Geodynamic conditions of formation of sedimentary basins of South Kazakhstan (Shu-Sarysu, Pre-Balkhash, Ili)

Z S. Tulemissova¹, M M Buslov², Z A Bekmukhametova¹
¹JSC «Kazakh-British technical university», Almaty, Kazakhstan
²Institute of Geology and Mineralogy of the Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia

E-mail: ztulemissova@gmail.com, misha@igm.nsc.ru, zaureb31@yahoo.com

Abstract. The features of geological and geodynamic formation of promising oil and gas basins of Southern Kazakhstan (Shu-Sarysu, Pre-Balkhash-Ili) are considered and the geological evolution of these basins is described, which is associated with the conditions of stable subsidence throughout the late Paleozoic-Mesozoic-Cainozoic. A model of the deep structure of the main structural units of Southern Kazakhstan (folded paleozoid base) and a cover of sedimentary basins along the profile of "Turkestan" are offered. As a result of interpreting geophysical data in the crustal section along the traverse of the profile, numerous gently sloping reflectors are described at depths from several kilometers to the Mohorovicic boundary. These reflecting planes in the regional section form a system of detachments that are associated with a system of gentle over thrusts and interformational disruptions, forming a system of intermittent packets of tectonic lenses folded by dynamometamorphic and metamorphic rocks. The position in the section of these tectonic lenses is an expression of the tectonic stratification of the earth's crust. The characteristic of the main tectonic elements of this region (suture, accretion prisms, intraplate complexes, collision thrusts and shifts, etc.) is given. As initial reconstructions, various paleogeographic, paleotectonic and geodynamic constructions were used.

The Central Asian orogenic belt (CAOB) (figure 1) is one of the largest Phanerozoic accretionary orogenes of the world, which extends from North China to the Siberian craton, capturing Tarim, through Kazakhstan [1]. CAOB contains sedimentary basins of interest to us, such as Shu-Sarysu, Balkhash and Ili. The final formation of the Central Asian orogenic belt occurred in Permian period, and was accompanied by significant collision, post-collision and magmatic activity. During the Mesozoic and Cenozoic periods, parts of the CAOB are periodically activated in response to collision events with active Late Cenozoic tectonic phases associated with the Indo-Eurasian collision [4]. As a result of these events, there is a large-scale activation of the CAOB, which relief is dominated by inland mountain structures (mainly consisting of deformed Precambrian and Paleozoic blocks), separated by intermountain and piedmont basins, which are characterized mainly by Late Paleozoic and Mesozoic-Cenozoic sedimentary deposits.

CAOB contains a number of sedimentary basins, which prospects for hydrocarbon raw materials are not fully understood. The Shu-Sarysu basin (figure 1), located in the central part of the CAOB, was formed starting from the Late Paleozoic. The boundary of the basin with the framing mountain systems runs along shear-thrust faults. The foundation of the basin consists of blocks (terranes) composed of metamorphic Precambrian rocks and volcanic rocks of the Lower Paleozoic period, broken by the late
Ordovician-Silurian collisional granites. Sediment cover reaches a thickness of 5 kilometers [10]. The main Karatau Fault (MKF) defines the south-western boundary of the basin. The MKF was active at the end of the Permian period and in the early Jurassic period. The amplitude of the shift (right) reaches 200-250 kilometers, on the Neogene period there are 10-15 kilometers. In the north-west, the MKF is divided into several branches, one of which is manifested in the north-west at the foot of the Ulutau Mountains, where the Precambrian basement is pushed onto Carbon formations, and the latter onto the salt-bearing Permian formations. The remaining branches form a system of oil-bearing Jurassic grabens in Southern Turga. The Zhezkazgan-Kokshetau right shift is located at the center of the depression with an amplitude of 100-150 kilometers. Late Perm large Tastinsky uplift is associated with it. Shear-folded deformations are formed as a result of rotational movements of the Kazakhstan continent in the event of a collision [12]. These movements formed the bulk of local structures with which several small gas fields are associated.

In the Paleozoic section of the Shu-Sarysu basin, three strata are distinguished: the lagoon terrigenous-salt-bearing Famennary Tournier (up to 500–800 meters), the terrigenous-carbonate marine shallow water in some parts of the coal-bearing of the Lower Carboniferous (500-2000 meters), alluvial-lacustrine predominantly red-colored Carbon-Permian (up to 2.5 kilometers). In the bottoms of the lower Perm salt-bearing strata are developed up to 500 meters. Paleozoic sediments overlap the continental and marine rocks of the Upper Cretaceous-Cenozoic. Along the MKF and other shifts, the thickness of the Cenozoic red-colored molasses increases to 3 kilometers. Igneous rocks include Famen-Tournaisian alkaline basalts, which are associated with faults along the central part of the depression and which indicate the expansion of the depression. The outlines of the Shu-Sarysu basin drastically changed over time, at very large time intervals it was limited from the north to the Shu basin, and from the south to the Main Karatau faults. MKF played the role of long-lived transform fault separating West and East of South Kazakhstan [6]. On the territory of Kyrgyzstan one of the borders of the basin was the line of Nikolaev. At the same time, the MKF and the Shu Fault, as well as the Nikolaev line, are the boundaries of the flanks of the Late Paleozoic volcano-plutonic belts associated with the absorption of the lithospheres of different paleoceans [6].

In the west of this basin, in the BigKaratau, red-colored terrigenous deposits of the Tulkubashsky suite, in the east, in the Shu-Kendyktas zone, red-colored sandstone conglomerate-Middle-Late Devonian Betpakdala and Late Devonian Sarykamysk and Gingeldinsk suites were accumulated. In the Famennian Tournaissian formations of the Small Karatau, quartz conglomerates and arcos of the Süleymansay sequence were formed. The deposits close in composition accumulated on the slopes of the Shu and Kendyktas terranes. In the center of the basin, the terrigenous-carbonate Bestyubinsk Formation of Famen with evaporites was formed, covered by sulphate-carbonate-terrigenous, carbonate-spongolite and serum-colored sulphate-carbonate-terrigenous strata of the Early Carboniferous. In the Middle-Late Carboniferous, initially variegated with layers of siliceous tuffites (Taskuduk formation), and then red-colored (Dzhezkazgan suite) alluvial plains were accumulated. In the early Permian period, a variegated terrigenous Zidilisay stratum with the marl-clayey with evaporites was formed. In the Late Permian there was a deposition of red-colored sandy-clay and variegated with gray siltstones and limestones and marls of lake sediments of the Kengir Formation [2].

In the northern part of the Shu-Sarysu basin, there is a unique rare-earth-lead-copper stratiform Zhezkazgan deposit, which many researchers consider to be the benchmark of the “copper sandstones” type. Presumably the base of the back-arc basin, which was filled in the Devonian-Carboniferous-Perm period by coastal-marine and continental sediments of great thickness (more than 4 km), as well as modern regional seas of the Okhotsk type, were affected by local thermo-anomalies that stimulated the groundwater convention in a thick column of cover rocks and foundations saturated with basite-ultramafic bodies [2].
Figure 1. The main tectonic units and the position of the sedimentary basins of southern Kazakhstan. A straight line segment indicates the orientation of the Turkestan geological and geophysical profile. Tien Shan tectonic units (TS): CTS - Central, MTS-Middle, NTS – North; STS – South. Main faults: TIF – Zailiysky, CKCF – Chon-Keminsky, DNF–Zhlair-Nymsansky, MKF– Main Karatau, NL – Linia Nikolaev. F– fault, Mts - mountains, R – ridge.

The Ili and Pribalkhash basins are the Mesozoic-Cenozoic foothill basins formed on the northern slopes of the Tien Shan and West Junggar orogens, located in the southwestern part of the CAOB (figure 1) [5]. The tectonically active inland Tien Shan orogen extends from west to east over a distance of 2000 km through Uzbekistan, Kazakhstan, Tajikistan, Kyrgyzstan and China (Xinjiang province), oriented in the latitudinal direction (figure 1). Tien Shan is divided into various tectonic units. Traditionally, in the post-soviet space, Tien-Shan is divided into three tectonic units: Northern Tien-Shan (NTS), Middle Tien-Shan (MTS) and South Tien-Shan (STS) [16], (figure 2). NTS mainly consists of Precambrian microcontinental blocks and Early Paleozoic granitoid plutons [5] (figure 3). The MTS base mainly consists of Precambrian metamorphic complexes, which are covered by Early and Middle Paleozoic sediments and the Late Paleozoic granitoids. The MTS is a Late Paleozoic accretionary complex, associated with the collision of Paleo-Kazakhstan with Tarim during the Late Paleozoic [15].

The geological and geophysical cross-section spatially coincides with the direction of the EEWM profile (earthquake exchange wave method) – DSS (deep seismic sounding) “Turkestan”, has a length of about 1300 km and reconstructs the structure morphology to the border of Mohorovich (M). The results of geological and geophysical interpretation were involved [6]. When constructing a geological cross-section, geophysical materials of the EEWM-DSS were used for three levels of generalization: 1) in the isolines of the seismic velocity, 2) in the isolines of positive or negative anomalies in the velocities of such waves, 3) in the isolines of the calculated elastic moduli. The geologic-geophysical profile “Turkestan” is spatially oriented across the strike of the main structural units of the paleozoids of southern Kazakhstan (figures 1-2). Its beginning is in the area of Arys station (Syrdarya depression). Further, this profile is oriented to the north-east, where it crosses the Great Karatau Range in its central part, then the profile passes on the Kokzhon plateau, crosses the Small Karatau Range, then the Shu-Sarysu depression in its central part, then crosses the Shu-Ili Mountains (in the region the southern end of the Zheltau pluton and the Karasai volcano-plutonic structure). The seismic profile
crosses the southern part of the Shu-Sarysu and the central part of the Balkhash basin, and its end is located in the northwestern part of the Sassykollake. Thus, this profile intersects and carries information about the sedimentary basins of southern Kazakhstan, in which we are interested in (figures 1-2).

According to the results of interpretation in the section of the Earth's crust, within the limits of the “Turkestan” profile, numerous horizontal and hollow-lying reflectors were found at depths from several kilometers to the border M (figure 2). Obviously, these reflecting planes are associated with a system of gentle uplifts, thrusts and interformational disruptions [8], and thus, they are an expression of the tectonic stratification of the earth's crust. In combination with the steeply dipping faults that we see on the surface, they form the lystric system. Clusters of reflectors are noted, as a rule, at depths of 10-20 km and near the M border. These are the main details (gentle disruptions) of the earth’s crust in the region under consideration. The upper part is the boundary layer between the folded complexes of high and low degree of metamorphism. It is outcropped in the Zhalair-Naiman and Sarytum suture zones and is composed of green shales with signs of an intense deformation flow. The revealed detailing divides the earth's crust into structural floors with different vergence. Above it, vergence varies everywhere depending on the primary direction of subduction, which, in turn, is determined by the polarity of Stepnyak-Betpakdala and Shu-Kedyktas island arcs. The vergence of the structures of the upper floor is controlled by the prevailing direction of collision movements. The position of the main suture zones is determined by the largest beams of inclined reflecting areas. The composition of the main terranes and blocks is determined by gravity and magnetic data. Thus, intense positive gravitational and magnetic anomalies serve to recognize the slabs and allochthons of the oceanic crust, indicating the position of the main suture zones. The blocks of the ancient continental crust have low gravitational and magnetic fields, their sedimentary cover is slightly deformed. Blocks of the young continental crust are recognized by the presence of collision intrusions of granitoids of the corresponding age in the upper structural floor. At the base of the Upper Paleozoic and Mesozoic sedimentary basins there are grabens formed by the lystric faults according to the simple shift mechanism. The sedimentary cover of the pools is deformed in a fold-waste and fold-thrust style.

The main tectonic units are clearly distinguished in the structure of the crust, which are marked above the geological and geophysical section. These include terranes, fragments of volcanoplutonic belts with accretionary prisms, and, separating them, suture zones. From west to east, the following tectonic units of the Paleozoic fall within the limits of the profile: 1) Syrdarya intercontinental basin; 2) The Big-Karatau rift zone; 3) Ishim-Karatau (Kokzhot) sutur zone; 4) Small Karatau terrane; 5) Shu-Sarysu intercontinental basin; 6) Ishim-Naryn suture zone; 7) Shu-Sarysu thrust-thrust zone; 8) Shuya Terrane; 9) Zhalair-Nyman accretionary prism; 10) Zheltau terrane; 11) Sarytum rift zone; 12) Ili and 13) Balkhash-Ili volcano-plutonic belts; 14) Salkinbel; 15) Tastau and 16) North-Balkhash accretionary prisms; 17) Balkhash volcanic belt (figures 2 and 3).

The boundary of the M under terranes and paleobasins has a depth of about 40-42 km, while under accretionary and riftogenic zones it increases to depths of 45-50 km. According to the geophysical data, in the section of the earth's crust, hollow and horizontally lying reflectors are found at depths from 5 km to the M boundary. These reflectors probably reflect the root zones of the listric system of faults formed under the conditions of the metamorphic transformation of rocks, penetrating to depths of 15-20 km (figure 2).

The second order structural units listed above are part of the following Precambrian-Early Paleozoic structures (figure 2) –Torgai-Middle-Tien-Shan microcontinent (1-4), Kokshetau-North-Tien Shan orogenic belt (5-11), Atasu-Junggar microcontinent 12, 13) and the Late Paleozoic orogenic Junggar-Balkhash belt (14-17). Within the geological-geophysical section, the Precambrian continental crust is noted in the Karatau, Shu-Ili mountains and Junggaria. Most of the crust beneath the microcontinents is of Precambrian age, while the crust of the early Paleozoic age underlies accretionary zones.
Figure 2. Geological and geophysical section along the Turkestan profile. The structure of the main sedimentary basins of Southern Kazakhstan to the boundary of the section M. is shown. The main structural units are shown above the section, and the main faulting structures of the region are indicated in circles: 1 - Main Karatau, 2 - Zhalaq-Naiman, 3 - Sarytum, 4 - South-Junggar 5 - Sarkansky, 6 - Main Junggar.
Young crust is probably formed during the Late collisions and lies under the suture zones and underlies Shu-Sarysu shear-thrust zone, Shumsky and Zheltau terranes, Sarytum rift zone Ili volcano-plutonic belt and Salkinbel, Tastau and North Balkhash accretion prisms (figure 2). The deformed oceanic crust underlies the Ishim-Karatau (Kokzhot) and Ishim-Narym suture zones, as well as all the accretion zones, and only a few allochone ophiolites come to the surface. These allochthons are exposed in an inclined (40-45°) to the west of the Ishim-Karatau suture zone, while within the Ishim-Narym suture and the Zhalair-Nyman accretion zone they smoothly sink to the northeast at angles of 30-35°. In the southern part of the Tastau accretionary prism, tectonic plates of deformed ophiolites fall to the south-west at angles of 35-40°, in the east - on the border with the North-Balkhash accretionary prism, similar zones are gently inclined to the east at angles of 15 to 30°. Within the Syrdarya depression and Karatau ridge geological and geophysical section is built according to the method of comparing the speed of transmission of longitudinal seismic EEWM-DSS waves. From top to bottom it shows: 1 - bodies with low and high speed (density) in the upper crust; 2 - low density lithoplates in the middle crust, usually identified with the granite layer; 3 - granulite-basite layer in the lower crust, characterized by high densities and speeds. In the area of Ishim-Karatau suture, this layer is pulled over the overlying crust. The sub-horizontal layer with a lower density in this upper crust in some places coincides with the layer of Late Riphean rhyolites, but, apparently, for the most part corresponds to detail along the border of the Precambrian and Early Paleozoic structural-material complex.

Within the Shu-Sarysu and Balkhash-Ili depressions (figure 1), the geological-geophysical section along the Turkestan profile was built with the identification of deep positive and negative anomalies of the seismic wave velocities corresponding to high-density and weakened laminated plates. Presumably a Vendian-Cambrian ophiolite lithoplatin lies at the base of the Kokchetav-North Tien Shan microcontinent. In the thrust zone, these ophiolites were moved to the upper part of the consolidated crust.

Plunging under the Zheltau short terrain, within the Shu-Ili Mountains, a fragment of the Zhalair-Naiman suture is traced in the form of a strip of three positive oval velocity anomalies. Until the end, the nature of the deepest crustal anomaly remains unclear.

Sarytum and Tekeli suture zones are fixed by a lens with a positive velocity anomaly, possibly belonging to ophiolite covers. Within the Junggar-Balkhash folded area, positive velocity anomalies of this type are noted in the consolidated crust, which, as they approach the Aktau-Junggar terrane, are divided into thrust and down lift components. In the lower crust near the interface of M, negative velocity anomalies appear in the basite-granulite plates, possibly associated with ophiolites. In the middle part of the consolidated crust there is a negative velocity anomaly associated with granite Permian pluton.

Aktau-Junggar terrane is characterized by negative velocity anomalies in the lower and middle crust. The Middle Crust anomaly is identified with the Proterozoic gneiss complex that has undergone partial metamorphic transformations and partial melting in the Riphean, Ordovician, Devonian, Carboniferous and Permian, which is fixed by the presence of granitoid plutons of the corresponding age on the modern surface. The band characteristic of the microcontinent, upper crust positive velocity anomalies may be due to the ophiolite covers from adjacent zones and the carbonate covering complex.

The direction along the Aktogai profile 245 km long, crossing the border of the Junggar-Balkhash folded area with the Balkhash segment of the Late Paleozoic volcano-plutonic belt is selected as the north-eastern extension of the Turkestan profile. The Junggar-Balkhash structural unit and the corresponding oceanic basin of the same name, as in the Turkestan profile, are characterized by the same features, that is, the presence of positive velocity anomalies in the upper crust and upper crust, possibly associated with Lithoplastins of Ordovician ophiolites. In the middle part of the crust of the South Balkhash region there is a large negative velocity anomaly, which is caused by the melting of basin greywackes with the formation of supersubductional granite batholith, whose outcrops are noted in the form of Permian granites.
Under the Balkhash fragment of the Pri-Balkhash volcano-plutonic belt at a depth of about 10 km, a positive velocity band is fixed, associated with a stratified gabbro-peridotite plate, the derivatives of which are likely to be Early Triassic syenites and granosyenitic ring arrays, which broke through volcanics, and they are part of the same pattern. It is located in the roof of the Muzbeliskypaleosubduction zone, fixed by a series of sustainable reflecting areas interpreted as the surface of the thrusts in the Southern Balkhash and under the Balkhash-Ayaguz terrain. Magnetic and gravitational fields in this area are characterized by a very complex structure. For the bottoms of the lower crust, an active, decompressed state characterized by negative velocity anomalies is characteristic here.

During the early Paleozoic, the foundation of the composite Kazakhstan paleocontinent was formed by successive accretion and subsequent amalgamation of Precambrian microcontinents (probably formed by Eastern Gondwania) and from Cambrian to Early Silurian island arcs [4]. These numerous Early Paleozoic accretion-collision events and, related magmatic series, gave rise to the formation of the Kazakhstan paleocontinent at the end of the Ordovician [2], and not at the end of the Silurian as a number of researchers believe [5]. As a result, the Early Paleozoic granitoids are associated with collision-accretion events that create the Kazakhstan paleocontinent, which can be found throughout Kazakhstan and the NTS foundation [2].

After this amalgamation, the composite Kazakhstan paleocontinent shifted to the north during the late Ordovician-Early Devonian [2]. During the Middle and Late Paleozoic, the Paleocontinent was isolated from Siberia, Europe and Tarim, and was surrounded by the Ob-Zaisan (NW), Ural (SW), Turkestan (SE) and Junggar-Balkhash (NE) oceans [2] (figures 2-3). These ocean basins are considered as sub-basins of the Paleo-Asian Ocean.

The subsequent tectonic history of Kazakhstan’s paleocontinent (figure 3) is linked to Siberia – Paleokazakhstan – Tarim collision. The subduction of the Junggar-Balkhash oceanic lithosphere under the northeastern flank of the Kazakhstan paleocontinent began in the early Devonian, which affected the main Andean magmatic belt [7] (figure 3). By the end of the Devonian period, the subduction zones moved to the east and arc magmatism continued in the Ili-Balkhash region to the Late Carboniferous-Early Permian period [7]. Simultaneously, to the south-east of the continent, the Turkestan Ocean was closed, starting from the Late Carboniferous to the early Permian, and was the result of a clash between Kazakhstan and Tarim (figure 3). In connection with the general convergent movements between Tarim and Siberia, with Kazakhstan imprisoned between them, the Devonian-Early Mesozoic oroclinic curve of the Kazakhstan paleocontinent appeared [19].

After the final accession of the Kazakhstan paleocontinent to Paleo-Eurasia in the Permian, the intracontinental mode prevailed (figure 3). During the late Permian-early Mesozoic period.

The Kazakhstan oroklin became completely closed and this territory was subjected to (post-) collision deformations and large-scale shear movements (for example, Main Karatau, Zhalair-Nyman, Main Junggar faults) [8] associated with the relative movement of the Baltic, Siberia, Junggar and Tarim and the tectonic effect of collisions occurring at the plate boundaries of several hundred kilometers [21]. Also in Permian period, the type of magmatism changes from a collision setting to a post-collisional [7]. The traces of these postcollisional magmatic series (mainly A-type and alkali magmatism) can be found, for example, in the Kyrgyz North Tien Shan [22], Central Tien Shan China [23], Western Junggar [24]. In connection with the closure of the ocean Paleotetis, several accretion-collisional events occurred as a result of which the Mesozoic structure of the Tien Shan was created [25]. These events are often grouped as Cimmerian orogenesis and include collisions of the Pamir-Tibet blocks.

In the Cenozoic period, this region became tectonically more stable and it is believed that the peneplain was formed at the end of the Cretaceous - the beginning of the Paleogene period [26]. From the Early Eocene, large structures in the southern part of the CAOB were activated, which is associated with the closure of the Ocean Tethys and the amalgamation of island arcs and continental fragments of Greater India and southern Eurasia [13]. From the end of the Oligocene-Miocene period to the present, the southern segment of the CAOB was subjected to deformation, this time caused by
the Indo-Eurasian collision, as indicated by the data of thermochronology [27], lithologic-facial [2] and structural [8] analyzes.

Figure 3. Paleogeographic and palinspastic schemes of Central Eurasia, Early Carbon, Vise-Serpukhov (1, 2), Early (3, 4) and Late Permian (5, 6)
In the Shu-Sarysu basin, there are small gas fields with explored reserves of about 30 billion cubic meters [1]. The productive deposits are confined to the Visean sandstones and the lower (subsalt) Permian formation. The main source of gases is the Lower Visean coal-bearing stratum, developed in the southeast, where industrial hydrocarbon deposits are located. The Perm salt-bearing stratum serves as a regional seal. The study of the material composition of the Lower Carboniferous-Permian rocks of the southeastern part of the Shu-Sarysu section has made it possible to establish the distribution of dispersed organic matter (DOM) [31]. The mineralogical interpretation of the analysis results showed the presence of quartz, feldspar, minerals of the group of layered silicates, carbonates, etc. It has been established that: 1) $C_{org}$ concentration in limestones occurs in micropores, as well as in cracks and chips of carbonates; 2) the background content of DOM in the Carboniferous-Permian section is evenly distributed in the range of 0.1-0.5%; 3) in terrigenous rocks, which include feldspars and clay minerals, the DOM content reaches 2%; 4) the data obtained allow correction of the forecast resources of the southwestern part of the Shu-Sarysu basin [31].

In the Ili and Balkhash basins, organic matter (OM) is found in many of the rocks represented. By thermal and X-ray structural analyzes, it was found that various inclusions are diagnosed according to a characteristic of organic matter — intensive oxidation of CO to the level of CO$_2$ and removal of the volatile combustion product to the atmosphere. During thermal analysis, the samples register on their curves only two subtle thermal effects associated with burnout in samples of a very small amount (0.3-0.5%) of organic inclusion. From the available amount of OM in the rocks, their differentiation by genetic affiliation was reduced to the isolation of the subcolloidal type. This type of diffuse chemical agent is associated with the formation of liquid hydrocarbons. In the clay and carbonate minerals, OM is presented, while the particles of organic matter are packed in the micropores of the carbonate-clay aggregate, some of which are part of the interlayer space of minerals. Such formations in favorable geochemical environments usually serve as OM acceptors [32].

In general, the potential of the source rocks of these sedimentary basins is low, which is associated with the inland sedimentation situation and the fact that the oil-producing strata on large areas contain a limited amount of OM.

The work was done with the financial support of the program number BR05236800 "Solving strategic and applied problems in the oil and gas industry of Kazakhstan" according to the contract number 208 of March 19, 2018. with Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan.
References

[1] The deep structure and mineral resources of Kazakhstan vol. 1 2002 Depth structure and geodynamics (Almaty: Oil and gas) p 272

[2] Atlas of lithological and paleogeographic, structural, palinspastic and geoeological maps of Central Eurasia 2002 (Almaty: YUGGEO) I 11 38

[3] Sengor A M C, Natal’ in B A , Burman VS 1993 Evolution of the Altai tectonic collage and Paleozoic crustal growth in Eurasia Nature 364 (6435) pp 299–307

[4] Mosakovskiy A A, Ruzhentsov S V, Samygin S G, Kheraskova T N 1993 Central Asian Fold Belt: Geodynamic Evolution and Formation History Geotectonics 6 pp 3–33

[5] Dobretsov N L 2003 Evolution of the structures of the Urals, Kazakhstan, the Tien Shan and the Altai-Sayan region in the Ural-Mongolian folded belt (Paleoasian Ocean) Geology and Geophysics 1–2 pp5-27

[6] Avdeev A V 1994 Paleogeodynamic map of South Kazakhstan Geology and Geophysics 35 pp 111-116

[7] Windley B F, Alexeev D, Xiao W J, Kroner A, Badarch G 2007 Tectonic models for accretion of the Central Asian orogenic belt Journal of the Geological Society 164 pp 31–47

[8] Korobkin VV, Buslov MM 2011 Tectonics and geodynamics of the western Central Asian Fold Belt (Kazakhstan Paleozoides) Russian Geology and Geophysics 50 pp 1585-1603

[9] Xiao WJ, Windley B F, Huang B C, Han C M, Yuan C, Chen H L, Sun M, Sun S, Li L 2009 End-Permiotand-Mesotricassic termination of the accretionary processes of the southern Altai: implications for the geodynamic evolution, Phanerozoic continental growth, and metallogeny of Central Asia International Journal Earth Science 98 pp 1189–1217

[10] Abdullin A A 1986 Geology and metallogeny of Karatau (Alma-Ata: Science of the Kazakh SSR) vol.1 Geology pp 240

[11] Chu-Ili ore belt The structure of the earth’s crust (Alma-Ata: Science of the Kazakh SSR) 1980 p 196

[12] Buslov M M, Watanabe T, Smirnova L V, Fujiwara I, Ivata K, De Grave I, Semakov N N, Travin A V, Kryanova A P, Koch DA 2003 The Role of Shifts in the Late Paleozoic-Early Meso-Cenozoic Tectonics and Geodynamics of the Altai-Sayan and East Kazakhstan Folded Areas Geology and Geophysics 44 (1-2) pp 49-75

[13] Buslov MM 2011 Tectonics and geodynamics of the Central Asian fold belt: the role of the Late Paleozoic large-amplitude shifts Geology and Geophysics 52(1) pp 66–90

[14] De Pelsmaeker E, Glorie S, Buslov M M, Zhimulev F I, Poujol M, Korobkin V V, Vanhaecke F, Vetrov E V, De Grave J 2015 Late-Paleozoic emplacement and Meso-Cenozoic reactivation of the southern Kazakhstani granitoid basement Tectonophysics p 416-433

[15] Biske Y S, Konopelko D L, Seltmann R 2013 Geodynamics of Late Paleozoic Magmatism in the Tien Shan and its Framework Geotectonics 47 pp 291–309

[16] Seltmann R, Konopelko D, Biske G, Divaev F, Sergeev S 2011 Hercynian post-collisional magmatism in the context of Paleozoic magmatic evolution of the Tien Shan orogenic belt Asian Earth Science 42 pp 821–838

[17] Buslov M M, De Grave J, Korobkin V V 2013 Growth and deformation of Eurasia in the Late Paleozoic – Mesoic: insights from the geodynamic and tectonic evolution of the Central Asian orogenic belt Germany: Central Asia Workshop pp 16-18

[18] Smirnov AV, Korobkin VV 2003 Tectonic Map of Kazakhstan, scale 1:1 000000 (Principles, legend, geological structures) Izvestiya Nan RK, Ser geol. 2 pp 77-89

[19] Abrajevitch A, Van der Voo R, Bazhenov M L, Levashova N M, McCausland P J A 2008 The role of the Kazakhstan orocline in the late Paleozoic amalgamation of Eurasia Tectonophysics 455 pp 61-76

[20] Choulet F, Chen Y, Wang B, Faure M, Cluzel D, Charvet J, Lin W, Xu B 2011 Late Paleozoic paleogeographic reconstruction of Western Central Asia based upon paleo-magnetic data and its geodynamic implications Asian Earth Science 42 pp 867-884
[21] Sengör AMC, Natali', BA 1996 Paleotectonics of Asia: fragments of a synthesis The Tectonic Evolution of Asia. Cambridge University Press pp 486–641

[22] Kröner A, Hegner E, Lehmann B, Heinhorst J, Wingate MTD, Liu DY, Ermelov P 2008 Palaeozoic arc magmatism in the Central Asian Orogenic Belt of Kazakhstan: SHRIMP zircon ages and whole-rock Nd isotopic systematic Asian Earth Science 32 pp 118-130

[23] Dong Y, Zhang G, Neubauer F, Liu X, Hauzenberger C, Zhou D, Li W 2011 Syn- and post-collisional granitoids in the Central Tien Shanorogen: geochemistry, geochronology and implications for tectonic evolution Gondwana Res. 20 pp 568-581

[24] Shen P, Pan H, Xiao W, Chen,X, Seitmuratova E, Shen Y 2013 Two geodynamic–metallogenic events in the Balkhash (Kazakhstan) and the West Junggar (China): Carboniferous porphyry Cu and Permian greisen W–Mo mineralization Int.Geo.Rev. 55 pp 1660-1687

[25] Yang W, Jolivet M, Dupont-Nivet G, Guo Z, Zhang Z, Wu C 2013 Source to sink relations between theTian Shan and Junggar Basin (northwest China) from Late Palaeozoic to Quaternary: evidence from detrital U–Pb zircon geochronology Basin Res. 25 p 219-240

[26] Allen M B, Alsop G I, Zhemchuzhnikov V G 2001 Dome and basin refolding and transpressive inversion along the Karatau fault System, southern Kazakhstan J. Geol. Soc.Lond. 158 pp 83-95

[27] Bullen M E, Burbank D W, GarverJ I, Abdakhatmatov K Ye 2001 Late Cenozoic tectonic evolution of the northwestern Tien Shan: new age estimates for the initiation of mountain building GSA Bull. 113(12) pp 1544-1559

[28] Hendrix M S, Dumitru T A, Graham S A 1994 Late Oligocene–Early Miocene unroofing in the Chinese Tien Shan — an early effect of the India–Asian collision Geology 22 pp 487-490

[29] Thomas J, Cobbold P R, Shein V S, Le Douaran S 1999 Sedimentary record of late Paleozoic to Recent tectonism in Central Asia — analysis of subsurface data from the Turan and Kazak domains Tectonophysics 313 pp 243-263

[30] Korobkin V V, Smirnov A V 2006 Tectonofacial analysis - the basis of the tectonic map of Kazakhstan of 1: 1000 000 scale Geology and minerals of the World Ocean, NAS of Ukraine 4 pp 91-105

[31] Korobkin, V V, Samatov I B, Tulemissova Zh S 2018 The data on the study of the mineral composition and dispersed organic matter in the rocks of the stone-coal-Perm section of the southwestern part of the Shu-Sarysuibasin Almaty: Geology and Subsoil Protection KazGEO 2(67) pp 16-30

[32] Tulemissova Zh S, Korobkin V V, Samatov I B 2018 Data from the study of the material composition of the promising oil source complex of the Mesozoic – Cenozoic cover of the Ili basin (Novosibirsk: Publishing House of the SB RAS) 188 pp 156-158