

GEOTECTONICS AND GEODYNAMICS OF PALEOZOIC STRUCTURES FROM THE PERSPECTIVE OF PLUME TECTONICS: A CASE OF KAZAKHSTAN

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*Corresponding Author, Received: 14 July 2019, Revised: 09 Dec. 2019, Accepted: 03 March 2020

ABSTRACT: Based on data from comprehensive studies of the international geotraverse system in Kazakhstan, lithosphere models were constructed to a depth of 100-200 km, which revealed the heterogeneous block structure of the upper mantle. The asthenosphere in geosuture zones rises to the level of 80-100 km, and asthenoliths penetrate into the earth's crust above the Moho border. The penetration of the plume and the intrusion of mantle and asthenosphere substances into the lithosphere led to a local uplift and the formation of a stationary nucleus, bounded by geosutures of the ring structure of the Kazakh continent – Qazaqia. The formation of such a peculiar geological structure is associated with the effect of superplumes in the Paleozoic and is clearly visible on geological and tectonic maps. In all paleogeographic reconstructions of the Paleozoic, Kazakhstan is shown as an isolated and integral continent. The pulsation of the planet and the gradual penetration of the mantle superplume into the lithosphere caused vertical movements in Qazaqia. Depending on the direction of the inclination angles of deep faults, the geosutures extending into the mantle represented compression or extension zones with a width of tens to hundreds of kilometers or more. Molten mantle substances with ore-bearing substances penetrated into these weakened zones, sometimes reaching the Earth's surface. The proposed model of the geodynamic development of Kazakhstan's territory can serve as a theoretical basis for forecasting mineral deposits.

Keywords: *Plume tectonics, Geotectonics, Geodynamics, Mantle, Lithosphere, Earth's crust, Mineral deposits*

1. INTRODUCTION

The late 20th century was marked by a major breakthrough in the understanding of the deep Earth's bowels based on well-organized research, including deep geophysical exploration, ultra-deep continental and oceanic drilling, as well as instrumental research from the Earth's surface and space.

New data on the deep structure of the crust and upper mantle of continents were obtained during comprehensive studies according to the international system of geotraverses. Some of them were laid on the territory of Kazakhstan. On their basis, lithosphere models were built in the republic to a depth of 100-200 km, which revealed the heterogeneous block structure of the upper mantle. At depths of about 200 km, the electrical resistance of the mantle substance sharply decreases, which is supposedly linked to the rise of the roof of the asthenospheric layer. The structures of the earth's crust in some cases spread to the upper mantle. The asthenosphere in geosuture zones rises to the level of 80-100 km, and asthenoliths penetrate into the Earth's crust above the Moho border (Figure 1).

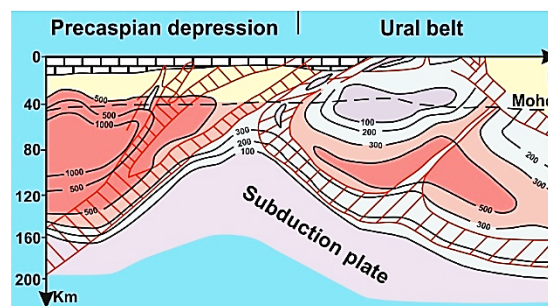


Fig. 1 The deep structure of the western part of Kazakhstan according to geophysical research [1]

2. A BRIEF HISTORY OF THE GEOLOGICAL DEVELOPMENT OF KAZAKHSTAN

Advances of the past fifty years in the study of the structure of the earth's crust, in particular, the revival and improvement of mobilist views, have lead to the reassessment of many traditional ideas about the dynamics of lithosphere development, both in general and for individual regions. The present study can be regarded as an attempt to recreate the chain of events of geological history that led to the formation of modern geotectonics.

According to various estimates, from half to three quarters of the present volume of the continental crust was formed in the cycle of Early Precambrian development, by the beginning of the Neoproterozoic. As a result of the disappearance and closure of the Paleoproterozoic deep-water basins, this crust in the Mesoproterozoic was drawn into a single supercontinent, called Pangea I or Megagea, in contrast to the Late Paleozoic and the Early Mesozoic Pangea II, first identified by A. Wegener. The unity of this supercontinent is indicated primarily by paleomagnetic data – the similarity of the curves of the apparent migration of magnetic poles defined for different continents.

The Grenville tectogenesis (“Issedonian orogeny”) played a significant role in Kazakhstan. It completed the foundation of the neighboring Siberian and East European ancient platforms. The Neoproterozoic, especially its second half, which started 850 million years ago, remains one of the critical eras in the Earth’s history – the era of the collapse of Pangea I and the beginning of the opening of the Paleozoic oceans. With the emergence of the Proto-Tethys mobile belt, Pangea I was split into two parts – Rodiniya in the north and Gondwana in the south. These two continental masses soon, if not simultaneously, also underwent a split under the influence of the superplume [2]. It is assumed that as a result of Rodinia’s split, such independent continents as Siberia, Kazakhstan (the continent Qazaqia, according to V.E. Khain) and Katazia were formed. As late as at the end of the Proterozoic Kazakhstan began to exist independently [3, 4, 5] (Figure 2).

In contrast to Gondwana, where the tendency toward unification prevailed, the remaining fragments of the Proterozoic Pangea I from the beginning of the Cambrian were scattered due to the emergence of newly formed ocean basins between them: one of them is the Proto-Atlantic Ocean or the Iapetus Ocean; the other is the Paleo-Asian Ocean, which separated Eastern Europe from Eastern Siberia and the latter – from the Tarim and Sino-Korean continents; the third ocean is the Mediterranean or Paleo-Tethys, which washed Gondwana from the north and separated it from North America, Eastern Europe, the Tarim block and the Sino-Korean continent. These oceans were connected with each other and with the Paleo-Pacific.

The intercontinental Iapetus, Paleo-Tethys, Paleo-Asian and Arctic ocean basins reached the maximum width in the Middle Ordovician period. Volcanic arcs continued to develop along their active margins; this process was intensively manifested in Qazaqia (in geosuture zones), the Altai-Sayan region and the Urals.

The situation in the mobile belts sometimes underwent significant changes due to Taconian

orogeny, which resulted in the significant expansion of the contours of the continent Qazaqia.

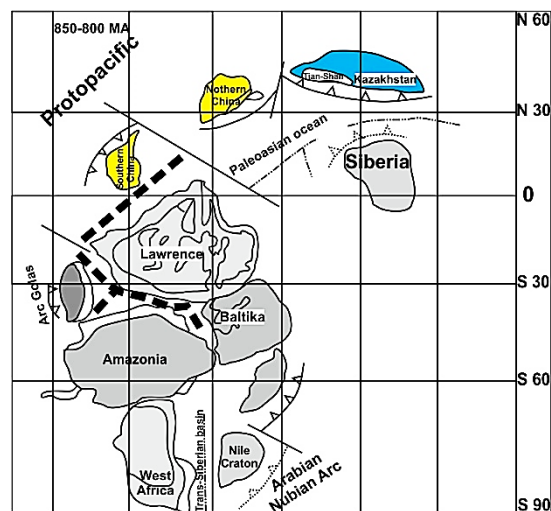


Fig. 2 Paleogeodynamic reconstruction for a time interval of 850-800 million years [5]

As a result of Caledonian orogeny, by the beginning of the Devonian, the situation on the globe was markedly changed. Mountain constructions arose and continued to rise in the Early Devonian in the geosuture zones of Kazakhstan, as well as in the Altai-Sayan-Mongol and Baikal regions. A new element, at least for the Paleozoic, was the formation of several internal volcanic island belts and a marginal volcanic-plutonic Andean-type belt in Kazakhstan, on the border of the caledonides and the Zhongar-Balkhash basin, intensively filled with detrital material. The position of the continent Qazaqia in the Devonian according to palinspastic constructions remained the same as an isolated island.

During the Paleozoic, Qazaqia experienced several phases of tectonic activity under the influence not of the surrounding continents, but of the mantle plume and its branches. In the Middle Devonian, new compression strains emerged. They are attributed to the Telbes era, distinguished in the Altai-Sayan region. In the center, from the east and southeast, Qazaqia was bordered by a powerful marginal volcanic-plutonic belt that separated it from the Zhongar-Balkhash basin, which belonged to the southern branch of the Paleo-Asian Ocean. In the rear of this belt, there was a subsidence of the Teniz and Jezkazgan depressions, filled with red-colored continental molasses.

The Tarim and Sino-Korean continents, being further to the east, also began to draw closer to Qazaqia, Siberia, and Central Mongolia. All this preceded the impending closure of the Paleo-Asian Ocean.

In the Middle-Late Carboniferous, the tendency

toward the convergence of the continental masses led to the collision and closure of Laurussia with Qazaqia and its northern burial near Western Siberia at the end of the Carboniferous. They were separated only by narrow foreland basins filled with flysch or molasses. They accompanied new powerful orogenic belts such as Ural-Mugalzhar-Nuratau-South Tien Shan-Zhongar. Their formation was followed by the intrusion of large granitoid plutons. The main compression impulses occurred at the end of the Early and the beginning of the Middle Carboniferous (the Sudeten era, which was preceded by the intra-Viséan era – Saurian), in the Middle Carboniferous and at the beginning of the Late Carboniferous (the Asturian era). In the inner areas of the ring structures, coal-bearing and oil-gas-bearing sedimentary basins and intermountain molasse troughs were formed.

By the beginning of the Permian period, the closure of Laurussia with Siberia and Laurasia with Gondwana was completed, resulting in the formation of Laurasia and Pangea II, respectively. From the east, from the side of Panthalassa (Paleo-Pacific), a wide bay of the preserved eastern part of the Paleo-Tethys entered the body of Gondwana. In this bay, gravitating towards its northern, Laurasian, side, Tarim, Sino-Korean, South China and Indo-Sinian, merged with the latter, continents were located. Closer to the southern, Gondwanan, side, there were Central Iranian, Central Afghan and Tibetan continents.

At the point of collision of Eastern Europe, Qazaqia and Siberia, a high mountainous country emerged, including the Urals, Tien Shan, Kazakh Uplands, Zhongaria, Altai and Sayan (the beginnings of the Ural-Mongolian belt) and stretching eastward through northern and central Mongolia to Transbaikalia and Dunbei, which later led to the formation of the Ural-Okhotsk belt. It was bordered from the west by the Pre-Ural trough, and from the south by a powerful and extended volcano-plutonic belt, uniting older and shorter belts and extending over the subduction zone of the Paleo-Tethys oceanic crust.

On the northern side of the Paleo-Tethys, there were highlands of the Tarim, Sino-Korean, South China and Indo-Sinian massifs adjacent to the denudation plains of Qazaqia and Siberia. Like on the Siberian platform, depressions in the relief were occupied by water bodies, mainly freshwater, in which terrigenous sediments accumulated.

In the Cretaceous period, crust spreading in the Tethys had stopped by this time; in the rear of the volcanic arc, the Black Sea trench opened, and to the east – probably, the South Caspian. Central Kazakhstan and Central Asia remained relatively uplifted, but the rate of uplift was noticeably reduced. In the Turgai Strait, which connected the West Siberian Sea with the southern basins,

terrigenous sediments were deposited. The coastal zone was characterized by oolitic iron ore deposits, and the coastal lowlands – by bauxite-bearing rocks. The area of development of continental and coastal-marine sediments continued in the Northern Aral Sea region and, enveloping Kazakhstan from the west, extended into the Fergana Depression. In the vast marine shallow basin of the Turan Plate, carbonate-terrigenous sediments with phosphorites were deposited. From the southwest, a large bay penetrated into the Kazakhstan-Central Asian land, in which lagoon gypsum-bearing and sometimes even purely continental carbonate red-colored sandy clay sediments accumulated.

3. THE SUPERPLUME NATURE OF KAZAKHSTAN'S PALEOZOIDS

According to modern data [5, 13], Kazakhstan, as the continent Qazaqia, existed independently and separately, from the Neoproterozoic Ediacaran period to the complete formation of the supercontinent Pangea II in the Permian Triassic (~250 Ma). Qazaqia developed without the active and direct influence of neighboring continents with its inherent geodynamic and geochemical conditions. The separation of the continent Qazaqia was facilitated by the fragmentation of the assumed megacontinent Rodinia and movements in the subcrustal part of the planet [5, 23].

The penetration of the plume and the intrusion of the mantle and asthenosphere substance, established by geophysical data [17], into the lithosphere led to a local uplift and the formation of a stationary nucleus in the form of a ring structure – the prototype of the continent Qazaqia. Its diameter was approximately 2.5-3.0 thousand km. The formation of such a peculiar geological structure is associated with the effect of the superplume in the Paleozoic and is clearly visible on the geological and tectonic maps of Kazakhstan.

Currently, there are about 30–40 active plumes and superplumes [2, 6, 7]. Plumes with a diameter of hundreds of kilometers are called superplumes; they cover several thousand kilometers in diameter on the surface of the territory (Figure 3). Some of them still operate periodically (e.g., the Hawaiian Islands, the Canary Islands, Iceland, Etna, etc.). Most of them were active in the geological past, beginning with the Archean and the Proterozoic (e.g., the South African superplume, etc.), and in subsequent periods of the Paleozoic, Mesozoic and Cenozoic. They are known within all continents and associated with the formation of large mineral deposits. Their effect is manifested in the form of active tectonic movements and large-scale volcanic eruptions.

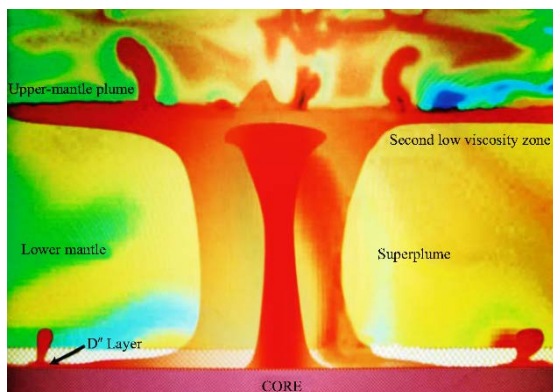


Fig. 3 A schematic illustration of the multiscale nature of the mantle plume and superplume [6].

The superplume, being active in the Paleozoic, covered a large territory of Kazakhstan, as well as Uzbekistan and Kyrgyzstan. On the surface, the effect of the plume manifests itself in the form of ring structures bounded by active geosuture zones. Such geotectonic features of these territories, i.e. the lack of linear geosynclines that were depicted on the tectonic maps of Kazakhstan in the 1930-40s, caused the abandonment of the geosynclinal paradigm.

The first signs of the ring geological structures of Kazakhstan were outlined in the 1950s, however, according to the view of that time, they were qualified as arc-shaped structures clearly identified on tectonic maps [8].

of planetary-scale structures, an attempt was made to correlate the tectonic structure of Kazakhstan with its basic elements. However, the mechanical transfer of plate tectonic elements that are obvious on a planetary scale (rifts, crust spreads, island arcs, collisions, etc.) did not find confirmation in practical geology and confused the geotectonics and geodynamics of the country's territory. The sophistication of applying the principles of plate tectonics is especially clearly seen on maps (Figure 5), where within the boundaries of the microcontinent Qazaqia "continents" and "oceans" began to be distinguished. They are, respectively, only geological blocks (terrains) and sea bays and/or straits of the neighboring Paleozoic oceans, for example, the Paleo-Asian, Ural and Tethys [23].

In all paleogeographic reconstructions of the Paleozoic, Kazakhstan is shown as a separate and integral microcontinent island [9, 10]. In this regard, it is impossible to imagine the existence of oceans within such a limited size of the microcontinent (Figures 4 and 5).

In the Cambrian-Ordovician, in the planetary subduction (or spreading) zone, the mantle superplume penetrated into the lithosphere and the nucleus was formed – the prototype of the continent Qazaqia, which, due to its fixation, could not drift independently like other continents. The active superplume, which operated during the Paleozoic, determined the formation of the geotectonics and geodynamics of Kazakhstan.

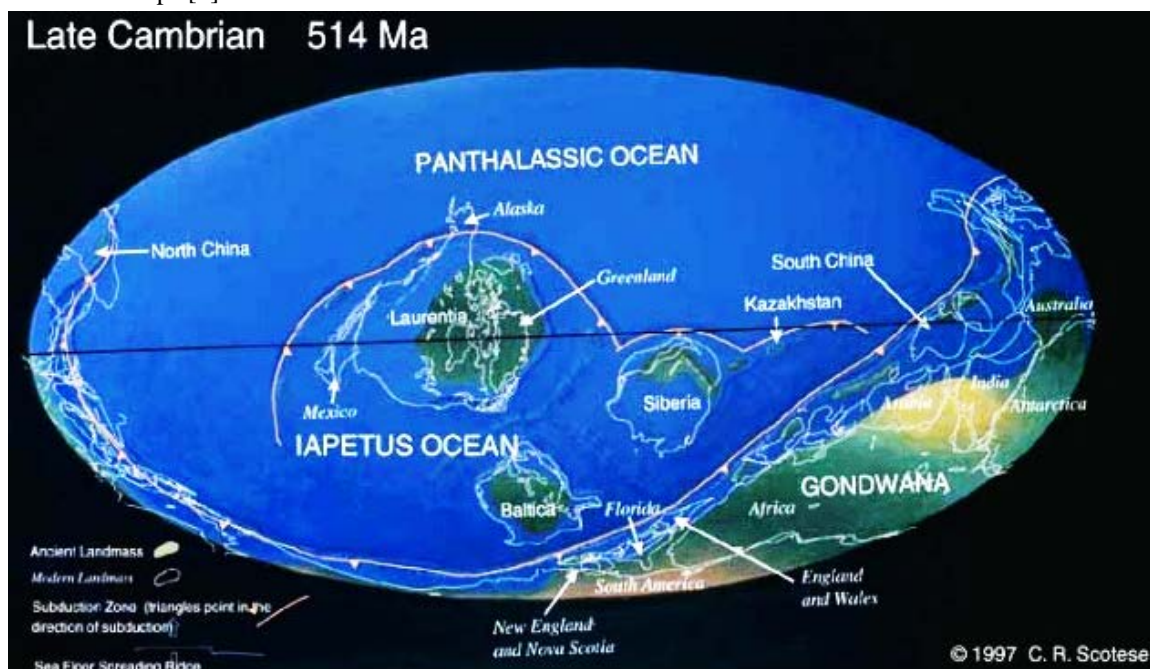


Fig. 4 The position of the continent Qazaqia in world space in the Late Cambrian [9]

With the adoption of plate tectonics, which is consistent with the geotectonics and geodynamics

The internal pulsations of the planet caused the vertical movements of the nucleus. With the phased penetration of the mantle superplume into the lithosphere and its reaching of the earth's crust, concentrically annular structures were formed in

the structure of the continent Qazaqia, which were limited respectively by the annular shape of the geosutures. The foundation of the ring structure included substances of the asthenosphere and the lower mantle, pressed into the lithosphere in the form of a relatively rigid core. The continent Qazaqia fixed in this manner was developed under the direct influence of the foundation. The rather rigid lithosphere under the pressure of the plume was subjected to brittle fracture with the formation of random faults, cracks and mosaic structures. The continent made mainly horizontal rotational and vertical oscillatory movements. During the rotation of the continent around its axis, strong friction and pressure occurred between the rings. Depending on the direction of the inclination angles of deep faults, the geosutures extending into the mantle represented compression (convergence) or extension (divergence) zones with a width of tens to hundreds of kilometers or more. Through these weakened zones, molten mantle substances actively penetrated into the lithosphere, sometimes reaching the Earth's surface.

influence of the surrounding continents. In the Paleozoic, the continent's margins were washed by ancient oceans between the approaching neighboring continents – the Paleo-Asian (between Siberia), the Paleo-Ural (between Eastern Europe) and the Paleo-Tethys (between Cathaysia, Tarim). Sedimentary rock masses with corresponding minerals were accumulated. The motions of the geosutures, concentric intra-ring faults, intensified under the pressure of the drifting neighboring continents, and individual stressed blocks underwent additional autonomous motions.

In the tensest parts of the continent, namely the mobile geosutures, deep magmatic foci were formed. Through these channels, mantle substances entered the upper layers of the earth's crust. Under the influence of the tense thermodynamic situation, core and near-surface magmas were melted within active and activated geological blocks. Volcanic edifices developed and lava erupted in the stretch areas, respectively. The movements of the geosutures and the continent's blocks bounded by them had both vertical and

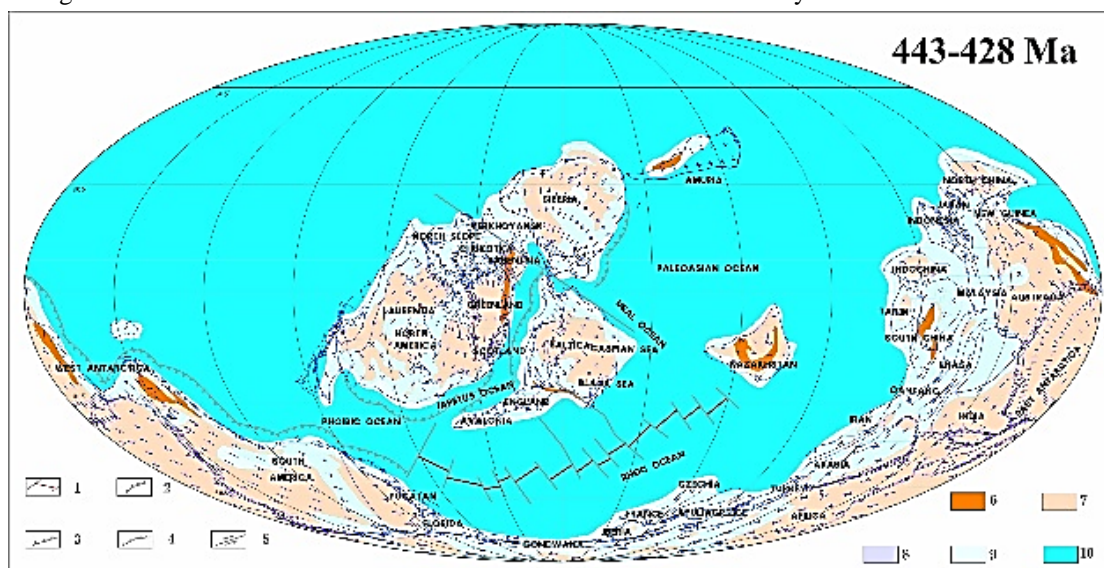


Fig. 5 The position of the continent Qazaqia in the Early Silurian [10]

Vertical oscillatory movements covered both individual rings and geosuture zones between the ring structures. In case of uneven oscillatory movement, when one edge of the continent or a separate ring structure fell and the other rose, the conditions of the sea or land accordingly formed in such areas. Seas in the form of bays and narrow straits often penetrated into geosuture zones. The general tense thermodynamic situation led to the formation of a rather dense network of discontinuous faults in the consolidated rigid ring structures.

Starting from the Ediacaran Period, the continent Qazaqia began to experience the

horizontal directions.

The edges of the continent experienced pressure (compression) or spreading (extension); the corresponding geodynamic processes proceeded here. Within the continent Qazaqia, for any kind of tectonic movements, there were classical processes, from the perspective of the modern tectonics of lithospheric plates, such as spreading, collision and subduction (thrust-shear movements). Based on the characteristics of the tectonic positions of the continent, these movements complied with shear movements.

Thus, the geotectonics of Kazakhstan is determined by the ring structures and tectonic blocks (terrains) of a single nucleus. In accordance with modern tectonic zoning [1, 5, 11-22], there are three ring structures on the territory of the

continent Qazaqia (Figure 6):

- the inner ring (diameter of about 600-900 km) – Zhongar-Balkhash and Shu-Iles tectonic system, bounded by the corresponding geosuture zones;
- the middle ring (diameter of about 1200-2000 km) North Tien Shan-Kendyktas-Shu-Sarysu-Central Kazakhstan-Kokshetau-Shyngys-Tarbagatai tectonic system, bounded by the Fergana-Karatau-Karsakpai-Central Kazakhstan-Shyngys-Tarbagatai geosuture zone;
- the outer ring (diameter of about 2500-3000 km) – Middle Tien Shan-Nuratau-Aral-Torgai-North Kazakhstan-Altai-Zaisan tectonic system, bounded by the Pamir-East Ustyurt-Mugalzhar-North Kazakhstan-Altai geosuture zone.

lithosphere with the formation of ring structures, respectively, occurred mainly in three stages (Figure 7).

Under the active influence of individual superplume branches on the rigid lithosphere, it was crushed into autonomous blocks with a chaotic and mosaic arrangement of faults and fragments of the lithosphere. Within their limits, there were structures with peculiar geological features such as Shu block, Kokshetau block, Northern Balkhash block, etc. Within such geological blocks, the ring structure and linearity of the geosutures of these territories were distorted.

The ring structures that had regular shapes once (before the Devonian) and the geosutures binding them began to change configurations with the beginning of Pangea II. The active southeastern

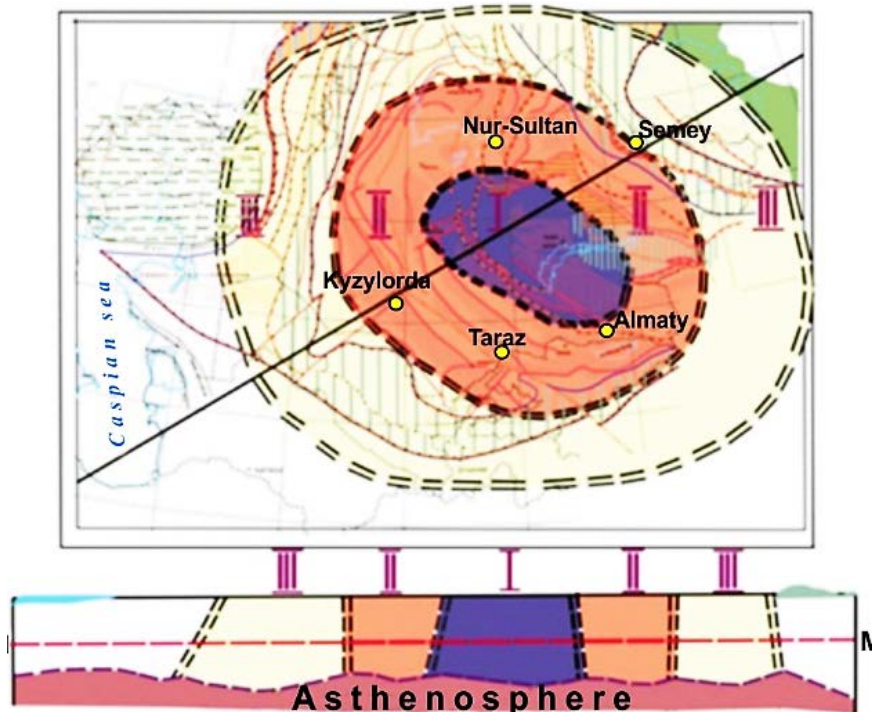


Fig. 6 A schematic tectonic structure of the continent Qazaqia: I – the inner ring; II – the middle ring; III – the outer ring (based on the tectonic zoning scheme of Kazakhstan's paleozoides)

The outer part of the nucleus with a width of about 500-600 km, located in the western part of Kazakhstan (Karakum-Ustyurt-Pre-Caspian-Ural tectonic system) and representing the passive margin of the continent, is a plate immersed in an ancient platform within the Ural Ocean. The penetration of the mantle plume and the intrusion of mantle and asthenosphere substances, established by modern geophysical data, into the

part of Qazaqia began to experience strong pressure from the megacontinent Siberia, and as it collided directly with it, the convex edges of the ring structures began to straighten and even were concave into the inside of the ring. During the formation of a shear-collision zone between the continents Qazaqia and Siberia, the edges of the outer ring structures were absorbed and destroyed in this area. The final adjustments to the configuration of the continent Qazaqia were made in the Cenozoic when connecting micro- and mesocontinents with the continent Eurasia from the south, southeast and southwest. In the more passive northwestern part of Qazaqia, there was a subduction adjoinment with the East European platform and the West Siberian plate.

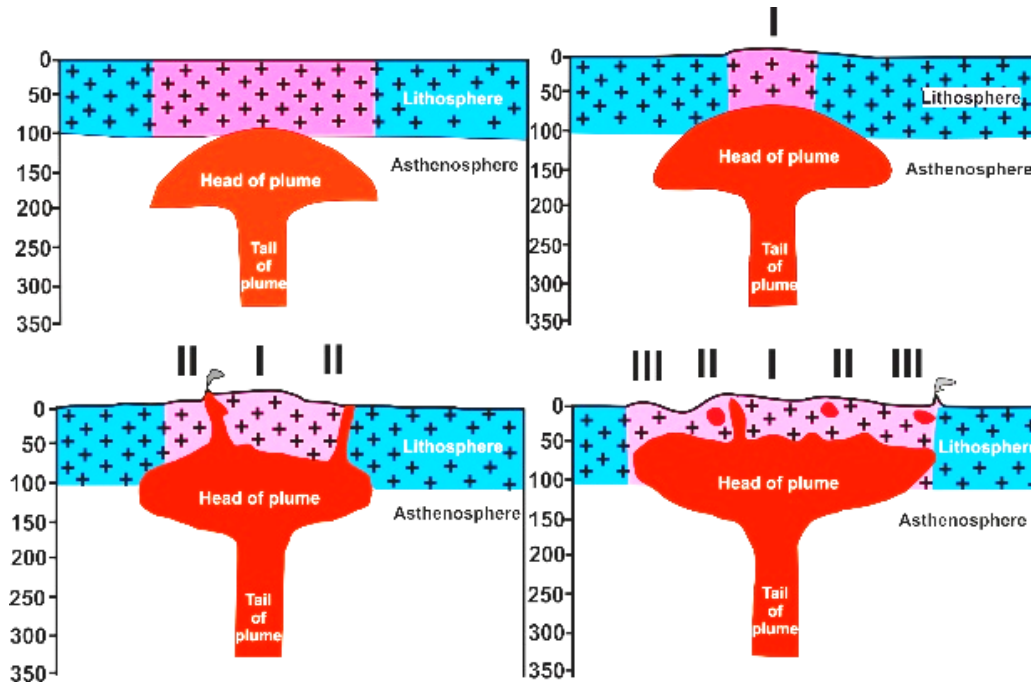


Fig. 7 A model scheme of the penetration of the mantle plume into the lithosphere and the formation stages of Kazakhstan's ring structures

In the modern geological structure of Kazakhstan, the inner and middle ring structures are quite fully preserved. The inner ring became elongated in a northwestern direction, and its northwestern edge was straightened, sometimes even concave. Due to the pressure of the corresponding lithospheric plates mentioned above and the formation of the collision zone, the middle ring from the south and southeast became closer to the inner ring, and the deformed northeastern edge was traced along the Altai shear zone. The outer ring also became flattened and crumpled into mountain-folded structures from the south and southeast, connected with the Ural mountain-folded belt and the West Siberian plate from the north and cut off by the shear-collision zone between Siberia from the northwest (Figure 8).

In divergence (or spreading) zones, there were rifts, along which magmas rose and lava flowed. When these zones were flooded, ophiolites with typical marine (oceanic) rock complexes were formed. Mantle substances – ultramafites and mafites – penetrated into the rifts and decompressed zones, sometimes reaching the earth's crust and being sources of many minerals. Ore-bearing solutions separated from the mantle substance also rose along the open faults and crushing zones and penetrated into the upper layers of the earth's crust. Such weakened and open geosuture zones favored the squeezing and rather free penetration of asthenoliths into the Earth's crust. It is in such areas that the location of ophiolite zones of the

Paleozoic age in Kazakhstan is observed.

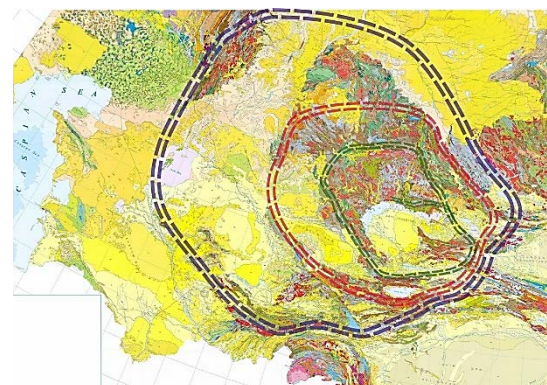


Fig. 8 Scheme of ring structures of Kazakhstan on a modern tectonic basis

Convergence (or collision) zones arose as a result of the movement of differently inclined ring structures and ring structures with counter-drop edges, their individual sections and geological blocks, which led to their contact and further collision. The collision proceeded in various forms – in the form of a clash with the formation of mountain structures, slip-shifts and thrusts. The interaction of large blocks of the lithosphere of Qazaqia resulted in the creation of a tense thermodynamic situation. Large magmatic foci of granitoid composition were melted in the areas that experienced the thermal influence of the asthenosphere, located rather close, and arising endothermic reactions during the interaction of the earth's crust with mantle emanations.

The distortion of the regular ring forms of the main tectonic structural systems of the continent

Kazakhstan was conditioned by the distortion of their original location during the movement and collision of the once neighboring but now interconnected continents and internal structural blocks, as well as the emergence of cut-through disturbed tectonic zones and faults, cutting and shearing the ring structures. The main role in this process was played by the final collisional stage in the Mesozoic-Cenozoic, which led to the formation of the modern so-called Ural-Mongolian belt. It is at this stage that the systems of thrust movements and large shears with an amplitude of up to 150-200 km were formed, which distorted the shape and changed the size of the ring structures in the southern, southwestern and southeastern regions of the continent. The northeastern Irtysh-Altai region also underwent further significant changes.

The proposed geodynamic development model of Kazakhstan explains the features of localization of the zones of active sedimentation, intrusive and effusive magmatism and metamorphism of geological formations, ophiolite zones and olistostromes, as well as the location of productive and promising metallogenic zones and areas with large and unique mineral deposits [3, 23-25] (Figure 9).

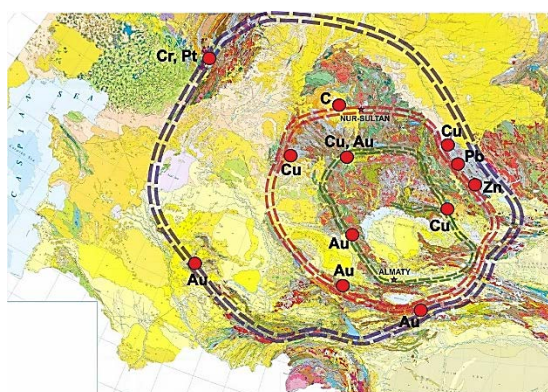


Fig. 9 The location of metallogenic belts with the largest mineral deposits along the geosuture zones of the ring structures

In general, the main geological structures were laid in the early stage of the territory's development and acquired the modern look in the form of the Ural-Mongolian belt in the Mesozoic-Cenozoic. In the Cenozoic, under the influence of the drifting southern continents, in particular the Hindustan plate, the lineaments of the northwestern extension were also laid, cutting in some places through the annular and geosutural zones.

The ring structure of Kazakhstan is also reflected in physical fields, especially in the gravitational field. One can also note the modern block structure of the earth's crust of Kazakhstan.

The extended, linearly elongated stripes of the adjacent isoanomalies (large gradients) of the Δg field distinguish the zones of deep faults dividing the earth's crust of Kazakhstan into a series of megablocks and blocks. Based on geophysical data, the most significant of them split the Earth's crust to its entire thickness and penetrate into the upper mantle [1, 17, 22].

4. CONCLUSIONS

The proposed new model of the geodynamic development of Kazakhstan's territory can serve as a theoretical basis for forecasting mineral deposits. According to this model, the channels for the penetration of the mantle substance with ore substances of chromite mineralization and copper-nickel mineralization with platinoids include deep faults in the form of geosutural zones and lithosphere crushing zones due to the effect of plumes and granitoids, promising for copper-porphyry mineralization, which are the result of stratification of the mantle substance during evolution in the earth's crust.

Currently, the tectonic structure of Kazakhstan can be described by the following statement: "...Kazakhstan's territory covers the western part of the Ural-Mongolian folded belt, located on the transition from the sub-latitudinal Mongol-Tien Shan structures to the submeridional Ural-Western Siberian. The Ural-Mongolian belt was established during the destruction of the Epiriphean platform in the Ediacaran (570–600 Ma)." However, the analysis of new data on the paleogeological structure of our planet and Kazakhstan shows that at the specified time there was neither the Urals, nor Mongolia, nor, especially, the Ural-Mongolian belt. Kazakhstan existed independently without visible ties with the above-mentioned structures and continents.

In the tensest parts of the continent, namely the mobile geosutures, deep magmatic foci were formed. Through these channels, mantle substances entered the upper layers of the earth's crust. Under the influence of the tense thermodynamic situation, core and near-surface magmas were melted within active and activated geological blocks. Volcanic edifices developed and lava erupted in the stretch areas, respectively. The movements of the geosutures and the continent's blocks bounded by them had both vertical and horizontal directions.

Such structures were laid in the early stage of the territory's development and acquired the modern look in the form of the Ural-Mongolian belt in the Mesozoic-Cenozoic. In the Cenozoic, the lineaments of the northwestern extension were also laid, cutting in some places through the annular and geosutural zones.

5. ACKNOWLEDGMENT

This work was supported by the scientific program BR05233713 "Comprehensive geological study of subsurface resources for the development of resource base and mining exploitation of new sources of ore raw materials in Kazakhstan."

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