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Gold metallogeny of China - with special preference to Xinjiang Uygur Autonomous Region

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China is endowed with world-class metallic mineral deposits, and since 2003 has been the world leader in total metal production (12 Mt), including copper, aluminium, zinc, nickel, tin, magnesium, mercury, antimony and titanium. Furthermore, China is now the third largest producer of gold in the world. In the last 20 years a great deal of knowledge of the geology and tectonics of China has been gained, due to vigorous cooperation between Chinese and western geologists.

China's mineral deposits are the result of metallogenic processes associated with the geodynamic evolution of tectonic plates, and their eventual amalgamation into the present-day configurations. An understanding of the complexities of the geology of China is continuously improving, while at the same time providing new frontiers and new challenges. The principal geotectonic provinces of China are: the North China Craton, the Yangtze Craton, the Tarim Craton, the Altay-Tian Shan-Hinggan orogens (part of the great Central Asian Orogenic Belt, also known as the Altaid), the Kunlun-Qinling fold belt, the South China Fold Belt, the Himalayan and Gandise fold belts and the Qingai-Yunnan fold belts. These tectonic elements are the result of a complex geological history spanning more than 3000 million years.

This presentation briefly explains the tectonic settings and associated mineral systems of China, with emphasis on gold and I will focus principally on selected areas of the Altay-Tian Shan in the northwest, the North China Craton, the Yangtze Craton, and the South China Fold Belt. These selections are somewhat biased, because they are based partly on my own experience of the areas in question, and partly on the fact that these do constitute important metallogenic provinces that hold much promise for future discoveries. Mineral deposits in these provinces include gold, silver, copper, molybdenum, tin, antimony, nickel, platinum group elements, lead and zinc. Ore-forming processes for these deposits relate to large scale tectono-thermal events that affected Central Asia and mainland China. New concepts are now being proposed and tested to explain the major tectonic and metallogenic features of China and Central Asia. These new concepts will lead to improved exploration models for discovery of new deposits in China.

Palaeozoic tectonic evolution of Chinese Tianshan

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Chinese Tianshan is a key area for understanding the Palaeozoic accretion of the southern Central Asian Orogenic Belt.

A first accretion-collision stage built the Eo-Tianshan range, before the Early Carboniferous (Visean), in which all tectonic structures verge northwards. Geodynamic evolution records: Ordovician-Early Devonian southward subduction of a Central Tianshan (CTS) ocean beneath the Tarim active margin, from which a CTS island arc was detached during the Silurian-Devonian by opening of the South Tianshan (STS) back-arc basin. The closure of the CTS ocean and of the STS back-arc basin led to the Central Tianshan Suture Zone (CTSZ) and South Tianshan Suture Zone (STSZ) respectively, both underlined by ophiolitic mélanges and HP metamorphic rocks. In Eastern Tianshan, CTSZ is often cut by the dextral strike-slip Main Tianshan Shear Zone or Nalati Fault, forming the faulted CTS northern boundary. But, in Western Tianshan, some sections exhibit the original geometry of the suture, where ocean-derived HP/UHP metamorphic units thrust northward over the basement of Yili, the eastern extension of the Kazakh plate. After the collision, subsequent uplift was significant with erosion of the arc root and basement.

A second accretion-collision stage involved southward Late Devonian-Carboniferous subduction of the North Tianshan (NTS) ocean beneath the Eo-Tianshan active margin, creating the Yili-NTS magmatic arc. Late Carboniferous-Early Permian oceanic closure and collision with the Junggar block led to the North Tianshan Suture Zone (NTSZ), outlined by the Bayingou ophiolitic mélange and former accretionary wedge. This collision developed north-verging structures in Yili-NTS, and some symmetrical south-vergent structures in CTS and STS.

The Late Carboniferous-Early Permian NTSZ, now partly hidden due to Cenozoic thrusting, is likely the trace of the last oceanic remnant of the Central Asian Ocean in this area, the youngest suture of the CAOB.

During the Permian, all the Tianshan units, already amalgamated, experienced a major dextral wrenching, accommodating an opposite motion of Tarim and Siberia indicated by paleomagnetic data. That was accompanied by pull-apart basin opening and post-tectonic magmatism (volcanics and plutons). The coeval emplacement of Permian calc-alkaline and alkaline suites is noteworthy.

Compressional deformations resumed in the Mesozoic, advocated by Triassic and Jurassic unconformities; but they were intracontinental, similar to the Cenozoic one responding to the India-Asia collision. The evolution of Chinese South Tianshan, typically linked to the Tarim-Yili welding, is somehow different from the welding known more to the west, where it is likely that some ocean remained open on the southern border of the Kazakh plate during the Carboniferous.

Southern Tian-Shan: general structure and main problems of geology.

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The Upper Paleozoic South Tian Shan (STS) thrust and fold belt was formed due to collision of the Kazakhstan continent with Alai, Karakum-Tadjik and Tarim microcontinents. STS consists mainly of sedimentary rocks ranging in age from Lower Paleozoic to Lower Permian, with some volcanics involved. The belt goes from Sultan-Uisdag mountains in Uzbekistan to northwestern China (Fig. 1), where it can be traced up to 92°E.L.

Collision of the Alai and Tarim microcontinents with Kazakhstan occurred after the Turkestan ocean plate has been subducted toward the north beneath Kazakhstan during the Late Carboniferous. A north dipping subduction zone is indicated by: a) prevailing direction of thrust motion toward the south in the STS, b) well expressed subduction volcanic belt in the south of the Kazakhstan continent in Chatkal and Kurama ridges; c) lack of any subduction derived Upper Paleozoic volcanic rocks in Tarim and Alai; d) well expressed Upper Carbonifeorus to Lower Permian foreland basin, which runs along the northern margin of Tarim and continues within the Alai microcontinent. Lithic and volcaniclastic greywacke flysch and olistostromes with carbonate blocks, ranging in age from late Carboniferous to Lower Permian (Asselian) represent typical formation of this foreland basin.

The STS belt consists of several thrust units which are represented from south to north by: a) deep marine turbidites and cherts, ranging from Silurian to Carboniferous in age, which accumulated on the continental slope of Tarim; b) shallow marine carbonates of the Silurian, Devonian and Carboniferous(?) age, which were deposited on isolated sea mounts; c) meta-greywackes and volcanic rocks of the Devonian age, d) ophiolites and serpentinite melanges and e) slope turbidites, presumably derived from Kazakhstan continent in the north. General structure and evolution of the collisional belt in the west of the Chinese Tian Shan remains poorly understood. Well expressed pre-Carboniferous angular unconformity in this area probably reflects an episode of accretion of the Bozdon-Kumyshtala terrane at the southern margin of Kazakhstan, which pre-dated collison of the Kazakhstan with Tarim.

Ongoing shortening during the late collisional stage of the Kazakhstan and Tarim led to deformation of the thrust sheets into the ENE- and E-trending synforms and antiforms. Then the STS and southern areas of Kazakhstan experienced left-lateral wrenching in the ENE direction, which led to formation of steeply plunging S-shaped folds and sinistral strike-slip faults (Atbashe-Inylchek, Nikolaev line and many others). Left-lateral wrenching most likely was also responsible for local transtension and formation of pull-apart structures, which controlled emplacement of subalkaline granite plutons and possible formation of ore systems during the Permian. The spatial distribution of Permian granites was not controlled by an older subduction system and they develop both within the South Tian Shan and Tarim. In the latter area granitoids shortly pre-dated plume-type basalt magmatism (Tarim-Bachu event), which took place at about 280 Ma.

A Dismembered Paleozoic Passive Continental Margin of the Paleo-Asian Ocean within the Eurasian

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The Eurasian continent is the youngest on the Earth, and amalgamated from the Paleozoic to the early Mesozoic. However, the Paleozoic geological processes forming the continent have since become a hotly-debated issue. Some geologists suggest that the continent originated from accretion around the Siberian continent from the Paleozoic through the Mesozoic, but others argue that the Paleozoic amalgamation of the continent is characterized by accretion around various continental blocks, and subsequent collision between them. It is well-known that there are Siberian, East European, Tarim, Sino-Korean and Yangtze continental blocks within the Eurasian continent. Whether some of these blocks existed and accreted beside the Siberian craton, and their relative locations in the Paleozoic global continent-ocean framework, are key aspects of the issue.

Available geology and paleontology data show Sinian through Paleozoic sedimentary sequences in the northern Yangtze and Tarim continental margins, which are similar to those in the passive continental margins. Similar sequences are also exposed on the eastern margin of East European continental block. In combination with the Paleo-magnetic data, the author suggests that those sequences were deposited in the passive continental margin of the Paleo-Asian Ocean. So, East European, Tarim and Yangtze continental blocks probably constituted a group of continents during the Paleozoic, similar to the group of African, Arabian, Indian and Australia continents in the late Mesozoic and early Cenozoic. This group of continents faced the Paleo-Asian Ocean on one side and the Paleo-Tethys Ocean on the other side during the Paleozoic to early Mesozoic. The formation of the Eurasian continent is the result of collision between the passive margin and the accreted margin of the Siberian craton from the Permian to the early Triassic.

Paleozoic Cu-Au Mineralization and Related Tectonic Setting in the Western Tianshan Mountains, Xinjiang, China

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Xinjiang Western Tianshan Mountains are located between the Northern Tianshan to the south of Kuitun and the Southern Tianshan to the north of Kuqa. The area is at the junction of the southeastern margin of the Kazakhstan- Junggar plate and the northwestern margin of Karakum-Tarim plate in Early Paleozoic, in which the main suture occurred along Chang'awuzi-Wuwamen ophiolite belt. The deep-seated Huocheng-Haxilegen fault in the south of Boluokeluo represents the junction of the two Ordovician-Silurian Sarim-Junggar and Wusun-Awulale microplates. In the late Late Palezoic, the rift was turned into a strike-slip fault and pull-apart basin system, with extensive and frequent magmatic events derived from crust-mantle interactions. This period is also the major period of mineralization in the area. Three major E-W-trending mineralization belts exist in the western Tianshan Mountains, a Cu-polymetallic, Au-polymetallic and a Cu-Ag polymetallic mineralization belt. According to discussions on the Paleozoic geodynamic evolution in the western Tianshan Mountains, the three mineralization belts mentioned above correspond to the Biezhentao-Keguqin Late Paleozoic island arc belt, the Boluokeluo Late Paleozoic back-arc basin and the Awulale Permian rift zone, respectively.

Early Permian ultramafic-mafic magmatism and accompanying Cu-Ni mineralization in the Gobi-Tien Shan belt as a result of the Tarim plume activity

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New data on the age, composition, and geodynamic environments of Early Permian ultramafic-mafic (picrite-dolerite) complexes in the Zaisan-Gobi zone in East Kazakhstan and in Hercynide structures in southwestern Mongolia will be presented. Ultramafic-mafic magmatism is synchronous with Early Permian alkali and tholeiitic basalts discovered beneath the cover of the Tarim and Junggar platform blocks, suggesting that they are derivates of the Tarim plume. Picrite-dolerite complexes in the Zaisan-Gobi zone seem highly promising for Cu-Ni and accompanying PGE mineralization. This is evidenced from their similarity to ore-bearing trap intrusions of the Noril'sk district (including similar models for their formation) and from discovered commercial Cu-Ni deposits associated with Permian ultramafic-mafic intrusions (Maksut, Kalatonke, etc.). Abundant ore occurrences of this type have been recently revealed within Permian picrite-dolerite intrusions of the neighboring Hercynides in the eastern Tien Shan. These structures are also part of the Gobi-Tien Shan rift belt (Mao and Goldfarb, 2003). Prerequisites for discovery of Cu-Ni mineralization were established (Polyakov et al., 1994) in the Baruun Huuray and Edrengiyn zones of Hercynides in southern Mongolia, including neighboring older structures of their framing.

Arc Magmatism through Geological time: Implications for Crustal Growth from Greenland to the Tien Shan

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The ca. 700 km long, Archean craton of West Greenland consists of six Meso-Neoarchean (ca. 3000–2720 Ma) crustal blocks that display similar cross-sections; from south to north Ivittuut, Kvanefjord, Bjørnesund, Sermilik, Fiskefjord, Maniitsoq. Each block has a southerly upper and a northerly lower zone, thus each faces upwards to the south. Upper zones have prograde amphibolite facies mineralogy and have never been in the granulite facies, whereas lower zones reached granulite facies and were partly retrogressed to amphibolite facies. Upper and lower zones consist predominantly of tonalite-trondhjemite-granodiorite (TTG) orthogneisses; geochemistry suggests generation by slab melting in subduction settings of island arcs and active continental margins. The gneisses contain km-thick meta-volcanic amphibolite layers typically bordered by km-thick layers containing anorthosite and leucogabbro. Most upper zones contain upper greenschist to amphibolite facies meta-volcanic belts including volcaniclastic, andesitic lithologies. The two most-prominent meta-volcanic belts in the Fiskefjord block at Qussuk (andesitic-volcaniclastic rocks; Garde, 2007) and Ivisaartoq (mafic–ultramafic rocks and anorthosite–leucogabbro from upper and lower parts of a supra-subduction zone system; Polat et al. 2008) have major-trace element island arc signatures. The 2 km-thick Fiskenæsset complex (Bjørnesund block) comprises chromite-layered anorthosites, leucogabbros and gabbros, and local roof pendants of pillow-bearing meta-basalt from overlying amphibolite. The Fiskenæsset complex occurs in upper and lower zones demonstrating the common development of the two zones. The style of deformation changes downwards within crustal blocks; upper zones are characterised by linear meta-volcanic belts that have been deformed by mostly one major phase of isoclinal folding, and lower zones by kilometre-scale double-triple fold interference patterns. Everywhere protoliths of the TTG gneisses have intruded anorthositic and volcanic rocks typically along ductile shear zones, often so extensively that only anorthositic or amphibolitic lenses are preserved. The Meso-Neoarchean crust in the blocks was thickened by a combination of thrusting, isoclinal folding and TTG injection. Dissimilarities in the proportions of anorthositic and meta-volcanic rocks in the six blocks suggests that they are not pieces of one original block, but that they evolved by similar processes in different micro-continents. These crustal blocks provide an exceptional example of how continents evolved in the Meso-Neoarchean. Comparable Archean examples in Kapuskasing and Pikwitonei (Canada) and modern analogues in the Tien Shan of Central Asia, Fiordland (New Zealand), Kohistan (Himalayas), Southern California batholith, Peruvian Andes, and Hidaka (Japan) demonstrate that processes of crustal growth from island arc to continental arc magmatism were broadly similar throughout Earth history.

Thermochronology in Central Asia – constraints on Meso-Cenozoic tectonics from Baikal to the Pamirs

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Since the late 1990's modern thermochronologic techniques, mainly apatite fission track (AFT) dating have been applied to study the tectonic evolution of the Central Asian Orogenic System (CAOS). Several areas have been involved in these studies; they include the Baikal rift zone and the Tunka depression, the Siberian Sayan Mountains, the Siberian, Mongolian, Gobi and Chinese Altai Mountains, Tuva, the Kokchetav massif, the Tien Shan and the Pamir Mountains. Palaeozoic 'Altaid' crystalline basement rocks represent the main sampled lithologies for these applied thermochronology studies, with an important objective, to evaluate the Cenozoic formation of the currently active intracontinental CAOS. However, only in some isolated cases, mainly in the Tien Shan and Pamirs, do the thermochronologic methods effectively date the Late Cenozoic events. In most cases though, thermochronology provides us with constraints on the timing of Mesozoic tectonic events that seem to have affected the entire 'Altaid' basement. An overview of the thermochronology results from the CAOS will be presented and a link will be made to higher temperature techniques such as Ar/Ar and U/Pb systems, in order to reconstruct the evolution of the crystalline basement underlying the Central Asian orogens from its formation to its neotectonic reactivation, all in a broader plate-tectonic framework.

Geotraverse studies and terrane reconstructions leading to new target regions in central Eurasia

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The Altaid orogenic collage extends from the Urals over Central Asia (Kazakhstan, Tien Shan) to the Mongol-Okhotsk belt. It comprises assembled fragments of sedimentary basins, island arcs, accretionary wedges and microcontinents of Neoproterozoic to Cenozoic age now joined to surrounding continental regions (e.g. East European craton). The clockwise rotation of Siberia relative to Eastern Europe during middle and late Paleozoic resulted in multiple episodes of arc collisions, both between themselves and with the cratons, as well as the progressive oroclinal bending. This complex cycle of rifting, subduction, accretion and collision has culminated in the current complex assembly.

Major porphyry Cu-Au and Cu-Mo deposits (e.g. *Oyu Tolgoi* in Mongolia >2.3 Gt @ 1.16% Cu, 0.35 g/t Au and *Kal'makyr-Dalnee* in Uzbekistan >5 Gt @ 0.5% Cu, 0.4 g/t Au) are distributed across central Eurasia [1]. These deposits were formed during a range of magmatic episodes from the Ordovician to the Jurassic [2]. They are associated with magmatic arcs within the extensive subduction-accretion complex of the Altaides, Mongolides and Baikalides Orogenic Collages that developed from the late Neoproterozoic, through the Palaeozoic to the Jurassic intra-cratonic extension, predominantly on the palaeo-Tethys Ocean margin of the proto-Asian continent, but also associated with the closure of two rifted back-arc basins behind that ocean facing margin. The complex now comprises collages of fragments of sedimentary basins, island arcs, accretionary wedges and tectonically bounded terranes composed of Neoproterozoic to Cenozoic rocks. Moreover, although belonging to two different terrane settings, the giant Cu-Au porphyries of the Chatkal-Kurama range (Almalyk district, Valerianov-Beltau-Kurama magmatic arc, Middle Tien Shan) and the giant orogenic Au mineralisation hosted by black-shale series of the Central Kyzylkum slate belt (Southern Tien Shan, Khanty-Mansi accretionary complex) have some striking similarities. This hints at crust-mantle interaction and dominance of a deep-seated regime during emplacement. They are temporally close (315 to 287 Ma [3]), their isotope signatures reveal the incorporation of a moderate mantle component, and geophysical patterns from the middle crust in the region exhibit zones of low reflection indicating the existence of extended mafic bodies beneath both giant ore-magma systems.

Based on utilization of existing data a working model of paleogeographic reconstruction and tectonic modelling has been assembled. Selective mapping in specific terranes has been used by to improve the existing database coupled with targeted wholerock geochemistry and precise geochronology. Proterozoic crustal slivers and Paleozoic oceanic-subduction-accretion complexes with former magmatic arcs in the regions formed the first priorities for established correlation. These could be better defined in time and space using new data, reconstructing their current and past distribution patterns, defining regionally controlling major fault structures and post-depositional processes. From this, known terranes hosting key deposit types were extrapolated into geographical gaps in exploration activity and new prospective regions could be outlined.

Based on the precursor study of the CERCAMS team and associated partners in the Eastern and Western Altaids situated to the south of Russian state border, and based on the vast experience and data sets existing in the research institutions of Russia, CERCAMS NHM and its partners from Russia have agreed to combine their efforts in a follow-up approach extending the study into Russian territory to the south of the Siberian craton from the Altai Republic in the west to Chita and Amur regions in the east.

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Large multi-ring structures and ore clusters of Central Kazakhstan

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Multi-ring structures (MRS) are central-symmetrical structures with rhythmic ring-concentric positions of various geological objects, such as faults, intrusives, volcanic edifices or volcanic belts, calderas and domes etc. MRS can be produced in different ways, including meteorite impacts, collapse into a depleted magma reservoir, cooling and contraction, rotation of rigid terrane, vortex flow of ductile material in the subduction zone, or by a combination of several above stated processes. In other words, MRS are the representative features of the numerous known geological processes of different type, age and size found on the Earth and seven other planets and satellites of the Solar System. Diameter of MRS varies from hundreds of meters to thousand of kilometers, and their ages range from at least Proterozoic up to Quaternary.

In spite of some important investigations carried out in the field, only the most obvious MRS were recognized and the methods and purpose of their mapping has not became a part of geological practice. At the same time, without such mapping, it is impossible to recognize the true tectonic structure of any area if it formed with the participation of vertical and/or rotational movements. It is especially important for exploration purposes because mapping of MRS allows the determination of the real shape of metallogenic provinces, and the position of the prospect in the context of a full (not just ‘linear’) tectonic pattern.

Methods of MRS mapping have been developed by the author during 25 years of hard minerals exploration in Russia, Kazakhstan, Mongolia, Central Africa, South-East Asia. Methods are based on GIS-integrated analysis of elevation models, geographic, geologic and geophysical maps, satellite images, deposit databases and field observations. Methods and results were discussed in three presentations at IGC32 in Oslo. The method was implemented in systematic small-scale analysis of the tectonics of Central Kazakhstan. Four major structures were delineated there.

The central drawdown part of **Zhezkazgan MRS** (700 km in diameter) is composed of Carboniferous to Permian sedimentary rocks, and its ring faults determine the shape of the syn- and anticlines in the Sarysu depression. Zhezkazgan copper ore field is located in the central depression, and the Zhaman-Aibat deposit– on the intersection of radial and ring faults. **Zhairem MRS** (230 km) determines the shape of the drawdown blocks filled with D3 to C1 sediments, hosting exhalative Pb-Zn and Fe-Mn deposits of the Karazhal and Zhairem ore clusters. Separate deposits are located at the intersections of the host Zhairam MRS, and ring faults of the Zhezkazgan MRS. The **East Kazakhstan MRS** (850 km) coincides with the Permian volcanic belt. It controls the positions of the largest copper-porphyry clusters of Kazakhstan (Kounrad and Aktogay), and of numerous Cu and Au deposits.

The **Central Kazakhstan MRS** (2300 km) controls tectonic patterns of the region. It is expressed through the location and shape of the main tectonic elements, including the Devonian volcanic belt, Carboniferous rifts, Tecturmas, Uspenskaya and Chu-Ili sutures, and numerous smaller MRS. There is corresponding regularity in the location of various deposits. Large W-Mo stockwork and skarn deposits (Verhnee Kairakty, Akchatau and others) are located in the central part and along the radial Konyrat-Bainazar fault zone.

These four structures were formed during a period from D2 till C3, with the last three supposedly volcanic-related and strongly renewed in late Permian. The origin of the Zhezkazgan MRS is not clear.

Nature of the boundary between the Eastern European Craton, the Uralides and the Altaids in the southern Urals of Russia and Kazakhstan: Implications for metallogenic correlations

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The geology of the Urals and their mineral endowment are dominated by the Paleozoic Uralide orogen, one of the main orogenic belts that formed during assembly of Pangea at the site of collision between the East European, Siberian, and Kazakh cratons. The metallogeny of the Urals can be mainly related to the Uralide orogen, which can be considered in terms of two major arc systems, a western Magnitogorsk arc developed from the Silurian to Carboniferous and an eastern Devonian to Carboniferous Valerianovka arc (Herrington et al. 2005). However, it is clear that the Valerianovka arc, developed on the Kazakh block, marks the western margin of the Altaid collage and is at least temporally linked to magmatic arc rocks developed in the Altaids, as far southeast as the Kurama arc.

The East Uralian zone, east of the Magnitogorsk arc, is a complex, fault-bounded collage of early Paleozoic rift sequences, volcanic arcs, and intrusions. It defines the site of the continent-continent collision between the East European craton and its accreted arc assemblage and the Kazakh block. Rocks of the East Uralian zone are intruded by at least two post-accretionary granitoid suites, one of which is spatially and genetically linked to major orogenic gold deposits that are distributed along trans-crustal shear zones; the other consists of arc-like andesite porphyries that host porphyry Cu-Mo-Au occurrences. The Trans Uralian zone, east of the East Uralian zone, formed an entirely separate continental arc sequence, the Devonian to Carboniferous Valerianovka arc, with associated undeveloped porphyry Cu-Mo-Au deposits and giant Kiruna-type magnetite orebodies.

The Valerianovka arc developed in a continental margin setting and shows metallogenic features in common with parts of the Chilean Andes, specifically the El Romerol belt. The Valerianovka arc is host to a number of giant Kiruna-type magnetite bodies and undeveloped porphyry Cu-Mo-Au and Au-Cu skarn deposits.

Evolution of the Uralian Paleozoic magmatism: composition, magmatic sources, geodynamics, comparison with the eastern part of Uralian-Mongolian belt

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The main stages of the Paleozoic intrusive magmatism in the Urals occur at 460–420, 415–395, 365–355, 345–330, 320–315, and 290–250 Ma, as well as two recognized virtually amagmatic periods between 375–365 Ma and 315–300 Ma.

In the time interval from 460 to 420 Ma, ultramafic and mafic primary melts were produced from mantle magma sources.

The dunite–clinopyroxenite–gabbro massifs of the Platinum Belt and miaskite–carbonatite association are specific derivates of these melts.

The presumably rift-related Tagil synform includes the volcanic–plutonic rock series (the oldest in the Uralides) comprising of gabbro, gabbro–granitoid, and gabbro-syenite series and comagmatic volcanic rocks. The geochemistry of these rocks fits modern island-arc volcanics, thus supporting the most popular idea of the island-arc nature of the Tagil synform and the igneous rocks that occur therein.

The Magnitogorsk megazone has existed since Devonian times. The most abundant Middle Devonian magmatism developed mainly in the form of volcanic eruptions. The large massive sulfide deposits are related to the volcanic rocks. The Rassypnyansk pluton composed of tonalite and trondhjemite is the only large intrusive body exposed at the surface. The U–Pb zircon age of this pluton corresponds to concordant values of 393 ± 6 Ma.

The Famennian gabbro-tonalite-granodiorite-granite intrusive complexes (formed around 360 Ma) complete the island-arc evolution of the Magnitogorsk megazone and change to large-scale granitoid magmatism of the Paleozoic Ural Orogen.

The formation of large gabbro-tonalite-granodiorite-granite plutons in the NW sector started at 370 Ma. This was accompanied by hydrous basic magmatism represented by Hbl and Bt-Hbl gabbro and diorite, which seem to be a source of material and heat energy for anatexis.

The anatectic granitoids are mainly tonalitic and granodioritic in composition. Their zircon ages are 320– 315 Ma.

The evolution of the plutons did not cease at this episode. Furthermore, probably owing to the effect of ongoing basic magmatism, tonalite and granodiorite experienced partial melting with the formation of the secondary adamellite or granite melt. Zircons crystallized from this melt have an age of 305 to 280 Ma.

The intense orogenic magmatism of the Urals finished in Permian times with formation of the large granite plutons with two peaks of magmatic activity: ~290 Ma and 255–260 Ma.

Thus, the Ordovician, Silurian, and Early and Middle Devonian mantle magmatism gave way to the Late Devonian–Carboniferous mantle–crustal magmatism and further to Permian crustal magmatism.

The main stages of Uralian Paleozoic magmatism correlate with magmatic episodes in such important parts of Uralian-Mongolian belt as Transbaikalia, western Sayan, Rudny Altai.

Pre-Ordovician and post-Permian events in the Uralides: new isotopic data and their geological and metallogenic implications

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The progress in isotopic timing of igneous and metamorphic rocks of the Urals has made it possible to specify and even substantially revise the geological history of the Uralides, which evolved from the Ordovician to Permian. In this communication, we call attention to new age determinations of the magmatic events that pre- and postdated this time span (Tables 1&2). The most important implications of these ages for geological history and metallogeny of the Urals are as follows.

(1) The preliminary data (Batanova et al., 2006, 2007) suggest a Paleoproterozoic age for harzburgite, the prevalent rock in the Uralian ophiolitic belts. Lherzolite is a refertilized harzburgite (Le Roux et al., 2007), dunite is a product of reaction of harzburgite with mafic melt at a shallow depth, and wehrilte and olivine clinopyroxenite as cumulates of such melts are coeval (Neoproterozoic-Cambrian). All these rocks predated the eruption of Ordovician basalts and the emplacement of Paleozoic gabbroic intrusions commonly included in ophiolitic complexes. Thus, the ophiolitic belts of the Urals are composed of rocks different in age, which never comprised an undeformed continuous section of oceanic crust. These rocks have been juxtaposed as a result of multi-fold deformation of the rifts, which periodically arose under transtensional conditions along boundaries of large tectonic blocks, and then were transformed under transpression into the sutures that separate these blocks at present.

(2) The ultramafic and mafic rocks of the Uralian Platinum Belt pertain to at least three associations of different ages and tectonic settings. The younger association of gabbro, gabbronorite, and plagiogranite is reliably dated at 430--415 Ma (Silurian) and correlated with coeval volcanics formed in the island-arc and backarc settings. The older association consists of (i) dunite - the main source of PGM placers (restites of wehrlitic mantle); (ii) olivine clinopyroxenite grading into wehrlite (cumulate); (iii) magnetite clinopyroxenite, or kosvite (evolved melt with elevated Ca/Al ratio); (iv) plagioclase-bearing clinopyroxenite, or tylaite (cumulates and residual melts as products of fractionation of the magma with a somewhat lower Ca/Al ratio), and olivine gabbro. This association is dated at the Late Vendian and Cambrian, and was formed during the Cadomian continental rifting. The rifts dissected an arch that occupied the Timanides and the Protouralides and is marked by a Cambrian break in sedimentation. The third association is composed of pseudoleucite tylaite and apatite kosvite, which are dated at ~440 Ma (Ordovician-Silurian boundary). They are coeval with miaskite and carbonatite of the Ilmeny and Vishnevy Mountains and completed the Cadomian cycle almost contemporaneously with eruption of the Ordovician basalts that mark the onset of the Caledonian cycle. The Early Devonian kosvite and websterite of the East Khabarny Complex completed this cycle in the South Urals.

(3) The Ural Orogen was eventually formed in the Permian. The waning stages of orogenic granitic magmatism extended in the Mesozoic. To date, four occurrences of granitic rocks with proved Mesozoic Rb-Sr ages are known in the Central and South Urals (Table 2). The Middle Triassic (~240 Ma) granitic rocks are synchronous with eruptions of bimodal basalt-rhyolite volcanics widespread in the Transuralia and West Siberia. However, the Triassic granitic rocks of the Uralides are sharply distinct from coeval rhyolite in composition. In the Magnitogorsk Trough, these are peralkaline granite and granosyenite. More aluminous leucogranite porphyry with fluorite phenocrysts (elvan) located in the East Ural Rise is markedly enriched in Rb, Cs, Li, Ta, and especially Nb. The Middle Jurassic rocks include (i) pegmatite veins that cross the Permian granite of the Adui pluton (formerly these pegmatites were mined for Ta an Nb) and (ii) glimmerite as a host rock at the Malyshevo emerald

deposit located nearby the east contact of the Adui pluton. The sources of Mesozoic granitic rocks in the Magnitogorsk Zone and East Ural Rise are distinct: most likely the fenitized crustal rocks in the first case and the granitic rocks that underwent phyllic alteration in the second case. As in the Gorny Altai and other Paleozoic provinces of Eurasia, the Mesozoic granitic rocks in the Urals are distinguished by enrichment in rare alkali metals, F, Ta, Nb, and Be. In particular, the Malyshevo emerald deposit is unique not only in its mineralogy and geochemistry but also in age.

Table 1. Isotopic age of pre-Ordovician mafic and ultramafic rocks in the Uralides

Locality and rock	Age, Ma (*t*)	ε_{Nd} (*t*)	Source
Ophiolitic belts			
Voikar: harzburgite	2100–2000 (Re-Os)		Batanova et al. (2006, 2007)
Mindyak	762 ± 68	3.76	Popov et al. (2008)
Nurali	578 ± 18	5.25	Tessalina et al. (2007)
Klyuchevsky: lherzolite, wehrlite, Ol clinopyroxenite	499 ± 13 (Sm-Nd)	6.21	
Voikar: chromitite in dunite	585 ± 6 (U-Pb, zircon)		Savelieva et al. (2007)
Platinum belt			
Kytlym: wehrlite, Ol clinopyroxenite, kosvite, low-K tylaite	551 ± 32 (Sm-Nd)	6.31	Popov & Belyatsky (2006)
Denezhkin Kamen: Ol clinopyroxenite, tylaite, Ol gabbro	552 ± 43 520 ± 53 500 ± 24 ? (Sm-Nd)	6.26 6.02 6.95	Efimov et al. (in press)
Ordovician and younger rocks			
Kytlym: pseudoleucite tylaite	441 ± 27 (Sm-Nd)	5.86	Popov & Belyatsky (2006)
Suroyam: apatite kosvite	444 ± 27 (Sm-Nd)	6.74	Authors' data (unpubl.)
East Khabarny: websterite	411 ± 12 (Sm-Nd)	4.56	Pushkarev & Biryuzova (2007)

Note: The original age determinations presented here and in Table 2 were performed at the Center for Isotopic Studies, the Russian Geological Research Institute, St. Petersburg, analyst B.V. Belyatsky.

Table 2. Rb-Sr age of Mesozoic intrusive rocks in the Uralides

Rock	Rb–Sr age, Ma (*t*)	$(^{87}Sr/^{86}Sr)_t$	$t(DM)_{Nd}$, Ma	Source
Adui pluton, Malyshevo emerald deposit, East Ural Rise				
Glimmerite	207.3 ± 5.2	1.10	838	Popov et al. (2003)
	206.6 ± 1.4	0.7096		Baksheev et al. (2003)
Adui pluton, Kvartalny Ta-Nb deposit (abandoned), East Ural Rise				
Pegmatite	196.3 ± 1.6	0.712622	1140	Authors' data (unpubl.)
Adui pluton, quarry in the northern part, East Ural Rise				
Pegmatite	200.9 ± 7.4	0.71108		Authors' data (unpubl.)
Close to the Dzhabyk pluton, East Ural Rise				
Granite porphyry	238 ± 1.8	0.7582	789	Tevelev et al. (2007)
Mt. Cheka intrusion, Magnitogorsk Zone				
Alkali granite and granosyenite	237 ± 21 (wr) 230 – 223 (mineral isochron)	0.7046 0.70479–0.70592	495	Tevelev et al. (2008)
Bimodal basalt-rhyolite volcanic association, Transural region				
Rhyolite	~240*	0.70394 0.70559	702 726	Authors' data (unpubl.)

Notes: Notes: $t(DM)_{Nd}$ is a two-stage Nd model age calculated using the parameters of the depleted (relative to CHUR) mantle (DM) accepted by DePaolo et al. (1991). There are grounds to consider these parameters close to those of the terrestrial primitive upper mantle (Popov, 2003).The $^{47}Sm/^{144}Nd$ ratio at the first stage is 0.118 (average value of tonalite, after Wedepohl, 1995). *Generally adopted estimate.

How orogenic are orogenic ore deposits? – the late Palaeozoic Laurasia-Gondwana junction in Europe and central Asia

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In 1998, Groves and coworkers published their formal definition of orogenic ore deposits. Hypabyssal Au-As deposits, epizonal Au-Sb deposits and shallow Hg-Sb and Hg deposits were brought together in a coherent framework along a steep crustal-scale shear zone. Eventually, orogenic deposits were combined with intrusion-related deposits (Sillitoe, 1991; Lang & Baker, 2001) in metamorphic belts (Groves et al., 2003), again with the sources of the metals in the Earth's crust.

Between the western Variscides and the eastern Tien Shan, the late Palaeozoic ore deposits include gold-dominated deposits viewed as 'orogenic', 'intrusion-related' or 'shear zone-controlled'. Isotope-geochronology suggests these were formed mostly between *c.* 305 and 290 Ma, together with deposits of tin-tungsten-copper-molybdenum and outbreaks of ignimbrite induced by mantle melts. Mercury and mercury-antimony deposits are generally thought to be of early Permian age on evidence from host complexes. The mercury deposits at Nikitovka and Idria are post-Carboniferous and mid-Triassic, respectively. The gold deposits in the Southern Tien Shan were formed between *c.* 290 and 280 Ma, together with copper-nickel deposits in association with ultramafic-mafic intrusions and with A-type granites which expand the age range to *c.* 300 and 270 Ma.

Charvet et al. (2007) conclude a change in the geodynamic regime of the eastern Tien Shan from collision and overthrusting during the late Carboniferous to Permian strike-slip at the lithosphere scale. Arthaud and Matte (1977) propose a similar translithospheric strike-slip regime operated between Laurussia and Gondwana in southern Europe and northern Africa during this interval. Instrumental in the formation of the Urals and the Appalachians, it destroyed the Variscan orogenic belt. Translithospheric extensional domains induced decompression melting in the lower lithosphere and asthenosphere. Emplacement of melts along corresponding extensional jogs is represented by practically synchronous gabbroid intrusions, A-type granite and flares of ignimbrite and is compatible with the concepts of 'mantle hot fingers' (Wilson and Patterson, 2001) and 'tube-like intrusions' (Pirajno et al., 2008). This concept was developed in relation to the emplacement of anorogenic magmas and Cu-Ni sulphide deposits, respectively. The 'hot finger' model can operate without a plume; the 'tube' model includes a superplume. Arguments for metal sources about the asthenosphere-lithosphere transition are listed in a companion poster.

In view of the timing of the above processes, during and even after breakdown rather than buildup of the orogens, the orogenic nature of the 'orogenic ore deposits' may well be questioned. Associated alkaline magmas would further support their identification as 'anorogenic'. However, even anorogenic magmas are not necessarily divorced from orogenic processes (Windley, 1993). They can still be viewed as a function of plate margin processes, as suggested here by the near-synchronicity across two autonomous orogens, even at present spanning over a hundred degrees of longitude. A lithosphere-scale strike-slip framework tends to resolve the debate on relations between 'intrusion-related', 'shear zone-related', 'orogenic' and probably even 'Carlin-type' deposits. They may well be birds of a feather, segments of one dynamic fabric with transitional and transient partitions. Whatever the classification, the exploration perspective is thus enlarged to include the continental lithosphere and the upper asthenosphere as potential sources not only of fluids but also of metals.

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For further references see the abstracts of two companion posters.

Paleozoic tectonics and evolution of Kazakhstan

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Kazakhstan represented a major site of accretionary crustal growth during the Paleozoic and was incorporated into Eurasia after collisions with Siberia, Baltica and Tarim. Mechanisms of this accretion and geodynamic setting during different epochs are a subject of current controversy.

Kazakhstan consists of several microcontinents and island arcs, which have distinctly different geological histories and in a recent structure represent allochthonous blocks, bounded by ophiolite-strewn suture zones. Occurrence of ophiolites in sutures implies that the terranes were mutually isolated by an oceanic crust. Microcontinents are characterised by Lower Proterozoic felsic metamorphic basement and a Vendian to Lower Paleozoic sedimentary cover. Except for Stepnyak-North Tian-Shan, they lack subduction-derived volcanic rocks.

Arc systems are reconstructed as paired belts where calc-alcaline volcanism (arc) and active deformations in deeper marine settings (accretionary wedge) occurred synchronously within narrow parallel strips. Relative positions of the arc and the wedge point at the direction of subduction. Arcs developed either on oceanic crust (Baidaulet–Akbastau, O_{1-2}), on heterogeneous basement (Selety, Cm-O_1, Boshchekul–Chingiz Cm_2-O_2), or on continental crust (Stepnyak-North Tian-Shan O_{2-3} and Chingiz O_3-S_1). The arcs are generally characterized by relatively short periods of activity, which were not synchronous in different arc systems.

Cessation of deep marine sedimentation within suture zones, followed by cessation of volcanism in the adjacent arc, by broad deformations and emplacement of batholiths indicate episodes of terrane amalgamation and accretion. Timing of suturing is also constrained by the age of overlap assemblages and stitching intrusions. Episodes of amalgamation are followed by jumping of subduction-related volcanic belts, which reflect initiation of new subduction zones. Two orogenic events in the middle of Silurian and in the Middle Devonian apparently also reflect local oroclinal bending of the arcs in the NE of Kazakhstan due to roll-back of an subducted oceanic plate.

The lack of volcanic rocks within microcontinents, the distinct differences between units, the presence of short-lived arcs and of non-synchronous multiple sutures all argue against a single arc and support a model of numerous terranes, which were welded together in an oceanic setting.

Principal terranes were amalgamated between Early Ordovician and Late Silurian. Since the Late Silurian, a major part of Kazakhstan represented a continental block. Active margins evolved in the east around Junggar-Balkhash area (~415-300 Ma), in the west (~415-390 Ma and 335-315 Ma) and in the south (~325-315 to 300 Ma). The start of collisions of Kazakhstan with Siberia, Baltica and Tarim can be dated as ~320 Ma, ~315 Ma, and ~300 Ma respectively. Structural patterns in the East Kazakhstan orocline indicate that the final episode of oroclinal bending in the Balkhash area took place during the Late Carboniferous and Early Permian. This is interpreted as a result of the opposing movements of Siberia and Tarim, which squeezed Kazakhstan during the latest stage of collision.

The age of gold deposits of the Eastern Kazakhstan, relationships with magmatism and mineralization of adjacent areas

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Eastern Kazakhstan is one of the very promising gold-ore regions of the Central Asia. Large commercial deposits of Au-sulfide (Au-As) (Bakyrchik, Bolshevik, Suzdal, etc.) and Au-Te (Sekisovskoye) types, and also whole series of small and average deposits of Au-sulfide-Q, Au-Sb, and Au-skarn types are revealed in the structures of this region. Two main ore complexes of gold mineralization can be recognized in the Eastern Kazakhstan: 1) Cu-Mo (Au) porphyry, Au-Te, Au-Ag associated with diorite-plagiogranite intrusions; 2) Au-sulfide-Q and Au-sulfide (Au-As) and Au-Sb-Hg. The same types of deposits occur in adjacent areas of NW China.

The earliest among them is Cu-Mo (Au) porphyry mineralization – 310 Ma (Re-Os, Song H.X. et al., 2007). The Au-Te mineralization closely associated with Cu-porphyry systems frequently forms independent industrial deposits. The age of one of Au-Te deposits (Sekisovsloye) is dated at 306.6±3.8 Ma (Ar-Ar, sericite). Mineralization of Au-As (±Sb, Hg) geochemical type is represented by several occurrences, which are characterized by different temperatures and are situated at different levels of the ore-forming system. The ages of Au-As mineralization are within the interval of 290-270 Ma (Ar-Ar, sericite). The deposit is mostly located in the Eastern-Kalba ore belt in black shales and grey sedimentary Carboniferous host rocks.

The model of the formation of these deposits consists of several stages, including processes of accumulation of the enriched by Au, Ag, Sb carbonaceous terrigenous rocks, their conversion during diagenesis, catagenesis of sediments and formation of shear zone, and hydrothermal-metasomatic processes related to the Later Paleozoic (C_3-P) magmatism. This multistage model of the Au-As mineralization forming is evidenced by geochemical data, isotope composition (C, S), and isotope-geochronological (Ar-Ar) data.

Gold and gold-silver deposits of Uzbekistan and the importance of mineralogy in mine-scale exploration

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Gold and gold-silver ores of Uzbekistan can be subdivided into gold-quartz, gold-sulphide-quartz and gold-sulphide types. The deposits are located within the Beltau-Kuraminsky volcano-plutonic belt, within the Kyzylkumsky, Nuratinsky, Kuraminsky and Chatkal ore camps. In the Kyzylkumsky and Nuratinsky regions (Muruntau, Kokpatas, Charmitan, Gujumsay deposits), the key geochemical signatures of economic resources are Au-W and Au-As; Au-Te, Au-Ag, Au-Sb and Au-Hg correlations are of secondary value. In the Kuraminsky region, Au-Te and Au-Ag deposits (Kochbulak, Kyzylalmasay) dominate, whereas Au-Sb and Au-Hg deposits (Kadamjai, Haidarkan) are most abundant in the Chatkal region.

In the larger, poorly-eroded deposits, or in orefields in which the full tectonostratigraphic sequence is well preserved, a characteristic vertical geochemical zoning (from bottom to top) may be readily recognized. The regularity of zonation is clearly reflected in the distribution and composition of tellurides and selenides within the ores.

Tellurides and selenides of bismuth are common in the deposits of Western Uzbekistan, in, for example, the Muruntau, Muytenbay, Charmitan and Gujumsay deposits.

Selenide and tellurides of silver and gold, and especially tellurides of Sb, Hg and Pb, are most abundant in Eastern Uzbekistan (Kochbulak, Kayragach, Kyzylalmasay and Chadak). Selenides of bismuth or silver are common at upper levels, but their abundance, and the role of selenium, decreases with depth. Conversely, the proportion of Ag-, Au-, Hg-, Sb-, Pb- and Bi-tellurides increases markedly with depth.

The telluride and selenide minerals form regular microparageneses within specific types of mineralization, generally at certain levels of the deposits. The distributions of the tellurides and selenides, and their tendency towards spatially-governed speciation within zoned deposits allows their presence to be used when undertaking mine-scale exploration to identify type of mineralization, zoning level and degree of erosion. Identification and mapping of telluride-selenide parageneses can greatly assist in exploration for hidden gold or gold-silver mineralization.

The Au-(Ag)-tellurides are, of course, also important gold- and silver carriers in many of the deposits. Detailed knowledge about them, their association, size and morphology is critical to optimizing efficient exploitation and ore processing.

Regional metallogenic evaluation on the basis of geophysical data

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During the last decade, in the Vernadsky State Geological Museum and Russian-French Metallogenic Laboratory, research using regional (1:1,000,000) scale geophysical data for evaluation of mineral potential has been conducted to determine the theoretical benefits, for practical application to different regions. The approach is built on two models of heat-and-mass through-crust transport (from the Moho discontinuity to the Earth’s surface), considered as an engine or source of energy supply for ore-forming processes. In the first case, a pipe-like seismically transparent structure of high density corresponds to mafic-ultramafic magmatism. In the second case, a cup-like shape, which is also seismically transparent, and is characterized by low density in the middle (15-30 km) crust, corresponds to felsic magmatic systems. Using the two models, specific techniques are developed as tools for selection of prospective areas for ore deposits relating to the two types of magmatism. To test the techniques, over 25% of Russian territory has been analyzed, and the results demonstrate it is possible to identify such areas for different (but not all) types of ore deposits.

Mineral Deposits at the Tien Shan Intraplate Stage

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The Paleozoic history of the Tien Shan was completed by intraplate processes related to the Paleotethys closure. This stage of deformation developed in the course of continuing collision and sinistral slip of the Tarim and Kyrgyz-Kazakh microcontinent.

Widespread rifting was typical of that time. A system of narrow grabens in the Chatkal-Kurama Zone was filled with subalkali basalt and andesite. In the western part of Middle Tien Shan, the boundary faults of the Kassan Graben controlled antimony- mercury mineralization. In this region gold and antimony mineralization is known in deposits of jasperoides type (Tereksai, Ishtamberdy, Kassan), where the ore is localized in silicified fractured marble confined to interformational detachments. Similar deposits are extensively developed in the Turkestan-Alai Mountain Chain: Khaidarkan, Kadamjai, Abshir and other deposits of the antimony-mercury belt in the Southern Tien Shan. Another type of mercury mineralization is represented here by a cinnabar ore hosted in listvenites; such mineralization is spatially related to ophiolite belts as sutures of former oceanic structures (Chonkoi deposit). Recently, this type of deposit took on great economic significance.

The intraplate stage was characterized by emplacement of ore-bearing Permian–Triassic intrusion complexes represented by one or two-phase intrusions, a part of which were of fissure-type. Small granitoid bodies, syenite, nepheline syenites, and carbonatites were emplaced. This association characterizes intraplate rifting post-collision tectonic conditions.

Peralkaline granite and alaskite (North Tien Shan) are accompanied by rare-metal mineralization (REE, Zr, Th, Nb, Be) with the Aktiuz ore field as the typical and most prominent example.

The magmatic activity in the Middle Tien Shan predetermined the formation of gold mineralization at the Makmal deposit. Complex mineralization occurred at contacts with Middle Carboniferous intrusions and Late Permian leucogranite. The magnetite skarn, massive sulphide ore, and episkarn greisen with Sn, W, and Be mineralization along with economic gold-sulphide ore were formed during the second stage when Late Permian leucogranite was emplaced.

The other granite associations (South Tien Shan), e.g. the rapakivi granites, reveal two different trends of magmatic evolution: (1) homodromic granite-type is completed by the formation of hastingsite leucocratic granites; (2) antidromic alkaline-type is completed by the formation of lujavrites and carbonatites. The metallogeny of both complexes is extremely variable. The REE mineralization is associated with carbonatites (Sarysai). Gold-sulphide-quartz mineralization is related to the rapakivi granite of the main intrusive phase (Djangart, Togolok). Tin mineralization is hosted in greisens associated with hastingsite leucogranite.

Geologic-economical map of Kyrgyzstan

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The geological-economical map of Kyrgyzstan was compiled to assist in developing a strategy for geological investigations and to provide a basis for mining and exploration.

All available information on infrastructure of the territory of the Kyrgyz Republic was used as a foundation, as these data indicate conditions and the difficulties for carrying out works in any defined area. The following parameters are shown on the map: relief, drainagesystems, highways of different categories of importance, railways, natural parks, settlements, power lines, airports, electric power substations, and mining enterprises.

More than 100 of the most significant mineral deposits comprising more than 20 commodity types are shown on the map; they are divided in accordance with reserves, composition, degree of study, ore quality and morphology of ore bodies. The map includes a table showing the economic parameters of each deposit. Deposits are subdivided into three groups depending on their economic parameters.

The map forms a good base for the selection of the most prospective deposits for exploration and exploitation.

Hercynian magmatism in the Tien Shan: research in progress

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The Hercynian Tien Shan orogen formed during Late Palaeozoic collision between the Karakum-Tarim and the Paleo-Kazakhstan continent. The western part of the Tien Shan is composed of three structural units or terranes: (1) the Northern Tien Shan, the deformed margin of the Palaeo-Kazakhstan; (2) the Middle Tien Shan, a Late Paleozoic volcano-plutonic arc; and (3) the Southern Tien Shan, an intensely deformed fold and thrust belt. The Middle and Southern Tien Shan terranes are separated by the Southern Tien Shan Suture (STSS), formed after the closure of the Paleo-Turkestan Ocean.

The post-collisional intrusions are spread out in all the terranes of the Tien Shan regardless of the STSS, and comprise diverse calc-alkaline, alkali-calcic granitoid and alkaline s.s. complexes closely associated in time and space. Most of the intrusions are tectonically controlled and are associated with major tectonic lineaments. Twenty intrusions in the Northern, Middle and Southern Tien Shan along a ca. 2000 km – long profile from the Aral Sea in Uzbekistan to the Pobeda Peak in Kyrgyzstan were dated using U-Pb zircon method by SHRIMP-II facility in VSEGEI St. Petersburg. To distinguish between subduction-related and post-collisional magmatism, 10 intrusions from the Middle Tien Shan volcanic arc were included in the data set. The results show that all the post-collisional intrusions formed within a very narrow time span from 295 Ma to 280 Ma. The intrusions of the Middle Tien Shan arc in Uzbekistan formed within a 320 – 305 Ma time span in a subduction-related environment.

Two stages of gold mineralisation are associated with subduction-related and post-collisional granitoids, making the Tien Shan the richest gold province in Eurasia. However, the two stages are represented by different genetic types of Au mineralization: porphyry and hydrothermal systems in volcanic arc rocks and orogenic gold deposits in post-collisional rocks. The new data show that subduction-related calc-alkaline magmatism is restricted in space while the post-collisional granitoids are spread out in all the terranes of the Tien Shan regardless of the STSS and comprise compositionally diverse magmatic series.

Several authors suggested that diverse post-collisional magmatism originated from a mantle plume which developed under Central Asia immediately after Hercynian collision. However, based on tectonic analysis and timing of post-collisional magmatic events, we propose a different model for the post-collisional evolution of the Tien Shan. From our point of view the emplacement of the post-collisional intrusions and orogenic gold deposits was controlled by the trans-crustal scale shear zones which formed as a result of the east-west strike-slip motions that affected the Tien Shan subsequent to collisional events. Our data show that these motions took place over a relatively narrow time span from 295 Ma to 280 Ma. We believe that plate-scale shear zones provided suitable conduits for ascending asthenospheric material and heat influx in the crust. The compositional diversity of post-collisional magmatism in various terranes of the Tien Shan probably reflects different compositions of the crust.

POSTER PRESENTATIONS:

Orogenic gold, intrusion-related gold and associated metals – current models as a basis for further work

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The orogenic ore deposit association as defined by Groves et al. (1998) has seen an evolution from a genetic model for mesothermal gold lodes in Archean terranes to a general exploration guide for mesothermal gold deposits in orogenic belts. Milestones in its evolution are the recognition of orogenic metamorphic belts as host complexes and the assimilation of intrusion-related gold deposits. Together with 'gold-dominant intrusion-related deposits' and 'gold deposits with atypical metal associations', the 'orogenic gold deposits' are now grouped as 'gold deposits in metamorphic belts' (Groves et al., 2003). Throughout this evolution, the continental crust has been viewed as the unique source of gold and, *mutatis mutandis*, the other metals of the association. The shear zone control of the original proposal provides a principal tool in exploration. While, in this view, the crust appears to remain the sole metal source, the associated fluids have increasingly revealed a mantle component (*e.g.*, Mao et al., 2008).

The Precambrian age of the host complexes of the early Cretaceous gold deposits of eastern China directs Goldfarb et al. (2007) to 'metamorphic decarbonation and dehydration of subducted oceanic crust and/or overlying sediments as the source of the hydrothermal system', to provide the metals, following Kerrich and Wyman (1990, 1994). The incorporation of the intrusion-related gold deposits in the 'gold deposits in metamorphic belts' could have led to the subcontinental lithosphere and asthenosphere as potential metal sources as recognized by Lang and Baker (2001). This does not yet appear to be the case.

There are, however, compelling arguments to look for the floor of the ore systems at least at the base of the continental lithosphere plates. These comprise *(i)* the tentatively suggested asthenospheric source of the alkaline mafic volcanics and mercury at Almadén (Higueras et al., 2000, 2005); *(ii)* the inferred asthenospheric sources of late Palaeozoic alkaline basalts and associated A-type granites, coeval (ultra)mafic intrusions and associated Cu-Ni deposits and Au deposits in the Tien Shan (Konopelko et al., 2007; Mao et al., 2008b; Pirajno et al., 2008); *(iii)* the concentration of Cu-Ni-PGE-Au at the top of the asthenosphere at Lanzo (Lorand et al., 1993); *(iv)* laboratory experiments of Karato and Jung (1998) and Pilet et al. (2008) on the evolution of partial melts in the asthenosphere; *(v)* the preferred distribution of both mesothermal Au deposits and epithermal Hg, Hg-Au and Sb-Au deposits in association with translithospheric plate-bounding strike-slip zones; and *(vi)* the similarities in proposed settings of gold and mercury deposits in the Tien Shan and the Coast Ranges (Konopelko et al., 2007). I propose to expand the orogenic ore deposit model from crustal to lithospheric scale, both mechanically and fully materially. We illustrate this proposal with the late Palaeozoic Laurasia-Gondwana junction in Europe and Central Asia (de Boorder and Zeylmans, CERCAMS 12, 2008).

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Orogenic metallogeny of the late Palaeozoic Laurasia-Gondwana junction in Europe and Asia

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Mesothermal and epithermal deposits of gold, antimony and mercury and associated minor metals formed during the late Palaeozoic in western Europe and central Asia are generally seen as a function of the Variscan, Tien Shan and Altaid orogenies. The mesothermal gold-dominated deposits have been viewed as ‘orogenic’, ‘intrusion-related’ and/or ‘shear zone-hosted’ deposits. In the Variscides, the late Palaeozoic ore deposits show a peak in preserved deposits formed between about 305 and 290 Ma. These include magmatic-hydrothermal deposits of tin, tungsten, molybdenum, and copper. During this period, the Variscan orogen was destroyed in a right-lateral translithospheric shear belt between Laurussia and Gondwana, from the Urals to the Appalachians (Arthaud & Matte, 1977; Bard, 1997). This period also saw outbreaks of felsic crustal melts across large areas of western Europe, even beyond the domain of the Variscan orogen, generated by systems of (ultra)mafic mantle melts.

In the southern Tien Shan, the observed ages of gold deposits appear younger than the above age range in the Variscide domain. However, while analytical methods are diverse, the age of the Muruntau deposit (287.5±1.7 Ma) is closely comparable. Similarly, ages obtained for A-type granites (Konopelko et al., 2007; ref. #14), (ultra)mafic intrusions and associated copper-nickel deposits in the Southern Tien Shan and in the Altaids (Mao et al., 2008; refs. #15-18) compare very closely with those obtained for the gabbro-rhyolite association in the present Southern Alps (Mulch et al., 2002; Schaltegger & Brack, 2007). Mao et al. (2008) conclude to a single mineralizing event, with production of different ore types, in the course of the late Carboniferous to early Permian, between Muruntau in the west and Kanggurtag to the east. Charvet et al. (2007) argue a change in deformation regime from subduction to lithosphere-scale strike-slip with dextral translation of the Tarim block relative to the Junggar block, in the course of the late Carboniferous to Permian. This compares directly to the late Palaeozoic translithospheric shear belt dissecting the Variscan orogenic system.

Thus, a paradox arises with ore deposits defined as ‘orogenic’, ‘intrusion-related’ or ‘shear zone-hosted’, if not coeval then geologically only slightly diachronous, formed within the domains of at least two autonomous orogenic belts, at a time when the orogenic belts are not orogenic anymore. This leads to the question ‘how orogenic are orogenic ore deposits?’. The paradox can be resolved in the translithospheric strike-slip framework through interaction between lithosphere and asthenosphere (compare Wilson and Patterson, 2001; Pirajno et al., 2008, refs. #15-18), possibly at the price of reclassification of [the] orogenic ore deposits as anorogenic deposits.

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Tectonic episodes of intracontinental deformation revealed by multichronology in the Tien Shan (Kyrgyzstan) and Altai (Siberia)

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This abstract reports on an ongoing project to reconstruct the chronology of formation and tectonic reactivation of important basement structures in the intracontinental Central Asian Orogenic System. The focus lies on two representative sutures: the Atbashi-Inylchek suture in the southern Kyrgyz Tien Shan and the Charysh-Terekta-Ulagan suture in the Siberian Altai. In both study areas, several profiles across the sutures are sampled with different rock types, each characterizing a typical geodynamic environment, such as ophiolites, granitoids and metamorphic basement. Apatite and zircon from these samples are being analysed, using a multichronological approach. We apply multiple complementary dating methods, sensitive in different temperature conditions, to evaluate the tectonic-geodynamic evolution of these regions. Preliminary apatite fission track (AFT) dating results from the central Kyrgyz Tien Shan will be presented. We take a closer look at three North-South profiles in the central part of the Kyrgyz Tien Shan that cover a narrow East-West oriented area between 74° E and 77°30’ E longitude, crossing the Djumgal, Moldo and Terskey Range. We focus on this area because it accommodates most of the strain and deformation in the tectonically active Tien Shan and therefore it provides us with the most information on the amount of differential fault movement and associated denudation. AFT ages vary between 160 Ma and 35 Ma (Late Jurassic to Eocene). Based on their lateral variation and structural position, we argue that the Precambrian-Palaeozoic crystalline basement was elevated along North-South fan-shaped thrust faults. This pattern can be explained in the broader geodynamical context of the study area with two distinct phases of exhumation and denudation in the Mesozoic and Cenozoic.

Sutures, Terranes and Plate Tectonic Reconstructions of the Central Asian Orogenic Belt

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The Central Asian Orogenic Belt (CAOB) can be divided into three main orogenic systems, the Peri-Siberian, Khazakhstan and the Northern Tarim-North China Orogens. The belt is delimited by the Urals Orogenic System to the West, the Siberian Craton to the North, the Pacific Realm to the East and Tarim-North China Block to the South.

The Peri-Siberian orogenic system is composed of the Tuva-Mongolian orogenic system, and the Sayan, Gorny-Altai and Altai-Mongolian terranes. The Tuva-Mongolian orogenic system is composed of three orogens: Dzhida-Bayangol, Bayanhongor-Herlen and Dariv-Agardagh. It was formed by the Early Cambrian and could be considered as exotic or autochtonous. The Gorny-Altai and Altai-Mongolian terranes are also considered as exotic and were accreted to the Siberian craton before the Middle Ordovician. The Sayan terrane is interpreted as a Siberian arc-backarc.

Recent works (Windley et al., 2007) show that the Kazakhstan orogenic system was not formed by a single arc but was created by five successive orogenic events (Kirgiz-Terskey, Dzhalair-Naiman-Urumbai, Erementau-Yili, Maikain-Kyzyltas and Junggar-Balkash). Two phases were distinguished: a pre-Silurian amalgamation of microcontinents and island arcs, and the final Junggar-Balkash Carboniferous closure as an orocline. The north side and the south side of the orocline could possibly extend in the Kelameili and in the North Tianshan-Mongolian Altan Uul suture, respectively. At this stage of current knowledge, it is difficult to constrain the origin and the geodynamic evolution of the different terranes forming the Kazakhstan orogenic system. A Neoproterozoic Australian origin was proposed but a double origin is possible. The Kazakhstan terranes or a part of them could also be located in the proto-Pacific during the Neoproterozoic.

We consider that the Northern Tarim-North China orogenic system is composed of the Turkestan, South Tianshan, Xiaohuangshan, Ondor Sum-Kedanshan and Liaoling orogens/suture zones. The North China-Tarim single Paleozoic evolution is induced by the correlation of the Lower Paleozoic sutures in the Southern Kunlun-Qilian-Qiling orogenic system. To the North of the Tarim-North China Block, the correlations of the sutures are more problematic. The plurality of the orogenic systems (Peri-Siberian and Kazakhstan) raises the concept of diachronous geodynamic events, and possible distinct geodynamic scenarios along the Northern North China-Tarim margin.

The Kazakhstan orogenic system is separated from the Peri-Siberian and Northern North China-Tarim orogenic systems by the Earliest Carboniferous Chara and Late Devonian Central Tianshan sutures, respectively. The final suture of the CAOB is located in the Junggar-Balkash and Solon Obo-Linxi (Inner Mongolia) suture zones. The closure was diachronic from the Late Carboniferous in Xinjiang to the Lower Permian in Inner Mongolia.

ADDITIONAL ABSTRACT CONTRIBUTION:

Geology and metallogeny of giant gold deposits Kumtor, Muruntau and Bakyrchik (comparative analysis)

Rafailovich M.S., Seltmann R., Fedorenko O.A., Golovanov I.M. & Nikonorov V.V.

Gold ore giants associated with black shales are a surprising natural phenomenon and a major commercial raw material.

Forecasting-prospecting models of the mesothermal deposits Kumtor, Muruntau and Bakyrchik are considered according to comparative plan.

Gold ore giants have clear-cut distinctions and similarities. The deposits differ by: age of carbonaceous strata (Dzhetymtau suite R_3-V for Kumtor, motley Besapan suite O_3-S_1 for Muruntau, Bukon suite C_2 for Bakyrchik); wallrock alterations (potassium feldspathization dominates in Kumtor and Muruntau, carbonaceous-sericitolite metasomatosis in Bakyrchik); forms of ore bodies (steeply-dipping megastockwork at Muruntau, gently dipping mineralized deposits at Kumtor and Bakyrchik), ratio of gold, quartz and sulfides (free gold in quartz prevails at Muruntau, fine gold in association with sulfides at Kumtor and Bakyrchik), mineralogical-geochemical specialization of mineralization (Au, Te, W, platinoids on Kumtor; Au, Ag, W, As, Bi, U, and platinoids at Muruntau; Au, As at Bakyrchik) and some other attributes reflecting local features of mineralization.

Comparative analysis of the studied deposits shows surprising similarity and uniformity between geological and mineralogical-geochemical scenarios of origin and evolution. We distinguish the most prominent similarities between the deposits at Kumtor, Muruntau and Bakyrchik. These points are important for finding solutions to problems in mineral forecasting and prospecting.

1. Long ore preparation (prehistory), with multi-step, multistage, successions of ore-generating processes; formation of the deposits in a mesothermal setting over hundreds of millions of years in varying geodynamic environments (marginal-continental, riftogene, subduction, collision); multiple sources and mechanisms for concentrating precious metals (sedimentary-diagenetic, metamorphogene, fluid-magmatogene). Polygenic and multistage gold of the Muruntau deposit is a product of long evolution, which can be subdivided into clastogene, chemogenic, metamorphosed types, connected with carbonaceous deposits, hydrothermolites and late silver minerals, located in dyke formations, quartz veins and stockworks (C.H. Arifolov, R.P. Badalova, E.A. Dunin-Barkovskaya, V.F.Protsenko et al.). At the Bakyrchik deposit, lead isotope studies on sulphide minerals (pyrite, arsenopyrite, galena) and various phases of organic substance, have revealed the following ages: synchronous to sedimentation (C_2); younger (Mz) and also Vendian-Early Paleozoic, which is 200-240 million years older than the age of ore host black shale strata. This testifies that Au and Pb concentration began long before the formation of the host Bakyrchik suite. Formation of ore components at Bakyrchik included five phases: V (560 ±18 million years), O_3 (447 ± 10 million years), C_{1-2} (320 ± 15 million years), T_2 (230 ± 20 million years) and K_{1-2} (100 ± 25 million years) (O.G. Koshevoi, N.G. Syromyatnikov, M.S. Rafailovich).

2. An important precondition of giant deposit formation is the specialized host rocks (Dzhetymtau, Besapan, Bakyrchik suites), which have the following characteristics: weak grain-size differentiation and low roundness of detrital material; tectonic-gravitational mixtites; carbonaceous substance of the kerite-anthraxolite-schungite-bitumoid array; clastogene gold, pyrite and pyrrhotite; syngenetic enrichment of rocks by Au, W, As, U, P, platinoids; low facies of metamorphism (greenschist, zeolitic); multiplane role of substratum in relation to mineralization (resource, barrier, structure-forming). Gold bearing black shale successions are the important component, containing volcanogenic and volcanogenic-hydrothermal products: cryptovolcanic breccias, bituminized porphyroids, volcanomiktic tillites and sandstones (L.G. Marchenko, A.K. Bukharin, LA. Maslennikov, F.A. Usmanov, V.F. Protsenko, V.A. Narseev et al.).

3. The favorable structural setting presented by the ore deposits and necessary for

formation of gold ore giants include: zones of crush and boudinage; thrusts; interlaminar detachment faults; shielding surfaces. The unique Muruntau deposit was generated owing to a combination of geological-structural features: location on limb of large Taskazgan anticlinal fold complicated by folding of higher orders; existence of Devonian and Intra-Besapan thrust screens; sharp flexural bend and tectonic delamination of pre-Devonian strata of motley composition; crossing node of three hetero-age break systems - sublateral, northeast and northwest; longitudinal shatter and schist formation zones of deep permeability, which defined the borders of the ore field and its block structure. The ore bearing zone of isoclinal folding in the Kumtor deposit is complicated by flat thrusts, schist formation and plication of rocks. Thrust joints with angular bends of surface, tectonic lenses with presence of cleavage and mylonitization, strips of layer by layer boudinage of rocks, intraformation detachments, and mixtite horizons are developed at Bakyrchik, in the Kyzyl ore bearing crush zone (Ju.I. Novozhilov, V.M.Yanovsky, V.A.Narseev, Ju.V.Gostev et al.). Similar structural elements allow (together with the original combination of tectonic, magmatic and physical-chemical factors) the formination of large volume ore deposits of great vertical extent – not less than 1-2 km thick.

4. All gold ore regions of black shale type are similar in geological-geophysical parameters and conditions of localization related to deep structures. The ore bearing system of the Muruntau gold-quartz deposit (motley Besapan in combination with sulfide-feldspar-quartz metasomatites) is characterized by a heightened magnetic field. The central part of the Muruntau field (Muruntau deposit) is distinguished by lowered density and polarizability, while the flanks (Besapantau, Myutenbai and Triada) – by high polarizability. Gold-sulfide Kumtor and Bakyrchik deposits have a distinct reflection in magnetic and electric fields. The characteristic position of the considered standards is related to sharp gradient zones of positive and negative anomalies of magnetic and gravitational fields (which depend on repeating structural and material heterogeneity of the Earth's crust): Precambrian and Early Paleozoic basements, deep troughs with terrigenous and carbonaceous-terrigenous material, "hanging lenses of basification", latent thermal domes (M.M. Konstantinov, T.S. Shayakubov, V.D. Bortsov, P.S. Revyakin, N.K. Kurbanov, V.N. Lyubetsky, J.V.Nechaev et al.).

5. Earlier, not fully considered parageneses and spatial combinations of gold mineralization with collision magmatism (of heterogeneous compositions), are very important for forecasting and evaluation purposes. At the level of root parts, the ores of mesothermal deposits are connected through systems of deep-seated faults with apical prominences of granite-leucogranite plutons (superdeep borehole SG-10 at Muruntau, geological-geophysical reconstruction of the Kumtor and Bakyrchik deposits). At upper-ore levels, truncation of the gold bearing bodies is integrated with dyke formation of middle, acid and subalkaline composition (Muruntau and Kunush complexes). Extensively investigated intrusive rocks of Muruntau are distinguished by the increased geochemical background. Dykes of syenite-diorite porphyrites (Muruntau complex) are related to Au, Ag, As, Bi, W, Mo, Cu, Pb, Zn; leucogranites of the Muruntau latent intrusion are related to W, Mo, U, Ag, Bi.

6. Enormous scales of metasomatism, variable composition of the altered rocks, and the balanced metasomatic zonality are characteristic of giant deposits. The stem zone of the deposit contains quartz-feldspar, quartz-sericite or quartz-sericite-chlorite hydrothermolites, the apical zone -quartz-dickite, quartz-kaolinite, chlorite-albite hydrothermolites, and the root zone - by high-temperature kalispatites, biotite and carbonate–bearing rocks (breunerite, ankerite, ferriferous dolomite). The carbonaceous substance migrates during metasomatism and is redeposited and concentrated on the flanks of the ore deposit ("schungite covers", "areas of enrichment by light isotope of carbon").

7. Full evolution of minerogenesis and the following common stages is peculiar to giant deposits: pre-ore stage – pyrite-pyrrhotite-marcasite-nickeline-cobaltite-gersdorffite; ore stage – gold-rare-metal (native gold, scheelite, molybdenite, bismuthine, chalcopyrite, tellurides), gold-pyrite or gold-pyrite-arsenopyrite, gold-silver-quartz-sulphosalt-gray copper ore-polymetallic; final late ore (or postore) stage – quartz-carbonate-marcasite-antimonite-tetrahedrite (with redeposited fine gold and Sr, Hg, Ba minerals). Recrystallization of mineral aggregates, various structures of disintegration, presence of reactionary and hybrid compounds, corrosion and cement textures are characteristic. Non-metallic minerals (quartz,

carbonate) have a minimum of 3-4 generations over a wide temperature range (420-75°).

8. A wide spectrum of elements, contrasting geochemical fields, and strongly differentiated vertical geochemical zonality (VGZ) are characteristic of Kumtor, Muruntau and Bakyrchik deposits (S.I. Anikin, E.B.Bertman, I.M. Golovanov, V.F. Skryabin, M.S. Rafailovich et al.). Early productive geochemical associations of Muruntau (Au, W, Mo, Bi) aresubconcordant with the host rock position, late associations (Cu, Zn, Pb, Sb, Ag, Ba) - steep, crossing position. The total geochemical halo narrows at depth and has the appearance of an asymmetric cone. The generalized model of VGZ of Muruntau is represented as follows (from bottom to top): U-Mo-V (uranium bearing association in root part of the deposit) – Ni, Co, Cu, W, Mo, As, Au_1 ("throughout" high-temperature pre-ore and early ore gold-quartz-rare metal association) – Ni, Co, As, Zn, Au_2 ("throughout" middle temperature ore gold-pyrite-arsenopyrite-quartz association) – Zn, Pb, Ag, Sb, Ba, Hg (final middle- and low temperature associations on the upper pinching-out and flanks).

VGZ of the Kumtor deposit is represented by the following: Co - Ni - Cr - W - Mo -Cui - Bii - As - Au - Agi - Tef Bi_2 - Se - Cu_2 - Zn - Pb - Ag_2 - Sb - Sr - Ba - Hg (S.I.Anikin). Vertical mineralogical zonality is adequate to VGZ: cobaltite - scheelite - tellurides of nickel - pyrite I-arsenopyrite - native bismuth - native gold- tellurides of Au and Ag- pyriteII - tellurides of Cu, Bi, Pb and Ag - selenides- native silver - kustelite- galena- sphalerite - gray copper ores - barite - strontianite - sulphosalts of Hg. Typomorphism of pyrite (habitus of crystals and admixture elements) serves as an indicator of erosional truncation of ores. Cubic pyrite of the above ore and upper ore horizons is enriched by As, Pb, Zn, Sr, Ba. Pentagondodecahedral crystals of pyrite in the middle horizons concentrate Au, Ag, Se, Te, Bi. Pyrites of octahedral habitus containing W, Cr, Ni, Co are developed in deep horizons.

Ore bodies comprising the large Bakyrchik field have bunch-shaped morphology and volumetric-concentric geochemical zonality. Zones are allocated in a vertical plane: upper Sb-Au-As; first intermediate Au-As-Sb (with W); second intermediate Au-As (with W) and lower Au-W-As-Cu-Mo. Two vectors of geochemical zonality are distinguished: centrifugal vertical (the vector is directed along the rise of the ore bunch) and centripetal horizontal (from flanks to the center). The main ore body is located in the axial zone of the bunch and is characterized by basic reserves of gold (more than 80 %) and high-contrast geochemical zonality (M.S. Rafailovich, M.M. Starova). VGZ line of ores and endogenic haloes: V, Ni, Co, Cr - Sn, Zr, Cu, Mo, W - As, Au - Zn, Pb, Ag - Sr, Ba - Sb, Hg (Ju.I. Novozhilov, A.M.Gavrilov). The order of element-indicators in pyrite and arsenopyrite is coordinated with this line (from bottom to top): Sn, Bi, As, - Ni, Co, Mo - Cu, Zn, Pb - Ag, Sb.

Giant deposits possess four reference geochemical zones: under-ore-lower-ore zone (Co, Ni, V, Cr, Mo, W), middle-ore (As, Cu, W, Bi, Te), upper-ore (Ag, Zn, Pb, Sb, As) and upper-ore-above-ore (Ba, Sr, B, Sb, Hg). Gold in these models of zonality has two positions: lower-middle-ore (gold I-rare-metal association) or middle-ore (gold-pyrite-arsenopyrite, gold-pyrite, gold-telluride associations). The geochemical indicator of the Kumtor, Muruntau and Bakyrchik deposits is increased concentration (up to commercial) of platinoids (Pt, Pd, Os).

Prediction and discoveries of new large deposits of gold ore in black shale are an important problem in practical geology. Future directions can promote successful solutions to the problem: comparative analysis of the standard deposits, development of not trivial forecasting-prospecting technologies, and detection of the most representative genetic and prospecting preconditions of giant deposit generation. Such techniques need to include: creation of a new generation of genetic (abstract) and individual (adapted for concrete setting) models of ore regions and deposits; stereometallogenic analysis of territories; perfection of tectonic, structural, mineralogic-geochemical and other prospecting methods.