorthoclase-hastingsite-lepidomelane assemblages carrying britolite and zircon. Britolite is the main REE mineral and this in itself is a unique feature of the Azov deposit. Coarse-grained taxitic ore-bearing rocks and the closely associated britolite-orthite-bastnesite (5:3:2) – zircon ores occur at intersections of conical and deep-seated linear faults. The Ce/Y ratio varies from 4.9 to 8.

Laboratory work has shown that these ores produce good concentrations of REEs, zircon and feldspar.

POLOKHIVKA, STANKUVATKA AND SHEVCHENKO DEPOSITS OF LITHIUM.

These deposits are associated with petalite-spodumene pegmatites and carry minor Nb, Ta and Cs. They are characterized by high concentrations of lithium (up to 2% Li_2O) and are closely associated with gold and uranium-bearing areas. The pegmatites formed in two stages – magmatic and metasomatic. The latter is more productive than the former, commonly obliterating the primary structural-textural features by recrystallization into medium to fine grained marble-like rocks. Such pegmatites are a new genetic type of rare metal deposits.

Pegmatite assemblages include: microcline-albite-spodumene-petalite-columbite-chrysoberyl (Shevchenko deposit); albite-orthoclase-spodumene-petalite-columbite-struverite (Stankuvatka deposit); petalite-columbite-chrysoberyl (Polokhivka deposit). A peculiarity of these deposits is the high concentration of lithium in the petalite mineral, a feature not noted in other lithium deposits of the world.

Petalite concentrates are used in glass and ceramic industries.

VOLYN' COPPER REGION

This region is located in the northwestern part of Ukraine and is associated with the Volyn' Paleozoic uplift, which is interrupted by the Lukiv-Ratne horst structural zone. Copper min-

eralization is associated with Vendian age traps consisting of three members – basalts, lava-breccias and tuffs, in total up to 450 m in thickness.

Mineralization is mainly of native copper. Rarely chalcocite is present. Locally minor chalcopyrite, bornite, cuprite, malachite and azurite are found also. The native copper occurs as aggregates commonly from 1 to 8 mm in size. In fractures it forms plates, films and veinlets up to 3-4 cm in width. The mineralized zones generally are from 1-2 to 4.5 m thick, and about 1% Cu on average. Recently, in 1999, a native copper nugget weighing 735.2 g was found in an open pit mined for rock fill. Other minor but significant elements associated with the native copper mineralization include gold, silver and precious group elements. The association of the precious group of elements makes the native copper deposit of Volyn' rather unusual. The native copper itself is very pure (99.8-99.9% Cu).

Occurrences of native copper in this region have been known for a long time, but recent investigations have shown it is analogous with the native copper deposits at Copper Harbor on Lake Superior in the USA.

The Volyn' copper region corresponds to the sublatitudinal Northern Ukrainian megazone of fracturing. Its western continuation corresponds to the well-known copper deposits in Silesia, Poland, and in its eastern continuation it corresponds to the copper-nickel deposits at Voronezh, Russia.

It is estimated that the resources of the Volyn' copper region are in the order of 30 Mt of copper, containing individual deposits with 1.5-3 Mt of copper.



A crystal of yellowish-green beryl from pegmatite, Volyn'



A quartz-gentgelvite vein in quartz-feldspar metasomatite, Perha beryllium deposit, Ukrainian Shield



Cassiterite mineralization in an albite-potassium-feldspar metasomatite, Perha rare metal deposit, Ukrainian Shield



Perha granite (apogranite) with aluminofluorine veins, Suschany-Perha zone, Ukrainian Shield



Amazonite in granite, Perha rare metal deposit, Ukrainian Shield

PERHA BERYLLIUM DEPOSITS

This is the only known deposit in the world where beryllium is concentrated in the mineral gentgelvite ($Zn_4(BeSiO_4)_3S$), (an end member of the isomorphic series of the gelvine group). Altogether there are about 50 known occurrences of minerals of the gelvine group in the world, which have only a mineralogical interest. Amongst them the gentgelvite is a relatively rare mineral. Of the ten known occurrences, seven are found in pegmatites.

The Perha deposit is located near the northern margin of the Ukrainian Shield in a tectono-magmatic zone in Precambrian rocks that have undergone alkaline metasomatism. The albite-potassic feldspar metasomatites are associated with the rare metal bearing granites of the Perha complex of the Late Proterozoic age. The mineralized matasomatites have lens-like or vein-like shapes and are characterized by an abundance of gentgelvite which is furthermore amenable to high concentrations. In terms of these parameters, the Perha deposit is better than all the known economic beryllium deposits in the world. In addition to beryllium, the Perha deposit also contains minor tantalum, niobium, zirconium, REEs, lead, molybde-

num, lithium, zinc, silver and fluorine. The deposit has been well explored, and is ready for production.

In terms of size, quality and the type of deposit, the Perha deposit is unique in the world.

POLISSIA AMBER REGION

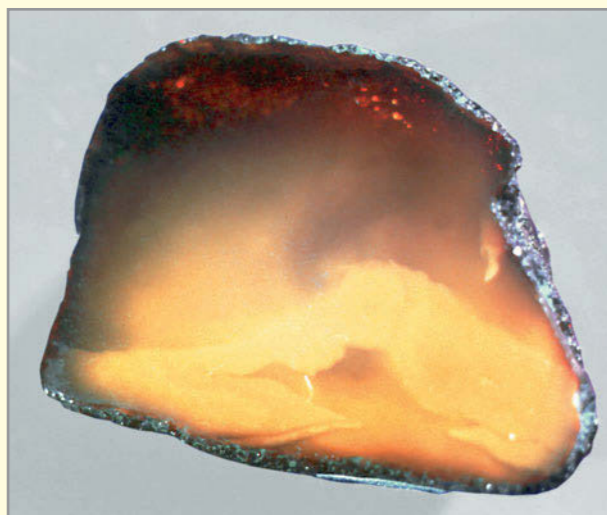
The region is part of the Polissia basin, which is part of the Baltic-Dnipro amber province, the largest in Europe. Amber is produced by the Pinaceae, Taxodiaceae and Cupressaceae group of plants from the Cretaceous-Paleogene ages. Amber in Ukraine is found associated mainly with the Upper Eocene near-shore marine sandstones.

The value of Ukrainian amber is in its unusual colors. In addition to the common brown, cherry-red, red and yellow colors, the Polissia ambers are noted for their lettuce-green, yellow-green, light-yellow, bluish-greenish as well as white and black varieties. They contain such interesting inclusions as air bubbles, insects, plants, cloudy patterns and smoky patterns.

In 1993 in the city of Rivne a company named "Ukrburshtyn" was organized. It is responsible for exploring for amber, its

mining and manufacturing into jewellery and other artistic products. A light yellow-green variety from the Klesiv deposit has been certified by the Polish Academy of Sciences, Museum of the Earth, as unique in the world (certificate N.1/96 dated 27.08.1996). Such amber is specifically called the Polissia amber.

Amber has been known since prehistoric times, from the III millennium B.C. In 1968, near the village of Ivanne, an amber pendant amulet was found at an eneolithic age burial site, known as the stone tomb of the spherical amphora culture. The amulet has the form of a round disk with a hole in the middle. The disk is about 12 cm in diameter, and is up to 1.4 cm in thickness. There is a solar sign in the form of a dotted cross on one side of the disk. On the other side there is engraved a schematic image of three human figures with upraised arms. A bow and a cross are discernible alongside. The find of an amber object of uncommonly large size in the prestigious stone tomb suggests that it probably belonged to a leading priest, and that the amber played an important role in the religious and cultural customs of the eneolithic peoples of the III millennium B.C.



Amber, Polissia

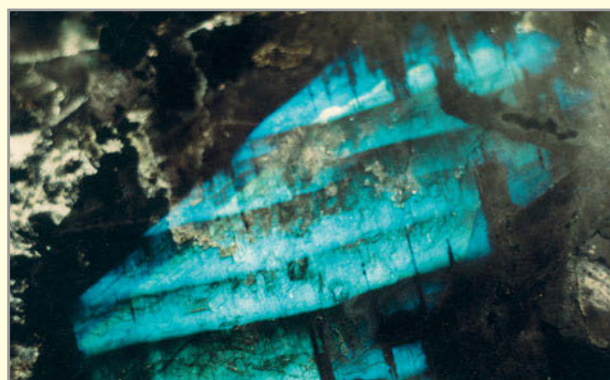


Polissia amber decorative products from the State Treasure House collection



Amber amulet with both sides illustrated, found in the burial place of the spherical amphora culture of the eneolithic period (last quarter of the III millennium B.C.)





Iridescent labradorite, Volyn'



Blue topaz, Volyn'



A tree trunk of petrified wood, Druzhkivka, Donbas



A close-up of petrified wood, Druzhkivka, Donbas

MORION PEGMATITE DEPOSITS OF VOLYN'

These types of deposits are associated with zoned pegmatites which are spatially and genetically related to the granites of the Korosten' pluton of the Ukrainian Shield. They are located in the western contact of the pluton adjoining the mafic Volodars'k-Volyns'kyi massif. This productive contact runs for 25 km and is from 0.3 to 3.5 km wide. It has been mined for over 60 years for morion (black quartz) crystals.

The mineralogy of the pegmatites is considerably variable, containing over 100 minerals. Of particular interest are quartz, feldspar, topaz and beryl.

Quartz in the zoned pegmatites has a number of shapes, colors and internal structures. Its habit varies from prismatic to rhombohedral, including prismatic-rhomboidal. Large crystals are typically zoned from clear quartz in the interior, to smoky quartz, to a morion exterior. The size of the quartz crystals also varies. The largest crystal mined weighed close to 10 tons. The piezoelectric feature of the quartz was the main purpose in mining these large crystals, which were cut and used in the electrical industry in the recent past.

Topaz is a typical mineral of the zoned pegmatites. Its color varies from colorless to amber, to light blue, to pink. Less

common are deep red colors. The dominant habit is prismatic. Colorless crystals weighing 1-50 kg are common. The largest crystal, found in 1964, weighed 117 kg. There are a number of unique crystals of topaz in the museum at Volodars'k-Volyns'kyi.

Beryl crystals from the pegmatites are highly variable morphologically and in terms of modification by fluids. The crystal habit is prismatic. Their colors vary from olive green, to grass green, to less common pale blue aquamarine to milky white (goshenite). The largest beryl weighed 66.6 kg and stood 130 cm in height.

These pegmatitic deposits of Volyn' are rather unique.

SHEBELYNKA GAS DEPOSIT

This gas deposit, the largest known in Ukraine (650 billion cubic meters), or in Europe, is located in the northern part of the Dnipro-Donets' Depression. The structure of the deposit is a brachyanticlinal asymmetrical fold of sublatitudinal orientation. Sedimentary rocks in the structure are terrigenous Devonian in age and younger. There are 13 gas-bearing horizons which altogether form a sheet-like deposit. The gas collectors are sandstones and siltstones with open porosities

depth of 1515 m, and the deepest open pit, 324 m. A superdeep bore hole NH-8, reached 5432 m depth (1984-1995). As a result, new data on the deep structures and the metallogeny of the basin was acquired, which helped in the formulation of the multifaceted model for the KRIB.

Azov area. They are porphyritic and contain veins and schlieren-like pegmatites, up to 35 m in length. The unusual feature of these pegmatites is that they are commonly vuggy. The peripheral parts of the granitic bodies are composed of aplitic phases with elevated quantities of fluorite, muscovite, zinwaldite and topaz, and lesser quantities of bastnesite and orthite. In the metasomatically altered granites there are also present cassiterite, columbite, tantalite, beryl, monazite, xenotime, zircon and molybdenite. Veins of quartz-fluorite contain cassiterite, columbite, monazite and beryl. A characteristic feature of these granites is the widespread sodium metasomatism, causing albitization of microclines. The granites are located at intersections of variably oriented deep-seated faults,

commonly from 1 to 22%, and rarely, up to 30%. Gas is methane, with high contents of heavy carbohydrates. The Shebelynka gas deposit was put into production in 1956.

DONETS' COAL BASIN

This basin is part of the riftogenic Dnipro-Donets' Depression which is up to 22 km in depth. The main coal-bearing horizon consists of sandy-clayey deposits with interlayers of limestones and coal of the Carboniferous age. The Donets' basin contains the largest well-studied section of rhythmically layered Carboniferous rocks in the world, which extends from 3 to 20 km in thickness.

Since 1796 8 Bt of coal have been extracted from this basin. Reserves are estimated to be in the order of 90 Bt. The highest annual production occurred in 1970, when 177.8 Mt were mined.

There is evidence that in this area chert and mercury (Mykytivka deposit) were mined in prehistoric times as well, the extraction dating back to IV-III millennium B.C. Chert was used to make work tools and weapons, whereas cinnabar was used in the production of bright-red paints and ritualistic

In the Carpathian region a bore hole investigating oil and gas potential was drilled down to 7520 m depth (at one time the deepest bore hole in Europe), yielding a gas flow from great depth. At other locations in the same region one bore hole yielded oil flow from the 5700-5800 m level, and another from the 5900 m level.

and could be taken as an example of Precambrian rare metal bearing granites of the albite-greysen genetic group. Of significance are the recently discovered rare metal bearing ongonites, which are interpreted to be subvolcanic analogs of the lithium-fluorine bearing granites. The ongonites form dykes and veins in the granites, commonly contain topaz, and chemically are more aluminous than the granites. Interestingly, such rocks have been found only in the Phanerozoic environments. Hence, the occurrence described here is the first one found in the Precambrian formations. The surface of this area has two plants which are not found anywhere else in the world – a variety of cornflower and yarrow.

powders. There are also ancient sites of mining for rock salt, copper and gold. At some of the ancient copper-mining sites fragments of coal have been discovered, indicating that coal was used as far back as the Bronze age, some 4-5000 years ago. Hence it can be said that the Donets' basin was one of the oldest regions known in the world where coal was used for metallurgical purposes.

MINERAL WATERS OF THE TYPE "NAFTUSIA"

Ukraine has a variety of naturally occurring mineral waters, but the "Naftusia" type, found in the Truskavets' area of L'viv oblast', is unique in the world. It contains health-benefiting ingredients of complex organic matter. "Naftusia" as a balm-ing substance is recommended especially for people with kidney-stone, liver and bile problems, and is helpful in treating various allergies and diabetes.

The more recent discoveries of the beneficial effects of the "Naftusia" include detoxification of various body functions and especially the blood-producing system (disturbed by the radiation effects related to the Chornobyl' disaster), and the accelerated extraction of incorporated radionuclides from human bodies (patent No. 2068, in Ukraine).

Bore holes over 6000 m have been drilled in the Dnipro-Donets' Depression (DDD), and over 5000 m in Crimea. The deepest bore hole under the Black Sea reached 4638 m, with a gas flow from the 4102 m depth. The deepest coal mine in the DDD reached the 1400 m level.

VENDIAN STRATA FROM PODILLIA

In Ukraine these strata were deposited on the Precambrian basement and covered by the Cambrian strata. The Lower Vendian rocks have been intersected by numerous diamond drill holes in the Volyn' region, whereas the Upper Vendian strata are very well exposed along the Dnister river. This latter section is the most complete, has no interruptions, has well-defined stratigraphic units and abundant organic remains including non-skeletal Metazoa, multicellular plants (Vendotenedes) and bioglyphs. In this area the boundary zone between the Cambrian and the Precambrian is well exposed and has been studied extensively.

DEEP DRILLING

Most of the deep drilling has been accomplished in the mining regions of Ukraine. In the Kryvyi Rih Iron Basin (KRIB) there are over 500 bore holes close to 1500 m in depth, and 128 bore holes deeper than that. The deepest mine shaft here reaches a

UNUSUAL GEOLOGICAL FEATURES

ANCIENT PRECAMBRIAN CRUST

One of the oldest relicts of the Earth's crust in the Euro-asiatic continent is found in the Novopavlivka complex in the Ukrainian Shield. This complex consists of an ultrabasic-basic-tonalite assemblage that has undergone granulite facies metamorphism and has been partially retrogressed to the amphibolite facies. The zircons from enderbite gneisses and tonalites are old (3650 Ma).

PRECAMBRIAN RARE METAL GRANITES

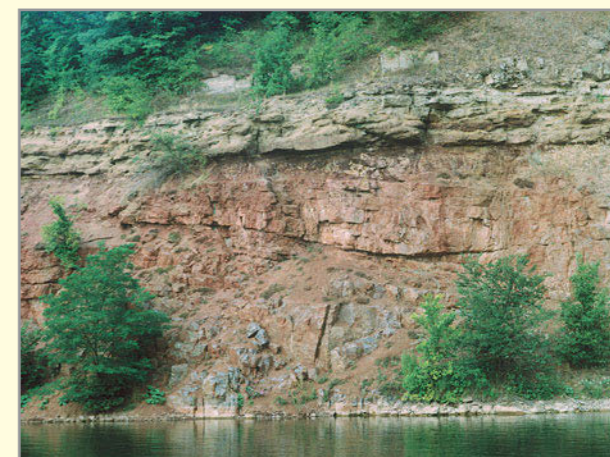
These granites, dated at 1800 Ma, form a ridge 50-70 m high in the



Manganese ore deposits, Nikopol' basin. Dnipropetrovs'k oblast'



Tovtry ridge. Tortonian reef limestones. Khmelnytskyi oblast'



Upper Vendian strata in the Dniester river. Vinnytsia oblast'

The Vendian section from Podillia contains several unique occurrences of Vendian Ediacarian fauna, known only in a couple of other places in the world – along the shores of the White Sea and Southern Australia. In addition, the section from Podillia has massive remnants of Metaphyta. Taking these features into account, it appears that the Vendian strata from Podillia could serve as a very reliable base for the international stratigraphic section and its subdivision into smaller units. Along the Dniester river there is also an important section of continuous Silurian-Lower Devonian strata with its flora and fauna.

TOVTRY RIDGE

This is a riftogenic-biothermal zone of Late Baden to Early Sarmatian age. The reef consists of predominantly plant-bearing shelly limestones. Such reefy massifs were produced during arching in fault zones, which are active to the present day. In this process the ground was elevated from 60 to 120 m, forming a ridge of small hills that extend for about 200 km.

KANIV DISLOCATIONS

An uplifted portion of the Ukrainian Shield, stretching along the west bank of the Dnipro river for some 40 km and some 15-20 km wide, it is known as a zone of Kaniv dislocations. The zone is topographically hilly, cut by deep ravines and is rather picturesque by comparison to the flat terrain on the east bank of the Dnipro river.

Faulting in the zone brought to the surface sedimentary Mesozoic-Cenozoic rocks. The tectonic history of the area is a subject of debate among various investigators who have studied the region. Some geologists consider that the zone was produced by normal endogenic tectonism accompanied by dislocations of blocks of crystalline basement. Others explain the zone as a result of glacial loading and unloading effects. According to this viewpoint, the glacier broke blocks of sedimentary strata, lifted, moved and then deposited some of the blocks of older rocks on top of younger rocks.

zoic-Cenozoic rocks. The tectonic history of the area is a subject of debate among various investigators who have studied the region. Some geologists consider that the zone was produced by normal endogenic tectonism accompanied by dislocations of blocks of crystalline basement. Others explain the zone as a result of glacial loading and unloading effects. According to this viewpoint, the glacier broke blocks of sedimentary strata, lifted, moved and then deposited some of the blocks of older rocks on top of younger rocks.

METEORITE IMPACT STRUCTURES

There are at present seven known impact structures in the Ukrainian Shield. Two of these are simple structures (Rotmistrivka and Zelenyi Hai), and the other five are complex craters with central uplifts (Bovtyshka, Obolon', Illintsi, Belylivka and Ternivka).

The Bovtyshka structure, the largest known impact crater in Ukraine, is about 24 km in diameter, and is located 50 km north of the city of Kirovohrad. Inside the structure there is a ring-like body of an impact melt sheet (impactite) estimated to contain close to 9 cubic kilometers of shock-melted country rocks. The melt sheet occupies an area close to 100 square kilometers and is up to 200 m thick. The central uplift in the crater is not covered by the impactite.

Outside of the crater structure there are relics of breccias ejected out of the crater during the impact, which are preserved in a number of places. Such breccias are generally known as the fall-back breccias. An estimate of the total area occupied by such fall-back

breccias around the Bovtyshka crater is in the order of 6500 square kilometers. The filling of the crater structure by later sediments lasted over several tens of million years. In this process, significant deposits of combustible shales were accumulated, amounting to about 3 Bt.

The Illintsi impact structure has a diameter of about 4 km. It is located some 50 km to the southwest of the city of Vinnytsia. Within the shock-melted country rocks, a colorful agate body measuring 14.5x25x32 cm was found. This is probably one of the largest chalcedony vugs known to occur in the impactites.

KERCH-TAMAN MUD VOLCANO PROVINCE

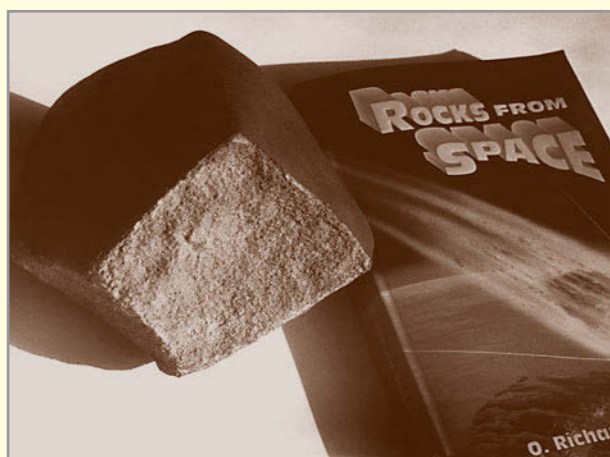
Within this province in Crimea up to 70 mud volcanoes are known, 45 of which are found on the Kerch peninsula. A muddy volcano is essentially a gaseous eruption with inclusions of volcanic breccias, water, gases, and solidified volcanic fragments. Such a volcano is commonly active under conditions of diapiric tectonism. Gas pressures in such volcanoes can reach up to 300-400 atmospheres. On the surface, muddy volcanoes appear as unusual hills up to 120 m in height or as craters, that can manifest themselves as small lakes with emanating bubbles of methane.

THE BLACK SEA

This is the only continental sea that is almost entirely contaminated by hydrogen sulphide in spite of the preponderance of free oxygen on the surface of the Earth. The Black Sea is up to 2 km deep, but only the upper 200-250 m layer is free

of hydrogen sulphide, where living organisms thrive. A number of other exclusive features are characteristic of the Black Sea. Its deep portion has the shape of a cylindrical cup with a flat bottom. Since the mantle under the sea is much higher than under the continent, the sea bottom is conducive to easier penetration of mantle gases and fluids. The Black Sea water has half the salt content of the normal ocean waters. Deep waters of the Black Sea contain up to 100 Mt of dissolved manganese. Under oxidizing conditions, manganese and iron have been precipitated in great quantities in the Kerch-Taman area of Crimea. Manganese-iron concretions are forming even in the present-day environment on its northern shore. This shelf environment also carries concentrations of oil and gas, and gold mineralization.

The present state of the Black Sea came into existence about 10 000 years ago, and replaced a fresh water basin of that time. The nature of its hydrogen sulphide contamination is controversial. Some investigators think that this contamination occurred during a break that allowed the salt waters from the Marmara Sea to enter the Black Sea, destroying the fresh water fauna and thus producing the noxious hydrogen sulphide. Others are inclined to think that the hydrogen sulphide contaminant is related to the dynamically active zone under the sea and that the hydrogen sulphide is supplied periodically from the mantle during tectonic activities. This is supported by abundant mud volcanoes in Crimea, a complicated set of faults on the floor of the Black Sea, and evidence of emanating fluids from the floor of the basin and along its walls.



Stone meteorite. Halkiv, Chernihiv oblast, fell on April 12, 1995. Weight 5 kg



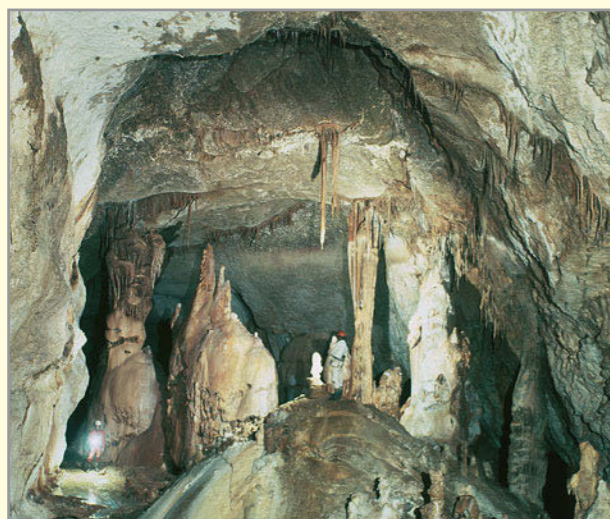
Mud volcano in the Kerch peninsula. Crimea



The Black Sea. The Aiu-Dag mountain. Crimea



The Kryvyi Rih superdeep hole Sd-8. Panorama of production complex in the vicinity of the village of Novo-Ivanivka, Dnipropetrovs'k oblast'



"Marmurova" (Marble) cave, Crimea



Volcanic massif — Karadah Nature Preserve, Crimea



The Museum of Polissia amber in the city of Rivne



Rafalivka quarry, in Vendian basalts. The biggest piece of native copper (735.2 g in weight) was found here in 1999.

MAJOR GEOSITES OF UKRAINE

There are over 400 major geosites in Ukraine used for excursions: stratigraphic, geochronological, paleontological, mineralogical, petrological, tectonic, volcanic, cosmogenic, geomorphological landscapes, hydrological-hydrogeological, esthetic and those related to mining activities. These are indicated on the map.

UNIQUE CAVES

The Optimistic cave is located near the village of Korolivka near the right bank of the river Nichlava, in the Ternopil' oblast' of western Ukraine. The cave is in the upper part of a 20 m thick coarse-grained gypsum bed. It consists of a multitude of narrow passages which formed along tectonic fractures. It is considered to be the largest known cave in the world that is found in gypsum. There are up to 200 km of underground labyrinths and a number of chambers and galleries.

GEOLOGICAL FIELD TRIPS

Geological field trips are given regularly to any interested groups. Some of these field trips are listed below:

I — Rivne field trip. Native copper and amethyst in basalts, amber and kimberlite sites are visited, as well as the "Ukrburshtyn" enterprise, and the museum of amber at Rivne.

II — Volyn' field trip. Titanium and rare earth elements in gabbroic rocks and placers, and semiprecious stone in pegmatites, the museum of semiprecious stones, and decorative stones are visited. The trip includes visits to the Irshans'k (Ti) region and its concentrating plant, the Perha deposit (rare metals) and the Holovyn deposit of iridescent labradorite.

III — Kyiv-Kaniv. Trips to museums, scientific centers, institutes, geological organizations of Kyiv, geohistorical sites of the Trypillian civilization along the Dnipro river (Trypillia, Vytachiv,

The **Marmurova (Marble)** cave is located near the village of Marmurove, about 32 km from the city of Simferopol', in the central part of the Crimean Mountains. As the name implies the cave is in marble limestones. Entrance to the cave is at an elevation close to 1300 m above the sea level, the length of the cave is over 2 km, and its depth is up to 70 m below the surface.

MINERALS IN UKRAINE

There are over 700 minerals that have been identified in Ukraine. Of this group, 20 new minerals have been discovered in Ukraine. Of significance to mineral collectors are the kerchite group of minerals from Crimea, and layer silicates (donbasites and tarasovites) from the Donbas.

METEORITE FINDS IN UKRAINE

On the territory of Ukraine, 40 falls and finds of meteorites were

Khalepia); in the city of Kaniv — the burial site of T.H. Shevchenko and its historical-memorial complex.

IV — Dnipro-Donets' field trip. Geology of the Dnipro-Donets' Depression, its deep structure, its history of development, its deposits of oil and gas and bischoffite, and its polymetallic occurrences are examined.

V — Carpathian field trip. Geology and metallogeny. Polymetallic gold deposits: Muzhiievo, Berehove, Bihan', Sauliak. Mercury deposit: Velykyi Shaian. Sotolvyna salt deposit. A deposit of germanium-bearing coal. White and colored marble deposits. Mineral waters: Berkut, Skhidnyts'ke, Truskavtsi. Landscapes — Carpathian Mountains, valleys, caves, waterfalls, lakes.

VI — Vendian section in the Podillia. Outcrops along the picturesque Dnister river of Vendian, Cambrian, Ordovician, Silurian, Cretaceous and Neogene rocks.

recorded. Of these, 38 are referred to as aerolites, and 2 as ferrous meteorites. A number of meteorites are known for the unusual circumstances of their fall or find. They are unique witnesses of early processes in the origin of the Solar System and are of scientific interest. The oldest known meteorite, the Berdians'k aerolite, was found as a ritual stone in 1843 in a Scythian burial mound of Azov. The first officially registered meteorite was Zhyhailivka. It landed as a "black bird" in 1787 in Sumy oblast' and was picked up by shepherds. After lying for 16 years in a drugstore, the meteorite was placed in the mineralogical collection of Kharkiv University. Three aerolites have fallen on the ground as part of a meteor shower. The Transcarpathian meteorite Kniahynia is the most notable, weighing about 500 kg. The meteorite Kaharlyk landed in Kyiv oblast' on 30 July, 1908. The rarest meteorite, Krymka, is the most interesting from the scientific perspective. It consists of primordial brecciated matter.

VII — Kirovohrad field trip. Uranium regions of the Ukrainian Shield: Michurin, Vatutine, Severynivka, Zhovti Vody. Uranium deposits: Inhul and Smolin. Eastern uranium concentrating plant.

VIII — Kryvyi Rih field trip. The Kryvyi Rih basin and its iron ores. Visit to the superdeep drilling site. Nikopol' manganese basin, concentrating plants, open pits and mines.

IX — Dnipro granite-greenstone belts. This field trip covers occurrences of gold, molybdenum, copper-nickel and talc-magnetite deposits in the Ukrainian Shield.

X — Donbas field trip. This field trip examines the Donets' coal-bearing basin; a unique section of the Carboniferous strata; Devonian vulcanism; salt domes; silicified forest of Carboniferous age; deposits of coal, germanium-bearing coal, gold, silver, polymetallic mineralization, copper-bearing sand-

GEOLOGICAL AND MINERALOGICAL MUSEUMS

The more important museums are indicated on the map. Some of them carry up to 14 000 samples, with excellent collections of iron minerals, manganese, mercury, titanium, zirconium and other minerals from various deposits in Ukraine. The museum at the National Taras Shevchenko University of Kyiv has an excellent collection of rocks and minerals, and in particular contains a unique collection of over 150 unusual minerals from the Perha deposit described elsewhere in this Atlas.

A unique collection of pegmatite minerals is found in the museum at Volodars'k-Volyns'kyi in Zhytomyr oblast'. It contains crystals of topaz, beryl, feldspars, micas, fluorite, goethite and gigantic crystals of morion (black quartz).

An attractive museum dedicated to amber is located in the city of Rivne.


stones, and mercury deposits in the Paleozoic volcanic-sedimentary strata; coal mines and coal concentrating plants.

















XI — Rare metals Azov field trip. Nepheline syenites (Oktiabr's'ke massif), rare metal bearing granites (Kamiani Mounds), syenites and granosyenites (Volodars'ke massif) and kimberlites. Visit to the deposits of rare earths, zirconium, niobium and tantalum.












XII — Crimean field trip. This field trip examines the geology and metallogeny of the Crimean peninsula. Its position with respect to the East European Platform, the Scythian Plate, the Mediterranean Folded Belt, the Kuban'-Black Sea Downwarp, and the Black-Azov Sea basins are examined. The problems of the geological system involving the continent-sea interface are also examined. Deposits of oil and gas, iron, building stones and opal are visited, and the mud volcanoes, avalanche slides and seismically active zones are also examined on this field trip.

LEGEND

UNUSUAL GEOLOGICAL FEATURES






-  **Ukrainian Shield**

-  **Kr** Kryvyi Rih iron basin
-  **Ke** Kerch iron basin
-  **Nk** South Ukrainian (Nikopol') manganese basin
-  **Irshans'k Region**
-  **Ir** Irshans'k zircon-ilmenite placer deposits
-  Stremyhorod apatite-ilmenite deposit
-  **1** Irshans'k concentrating plant
-  **Pr** Near-Dnipro titanium-zirconium placer field
-  Malyshev ilmenite-rutile-zircon placer field
-  **2** Vil'nohirs'k mining-metallurgical plant
-  **Kirovohrad Uranium Region**
-  **1** U X Vatutin uranium field, Smolin uranium deposit
-  **2** U X Michurin uranium field, Inhul uranium deposit
-  **3** U Severynivka uranium field
-  **4** U Zhovta Richka uranium field
-  Eastern uranium concentrating plant
-  **REE** Azov Rare Earth Area
-  **I Li II** I - Stankuvata Li field
II - Polokhivka Li field
-  **4** Li deposits:
1 - Stankuvata, 2 - Lypniazhka, 3 - Nadiia, 4 - Polokhivka
-  **Volyn' Copper Region**
-  **Cu** Native copper occurrence (735.2 g)






-  **Perha Rare Metal Field**
-  **Be** Perha deposit
-  **Polissia Amber Region**
-  Klesiv amber deposit
-  Volyn' deposit of quartz-beryl-topaz-morion
-  Holovyn deposit of iridescent labradorite
-  Dnipro-Donets' oil and gas area
-  Shebelynka gas deposit
-  Donets' Coal Basin
-  Basins of mineral waters of the "Naftusia" type
I - Carpathian, II - Podillia
-  **1** Sources: 1 - Skhidnytsia, 2 - Truskavets', 3 - Vyzhnytsia,
4 - Sataniv, 5 - Husiatyn, 6 - Makiv

DEEP DRILLING SITES











Ukrainian Shield Area

-  **Sd-8** Superdeep bore hole (5432 m), Kryvyi Rih
-  **S-2** 3041 m depth
-  **S-3000** 3500.3 m depth
-  **K-3003** 3290 m depth
-  **N-11** 2600 m depth

Oil and Gas Exploration

- In the Carpathian Region:**
-  **Sh-1** 7520 m depth
- In the Dnipro-Donets' Depression:**
-  **EP-12** 6750 m depth
-  **800** 6106 m depth
- In the Crimean Region:**
-  **NV-1** 5204 m depth
- In the Black Sea:**
-  **SH-3** 4638 m depth



Oil and Gas Flows from Deep Bore Holes

- In the Carpathian Region:**
-  **Sd-2** Oil at 5900 m depth
-  **Sh-1** Gas at 7520 m depth
- In the Dnipro-Donets' Depression:**
-  **Kr** Oil from 4981-5018 m interval
-  **Pr** Gas from 6287 m depth
-  **701** Gas from 5400 m depth
- In the Crimean Region:**
-  **Sr** Oil from 3600 m depth
-  **Ok-1** Oil from 2630-3400 m interval
-  **Pd** Gas from 4939-4967 m interval
-  **Tn-3** Gas from 4431-4438 m interval
- In the Black Sea:**
-  **HI-4** Gas at 4102 m depth

Mines

- Donets' Coal Basin:**
-  **Kl** Kalinin, 1400 m depth
- L'viv-Volyn' Coal Basin:**
-  **Vm** Velykomostiv No. 10, 550 m depth
- Kryvyi Rih Iron Basin:**
-  **Gv** Hvardiis'ka, 1300 m depth
-  **Ln** Lenin, 1250 m depth
-  **Pr** Pravda, 1515 m depth

Open Pits

-  **1** Southern, 324 m depth, Kryvyi Rih
-  **2** Bandurivka, 95 m depth, brown coal, Dnipro basin

UNUSUAL GEOLOGICAL FEATURES



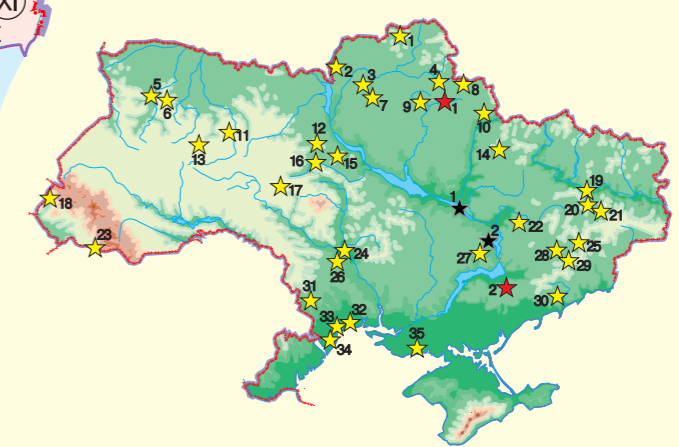
LEGEND

UNUSUAL GEOLOGICAL FEATURES

- 3650 Ma *Relics of 3650 Ma basement crust*
- Vendian strata from the Podillia region*
- Unique outcrops of Vendian strata*
- 4 *Ediacarian fauna: 1 – Mohyliv Podil'skyi, 2 – Vinozh, 3 – Dnister river (hydropower station) Vendian flora, 4 – Myn'kivtsi*
- ▲ *Outcrop of contact between the Vendian and Cambrian (near Kytaihorod village)*
- Tovtry Ridge – barrier reef of the Middle Miocene age*
- Kaniv Dislocations*
- ⊗ 1 *Impact Structures: 1 – Bovyshka, 2 – Illintsi*
- Kerch-Taman Mud Volcano Province: Vernads'kyi, Andrusove, Obruchev*

- Geosites*
- Unique Caves: 1 – Optimystychna (Optimistic), 2 – Marmurova (Marble)*
- ▲ 3 *New minerals in Ukraine*
- 5 *Geological and Mineralogical Museums*
- III *Geological Field Trips*

METEORITE FINDS



- ★ **Chondrites**
- 1 – Leonivka
- 2 – Halkiv
- 3 – Kukshyn
- 4 – Bochechky
- 5 – Dovha Volia
- 6 – Okniny
- 7 – Oleksandriv Khutir
- 8 – Richky
- 9 – Kuleshivka
- 10 – Zhyhailivka
- 11 – Zaborytsia
- 12 – Zvonkove
- 13 – Bilokrynynchie
- 14 – Mel'nykove
- 15 – Kaharlyk
- 16 – Andrushky
- 17 – Ocheretnia
- 18 – Kniakhynia
- 19 – Andriivka
- 20 – Bakhmut
- 21 – Horlivka
- 22 – Mordvynivka
- 23 – Borkut
- 24 – Mygei
- 25 – Marinka
- 26 – Krymka
- 27 – Tomakivka
- 28 – Olenivka
- 29 – Zhovtnevyi Khutir
- 30 – Berdians'k
- 31 – Savchens'ke
- 32 – Groslibental'
- 33 – Odesa
- 34 – Sukhyi Lyman
- 35 – Vavylivka
- ★ **Achondrites**
- 1 – Chervonyi Kut
- 2 – Yurtuk
- ★ **Iron Meteorites**
- 1 – Upper-Dnipro
- 2 – Mordvynivka

GEOSITES (number, name, oblast')

- 1 – Cretaceous rocks, Pushkari village, Chernihiv oblast'
- 2 – Granitoids from the Osnyts'k complex, Rivne oblast'
- 3 – Basalts from Ivanova Dolyna, Rivne oblast'
- 4 – Sokolyni Hills, Rivne oblast'
- 5 – Rapakivi granites (Ol'zhyni Kupal'ni, Veletens'ki Kotly, Baraniachi Loby), Zhytomyr oblast'
- 6 – Original site of the discovery of a mammoth, Kushelivka village, Sumy oblast'
- 7 – Romny salt stock, Sumy oblast'
- 8 – A section of the Quaternary deposits, city of Pryluky, Chernihiv oblast'
- 9 – A section of Paleogene deposits, Stari Petrivtsi village, Kyiv oblast'
- 10 – Neogene and Paleogene deposits, Pyrohovo village, Kyiv oblast'
- 11 – Zhytomur-type granites, Chotyry Braty cliff, Zhytomyr oblast'
- 12 – Kremets' Hills, Ternopil' oblast'
- 13 – Kamin'-Veleten' cliff, L'viv oblast'
- 14 – Vysachkiv salt dome, Poltava oblast'
- 15 – A section of Quaternary deposits, Viazivok village, Poltava oblast'
- 16 – Berdychiv Complex granites, Zhezhliv village, Vinnytsia oblast'
- 17 – Kaniv Hills, Cherkasy oblast'
- 18 – Granites, city of Bohuslav, Kyiv oblast'
- 19 – Urytski cliffs, L'viv oblast'
- 20 – Lumshor waterfall, Zakarpattia oblast'
- 21 – Cretaceous rocks, Kremin' hill, Kharkiv oblast'
- 22 – Cretaceous rocks, Artem hills, Donetsk oblast'
- 23 – Byvykha Hill (glacio-tectonic), Poltava oblast'
- 24 – Hirs'kyi Tikych river canyon, Radion cliff and Vyr waterfall, Cherkasy oblast'
- 25 – Optimistic cave in gypsum, Ternopil' oblast'
- 26 – Atlantyda cave in karst terrain, Khmel'nyts'kyi oblast'

NEW MINERALS FOUND IN UKRAINE

- 1 – Skolite. Veins in sandstones of the Carpathian region (K. Smulikovs'kyi, 1936). Requires further studies.
- 2 – Kalushite, $K_2Ca(SO_4)_2 \cdot H_2O$, salt deposits near the city of Kalush (Ya. Rumf, 1872).
- 3 – Podolite, $Ca_{10}(PO_4)_6(CO_3)$, northern Podillia (V.M. Chyrvinskyi, 1913).
- 4 – Volninite, $Ba(SO_4)$, a variety of barite strongly elongated along (001), (I. Ionas, 1820, F. Bedan, 1822) found in hydrothermally altered rocks of Transcarpathia.
- 5 – Carpathite, $C_{32}H_{17}O$, organic mineral found in a mercury deposit, Transcarpathia (H.L. Piotrovs'kyi, 1955).
- 6 – Mn-stilpnomelane, Chyvchyn ravines (O.I. Matkovs'kyi, 1964).
- 7 – Donbasite, $Al_4(OH)_8(Si,Al)_4O_{10}$, Nahol'nyi Ridge area (Ye.K. Lazarenko, 1940). Requires further studies.
- 8 – Tarasovite, $Mg_{0.12}Ca_{0.17}(3.8H_2O) \cdot Na_{1.24}K_{1.18}Al_8(OH)_8(Al_{3.1}Si_{12.9}O_{40})$, Nahol'nyi Ridge (Ye.K. Lazarenko, Yu.M. Korol'ov, 1970).
- 9 – Ti-biotite of 4M₃, from camptonites in the Azov area (V.I. Pavlyshyn, 1962).
- 10 – Ferdasilicite, $FeSi_2$, from sands in the Azov area (V.Kh. Hevorkian et al., 1957).
- 11 – Ferosilicite, $FeSi$, from sands in the Azov area (V.Kh. Hevorkian et al., 1957).

GEOLOGICAL AND MINERALOGICAL MUSEUMS

- 1 – Amber museum at Rivne
- 2 – Volodars'k-Volyns'kyi museum of semiprecious stones and decorative stones
- 3 – National Scientific Museum of Natural History
- 4 – Institute of Geochemistry, Mineralogy and Ore Deposits, National Academy of Sciences of Ukraine
- 5 – National Taras Shevchenko University of Kyiv
- 6 – "National Treasures" at the National Bank of Ukraine
- 7 – Ivan Franko National University of L'viv
- 8 – Technical Institute of Kharkiv
- 9 – Donbas Mining and Metallurgical Institute
- 10 – Dnipropetrovs'k Mining Institute
- 11 – Technical University of Donetsk
- 12 – Kryvyi Rih Ore Mining Institute
- 13 – Odesa State University
- 14 – Regional Museum of Crimea

- 27 – Vendian strata, Khmel'nyts'kyi oblast'
- 28 – Silurian and Devonian deposits, Ternopil' oblast'
- 29 – Folds and flexures of Dor, Ivano-Frankivs'k oblast'
- 30 – Volcanic remnants, city of Khust, Zakarpattia oblast'
- 31 – Sototyn salt stock, Zakarpattia oblast'
- 32 – Hoverla Mountain, Ivano-Frankivs'k oblast'
- 33 – Protiate Kaminnia cliff, Chernivtsi oblast'
- 34 – A stratotype of the Nahorian suite of Cenomanian age, Liadova river, Vinnytsia oblast'
- 35 – Archean granites and migmatites, city of Haivoron, Kirovohrad oblast'
- 36 – North-Donets' thrust, Konhres canyon, Luhans'k oblast'
- 37 – Petrified wood, city of Druzhkivka, Donetsk oblast'
- 38 – Moprovian historical-geological site, quartzites and schists, city of Kryvyi Rih
- 39 – Proterozoic Trykratian granite massif, Mykolaiv oblast'
- 40 – Archean granites, Khortytsia island, Zaporizhzhia
- 41 – Devonian deposits, Rozdol'ne preserve site, Donetsk oblast'
- 42 – Granite massif of the Kamiani Mounds, Zaporizhzhia oblast'
- 43 – A section of the Quaternary deposits, Shyroka Balka village, Kherson oblast'
- 44 – Stratotype of the Kuial'nyts'kyi layer, city of Odesa
- 45 – Paleontological site, Odesian catacombs, city of Odesa
- 46 – Kamysh-Burun section of Neogene deposits, city of Kerch, Crimea
- 47 – Mud volcano Dzhan-Tepe, Crimea
- 48 – Volcanic massif of Karadah, Crimea
- 49 – Marmurova cave, Crimea
- 50 – A section of Neogene deposits, Kacha village, Crimea
- 51 – Waterfall Uchan-Su, Crimea
- 52 – Mountain massif Aiudah, Crimea

- 12 – Auerbachite, $Zr(SiO_4)$, a variant of dipyrimal zircon, Mariupol' region (R.F. Herman, 1858; P.V. Yeremeyev, 1897).
- 13 – Taramite, $Na(Na, Ca)_2(Mg, Fe^{2+})_3(Al, Fe^{3+})_2(Al_2Si_6O_{22})(OH)_2$, from alkaline rocks in the Azov area (I.A. Morozevych, 1923).
- 14 – F-Taramite, fluorine-bearing taramite (I.A. Morozevych, 1923).
- 15 – Sr-pyrochlore, Sr-bearing pyrochlore, from alkaline rocks in the Azov area (O.M. Donskoi, 1985).
- 16 – Pryazovite. Possibly an alteration after samarskite, found in pegmatites from western Azov area (Yu.Yu. Yurk, 1941).
- 17 – Hydro-troilite, $FeS \cdot nH_2O$, Mud sediment of Kuial'nyk Liman (M.D. Sydorenko, 1897).
- 18 – Paravivianite, a chemical variant of Mn-Mg-vivianite, Kerch iron deposits (S.P. Popov, 1906).
- 19 – γ -Kerchenite, β -kerchenite, α -kerchenite, oxykerchenite, bosporite, a series of phosphate alteration products after vivianite, from Kerch iron deposits (S.P. Popov, 1910; P.A. Dvoychenko, 1914; F.V. Chukhrov, 1935).
- 20 – Tosudite, $Al_6(Mg, Li)(Si_{7-x}Al_{1+x}O_{20}) \cdot (OH)_{10}(Na_x, Ca_{x/2}, 1 \dots 2H_2O)$, from a vicinity near the city of Alushta, Crimea (V.A. Frank-Kamianets'kyi et al., 1963).

GEOLOGICAL FIELD TRIPS

- I – Rivne (copper, amber, kimberlites)
- II – Volyn' (Ti, REE, semiprecious stones)
- III – Kyiv-Kaniv (scientific centers, institutes, museums, geological organizations)
- IV – Dnipro-Donets' (oil and gas)
- V – Carpathian Mountains (gold, mercury, polymetals)
- VI – Vendian rocks of Podillia
- VII – Uranium in the Ukrainian Shield of the Kirovohrad region
- VIII – Kryvyi Rih (Fe and Mn ores)
- IX – Archean granite-greenstone belts of the Dnipro river area
- X – Donbas (coal, germanium, mercury, precious metals)
- XI – Rare earth metals of the Azov (REE, Zr, Nb, Ta)
- XII – Crimea (geology and metallogeny)

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