EXPLANATORY NOTES
TO THE ATLAS OF LITHOLOGY-PALEOGEOGRAPHICAL, STRUCTURAL, PALINSPASTIC AND GEOECOLOGICAL MAPS OF CENTRAL EURASIA.

The task of compiling the "Atlas of lithology-paleogeographical, structural, palinspastic and geoecological maps of Central Eurasia" (Atlas below) was initiated by the various geological services of Kazakhstan, Kyrgyzstan, Russia, and Uzbekistan in 1996. Geological agencies and scientific centers of Azerbaijan, China, Tajikistan and Turkmenistan joined this Project in 1997-1998. In 1997, the editorial group was established, the program and work methodology were elaborated, and the legends for the main maps were approved. The Scientific Research Institute of Natural Resources "YUGGEO", (YUGGEO below) was elected as the Project coordinator. YUGGEO is also the executive coordinator for Kazakhstan.

Numerous published papers and bocks on stratigraphy, tectonics, magmatism, paleogeography, geodynamics were used during Atlas compilation. List of most significant publications is referred in the end of the Notes. (1-8, 12, 14-17, 20).

The Atlas covers the central part of the Eurasian lithospheric plate, which has a total area of more than 7,500,000 km^2. 15 petroliferous basins are located within this territory (Volga-Uralian, Precaspian, South-Precaspian, North Ustyurt, Aral, Ciscaucasia-Caucasus-Mangyshlak, Amudarya, Afgan-Tajik, South-Turgay, Chu-Sarysu, Fergana, Tarim, Junggar, Turpan, southern part of West Siberian sedimentary basins) as well as folded structures of Caucasus, South Ural, Tian Shan, Pamirs, Kun-Lun, Altay and Central Kazakhstan.

The Atlas is based on up-to-date geodynamic concepts, a huge amount of geological and geophysical seismic data as well as many thousands of bore holes. The Atlas comprises 71 maps, which illustrate geological structure, development history, mineral resources and the current state of the natural environment of Central Eurasia. As a cartographic base, the Geological map of the USSR at 1:2,500,000 scale (1980), the Geological map of Kazakhstan and Middle Asia at 1:500,000 scale (1986), and the Geological map of Xinjiang-Uygur region (1993) and others were utilized.

Lithology-paleogeographical maps were compiled for 43 stratigraphic levels from Riphean to Pliocene. (main compiler YUGGEO). These maps are essential for palinspastic reconstruction. They contain a large amount of information on the current position of geological bodies, composition, stratal thickness, paleogeographical and paleotectonic evolution and mineral deposits. Tectonic sutures, accretional prisms, and ophiolitic allochthons were plotted on the maps. Maps for 18 of the most typical stratigraphic intervals are presented in this Atlas.

The basic material for Lithology-Paleogeographical map compilation were numerous **historic geological sections** (more than 2000). Each section is the synthesis of factual data for local areas. They were grouped according to their ages and contain information on stratigraphic correlation, material composition of sedimentary and volcanic rocks, their thickness, mode of generation and the development of mineral

deposits formation. The most representative sections (more than 600) were used in the construction of the Atlas. 280 sections were used for the definition of paleogeographical zones in this issue.

Structural maps were compiled for the sedimentary cover (executive coordinator YUGGEO) and the top of the basement (executive coordinator GEON). These maps are based predominantly on seismic and borehole data. The structural map for top basement is presented in this Atlas.

Palinspastic maps. (executive coordinator GNPP Aerogeofizika) were compiled for 23 time intervals on the basis of lithology-paleogeographical maps, paleomagnetic data, and geodynamic and structural reconstruction. Palinspastic reconstructions have been done for areas between the European, Siberian and Tarim continents. Oceans, marginal and internal seas, volcanic island arcs, active, passive and transform margins of continents are shown. Also paleogeographical sedimentary environments of magmatic activity, metamorphism, active tectonic structures, and paleoclimatic conditions are shown. Maps for 17 of the most prominent time intervals are presented in this Atlas.

Two **geoecological maps** (executive coordinator VSEGINGEO) reflect current state of the geological environment, natural and man-made processes which occur, their impact on the human community, its living environment and the ecosystem as a whole. Only one map, reflecting technical effects on the natural environment, has been chosen for illustration in this issue.

The map of **main tectonic elements** shows terrains, shear zones, volcanic belts, sedimentary basins, including petroliferous basins, and typical ore fields.

Lithology-paleogeographical, structural, and geoecological maps were loaded on computer disks at 1:2,500,000 scale. Palinspastic maps were compiled in scale 1:10,000,000 and 1:20,000,000 (Riphean, Early Paleozoic).

More than 200 experts from 23 organizations from countries-members participated in the compilation of this Atlas. The organizations combined maps and others materials for their areas. After that, materials were passed to YUGGEO for adjusting, edition, compiling final maps and transferring them in digital format. A part of these final maps was submitted to “Aerogeofizika” GNPP for palinspastic maps compilation. Final geoecological maps in paper base were compiled in VSEGINGEO and then submitted to YUGGEO for digital versions combining.

Nine Conferences of executive coordinators were held in Shymkent 1996, Almaty 1997, 2000, 2001; Urumchi 1998, Tashkent 1999, Moscow 1999, Kokshetau 1999, Bishkek 2000. They allow discuss and solve all disputable items, elaborate and approve legends and content of Atlas.

The successful presentation of this Atlas took place on 31st International Geological Congress (Rio-de-Janeiro, August 2000) and XXXIV Tectonic Symposium (Moscow, MGU, 30 January 3 February 2001) and London meeting of the British Natural History Museum (London, May 2002).

Atlas compilation and publishing became possible owing to precise organization and creative work of large teams of professional geologists from scientific and productive organizations from Kazakhstan, Russia, China, Uzbekistan, Kyrgyzstan, Turkmenistan, Azerbaijan, Tajikistan. Project executive producers are as follow: O.A.Fedorenko, V.A.Bykadorov, A.V.Smirnov, R.T.Akhmetov, V.M.Chernyakov, S.L.Bryzgalov, V.K.Krasnoborodkin, T.N.Kheraskova, N.V.Nesterkina, T.O.Fedorenko (Kazakhstan), G.S.Vartanyan, V.N.Ostrovsky , I.M.Zipina, A.A.Shpak, V.A.Bush , I.B.Filippova,, V.G.Kazmin, Yu.A.Volozh, V.N.Puchkov, L.V.Smirnov, S.P.Shokalsky, V.F.Volchegursky, (Russia); Sun Zhichi, Cheng Shoude (China); A.K.Bukharin, R.I.Golshtein, V.I.Troizky, I.A Maslenikova, B.I.Pinkhasov (Uzbekistan); A.V.Zhenchuraeva, R.A.Maksumova, (Kyrgyzstan); R.G.Babaev, M.I.Rustamov, A.B.Alekperov, (Azerbaijan); A.Allanov, H.H.Hudaikuliev (Turkmenistan) S.S.Karapetov (Tajikistan).

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PRINCIPALS OF THE LITHOLOGY PALEGRAPHYCAL MAPS COMPILATION

Determination of the paleogeographical environments have been done on the basis of lithofacies and analyses of organic fossils in accordance with the main ideas of lithogenesis theory elaborated in some studies (9,10,11,13,18).

The factual data utilized for determination of paleogeographical environment is shown on the maps as observation points, where lithology- stratigraphic sections were studied from outcrops and boreholes. Generalized lithological composition, typical flora and fauna groups, thickness in meters, completeness of section of stratigraphic interval are shown nearby to observation points. Observation point distribution varies for different areas and a map's reliability is unequal for those areas because of erosion of orogenic belts or formations buried beneath thick formations of younger sedimentary basins. To show a map's reliability, a lithology speckle is shown there, where mapped formations are based on outcrops or borehole information. Paleogeographical environments are shown only by color without lithology speckle for areas where maps are compiled on the basis of geophysical data and interpolation or extrapolation of distant geological data.

“Blind spots” were used on the maps of Precambrian and Early Paleozoic time levels for those areas where data absence of studied formations is due to their metamorphism in lower levels of the earth crust or younger age of the crust generated in the course of further spreading.

Because the lithology-paleogeographical maps were compiled for wide intervals of geological age, there were sometimes remarkable changes of paleogeographical environment not only along stage borders, but also within stages. In these cases, it is shown on the maps as either the most typical environment, or two (or rarely three) horizontal color strips that marked alternating environments.

Marine and oceanic paleogeographical environments were shown on the maps by various shades of light-blue, dark-blue and violet colors. Classical scheme for oceanic margins' facies zones (14) were taken as a basis for their subdivision. Oceanic floor environment is defined from abyssal, clayey-cherty facies predominantly. Continental slope is defined by bathyal turbidites. Shelf environment is defined from terrigenous and calcareous facies of littoral and sublittoral origin. Shelf is divided into internal and external. Internal is characterized by shallow water sediments, a proximal land position and an active hydrodynamic regime. Characteristics include rudaceous content, good sorting and roundness level of sediments. Internal shelf could be formed by carbonate facies, under low relief of coastal plain and the absence of erosional river systems. In this case shallow water origin of sediments could be identified only from fossil fauna Carbonate platforms generated in isolated shoals are classified as internal shelf. External shelf is characterized by predomination of aleuritic silt and clayey components, which are often enriched by organic substance.

Abyssal troughs of bathyal internal and marginal seas are classified as a distinct environment. It is typical for them to exhibit small fragmental clayey, carbonate, and cherty sediments or turbidites, enriched by organic material. Some hydrothermal-sulfide sediments are observed in abyssal troughs.

Transitional, from continental to marine, environments have a significant role in defining the limits of orogenic belts. They are shown on maps by various shades of green and lilac colors. They are represented in lithology-stratigraphic sections as interbedding of marine and continental sediments. This reflects periodic transgression of the coastal areas by the sea. Those sediments include deltaic facies as well. Lagoons and semi-closed basins of high salinity also play a significant role in regional paleogeography, because they accumulate evaporites and hard salt.

The volcanic environment of island arcs is also classified as transitional. These are built by marine and terrestrial volcanic and volcanogenic- terrigenous sediments, are quite variable in extent and in thickness.

Terrestrial paleogeographical environments are shown on maps by brown, yellow, light-green and lilac colors. Internal continental basins are of primary importance. Alluvial and lacustrine sediments constitute basin fill. Continental volcanic beds, which are characterized by ancient volcanic plateau, highland and volcanic constructions occupy specific places. High, moderate and low-relief mountains, peneplained highlands, hillocky areas, and denudation plains are shown on maps. Orogenic features were used to specify mountains and collision plutons, overthrust structures, and zones of compression. They are also marked by rudaceous sandy-conglomerates, and flysch-olistostrome facies in neighboring areas. The terrigenous and calcareous facies of these basins indicate hillocky or plain character of enclosed land. Internal continental lakes and seas are shown by special indexes.

Geodynamic orientation of the work needs some deviation from strong paleogeographical style. Consequently, paleo-geodynamic environment is shown by mottled color, demonstrating a substantial composition of volcanic and plutonic

complexes. Intrusions are plotted on lithologo-paleogeographical maps synchronous with time of intrusion, in spite of, in some places, them not outcropping at that time. Evidence for high- and low-pressure metamorphism, deformation structures originating from sutures, collision and other geotectonic environments were plotted on maps. They include also accretionary prisms, tectonic melanges, and intensive deformational zones, shear zones, large-scale strike-slip features, overthrusts, and tectonic allochthons.

Special attention has been paid to identification of sutures. They are specified as collision (located at convergent borders) and transform (located on transform borders) sutures of first and second order. First order sutures were interpreted as closed oceanic basins, second order sutures as closed marginal seas. Sutures of that age are painted by black color, and later ones by red color.

MAIN FEATURES OF PALEOGEOGRAPHY AND GEODYNAMICS.

Early-Middle Riphean. Paleosiberia and the continental masses of Southern Siberia, Kazakhstan and Tian Shan existed during Early-middle Riphean as a set of fragments of the Pangea super continent, which was broken in the rifting and spreading process. Grenville orogeny saw collision and obduction of ophiolite complexes and passive margin complexes on the margins of these microcontinents. The end of this process was marked by granitic intrusions and granitization of 1100-1050 Ma. As a result of his, the Rodinia super continent was created, combining all continental masses on the Earth.

Late Riphean. After Grenville orogeny, all continental blocks of the South Siberia, Kazakhstan, North Tian Shan were characterized by silicic volcanic activity, including ignimbrite at 800-900Ma. Very close in age and composition complex of terrestrial volcanic rocks and comagmatic granites is developed in Iberia, Iran, northeast Africa, northwest India. All these regions combined in earlier times to form a marginal volcanic belt or continental margin of Andean type. At the end of the Riphean all these blocks were located on the margin of Rodinia. The structures of northern, western, and southern (in modern projection) margins of the Paleosiberia plate were distinctly different. Most of them are related to West Pacific type with systems of island arcs and marginal seas. At the same time, a passive margin with thick terrigenous sedimentation on its shelf and continental slope existed along the eastern (in modern projection) part of Baltia.

Late Riphean-Vendian. Intense processes of rifting and the break-up of Rodinia took place during this age. A large rift system developed in eastern Gondwanaland, part of the Rodinia super-continent. This rift can be traced from South China through Tarim and central Tian-Shan in western part of Kazakhstan. Some fragments of these paleorift systems remain to the present day at the margins of continental blocks. Movements along marginal faults, which delimited Riphean rifts of Baltia, began at that time. Molasse sediments of Vendian age are developed in graben and associated with subalkaline basalts. The erosion of detrital material took place in many cases from rift shoulders. A good example of this is the Baikonur-Karatau paleorift. The Vendian rift

systems separated some terrains along the continental margin of Rodinia; for example Tarim, Kokchetau, Ulutau, North Tian-Shan, Aktau-Mointy, Tuvino-Mongol. The Paleoasian Ocean began to form as a result of rifting and sea-floor spreading between Siberia and Lawrencia.

Not only subduction, but also mountain-building collision processes occurred in that area during the Vendian epoch. These processes developed mainly along the eastern margin of Baltia, where the Kadomian orogeny is reconstructed and the East European continent was formed. Clastic material is transported on the Baltia margin from island arcs and this is a source of conglomerates containing andesite fragments. An essential role is played by movements along large strike-slip faults.

A specific feature of the Vendian age is the development of glaciations, marking Eastern Paleo-Gondwana land position in circumpolar latitudes of the Southern hemisphere (Middle Tian-Shan). There are a number of layers (often two) of glacial sediments. The most remarkable layer is found on the boundary between Vendian and Cambrian ages.

Cambrian - Early Ordovician. At the beginning of the Cambrian the partial collapse of the Vendian rift systems occurred. At the same time there was widespread generation of oceanic crust and complete separation of all of the above microcontinents and terranes the northern margin of Rodinia. At the same time, apparently final separation of Siberia from Lawrencia occurred and the Paleoasian Ocean finally formed.

Spreading processes were developing, influenced by subduction of fragments of Rodinia beneath the Siberia continent and microcontinents.In the Cambrian epoch the island arc system became more complicated, as compared to Vendian. New island arcs developed Boshekul, Chingiz, Sarybulak, Kuznetsk-Alatau, and Zapadno-Sayany. Some fragments of accretion prisms stayed within the current structure. They are represented by black shale, turbidite and greywacke beds, with blocks of the Precambrian rocks of terrestrial origin, and with olistostrome horizons or ophiolite plates of Riphean, Vendian and Precambrian age. A typical example is Boshekul island arc. The formation of Middle Cambrian eclogites is related with subduction and accretion processes Basins formed with the oceanic crust were dominated by the deposition of black shales or tephroturbidites. Carbonate sedimentation predominated in the sub-equatorial zone on middle ocean uplifts, where some phosphorite deposits were also formed. Subalkaline basaltic volcanic rocks are reported on those uplifts.

Early Middle Ordovician. At the end of the Cambrian - beginning of the Ordovician the Uralian and Turkestanian oceans occurred as a result of rifting and spreading margins of East-European and Tarim continents. Cambrian island arc systems continued to develop. Their extension into Kazakhstan increased as the Stepnyak and Erementau island arcs developed. Thick accretionary prisms were developed in frontal areas of Ordovician island arc systems. These prisms incorporate turbidites, tephroturbidites, olistostrome horizons, and ophiolite complexes of various ages. More mature island arcs occurred with more differentiated volcanic rocks and

thick turbidites. These volcanic rocks are more alkaline when compared with Cambrian rocks. New fragments of the oceanic crust were generated in marginal basins.

The collision of island arc terranes along the Siberian periphery began in the Middle Cambrian. It led to gradual decrease in island arc volcanic activity and the formation of thick turbidite beds of quartz-greywacke composition on the passive margin (Gorno-Altaiskaya and Bratolubovskaya series). These island arcs collided with Ulutau and North Tian-Shan microcontinents during Early Ordovician and this event changed the polarity of the island arcs.

Late Ordovician. The first major collision events in Central Eurasia correlate with the end of the Ordovician epoch. On the boundary of the Middle and Late Ordovician changing of island arc polarity occurred in Kazakhstan. This was related with the opening of the Uralian and Turkestanian oceans. Those processes led to collision between Kazakhstan and Tian-Shan island arc systems with some microcontinents. Large ensialic island arc uplift developed here in the Late Ordovician. This uplift was associated with crust subduction along the eastern and western margins. A thick collision zone occurred along the Erementau-Buruntau strike-slip fault during Late Ordovician. Its development led to the intrusion of granitic plutons.

As a result of the accretion and collision processes, the Kazakhstan continental landmass formed here at this time. The continent combined microcontinents and island arcs. It was created by opposing movements of Gondwanaland, Siberia and East-European plates during spreading process in the Uralian, Turkestanian, Ob-Zaisan, and Junngar- Balkhash oceanic basins. Their sizes corresponded to Mediterranean seas.

At the end of the Ordovician, the East-European continent was located in low latitudes of the Southern Hemisphere. The Urals paleoocean was located along the equator. Kazakhstan, Tarim and Siberia continents were located in low northern latitudes. Oceans extended in north-south direction. Paleotethys was towards the south-east.

Silurian. This period was a relatively quiet stage with some local volcanic activity. During the Late Silurian, processes of crust subduction beneath the Kazakhstan continent began in the Uralian, Turkestanian, and Junngar- Balkhash oceanic basins. This led to the creation of Sakmarskaya, Tagilskaya, East-Uralian volcanic island arcs. The type of sedimentary processes was changed in the Turkestanian Ocean, where the deposition of black bituminous shale with graptolites began. These characterized bathyal or abyssal plains. Volcanic island arcs developed along ocean margins. The dip of the subduction zones was oriented eastward (to Tarim) and westward (to Kazakhstan). During the Silurian, collision of continent and island arc took place along Tarim's eastern margin. This led to the formation of an ophiolite nappe and the uplift of the Tarim margin.

Early-Middle Devonian. (Eifelian) Plate movements and volcanic processes became active at this time. The East European plate was moving northwards, but the Kazakhstan and Tarim continents were moving southwards with a clockwise rotation. Ob-Zaisan, Turkestani and Urals oceans were spreading. Ural Ocean widening was

accompanied by spreading in the West-Mugodzharsky oceanic rift. Subduction process beneath the East-Ural microcontinent and Magnitogorskaya volcanic arc system began at this time.

The Siberian continental margin was active at this age. A system of island arcs was originated here, including the Kuznetsky Alatau - Rudny Altai marginal-continental volcanic arc. However the margins of Tarim and Alai microcontinents and the East European continent were passive. The Kazakhstan continent had active margins on all sides. The Turgai volcanic belt extended along its southern margin and joined with the Central Tian Shan belt on the east. The Southern Tian Shan volcanic belt was separated from continental crust by a spreading marginal sea. The Junggar-Balkhash oceanic basin also had active margins along with developing volcanic belts. Convergence of the basin margins leads later to its closing and the formation of the Central Kazakhstan orocline. Systems of island arcs (Zharma-Saur and East Junggar) and inter-arc basins were formed on the boundary of the Ob-Zaisan and the Junggar-Balkhash basins.

Middle-Late Devonian (Givetian-Fransian). In the second part of the Middle Devonian, spreading processes in all oceans finished and their closure began. In Frasnian time, the south-western part of the Junggar-Balkhash Basin was closed. Here transform faults played an important role. A volcanic belt developed where the basin had closed. Other areas were still open deep-water basins. By the end of the Frasnian age, geodynamic and volcanic activities had calmed down. Orogeny and granitic intrusion began along the continental margins. The Tarim continent remained uplifted throughout the Devonian.

Late Devonian (Famenian). This stage was a relatively quiet period, with slow movement of the lithospheric mass. The south-east side of the Kazakhstan continent exhibited some volcanism (South Tian Shan volcanic arc) due to subduction of the oceanic crust of the Turkestansky Ocean. In the Famenian, the Uralian Ocean started to close along the Main Uralian Fault, where evidence of uplift can be identified. This uplift supplied sediments into the Urals foredeep and Precaspian Basin (eastern part). Inner areas of the Kazakhstan continent suffered extension and several rifts formed, namely the Zhailma and Karatau rifts. A degree of volcanism is associated with these rifts. At the same time the Donetsko-Tuarkyr rift, located on the margin of the East European plate, spread out since Middle Devonian time. Reef massifs appear on the East European shelf slopes opposite the Urals Ocean and on the shoulders of all named rifts. The Precaspian depression was isolated by these reefs and accumulated clayey-calcareous and bituminous sediments. Subduction and island arc volcanism continued at the northern margin of the Junggar-Balkhash and both margins of Ob-Zaisan basins.

Early Carboniferous. The beginning of this period was very similar to the Famenian stage. Reactivated northward plate movement had a clockwise rotation. The subduction of oceanic crust was renewed along all margins of the Kazakhstan continent, creating the Valerianovsky and Prebalkhashsko-Ilisky marginal volcanic-

plutonic belts. This generated volcanic arc activity and closed back-arc basins. The Bogdoshan volcanic arc developed in the Junggar-Balkhash ocean.

North-Caucasus Ocean Basin was closed on the Paleotethys margin within the Caucasus sector. New volcanic arcs (North Pamirs) and marginal basins (South Hissar) developed in the Tian Shan Pamirs sector.

Extensive low relief carbonate shelves were typical for central areas. On Kazakhstan continent, behind the volcanic belt, large marsh-lacustrine systems accumulated thick coal beds (Chu-Sarysu depression, Karagandy basin and others).

Middle Carboniferous. Direction and rate of plate movement remained the same from the Early Carboniferous. The rotation center was located within the Tarim Basin. All continental margins and volcanic-plutonic belts were active. All ocean basins were closed.

Late Carboniferous. A collision stage had begun together with the intrusion of granitoid plutons. The formation of orogenic belts occurred in the Urals, Kazakhstan, Junggar, Tian Shan areas at that time. Main part of the Tarim continent was covered with a shallow sea. Central Kazakhstan had an arid climate and developed enclosed intermontane depressions. Residual intercontinental seas of the Junggar-Balkhash and Ob-Zaisan oceanic basins were still connected to the ocean on the East. The Precaspian Basin remained in deep-water conditions.

Early Permian. Collision of the Kazakhstan continent with the Tarim and East-European continents continued at this time. Collision was accompanied with granitic intrusions and orogeny. Central Kazakhstan and Tarim did not suffer any lateral movements. The Caucasus and East European plates shifted in short distance northward. The Donetsk-Tuarkyr rift had closed and produced a fold and thrust belt on the Precaspian boundary. The remaining Ob-Zaisan Basin had also closed. Moved structures were turned clockwise up to east-west direction.

The subduction of oceanic crust, which began in the Late Carboniferous, had developed along Tethyan margin of Eurasia. Subduction was accompanied by continental margin volcanic activity in the Caucasus, Karabogaz and Karakum blocks, in South Hissar, Pamir, and Kun Lun. The flanks of volcanic belts was marked by rift-related volcanism (Ustyurt, Tarim).

Active dextral strike slip movements began to occur due to clockwise plate rotation (Chelyabinsky, Main Karatau, Zhalair-Naiman). During the Permian period residual deep-water basins were preserved, together with mountain uplifting. For instance, thick flysch with bitumen shales was formed within the Junggar Basin. Sediments mainly accumulated in intermontane and piedmont depressions along with red colored molasse and, in places, volcanic rocks. Evaporites accumulated in the Precaspian area and along the Donetsk-Tuarkyr rift.

Late Permian. This was the time when orogenic belt formation in Central Eurasia was finalized. This event was accompanied with intense strike-slip movements. The Eurasian continent had an active margin with the Paleotethys Ocean. Significant northward movement of Eurasian continents took place during the Late Permian stage.

Rotation has, in contrast to the Devonian- Early Permian periods, a counter-clockwise direction. Such movements cause sinistral strike slip movement and rift development in the Tarim , Ustyurt, Mangyshlak, Tian-Shan areas. The Donetsk-Tuarkyr and Urals fold belts were moved to the Precaspian depression and Ustyurt area, where thick terrigenous and saliferous terrestrial beds accumulated. Residual intermontane basins of Kazakhstan and China (Chu-Sarysu, Teniz, Junngar and Tarim) were filled in with red colored clastic material. Intrusion magmatism and volcanism was of alkali character. Only along borders with the Siberian continent in Tom-Kolyvanskaya and Altae-Sayanskaya zones, were collision granites intruded. Those zones were thrust-emplaced on Kuznetsk basin.

Triassic. Most of the Central Eurasian territory is considered to be land with prevailing denudation processes. Also, several marginal lacustrine-alluvial basins such as Precaspian, Usturt, Amu-Darya, Tarim and others, had accumulated 5-7 km of the red-colored terrigenous sediments. Shelf seas (the Caucasus, Kopet-Dag, North Pamir and Kun-Lun) are identified far to the South.

The development of basalts within the rift systems of Western Siberia and Northern Kazakhstan began in Early Triassic times. The grabens of these rift systems were filled with lacustrine-alluvial, and often coaly (Late Triassic) deposits. Passive margin and volcanic belts (Kun Lun and Northern Pamir) had formed along the edge of Paleotethys. Acid volcanic activity is known within Ciscaucasia and Karabogas block.

At the end of the Triassic, Iran, Farakhrud, Central Pamir and North Tibet (Kimmeriya microcontinent) blocks collided with the Eurasian active margin. To the south, Transcaucasus block also merges. This is the reason for the intensive folding within Caucasus and adjacent areas (Ciscaucasia , Ustyurt, Mangyshlak, Amu-Darya depression) at this time. The marine basin reduced in size and covered the Middle and Northern Caspian. The Late Triassic is known for intensive thrust movements in the Urals, Karpinsky range, along Central Usturt, Amu-Darya, Main Karatau and others faults. This stage results in development of the South-Turgay graben. By the end of Triassic in comparison with the end of the Permian, Eurasia moved in 140 -160 northward.

Jurassic. As in Late Triassic time almost all Eurasian territory was above sea level, with only a few separated basins preserving continental sedimentation (Turgay, Fergana, Amu-Darya, Ustyurt, Tarim). Active strike-slip tectonics had formed pull-apart graben that accumulated lacustrine-alluvial coaly deposits. Marine conditions occurred only in the Southwest (Caspian region) and in the south (Pamir and South Kunlun). Opening of the Big Caucasus back-arc basin started at the end of Triassic time and continued during whole Jurassic epoch.

The Middle Jurassic is typified by high sedimentation. Central Eurasian sedimentary cover is preserved from this time onwards. Marine transgressions advanced from the Southwest and reached their maximum in the Callovian stage, where they covered the entire west and southwest parts of Central Eurasia. Clastic sedimentation prevailed in shelf seas. The Tethys marine basin had joined the

Caucasus and Pamir-Kun-Lun basins along the Urals with northern seas. The marine basin from the North had penetrated into the West Siberia Depression. The altitude and the relief of the landmass decreased and carbonate deposits played a major role in sedimentation at this time. During Callovian time sedimentation was active within the majority of the intercontinental basins, except the Turgay and Junggar basins which had freshwater lakes. The sediments of the Middle Jurassic epoch are known as sources of major gas and brown coal fields.

The climate becomes more arid during Late Jurassic time simultaneously with essential paleogeographical reconstruction. Intensive compression due to Tethyan subduction and Rushan-Pshart Basin closure occur in the South. However the Karabogazgol and Central Karakum blocks remained stable. As a consequence the southwestern seas were disconnected from the ocean and became deep marine half-closed basins which accumulated black calcareous carbonaceous sediments with reef limestone at the margins and evaporite deposits later in the Tithonian. The Precaspian marine basin retained a northern connection and accumulation of carbonate-terrigenous sediments and combustible shales took place here. West Siberia was characterized with deepening of the marine basin and the deposition of black shale sediments ("bazhenitovskaya" suite) which are identified as the major oil-generated formation of this famous petroliferous province. Some lacustrine-alluvial sediments were being deposited onshore.

Early Cretaceous. Neocomian paleogeography did not differ significantly. Big Caucasus back-arc basin decreased in size, southwestern seas renewed their connection with Tethys, evaporite accumulation ceased. The Aral-Syrdarya, Turgay and Tarim basins accumulate sediment.

Aptian-Albian time started with marine transgressions on the South and Southwest that covered the Afgan-Tadjik, Amudarya, Precaspian depressions, and the Ustyurt and Ciscaucasia. A deep basin with terrigenous sediment fill appeared on the shelf within the Middle Caspian area. This accumulated black clays during Aptian Early Albian time. Late Albian filled in the basin with sandy-clayey clinoform sediments. In Early Cretaceous time we interpret rifting within the Iran block (Kimmeriya microcontinent) that leads to the deep marine basin occurring along the southern periphery of the Elburs Sabzevar marine basin and extending to the West Pamir. Meanwhile the Trans-Caucasian microcontinent continued to be influenced by volcanic activity attributed to Tethyan subduction.

Late Cretaceous. During Cenomanian time southwestern seas were separated from those in the north. Tethyan wide transgression was known since Turonian time. In the Early Turonian a marine incursion penetrated the Turgay, Chu-Sarysu, Syrdarya and Fergana depressions, as well as West of Tarim. The West Siberia Basin extended southward and at that time was divided from the southern seas by narrow passageway near Kustanay. Karstic bauxites are known in this region from that time.

Late Turonian-Coniacian time saw sea level lower, leading to the widespread lacustrine-alluvial plain formed within Southwest Kazakhstan and adjacent Uzbekistan.

Unique hydrothermal uranium fields are known here, and sediments of Neogene time were source of them. During the Maastrichtian the West Siberia Basin was connected with the southern seas through the Turgay depression.

During Late Cretaceous time the Precaspian Depression, Ustyurt and Ciscaucasia accumulated mainly carbonate rocks (chalks, marls, limestones). Meanwhile to the southeast a marine basin develops far inland extend to west of Tarim. During Late Cretaceous (Maastrichtian) time the Big Caucasus basin margin was partly closed. However the residual basin still retained a deep sea. Oceanic crust of the Sabzevar and Central Iran basins began to be subducted beneath the Elburs and Binalud plates. Back-arc rift was formed on the North of Elburs at that time, or later during Early Paleogene. Eocene time saw reefs evolve in the South Caspian Basin on what was still oceanic crust.

Paleogene. In Early Paleocene times marine regression occurred due to the Tethyan shortening and subduction beneath the south-western edge of Eurasia. As a result Southwest seas were separated from those in Western Siberia and gypsum-dolomite lagoons appeared in the South (Tarim, Fergana, Afgan-Tadjik and Syrdarya basins). Shelfal seas accumulated limited sediments of carbonaceous clays and quartz-glauconite sands with phosphate.

At the end of the Paleocene a new transgression spread from the southwest. By Middle Eocene time the marine basins reached their maximum extent (the size of the Maastrichtian seas) in Central Kazakhstan, Tarim and Urals. The outer shelf accumulated coaly-carbonate rocks, while inner shelf saw sands and shelly limestones develop. Flysch was formed on the South Caspian and East Black Sea slopes. Most lands were peneplained to low altitude planes with some lacustrine-alluvial fresh or brackish water basins (Tarim, Junggar, Pribalkhash).

Some tectonic activity was reactivated at Paleogene time leading to the new tectonic structures which occurred afterwards.

Oligocene-Miocene. In the Oligocene the Tethyan Ocean was finally closed, while the Arabian and Indostanian microcontinents collided. That caused the development of the Alpine-Himalayan fold belt, formed within the Eurasian continent and isolated intracontinental marine basins. Post platform orogenic uplifts, lakes and lacustrine-alluvial basins were formed at this time. Oligocene and Early Miocene times are typified by considerable marine regression southwestwards. Marine conditions ceased in the Western Siberia, Turgay, Chu-Sarysu and Syrdarya depressions, where lacustrine basins developed. Large lacustrine basins existed within Pribalkhash, Zaisan, Tarim, and Junggar depressions. The northern basins (Turgay, West Siberia) accumulated grey-colored clay-sandy rock with coal, while southern basins developed red-colored, calcareous, sometimes gypsum rich, terrigenous rocks. The Tian Shan, Urals, Altay mountains had developed. Sedimentary cover, emplacement of collision-granites and volcanism occurred on Pamir mountains. The Tian Shan and Pamir intermountain depressions accumulated red-colored clays and sands often with associated evaporites. Marine incursions are periodically identified.

Oligocene Early Miocene marine basin was deep, with over half it's area being beyond external (deep) shelf. The Maykopsky thick clay suite was deposited within this shelf zone. The deepest part of the basin and the brow of the sedimentary scarp can be mapped by clinoform in Ciscaucasia and Mangyshlak. Land block existed within Small Caucasus.

During Middle - Late Miocene times collision processes continued at the Tethyan edge of Eurasia and the marine basin became shorter and shallower, while mountain belts rose and river networks developed. Piedmont sediments accumulated at the periphery of intermontane molasse depressions, while in central parts marls and clays were deposited with evaporite formations. The Big Caucasus area became mountainous, as well as Kopet Dag. The shallow marine basin had reached only the west coast of the Aral Sea (Sarmatian time). 5 or 6 marine transgressions were identified during Middle Late Miocene time. Sea level lowering caused the development of terrigenous-calcareous rocks which are altered with gypsum. Continuous overthrusts and faults which penetrating inland are identified along the southern mountain margin of Central Eurasia. Collision related magmatism continued on South Pamir.

In the Late Miocene Early Pliocene intensive orogenic processes occurred which caused the sea level to lower (Messine crisis). The Caspian Sea was separated from the Black Sea at this time. Only the South Caspian remained underwater (brackish water lake) where the paleo-Volga and paleo-Amu Darya rivers flowed. The deltas from these were near Baku and Turkmenbashy (Krasnovodsk). As result South Caspian had developed a thick (about 5 km) unit of multicolored delta sandy-clay reservoir rocks that accumulated the hydrocarbons in the unique oil fields found in this area.

During the Late Pliocene time Central Eurasian paleogeography was similar to the present day. The mountain ranges of the Caucasus, Kopet Dag, Tian Shan, Altay, Kun Lun, Pamir originated in the South and East. Widely developed rivers systems carried a large quantity of sedimentary material, forming wide alluvial plains, with some lakes. One large lake accumulated lignitic sands in West Siberia. Unusual intracontinental transgressions were developing within Caspian region. Here water advanced along earlier deep river valleys far inland. We can explain the transgression as increase of the rivers runs-off due to a wetter climate as well as water flowing away from the South Caspian basin due to the rapid sediments inflow at the beginning of the Pliocene. Occasionally waters flowed from the South Caspian to the Black Sea through Manych channel.

MAIN FEATURES OF METALLOGENESIS.

Mineral deposits are plotted on the lithology-paleogeographical maps and maps of main tectonic elements according to their position within the geological framework. As a result, the principal local and regional structural and lithological characteristics of various deposits environment identified. Real ability of minerals forecast were obtained.

During the Baikalian and Caledonian stages continental rifting played a primary role in the formation and localization of large ore-bearing systems, while oceanic

spreading and subduction processes play a lesser role. Collision, subduction - overthrusting and aulacogen formation governed metallogenesis in the Hercynian and Kimmerian stages.

Oceanic spreading environments are characterized by the formation of differentiated dunite-harzburgite (O_1), which are genetically linked to the chromite fields of the Kempersay region (Almaz-Zhemchuzhina and others). An overthrusting environment (D_{2-3}, C_{1-2}) relates to the formation of massive-copper sulfide and sulfide-polymetalic fields of the Urals and Rudny Altay (Gaiskoye, Leninogorskoye, Tishinskoye), the skarn-magnetite ore of Turgay (Sokolovskoye, Sarbaiskoye), and the gold-sulfide-quartz epithermal fields of China and Uzbekistan (Ashchi, Kochbulak). At the collision stages of the Devonian, Carboniferous and Permian (D_{2-3}, C_3 - P_1) large and unique gold (Muruntau, Kumtor, Vasilkovskoye, Bakyrchik), copper (Kalmakyr, Kounrad), uranium (Kosachinoye), mercury (Khaidarkan), and tantalum (Belogorskoye) fields were formed within the Central Eurasia area. While cupriferous sandstones fields (Zheskasgan), uranium infiltrated deposits (Inkay, Karamurun), large bauxite bodies (Arkalyk, Krasnooctyabrskoye) were formed within the superimposed terrigenous depression during Pz3 and Mz-Kz due to sub orogenic processes of continental type.

The cyclical evolution of the Central Eurasian fold belts is typified by heterogeneous trends of lithology-geochemistry in the host rocks, ore-bearing rocks and ore bearing complexes, as well as variability in the associated minerals. 15 stratigraphic intervals are known to contain large mineral associations as follows: PR_{1-2}, R-V, O_{1-2}, O_3-S_1, D_{1-2}, D_{2-3}, D_3fm, C_{1-2}, C2-3, P_1, K_2, J_2 and others. The original geodynamic regime, and type of mineral assemblage are typical for each stratigraphic interval. R-V, D3fm and C1-2 levels are the most favorably developed.

Black shales and carboniferous dolomites of the R-V interval (Sharyk, Zhetymtau, Tekely and other suites of this level) host various mineral assemblages, including the giant gold fields in Kumtor and Vasilkovskoye, the uranium in Kosachinoye and Grachevskoye, lead-zinc in Tekely, tin in Sarymbet and iron in Zhetymskoye. Riphean-Vendian calcareous intervals played various roles with respect to the ores. Sometimes they are ore source, fluid barrier or structural frame. Mineralization is complex, being single- or multistaged, syn- or epigenetic, and coupled with rifting, subduction and collision events.

Rift-related siliceous-calcareous rocks of Devonian age contain large barite-lead-zinc (Zhairem, Mirgalimsay) and manganese (Karazhal) fields.

Gold (Bakyrchik, Ashchi, Kochbulak), copper-porphyry (Kounrad, Aktogay, Aidarly), skarn-magnetite (Sokolovskoye, Sarbaiskoye), copper-nickel (Khuanshan), mercury-antimony (Khaidarkan) and others elements are emplaced within terrigenous volcanic and terrigenous calcareous and black shale formations of the Low-Middle Carboniferous.

The age of mineral fields varies widely between the Precambrian and Mesozoic-Cenozoic. The most productive metallogenic epochs for gold, ferrous, non-ferrous and rare metals are as follows: D_{2-3} massive sulfide-polymetalic fields of Rudny Altay, the

Sarymbet tin field, Vasilkovskoye gold field, Kosachinoye uranium field; C_{1-2} - Magnitogorskoye, Kacharskoye, Sokolovskoye, Sarbaiskoye skarn-magnetite fields, and Uchkulak sulfide-polymetallic field; C_3-P - Zhezkazgan, Aidarly, Kalmakyr copper fields, Muruntau, Bakyrchik, Kumtor gold fields.

Main ore formation types of minerals deposits and geodynamic environments of Central Eurasia

Ore formation type	Host geological formation (age)	Geodynamic environment of ore formation epoch (age)
Chromite (Almaz-Zhemchuzhina)	Dunite –harzburgite (O_2)	Oceanic spreading (O_1)
Massive-sulfide polymetallic (Tekeli)	Dolomite (R_3)	Rift (R_3, O_1, D_1)
Massive-sulfide polymetallic (Zhairem)	Terrigenous-carbonate (D_3)	Rift (D_3-C_1)
Massive-sulfide- polymetallic (Leninogorskoe)	Basalt-rhyolite-cherty-terrigenous (D_{2-3})	Subduction (D_{2-3}-C_1)
Copper-massive-sulfide (Gaiskoe)	Rhyolite-basalt (D_{2-3})	Subduction (D_{2-3})
Gold-massive-sulfide-polymetallic (Maikain)	Andesite-basalt (Pz_1)	Subduction (O_1-S_1)
Skarn-magnetite (Sokolovsko-Sarbaiskoe)	Tufogenic-terrigenous-carbonate (C_1)	Subduction (C_1-C_2)
Gold-sulfide-quartz-vein-stockwork (Kochbulak, Ashchi)	Andesite –dacite – trachyandesite (C_2)	Subduction (C_{2-3})
Copper-porphyry (Kalmakyr, Kounrad)	Andesite–dacite, andesite – basalt (D_3-C_{1-2})	Collision (C_{1-2} C_3 – P_1)
Uranium - albitite (Kosachinoe)	Carbonaceous-terrigenous (R-V)	Collision (D_1)
Cassiterite-quartz (Sarymbet)	Carbonaceous-terrigenous (O_2)	Collision (D_3)
Antimonite –cinnabar – jasperoid (Khaidarkan)	Terrigenous-carbonate (C_{1-2})	Collision (C_3 -P_1)
Gold-sulfide-streaky-impregnated (Bakyrchik)	Carbonaceous-terrigenous (C_{1-2})	Collision (C_3 -P_1)
Tantalum-bearing pegmatite (Belogorskoe)	Carbonaceous-terrigenous (C_3)	Collision (C_3 -P_1)
Gold-sulfide-quartz-stockwork (Muruntau, Vasilkovskoe, Kumtor)	Carbonaceous-terrigenous, Carbonaceous-terrigenous-carbonate (R-V, O_1-S)	Rift (R-V, O_1-S) Collision (D_{2-3} C_3 -P_1)
Cuprous sandstones (Zhezkazgan)	Terrigenous (C_{2-3})	Midland, postcollision (C_3 - P_1)

Uranium-infiltration (Inkai, Karamurun)	Terrigenous (K_2 Pg_1)	Midland (Pg-N)
Bauxite (Arkalyk, Krasnooktyabrskoe)	Eluvial-sedimentary (K_2 –Pg_1)	Midland (E_2-D)

We propose a genetic classification for the types of mineral fields to be as follows: magmatic, skarn-hydrothermal, hydrothermal, volcano-hydrothermal-sedimentary, hydrothermal -metamorphogenic, sedimentary and exogenic. -

Unique ore fields such as Muruntau, Kumtor, Vasilkovskoye, Kalmakyr were formed during hundreds of millions of years. They developed through the rifting, subduction and collision stages and were affected by the multistage remobilization and redistribution of their chemical materials and activity of the several ore generating processes. The polygenous and multistages deposits are localized within long existed zones of sutures (Erementau-Buruntau, Transuralian, Muruntau-Mailisu, Atbashy-Inylchekskaya) or within Middle-Late Paleozoic volcano-plutonic belts (Valerianovsko-Kuraminsky) composed (or underlain) by geochemically specific terrigenous and volcanic sediments ("multicolored" Besopan, Zhetymtau and Sharyk suites and others).

MAIN FEATURES OF PETROLIFEROUS BASINS.

Some sedimentary petroliferous basins are located within the limits of Central Eurasia, namely the Precaspian, South-Precaspian, Chu-Sarysu, Tarim, Junggar, south part of Volgo-Ural, Ciscaucasia-Mangyshlak, Amu-Darya , South-Turgay ones.

Various geotectonic and paleogeographical conditions of sedimentary basin formation caused their distinct development of hydrocarbon accumulation. The Precaspian and Volgo-Ural basins form a single petroliferous province, located on the passive margin of the East-European continent along its border with Urals paleoocean. This province is characterized by gradual sagging in the Paleozoic epoch, marine sedimentary conditions, wide development of bituminous sediments, and regional salt trapping mechanisms. More than 80% of the hydrocarbons here are concentrated within Upper Devonian Low Permian formations, mainly in rift-related structures. The vertical migration of hydrocarbons has developed oil fields in the Upper Permian Mesozoic intervals.

Chu-Sarysu gas-bearing basin is located in the central area of the Early Paleozoic Kazakhstan continent. Sedimentary cover has been deposited in shelf and continental conditions during the Late Devonian to Permian periods and has limited petroliferous potential.

The south-western part of the East-European plate, known as the Scythian Turanian young platform, was located close to the active margin of Paleotethys in the Late Paleozoic era and the Triassic period. This led to the degradation of the main part of Devonian-Carboniferous hydrocarbons or their migration into Mesozoic and Cenozoic formations.

The Tarim Basin is located on the Presinian microcontinent. It approximates the Precaspian Basin in area and sediment volume. However, sedimentation processes in the Paleozoic era were unstable, being mainly of shallow marine origin, and often having depositional breaks and the development of unconformities. The present basin structure was built up mainly during the Mesozoic collision of Indostan and Eurasia. Numerous episodes of tectonic activity, the development of unconformities, and a lack of regional seals led to the dispersion of Paleozoic hydrocarbons throughout the stratigraphic section and partially to their loss.

Large petroliferous basins (Ciscaucasia-Mangyshlak, Amu-Darya, Afgan-Tajik) were formed along the northern margins of the Tethyan back-arc marine basins (Great Caucasus and Fararud). A high petroliferous potential characterizes the basins of the South-Caspian (Pliocene) and Junggar (Permian).

Specific types of petroliferous basins are related with intracratonic pull apart processes. They include South-Turgay, Fergana and Turfan basins. Oil-generating formations are present in Jurassic terrigenous marsh and lacustrine sediments.

ESSENTIAL FEATURES OF THE PRESENT DAY GEOENVIRONMENTAL CONDITIONS.

Central Eurasia covers the area placed within different structural-geological and landscape-hydrogeological zones.

The geoenvironmental maps within the Atlas show natural parameters and indices, and on-going natural and technological changes that influence human activity. The Geological Environment (GE) includes the lithosphere, hydrosphere and atmosphere. The ecological status of the GE during normal conditions mainly defines its reaction to the technological impact. In considering the close conditions, variety and intensity of the technological impact we combine two maps. One shows the natural geoenvironmental conditions, the other shows the current environmental assessment rating and technological changes (or hazards).

GE Ecological status at normal conditions is defined by a number of factors, the most valuable of which are: underground water resources, the protectability of natural resources from contamination, and critical element concentrations in water and land, etc. We defined 4 categories of the GE human impact.

- Areas with highly unfavorable GE conditions (deserts, high altitude mountains);
- Areas with unfavorable GE conditions (semi-deserts, mountains, dry lands);
- Areas with relatively unfavorable GE conditions (limited natural water supply);
- Areas with relatively favorable GE conditions (normal natural water supply, lowlands with favorable climate).

Human economic activity results in negative GE changes. Agricultural irrigation and wide expansion of the irrigated areas, brings negative changes in the GE. Ground water collection lead to a deleterious and even catastrophic decrease in river run-off and lake shrinkage, for example the Aral Sea ecological disaster.

Secondary salinization processes on land and in underground waters affect the irrigated areas. Artificial water reservoirs developed along the Karakum Chanel and the Amu Darya Murgab interfluval. An evaporation here increased in 15-17 times and is identified from an area of 7-8 000 km2.

Irrigation also causes contamination of the land by nitrates and pesticides. Natural cycles of geochemical fluid migration have become unbalanced and new areas of accumulation of the contaminating elements have developed (Sarykamysh, and Arnasay artificial lakes). Technological development has become so widespread that GE recovery is now impossible.

Increasing contamination through technological development of the underground water supplies has become an essential problem for most countries in the Region. The difficulty in protecting natural aquifers from pollution compounds the problem and allows some polluting elements to penetrate through the aeration zone. Rational utilization and protection of the existing aquifers of fresh and brackish water has became the most important priority.

Over-mining is the second most-important GE problem for the Region. For instance Kuznetsk and Karaganda coal basins, and Gorny Altay etc. all suffer from exogenous geological processes, and land and water contamination. A number of mines were closed during recent years. However, no protection arrangements for these were organized. Usually these mines are in mountain areas which undergo active denudation processes. This allows contaminants and toxic elements to flow down the rivers and over the plains.

A high level of technology-derived pollution occurs in areas of petroliferous production. Practically all nature environments are contaminated: surface-water underground aquifers, land and plants, atmosphere and biosphere. Moreover, oil production leads into an increase in seismic activity. There is evidence for this from the Caspian petroliferous basin.

GE technological contamination by heavy metals, oil, organic materials and radioactive elements is identified at Semipalatinsk and Lobnor nuclear testing areas and at Chelyabinsk recycling storage, some oil wells have become a regional environmental problem.

Negative geoenvironmental trends are complicated and ambiguous. Most Central Eurasian areas originally had hostile and unprotected natural environments. Rash and adverse economic activity has lead to considerable damage to the natural potential of the area.

The Atlas, and our experience in geoenvironmental mapping illustrates the public benefits of international cooperation. The Geological Environment and technological-anthropogenic developments, as well as protection measures, are not limited by the borders of a country.

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