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AGE AND GEODYNAMICS OF CENTRAL KAZAKHSTAN CARBON ORE COPPER PROVINCES

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ВІК І ГЕОДИНАМІКА ЦЕНТРАЛЬНО-КАЗАХСТАНСЬКОЇ КАМ'ЯНОВУГІЛЬНОЇ МІДНО-РУДНОЇ ПРОВІНЦІЇ

Purpose. To evaluate geodynamic processes of copper-ore deposits of the central and south-eastern regions of Kazakhstan which are spatially separated and different in genesis.

Methodology. We use the new U-Pb (zircon), Re-Os (molybdenite) dating and older K-Ar (biotite) data obtained from the use of the conditional analysis by biotite (K2O >7 %) only.

Findings. Based on the latest dating of rocks and ores of copper-porphyry deposits of Central Kazakhstan and Western Zhongar (China), a new model of the emergence and development of the copper-ore province is proposed.

Originality. A model of the origin and development of the Central Kazakhstan copper-ore province, uniting the fields of different origin, age and ore potential in a single ore-magmatic system is developed. The model of porphyry copper deposit formation (accumulation - transportation – sag) perfectly explains the different genesis of the Central Kazakhstan coeval deposits.

Practical value. Within the Central Kazakhstan copper-ore province it is necessary to conduct isotopic studies. Caldera ore magmatic system Besshoki is a priority object for a detailed study, based on the fact that according to statistics, about 85 % of copper-porphyry, and 100 % of copper-skarn ores occur either in magmatic rocks or in contact to them.

Keywords: *geodynamics, dating, province, magmatic rocks, Central Kazakhstan*

Introduction. On the basis of geological dating the correlation is to be established as well as reconstruction of geological situations of the past and the magmatic system connection with the fields of the copper-ore coal province which are different in genesis, age and potential are to be carried out.

Analysis of the recent research and publications. New isotope U-Pb and Re-Os methods for dating rocks and ores of the fields, as well as application of the mantle plumes models and the generalized genetic model of copper-and-porphyritic fields allow considering all the fields of the Central Kazakhstan province as a uniform geodynamic process of long development (~35 million years).

The process energy is connected with the Central Kazakhstan plume that formed the mode of "tectonics of hot fields" in the lower layers of the crust in the Carbonic period.

Unsolved aspects of the problem. Until quite recently, the separated spatially and different in genesis copper-ore fields of the central and south-east regions of Kazakhstan, as well as similar fields of the adjacent areas of Zhongar (Fig. 1) were considered out of the connection with the uniform geodynamic process. Little age difference and rather a wide range of genetic types, such as copper-and-porphyritic, copper-skarn and copper-nickel, magmatogene were considered as obstacles.

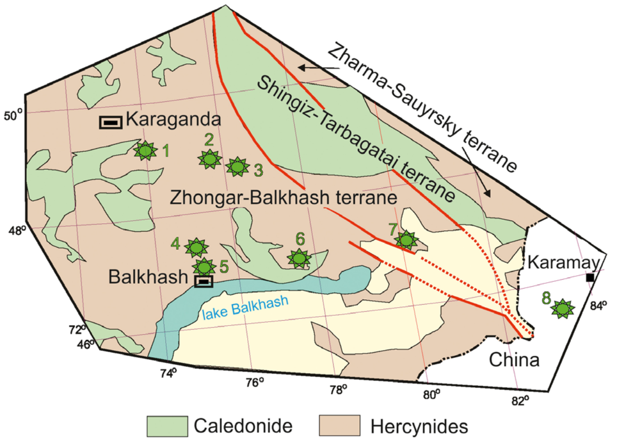


Fig. 1. Position of copper deposits in the Zhongar-Balkhash terrane:

1 – Kamkor; 2 – Bayskoye and Ozernoye; 3 – Besshoky ore field (5 small deposits and ore occurrences); 4 – Borly; 5 – Konyrat (Kounrad); 6 – Sayak I-III; 7 – Aktogay-Aidarly (2 deposits) 8 – ore area Baogutu-Adayi (8 small deposits and ore occurrences). In most cases, the listed deposits are associated with similar intrusions like batholith, the size of which is overlapped with marks of deposits. An exception is the Konyrat (Kounrad) deposit associated with the largest Tokyrau batholith

Objectives of the article. The analysis of new U-Pb and Re-Os methods for dating with involvement of separate old K-Ar of data showed a long (about 35 million years) evolution of the Central Kazakhstan coal copper-ore province. Its development came in three phases.

The main phase 339–327 mln. years. There were formed three large-scale deposits: Konyrat, Sayak and Aktogay. Their unification in this phase is proved by the coevality of magmatic rocks and their identical structure. The existing genetic distinctions are explained from the position of the general theory of forming copper-and-porphyritic and copper-skarn fields. Copper stocks were estimated at tens and hundreds million tons.

The additional phase 316–309 mln. years. There were formed more than 10 small fields in the territory of Kazakhstan and the adjacent region of China. They include three genetic types: copper-and-porphyritic, liquation and scattered-metasomatic at the level of rich geochemical halos. All of them are united by the close identical age of magmatic rocks and in the Borly field there was proved the identical age of magmatic and ore processes. Copper stocks make hundreds of thousands of tons.

The post-ore phase 309 mln. years and younger. Small bodies of granodiorites, granodiorite-porphyries and bimodal complex of dikes. There are no copper manifestations, but it is possible that arsenic gold in Sayak-4 is connected with this complex of dikes.

Presentation of the main research. For justification of the model there are used new U-Pb (zircon), Re-Os (molybdenite) methods for dating and the old K-Ar (biotite) data obtained as a result of using only standard analyses on biotite (K_2O >7 %). The first dating defines the age of magmatic rocks, the second one – the age of metallogenesis, and the third one – the supplement data on zircon in which there are discrepancies. When obtaining the coordinated dating it is possible to define the ore and magmatic system evolution in general in which the age of mineralization is always younger than the magmatic process and by million years**.**

New isotope studies established that the development of the copper-ore province took place in three phases: the first one is the main phase, the second one is additional and the third one is post-ore. At this, the ore potential of the main phase is much higher than that of the additional phase.

The main phase. In the main phase there formed three large fields: Konyrat, Sayak and Aktogay.

Konyrat. The simplified geological map of the Konyrat field is shown in Fig. 2. In the geological development of the field there are distinguished such episodes:

1) formation of the volcanogenic sedimentary C_1t(?) complex featuring basalts, andesites and dacites;

2) formation of volcanic dome structure (an ignimbrite, lava breccias, caked tufa, streams the spherolite porphyries and the fluidic felsite porphyries) with obvious structural disagreement on the volcanogenic and sedimentary C_1(t?) complex;

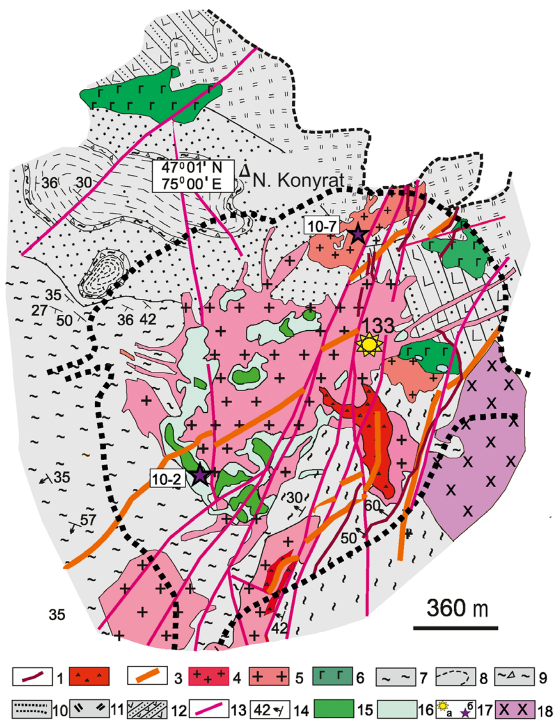


Fig. 2. Scheme of the geological structure of the Konyrat deposit with simplifications:

1 – "pebble" dike; 2 – explosive breccia undivided; 3 – granodiorite-porphyry dikes; 4 – stock quartz diorite – quartz-granodiorite porphyry; 5 – porphyritic quartz-plagioclase granodiorites – plagiogranites; 6 – stocks diabase; 7–12 – effusive-extrusive complex: 7 – felsite; 8 – micro spherulite porphyries; 9 – ignimbrites; 10 – quartz porphyry; 11 – sintered tuffs; 12 – volcanic-sedimentary formations; 13 – undifferentiated faults; 14 – elements of occurrence; 15 – rich ore; 16 – simple ore; 17 – sampling points on isotopes: a – by P. Yermolov, 2013; b – by X. Chen, 2012; 18 – biotite granodiorite late Devonian

3) subsidence of the ring collapse caldera;

4) intrusion of granodiorite magma into the formed empty space and formation of the central caldera stem, 339 million years;

5) metallogenesis in the form of explosive ore breccia, shield and fracture ore metasomatosis, 327 million years;

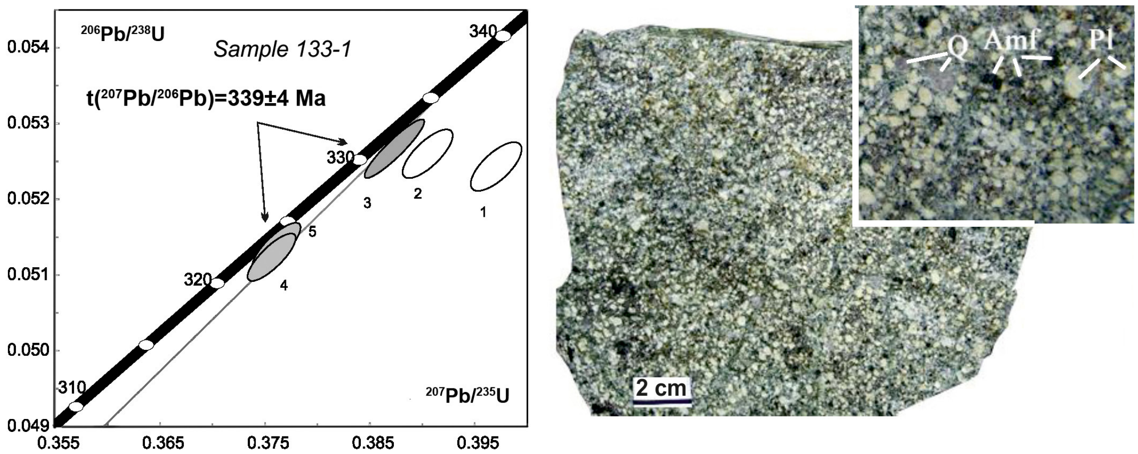
6) phase of relative rest;

7) small intrusions of granodiorite-porphyries of the additional stage, 308 million years.

At this the medium-grained granodiorites developed to the south-east of the ditch (Fig. 2) and referred earlier to the deeper facies of the Balkhash C_1 complex turned out to be, according to our data, late Devonian: 369.2±4.9 and 381.8±3.1 Ma.

The age of the volcanogenic and sedimentary complex of episode 1 has not been established authentically. The expected age of C_1t is determined by crinoids. The age of the porphyritic granodiorites of the main stage is determined on zircon by the classical "wet" method in the laboratory of the Institute of the Precambrian Geology and Geochronology of the RAS in St.-Petersburg by A. B. Kotov (Yermolov, et al., 2015, Table 1). The rock example was selected from the operating face of the east board of the Konyrat pit in 2014 (test 133 in Fig. 2).

The rock has no visible signs of contact with metasomatic processes, the age at the concordia crossing with discordia and on $^{207}Pb/^{206}Pb$ corresponds to C_1v_1 (Fig. 3, Table 1). From this it follows that geological and isotope



a *b*

Fig. 3. Discordia (a) and polished sample (b) of porphyritic granodiorite of the main phase of the Konyrat deposit [Yermolov P. V. et al., 2015]. Pictured: Q-, Amf-amphibole, Pl-plagioclase

Table 1

Results of U-Pb geochronology research on accessory zircon from porphyritic biotite-hornblende granodiorite of the main phase, the Konyrat deposit (sample 133)

№	Size fractions (micrometer) and the characteristic of zircon	U/Pb*	Isotope ratio				
			$^{206}Pb/^{204}Pb$	$^{207}Pb/^{206}Pb$a	$^{208}Pb/^{206}Pb$a	$^{207}Pb/^{235}U$	$^{206}Pb/^{238}U$
1	>150, 20 grains	17.71	1578	0.0549 ± 1	0.1971 ± 1	0.3971 ± 13	0.0524 ± 1
2	100–150, 23 grains, *A* = 20 %	17.28	933	0.0539 ± 1	0.1983 ± 1	0.3906 ± 12	0.0526 ± 1
3	50–85, 40 grains	18.04	2166	0.0532 ± 1	0.1924 ± 1	0.3757 ± 8	0.0512 ± 1
4	<50, 60 grains	18.27	3582	0.0531 ± 1	0.1832 ± 1	0.3761 ± 6	0.0514 ± 1
5	100–150, acidizing 2.0	18.46	45813	0.0533 ± 1	0.1333 ± 1	0.3874 ± 4	0.0527 ± 1

№	Dimensional fraction (mkm) and characteristics of zircon	Rho	Age: $^{207}Pb/^{235}U$	Age: $^{206}Pb/^{238}U$	Age: $^{207}Pb/^{206}Pb$
1	>150, 20 grains	0.71	340 ± 1	330 ± 1	409 ± 5
2	100–150, 23 grains, *A* = 20 %	0.75	335 ± 1	331 ± 1	365 ± 5
3	50–85, 40 grains	0.81	324 ± 1	322 ± 1	336 ± 3
4	<50, 60 grains	0.80	324 ± 1	323 ± 1	333 ± 3
5	100–150, acidizing 2.0	0.92	333 ± 1	331 ± 1	343 ± 1

*Notes: a – isotope ratios corrected on the form and usual Pb; Rho – coefficient of correlation of the 207Pb/235U–206Pb/238U ratios errors; A = 20 % – amount of the substance removed in the course of aero-abrasive processing of zircon; * – the weight of zircon was not defined; acidic form. 2.0 – acid processing of zircon with the set exposition (hours); 20 gr – amount of zircon grains in the micro-weight. The error values (2σ) correspond to the last significant figures* data show the approved time of forming the volcanic plutonic structure of Konyrat as C_1t-v_1.

In 2013 similar works were carried out by the staff of the Academy of Geological Sciences of China under the leadership of Professor H. Chen, Beijing. From the Konyrat pit there were selected two samples: xh080910-2 (the southern board) and xh080910-7 (the northern board) for dating the main and additional phases of the Balkhash complex. The geological position of the samples is shown in Fig. 2. The age of the xh080910-2 sample by 12 points made 327.3±2.1; MSWD = 0.95. This dating can be considered the age of zircon participating in the ore process and transformed by it. The sample in the northern board of the pit was taken from the small body of granodiorite-porphyries which was not affected by metasomatosis. The age of the xh080910-7 sample by 10 points made 308.7±2.2 million years; MSWD = 1.03. These rocks, as it will be shown below, belong to the post-ore phase which was not manifested on each field of the province. In this case, the rock at this point was not affected by the ore process, and the grains of zircon have the primary magmatic structure.

Sayak. Three fields of this ore field are located in contact with the Umit bathylite and belong to the skarn type. The Umit bathylite was dated before as C_{2-3}, P_1, C_1 according to paleontology, paleophytology and K-Ar method for dating. All three methods for determining the age have their weaknesses and therefore the results of the dating can have divergences.

Thus, for example, in the weak point the K-Ar method is the low temperature of destruction of the biotite lattice and change in the developed balance of isotopes at the same time. Therefore any repeated warming up of biotite leads to violation of the formed isotope balance and restart of the radiogenic clock. For the Umit bathylite Yu. A. Kostitsyn cleared long-term selections of K-Ar methods for dating from non-standard micas. The obtained average age was comparable to that of porphyritic granodiorites of Konyrat: 336±13 Ma. In Sayak H. Chen has selected and studied three samples. The xh080917-6 sample represents granodiorite of the Moldybay body with which the Sayak-1 field is connected. It has the mineralogical structure and the age identical to the main phase of the Konyrat field: phenocryst of plagioclase 10–15 %, matrix: quartz 25–30 %, plagioclase 20–23 %, potassium spar 7–10 %, protobase 3–8 %, biotite 3–6 %. The age is 335±2 Ma. Taking into account admissible errors the age turns out identical to that of granodiorite of the main phase of the Konyrat field. Two other samples were taken at the site to the south of the Sayak III pit at a small distance from each other (Fig. 4). This part of bathylite is crossed by a very dense belt of

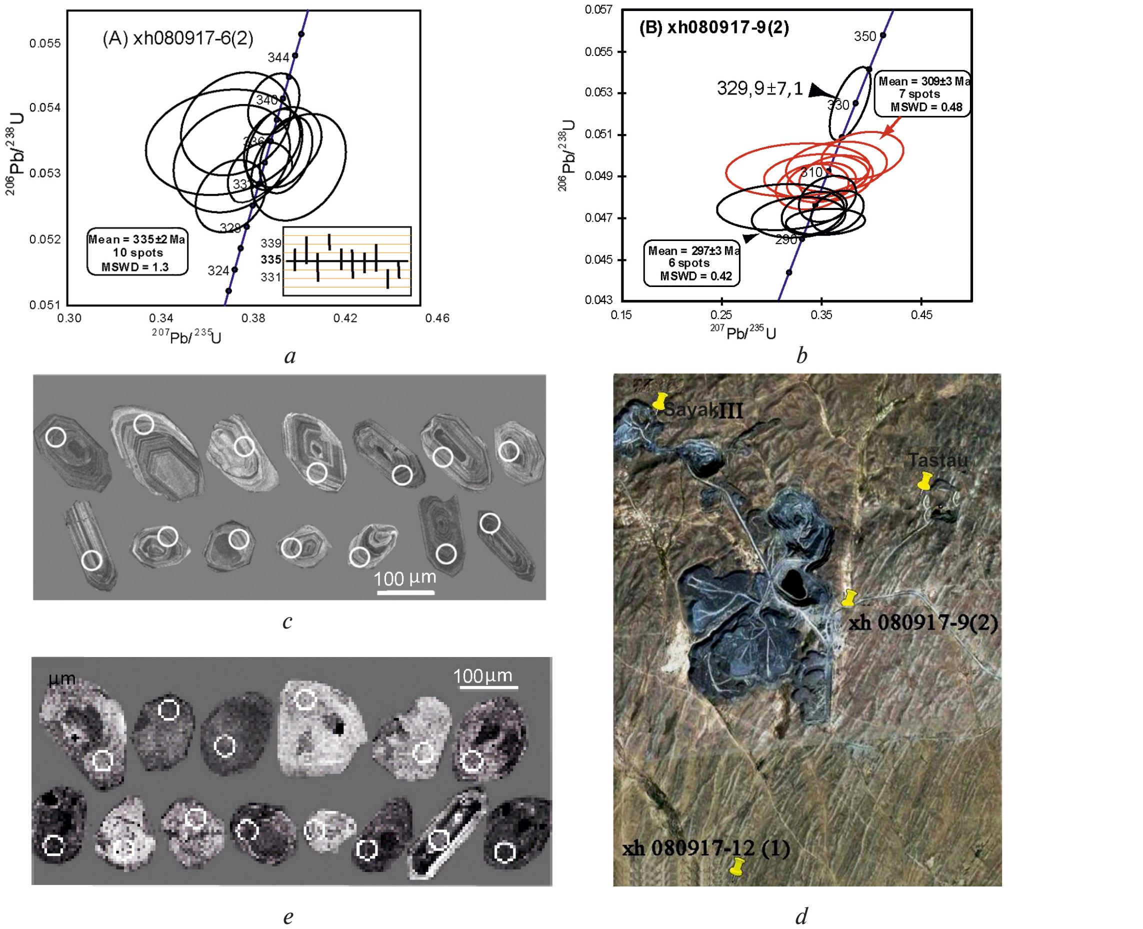


Fig. 4. The dates by X. Chen (Chen, et al., 2014):

a – sample Concordia xh 080917-6 (2) of the granodiorite of Moldybay massif (Sayak I); b – Concordia sample xh080917-9 (2) of the granodiorite of Umit massif in Fig. 4, d, c, e – the structure of zircon samples: xh 080917-6 (2), massif Moldybay and xh 080917-9 (2) – massif Umit at the intersection of its tight belt late dikes

dikes of the basic, diorite and granodiorite-porphyritic structure. At the points of selecting the above-stated samples the density of dikes reaches 10–15 per 100 meters (Fig. 4, *d*). During their implementation there took place a repeated increase in the thermal field under the impact of which zircon transformation and the loss of the primary isotope memory by it occurred. The comparison of Figs. 4, *c* and 4, *e* shows the primary rhythmical and zone magmatic zircon in the first picture and the secondary transformed zircon with "cloudy" (not magmatic) structure in the second one. The primary magmatic structure remained only in one grain (in the right corner of the lower row).

As a result, the isotope memory was updated twice in this rock after forming magmatic zircon: in the late Carbonic period (309 Ma) and in Perm (297 Ma) (Fig. 4, *b*), while the primary memory was held only in one grain whose age was 329.9±7.1. Taking into account the admission ±7.1 Ma, the age can be interpreted as 337 Ma, i.e. identical to the xh080917-9(2) sample of zircon and with the 133 sample in the Konyrat pit. Thus, the impact of the external factor on zircon of the xh080917-9(2) and xh08091712(1) samples after their crystallization is obvious.

Aktogay. In the Aktogay ore field two fields have been studied and are at the State balance: Aktogay and Aydarly. Both are referred to the copper porphyritic type. The present day level of the fields cut, unlike the Konyrat, belongs to meso-abyssal, but the presence of explosive breccias and a quartz kernel assume the existing but bald-headed, volcanic structure. H. Chen has studied two samples: diorites of the first phase and granodiorites of the second phase.

The results repeated exactly the results in Konyrat: pure diorites showed the age of 335.7±1.3 Ma, mineralized granodiorites (~0.2% of Cu) showed the age of 327.5±1.9 Ma.

So, in three deposits (ore fields) of different genetic types and formed at different depths there were established three couples of dating in the main phase of forming the copper province. In Table 2 there are shown new U-Pb methods for dating (Chen, et al., 2014, Yermolov, et al., 2015) in three deposits (ore fields) of the main phase of forming the copper province. For comparison there is shown the average age of the Umit bathylite obtained by after rejection of the analyses with biotite that was non-standard for potassium. The age of rocks of the pre-ore phase is in the range of 335–339 million years, which corresponds to the Visean phase of the early Carbonic period on the International Geochronological Scale. The data for the Umit bathylite are also in accord with it. The rocks with the imposed mineralization and the affected strong indications of the repeated thermal field were made on average by 10 million years younger that can indirectly testify to the time of manifestation of the ore process. But in this case all the dating given in the Table corresponds to the early Carbonic period. The same age of ore-bearing magmas in all three large-scale copper deposits allows considering their evolution in the uniform geodynamic process. The age level of 327–339 Ma is the beginning of the first wave of introducing moderate sour campanite magmatism (quartz diorites, monzo-diorites, tonalite, granodiorite) which has formed the Central Kazakhstan copper province.

All three fields can be united in a common model of origin that includes such evolutionary phases: accumulating metal in the basic magmatic center – heat-and-mass transfer to the peripheral center – explosive nature of violation of the peripheral center integrity – ore deposition (unloading of the ore fluid). In this model in the Konyrat all four phases are manifested.

In Sayak there are noted two evolutionary phases: accumulating metal in the basic center and unloading the ore fluid at the meso-abyssal level in the medium of limestones which played the role of the geochemical barrier. In the Koldar massif (the Aktogay ore field) there is obviously observed a trace of the conductor for heat-and-mass transfer in the form of the weakened zone crossing the massif in the subwidth direction, along which there is placed a chain of copper geochemical halos. The Aktogay and Aydarly fields are, in fact, the richest halos in this chain. The identical isotope datings unite such a model (from the point of view of such a concept as "geological time"). The common time assumes as well the common energy source, and in particular, the upper cloak in the form of a plume or a hot spot. In the territory of Kazakhstan the center or one of the sites of the central area of the plume, according to the isotope analysis of ore-enclosing magmatic rocks, was located near the Koldar massif (Aktogay-Aydarly field). For the Sayak there are no data on magmatic rocks, but in Konyrat the $_{e}Nd_{(t)}$ values correspond to the mantle-crust rocks contaminated with the mature crust.

The additional phase. By the results of isotope and geochronological studies the duration of the second phase of forming the copper-ore province is estimated at

Table 2

Age of the magmatic rocks of the main stage of the Central Kazakhstan copper-ore province

U – Pb dating Shrimp and "wet" classic methods (Chen, et al, 2014, Yermolov, et al., 2015)						K-Ar
Konyrat		Sayak		Aktogay		Sayak
Porphyritic granodiorite		Quartz diorite massif Moldybay	Converting granodiorite massif Umit under the influence of a young dyke belt	Diorite	Granodiorite	The average age of the batholith Umit
Barren	Mineralized	Barren	Barren	Barren	Mineralized	
339±4 Ma	327.3±2.1 Ma	**335±2 Ma**	329.9 ± 7.1 Ma	**335.7±1.3 Ma**	327.5±1.9 Ma	**336±13 Ma**

5–6 million years, from 315 to 310–309 million years. In the absolute chronology this time corresponds to the Serpukhov phase of the Carboniferous Period of the World Geochronological Scale. The main differences in the fields of the additional phase are as follows: 1) isotope studies established the closest age connection of the fields with the ultrabasic magmatism and Cu-Ni mineralization; 2) the size of the fields and commercial stocks of the basic metals is 1–2 orders lower than that of any of the fields of the main phase: Kamkor 200 kt, $Cu_{av.}$ 0.56 %; Bayskoye 400 kt, $Cu_{av.}$ 0.39 %; Ozernoye 500 kt, $Cu_{av.}$ 0.36 % (the data of the Centrgeolsyemka JSC that explored our fields); Borly (Chen, et al., 2014) about 600 kt, $Cu_{av.}$ 0.34 %, Baogutu 660 kt, $Cu_{av.}$ 0.28 %, Besshoki (there are no balance reserves, only predictions).

Bayskoye and Ozernoye. The main phase at the sites of developing the Ozernoye and Bayskoye fields involves biotite-amphibolic granodiorites that are followed by fine-grained granites and numerous and various in structure dikes. The massifs compose almost a uniform body and are divided only by the hornfelsed roof. Both massifs are referred by the previous researchers to the Topar C_2 complex. The massifs are 15–20 % naked therefore the samples were selected from prospecting developments and the core of wells which were drilled in the previous years at the South-Konstantinovskaya Square of the Bayskoye field. So far there are the following data on the ore-enclosing magmatic rock age.

1. Granodiorites break through multicolored deposits of the Devon and grey deposits of the problematic Tournai stage of the early Carbonic period.

2. In the Ozernoye massif potassium-argon dating has the age from 218 to 338 million years. There was studied biotite with the potassium content of 2.45 and 2.29 % that considerably impacted reliability of definition.

3. In 2005 at the A. P. Karpinsky Russian Geological Research Institute Isotope Center there was studied a zircon monofraction from the Bayskoye massif by the local isotope and geochronological method. There were defined the uranium-lead ratios in 10 grains of zircon and the obtained values were taken out to the uranium-lead concordia (Fig. 5). There was obtained the age of 316±2 million years. This figure corresponds to the Bashkir stage. This age is accepted by us as the age of the copper and porphyritic level in the Karagayly ore district of the Central Kazakhstan copper-ore province.

Kamkor. The Kamkor massif is located 80 km to the west of the Bayskoye field. It has the peridotite-gabbro structure and is specialized in copper-nickel mineralization. In the structure of this massif there also participate granodiorites of the Topar type.

The concordia of zircon separated from the mineralized interval of gabbro-norites of well 32 (Baydalinov, et al., 2008) is shown in Fig. 5. The average age of the mineralized gabbroid is 314±3 million years (the Bashkir stage); the statistical probability of dating makes 96 %.

The history of forming the ultrabasite-gabbro massif and the copper-nickel field of the same name according to geological data and on the basis of studying a series of the transparent and polished slides, can be described by three following phases: 1) introducing the picrate structure in C_2 from the mantle magma, its stratification into

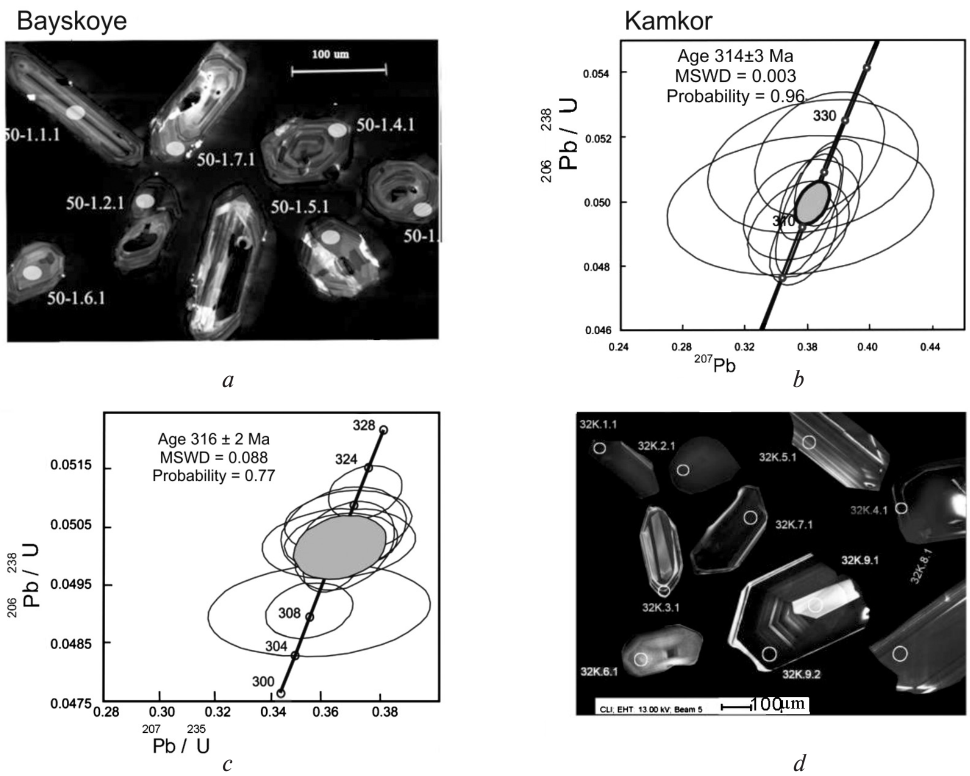


Fig. 5. Concordia magmatic rocks of Bayskoye and Kamkor:
a – structure of zircon samples of Bayskoye deposit; b – Concordia sample Kamkor deposit; c – Concordia sample Bayskoye deposit; d – structure of zircon samples of Kamkor deposit

the gabbroid and peridotite phases and forming a small-scale copper-nickel field of the liquation type; 2) introducing granodiorite magma of the Topar type in C_2; 3) introducing granite pluton, presumably P_1.

Within the two last phases there occurred the partition of the peridotite-gabbro massif and the copper-nickel field lying in it, skarnification of the enclosing rocks and peridotites, manifestation of the shield alkaline metasomatosis in the form of biotitization and amphibolization which are imposed on more and more early rocks except late granites. The spatial proximity of the Bayskoye and Ozernoye massifs with the Kamkor massif, the presence of granodiorites of the Topar type in all three fields, identical in all three massifs copper specialization and identical U/Pb age of peridotites and granodiorites prove the similarity of their genesis.

Borly. The field is located 60 km to the north of Balkhash and 45 km from the Konyrat field. It is adapted to the southern wing of the Tokrau synclinorium. Its stocks constituted about 600 kt with the average content of copper of about 0.34 % with the Cu:Mo ratio = 33. In the field there dominate aplite-like rhyolites and dacitic tufa composing two complexes: 1) lito-crystal clastic tufa, lavas and subvolcanic C_1 rocks and 2) dacites, sometimes dacitic and andesite- dacitic ignimbrites, microlitic tufa, lavas and subvolcanic C_2 rocks. In the center of the field there are located Borly apophyses put by quartz diorites, biotite-amphybolic granodiorites and leucocratic granite-porphyries. The entire complex of rocks is broken through with granodiorite Pluton. Implementation of this intrusion was followed by crypto-explosive formation of breccia, hydrothermal changes and forming quartz-sulfidic ore fold. The central ore body has the length of 800 m, width of 15–340 m and is traced at the depth of 200–340 m. H. Chen published the average Re-Os age of 315.9±6.5 Ma for molybdenite which was interpreted as the age of mineralization in the Borly field.

In 2013 H. Chen carried out studies of the given fields. There were selected two samples (porphyritic granodiorite and granodiorite) from which zircon was separated. The petrographic structure of the rocks was as follows: porphyritic granodiorite-plagioclase 15 % (phenocryst), quartz 5 % (phenocryst), plagioclase 20 %, quartz 20 %, K-spar 15 %, protobase 10–15 %, biotite 2 %. From the selected samples there was separated zircon and dated by the Shrimp technology in Australia. The results are given in Fig. 6. There were obtained two dates: 316.3±0.8 and 305±3 Ma. The first dating is coordinated in age with the volcanic structure, granodiorite of the Bayskoye and Ozernoye fields and ore molybdenite in the Borly field. Thereby the age of the ore-magmatic system of the additional phase field and the copper province is proved in general. The second dating is coordinated with the similar dating of zircon in small non-ore field bodies of Konyrat (308.7±2.2 Ma) and with the belt of bimodal dikes in the Umit massif which have erased the initial isotope memory and have restarted the isotope clock in the late Carbonic period and in early Perm (309±3 and 297±3 Ma, Fig. 4).

Copper ore district Baogutu, N-E Zhongar, China. Under this name in the People's Republic of China there is described a copper-and-porphyritic belt in which Cu-Mo-Au mineralization is contained in small diorite stems (Fig. 7). The belt begins practically from the Kazakh-

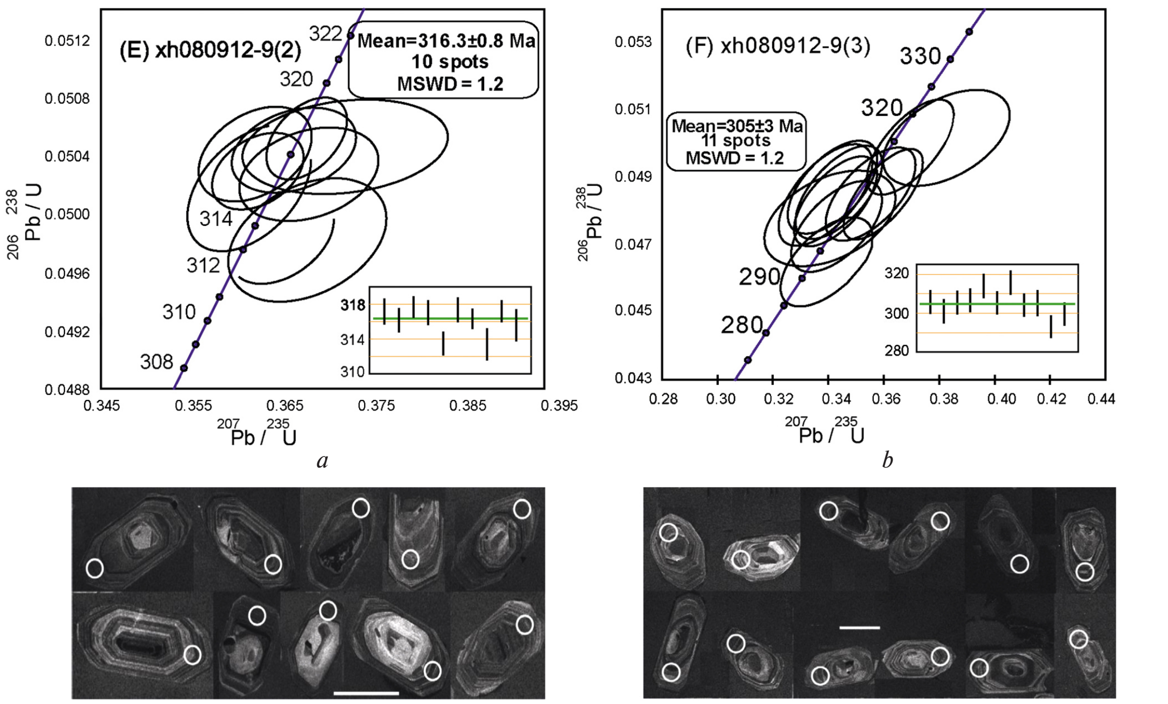
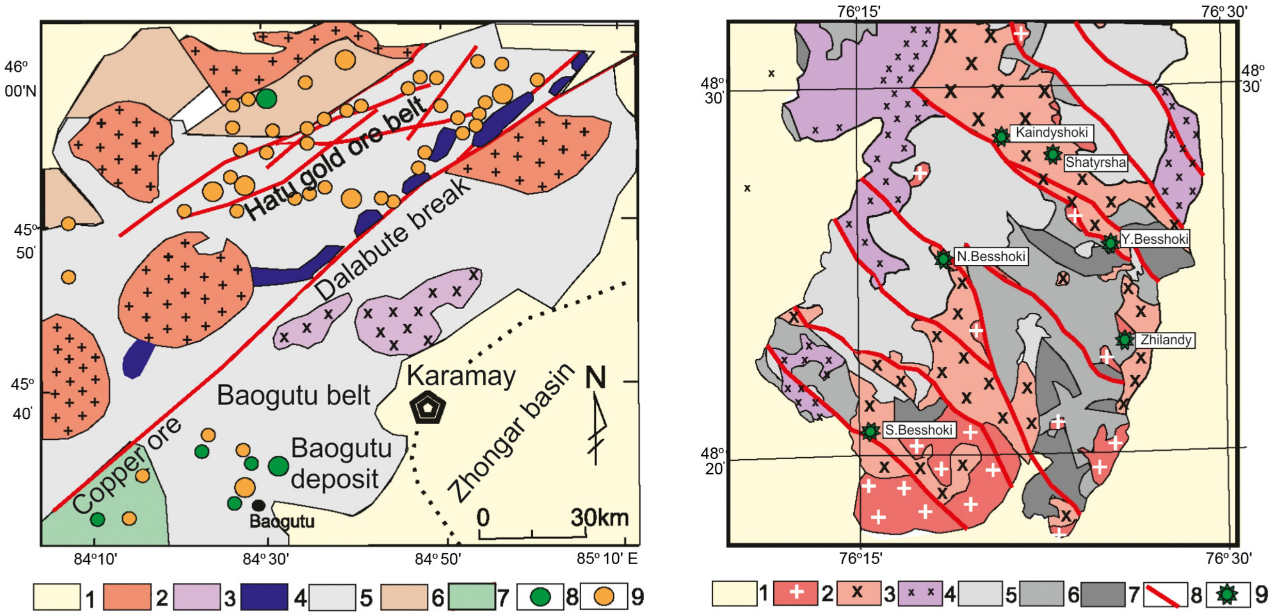


Fig. 6. Concordia zircon of Borly deposit (Chen, et al., 2014):

a – Concordia sample xh080912-9 (2) of the porphyritic granodiorite; b – Concordia sample xh080912-9 (3) of granodiorite; c, d – the structure of zircon samples xh080912-9 (2) and xh080912-9 (3) of Borly deposit



a *b*

Fig. 7. Geological scheme position of Baogutu ore belt (a) and Besshoki ore node (b):
a: 1 – loose sediments; 2 – Late Paleozoic granites; 3 – Carbon porphyritic diorite and porphyritic; 4 – serpentinite melange; 5 – Carbon volcano-sedimentary complex; 6 – Devonian volcanic-sedimentary complex; 7 – Caledonian; 8 – copper- porphyry deposits; 9 – gold deposits; b – State geological map of scale 1: 200 000: 1 – loose sediments; 2–4 – complex of Topar C2: 2 – granites; 3 – granodiorites; 4 – diorites, tonalites; 5 – volcanic complex C1-2; 6 – volcanogenic-sedimentary complex C1; 7 – basically sedimentary complex C1; 8 – breaks; 9 – copper-porphyry ore and small deposits

stan-Chinese border and goes in the northwest direction under deposits in Kazakhstan, and in the northeast is traced to the west of the city of Kalamay. In the belt there are more than 20 stems of the diorite structure having their own numbering from I to XX. A summary of two largest and well-studied fields Boagutu and Adayi is given below (Shen, et al., 2010). According to P. Shen et al., diorite stems intrude the Devonian and fossil coal volcanic rocks which age is about 322 Ma, and form the badly naked intrusive Baogutu complex. It has been revealed by intensive hydrothermal changes in the enclosing rocks. There are allocated two intrusive phases: 1) equigranular porphyritic diorites and quartz diorites; 2) diorite porphyries (Shen, et al., 2010).

There are also developed hydrothermal breccias which have gradual transitions to diorites of the 1st phase. Mineralization associates with diorites of the 1st phase and hydrothermal breccia. The age of zircon of magmatic rocks by the methods of Shrimp and LA-ICP-MS makes 314.9±1.7 Ma and 309±1.9 at the Baogutu and Adayi deposits, respectively. Re-Os dating of molybdenite from copper-and-porphyritic ores shows that mineralization manifested about 310 Ma [by Song X. H., et al., 2008].

Besshoki Ore cluster. This ore cluster has an external similarity to the northeast termination of the copper-and- porphyritic belt of Baogutu only by the fact that it compactly includes six copper-and-porphyritic manifestations: Southern, Northern and East Besshoki, Kaindyshoki, Shatyrsha and Zhilandy (Fig. 7, *b*). They form an ellipse hemisphere extended in the northeast direction in which distances between ore manifestations fluctuate within 5–10 km. Orientation of the hemisphere is northeast that sharply contrasts with the dominating northwest numerous breaks and testifies to asynchronicity of the hemisphere and explosive tectonics. It is seen from the geological diagram that mainly volcanogenic and intrusive complexes of the early and late Carbonic period took part in the formation of the ore cluster. However, the absence of accurate geological reference points and total absence of isotope dating exclude the possibility of restoring the history of developing this complex ore and magmatic system. In the entire territory of the fragment of the map with the scale of 1:200 000 shown in Fig. 7, *b* there is known only one point with flora of the Visean age in the sedimentary thickness lying in the basis of the coal pit. The ellipse-like structure of the ore system testifies to its caldera origin. Forming the ore system can be estimated by the age of the volcano that existed in early Carbonic period as, for example, in case with Konyrat that causes to anticipate million stocks of copper. If forming the ore system is connected with the late coal volcanic-plutonic system, such as Bayskoye, Borly, Baogutu which complete the evolution of the Central Kazakhstan copper-ore province after its long development within 35 million years, then the present day small stocks of copper confirmed by drilling up to the depth of 700 meters are, most likely, not predicted but real. It is necessary to understand that after 35 million years of vigorous activity of the deep center its resources by the end of this time have been exhausted. There are a lot of examples: Ore-Altai polymetal (~30 Ma), Kalbinsky rare-metal (~35 Ma), North Kazakhstan gold (~ 45 Ma) and other provinces of long development. The history of forming the ore-magmatic system of Besshoki is of huge interest from the point of view of assessing the perspective stocks of copper ores.

Conclusions. On the basis of the newest methods of dating rocks and ores of copper-porphyritic fields of Central Kazakhstan and Western Zhongar (China) there is proposed a new model of origin and development of the Central-Kazakhstan copper-ore province uniting the fields of different genesis, age and ore potential in a common ore-and- magmatic system (Fig. 1, Table 3). Such a consolidation is dictated by the identical composition of ores and rocks of the fields, a common source of ore-bearing magmas, the continuity of developing the process of forming the province in time and the absence of any other ore-and-magmatic systems of another metal structure which could interrupt its continuous development. The isotope geochronological history of forming the province is shown in Table 3.

In this model the following phases of forming the belt are distinguished: 1) the main phase, age of 339–327 million years; 2) the additional phase, 316–309 million years; 3) the post-ore phase, 309 million years and younger.

In the main phase there formed three large-scale deposits: the Konyrat, the Sayak and the Aktogay fields with the stocks constituting million tons of copper.

It was considered earlier that ores of the Konyrat and Sayak fields had different genesis. This evaluation criterion was sufficient in order not to connect them in a common ore-and-magmatic system. However, frequent occurrence of porphyritic and skarn mineralization in the common model forces researchers to call such cases skarn-porphyritic fields. The above-stated general theoretical model of forming copper-and-porphyritic fields (accumulating – transportation – deposition) ideally explains the different genesis of the Central Kazakhstan even-aged fields: Konyrat was formed in the volcanic caldera (metal deposition owing to a sharp pressure drop in the camera), and Sayak in the meso-abyssal conditions (metal deposition owing to the emergence of a chemical barrier in the form of limestone at this level).

Aktogay has general signs of formation in the transition phase from transportation to deposition. These are extensive geochemical halos of copper along the principal break crossing the Koldarsky massif from the east to the west, and the presence of explosive breccias and a quartz kernel in the Aktogay field showing as well as in Konyrat that the deposition occurred in the conditions of a sharp pressure drop in the camera. However, the main thing is that all three fields have the identical age, namely, early Carbonic period (C_1t-v). And irrespective of small oscillations of the age of the main phase within 339–329 million years (Tables 2, 3) the age of the main phase remains early fossil coal.

After the main phase of forming the Central Kazakhstan copper-ore belt within the period from 327 to 318 million years there was obtained no dating which confirmed the activity of U/Pb systems in zircon. This period lasting 9–10 million years is considered the time of the relative quiet condition of the deep subsoil and tectonics of the top crust.

In the additional phase there occurred interrelation of the crust and the mantle in the form of a consecutive introduction of peridotite and granodiorite magma in the Kamkor field. The picrite magma in the peripheral center was stratified into the basalt magma and peridotite cumulate with formation of a small copper-nickel field of the liquation type. Under the impact of open channels of heat-and-mass transfer from the mantle to the crust the centers of the main phase were reanimated and new copper-and-porphyritic fields were formed. The

Table 3

Isotope-geochronological history of the formation of the Central Kazakhstan copper ore province

<table>
<tr><td colspan="42">Postmineral stage: a small body of granodiorite porphyry, granodiorite and dykes</td></tr>
<tr><td colspan="14">Konyrat: granodiorite-porphyry
308.7±2.2</td><td colspan="14">Borly: granodiorites
305±3</td><td colspan="14">Sayak: granodiorites main phase in a belt of young dykes, have undergone a rejuvenation to 309 ±3 and 297±3, Ma (Fig. 4)</td></tr>
<tr><td colspan="42">Additional ore stage of 310–316 million years, U/Pb and Re-Os dating</td></tr>
<tr><td colspan="7">Re/Os 315.9±6.5
U/Pb 316.3±0.8</td><td colspan="7"></td><td colspan="7">U/Pb 316±2</td><td colspan="7">U/Pb 314±3</td><td colspan="7">U/Pb 314.9±1.7
Re–Os 310</td><td colspan="7">U/Pb 309±1.9</td></tr>
<tr><td colspan="7">Borly, granodiorites</td><td colspan="7">Ozernoye, granodiorites</td><td colspan="7">Bayskoye, granodiorites</td><td colspan="7">Kamkor, Cu-Ni mineralized gabbro-peridotite</td><td colspan="7">Baogutu, quartz diorite</td><td colspan="7">Adayi, quartz diorite</td></tr>
<tr><td colspan="42">The main ore stage of 339–327 million years</td></tr>
<tr><td colspan="36">U-Pb dating methods Shrimp and using “wet” chemistry</td><td colspan="6">K/Ar method</td></tr>
<tr><td colspan="6">339±4, Ma</td><td colspan="6">327.3±2.1, Ma</td><td colspan="6">335 ±2, Ma</td><td colspan="6">329.9±7.1, Ma</td><td colspan="6">335.7±1.3, Ma</td><td colspan="6">327.5±1.9, Ma</td><td colspan="6">336±13, Ma</td></tr>
<tr><td colspan="12">Konyrat</td><td colspan="12">Sayak</td><td colspan="12">Aktogay</td><td colspan="6">Sayak</td></tr>
<tr><td colspan="6">Barren granodiorite porphyry</td><td colspan="6">Mineralized porphyritic granodiorite</td><td colspan="6">Barren granodiorite of Moldybay intrusion</td><td colspan="6">The impact of younger dike belt on the granodiorite of massif Umit</td><td colspan="6">Barren quartz diorite</td><td colspan="6">Mineralized Cu ~ 0,2 % granodiorite</td><td colspan="6">Granodiorite batholith Umit [Ermolov P. V., 2013]</td></tr>
</table>

scales of introducing mantle magmas into the crust were not so large as in the main phase, therefore the fields conceded to the main phase in resources and in the content of metals. As it is seen in Fig. 1, small fields of the additional phase are concentrated in the southeast and northwest flanks of the belt. They are present, perhaps, in the ore fields of the main giants, but visually they are not still distinguished from the ores of the main phase.

The post-ore phase is presented by granodiorie-porphyries and granodiorites. It is important to note that within 30–35 million years of the ore-and-magmatic system development the composition of ore-bearing magmas did not practically change.

Theoretical bases. Copper and molybdenum are connected with the lower basic crust and with the mantle. Heat-and-mass streams from the mantle, penetrating the entire crust, promote formation of ore-and-magmatic systems. The Central Kazakhstan province and concrete copper skarn-porphyritic fields are well-coordinated with such a model. The province has existed and developed within 30–35 million years.

Practical recommendations. On the representative isotope and geological material it has been proved that the mantle diapir (plume) concerned the lower crust in this region in the early Carbonic period. At the peak of activity it caused mass melting in the crust which resulted in the formation of three very large copper skarn-porphyritic fields. At the plume attenuation there took place local injections of picrite magma and local diorite-granodiorite centers which generated small fields of the same type. It is shown that within the Central Kazakhstan copper-ore province it is necessary to carry out isotope studies in the light of the fact that at the already studied objects early fossil coal magmatic systems generated large and very large-scale deposits, while medium fossil coal systems made only small fields. In this regard the priority object for detailed studying is caldera ore magmatic Besshoki system. The emphasis on magmatic systems is placed because according to statistics, about 85 % of copper-and-porphyritic and 100 % of copper-skarn ores lie in magmatic rocks or are in contact with them.

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Мета. Оцінити геодинамічний процес роз'єднаних просторово й різних за генезисом мідно-рудних родовищ центрального й південно-східного регіонів Казахстану.

Методика. Використані нові U-Pb (циркон), Re-Os (молибденит) датування й старі K-Ar (біотит) дані, отримані в результаті використання тільки кондиційних аналізів по біотиту (K2O > 7 %).

Результати. На основі новітніх датувань порід і руд мідно-поріфрових родовищ Центрального Казахстану й Західної Жонгарії (Китай) пропонується нова модель виникнення та розвитку мідно-рудної провінції.

Наукова новизна. Розроблена модель виникнення й розвитку Центрально-Казахстанської мідно-рудної провінції, що об'єднує родовища різного генезису, віку та рудного потенціалу в єдину рудно-магматичну систему. Модель формування мідно-порфірових родовищ (накопичення – транспортування – садка) ідеально пояснює різний генезис Центрально-Казахстанських одновікових родовищ.

Практична значимість. У межах Центрально-Казахстанської мідно-рудної провінції необхідно проводити ізотопні дослідження. Пріоритетним об'єктом для детального вивчення є кальдерна рудно-магматична система Бесшокі, на основі того, що, за статистикою, близько 85 % мідно-порфірових і 100 % мідно-скарнових руд залягають або в магматичних породах, або на контакті з ними.

Ключові слова: *геодинаміка, датування, провінція, магматичні породи, Центральний Казахстан*

Цель. Оценить геодинамический процесс разобщенных пространственно и разных по генезису медно-рудных месторождений центрального и юго-восточного регионов Казахстана.

Методика. Использованы новые U-Pb (циркон), Re-Os (молибденит) датировки и старые K-Ar (биотит) данные, полученные в результате использования только кондиционных анализов по биотиту (K_2O >7 %).

Результаты. На основе новейших датировок пород и руд медно-порфировых месторождений Центрального Казахстана и Западной Жонгарии (Ки-

тай) предлагается новая модель возникновения и развития медно-рудной провинции.

Научная новизна. Разработана модель возникновения и развития Цетрально-Казахстанской медно-рудной провинции, объединяющая месторождения разного генезиса, возраста и рудного потенциала в единую рудно-магматическую систему. Модель формирования медно-порфировых месторождений (накопление – транспортировка – садка) идеально объясняет разный генезис Центрально-Казахстанских одновозрастных месторождений.

Практическая значимость. В пределах Центрально-Казахстанской медно-рудной провинции необходимо проводить изотопные исследования. Приоритетным объектом для детального изучения является кальдерная рудно-магматичексая система Бесшоки, на основе того, что, по статистике, около 85 % медно-порфировых и 100 % медно-скарновых руд залегают либо в магматических породах, либо на контакте с ними.

Ключевые слова: *геодинамика, датировка, провинция, магматические породы, Центральный Казахстан*

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TAKING INTO ACCOUNT OF INFLUENCE OF EARTH CRUST FAULTS IN SOLVING GEOLOGICAL AND GEOECOLOGICAL TASKS BY GEOPHYSICAL METHODS

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УРАХУВАННЯ ВПЛИВУ РОЗЛОМІВ ЗЕМНОЇ КОРИ ПРИ ВИРІШЕННІ ГЕОЛОГОРОЗВІДУВАЛЬНИХ І ГЕОЕКОЛОГІЧНИХ ЗАВДАНЬ ГЕОФІЗИЧНИМИ МЕТОДАМИ

In honor of the famous scientist-geophysicist
Doctor of Geological and Mineralogical Sciences, Professor,
Corresponding member of NAS of Ukraine
Konstantin Fedorovich TIAPKIN

Purpose. Application of the New Rotational Hypothesis of Structure Formation in the Earth's Crust, advanced and substantiated by K. F. Tiapkin for solving not only geological exploration problems, but also geoecological ones of technogenically loaded regions of Ukraine.

Methodology. Theoretical and empirical methods of studying tectonic movements in the features of the fault-block structure, as well as modeling and prediction of the modern geoecological situation according to the complex of geological and geophysical methods are used.

Findings. It has been confirmed that almost all movements of the earth's crust are associated with tectonic faults. The nature of these movements can be determined from the geological and geophysical data on the forms of the fault-block structure of the earth's crust. And the faults are not only of structure-forming and ore-controlling importance, but are one of the main factors determining the geo-ecological situation in any region as well.

Originality. The New Rotational Hypothesis of Structure Formation in the Earth's Crust, advanced and substantiated by K. F. Tiapkin in the mid-1980s became one of the most important stages in the study of faults. This hypothesis does not only explain the global patterns (which allow us to successfully predict ore and oil-and-gas deposits in various structural and geological conditions), but it has also become the basis for solving modern geoecological problems of technologically stressed regions of Ukraine successfully.