Selected CERCAMS publications

2010 & papers IN PRESS:

Biske Yu S & Seltmann R 2010. Paleozoic Tian-Shan as a transitional region between the Rheic and Urals–Turkestan oceans. *Gondwana Research* **17 (2–3)**: 602–613.

Abstract: The Upper Paleozoic orogenic belt of South Tian-Shan (STS) in Kyrgyzstan, Uzbekistan and Tajikistan consists of two structural domains: the south-vergent Bukantau–Kokshaal (BK) in the north and continuing into Xinjiang (China), and the north-vergent Zeravshan–Hissar (ZH) in the south, in Tajikistan. The Bukantau–Kokshaal fold belt was thrust south onto the Kyzylkum–Alai and Tarim continents in the Late Carboniferous. The BK belt is the most prominent collision-related, alpine-type part of the Paleozoic Tian-Shan and, as a prolongation of the Tian-Shan structure, shows close resemblance to the western (outer, west-vergent) part of the Urals. The Kazakhstan continent acts as a hinterland to the BK collision belt. Kazakhstan was constructed by accretion processes in which ancient (presumably Gondwanan) continental terranes and ocean-derived crustal elements of the Early Paleozoic to Early Carboniferous age played a role. The main episode of terrane amalgamation took place during the Middle and Late Ordovician. This appears to reflect active margin development in the Paleoasiatic Ocean, and resembles processes occurring in the recent Western Pacific. Geological differences in construction and protolith age of continental crust in the region are in general agreement with Pb– and Sm–Nd isotopic data. Relatively early (Visean) north-vergent thrust structures in Zeravshan–Hissar and eastern Alai (southwestern STS) bear some resemblance to the Central European Hercynides of Rheic origin, although this region became the location of active margin tectonic processes associated with the closure of the Paleotethys Ocean during the Carboniferous. Post-collisional magmatism occurred from ca. 300 to 270 Ma and is represented by a variety of magma types from A-type granites to nepheline syenites. The spatial distribution of plutons appears to be controlled by transtensional structures associated with east–west, left-lateral wrench faulting. The presence of coeval alkali intrusions and plateau basalts in adjacent areas suggests that this magmatism may have been associated with a mantle plume.

Gonevchuk V G, Gonevchuk G A, Korostelev P G, Semenyak B I & Seltmann R 2010. Tin deposits of the Sikhote-Alin and adjacent areas (Russian Far East) and their magmatic association. *Australian Journal of Earth Sciences* **57(5)**: 777–802.

Abstract: The Sikhote–Alin accretionary belt along the northwestern Pacific Plate hosts the most important tin province of Russia. Here, more than 500 ore deposits were formed between 105 and 55 Ma at transform and active subduction margins. Petrological models suggest an active role of the mantle in the mineralisation processes. The deposits can be divided into three groups according to their mineral content and associated magmatism. The first group, a cassiterite–quartz group is defined by tin-bearing greisens as well as quartz–cassiterite and quartz–cassiterite–feldspar veins and stockworks. The mineralisation shows distinct genetic relationships with S- and A-type granites. The deposits are located mainly in Jurassic accretionary prisms adjacent to the Bureya–Khanka Paleozoic continental terrane margin. The second group is represented by the economically important cassiterite–silicate–sulphide deposits, which produce about 80% of Russian tin. Mineralisation in this group is represented by metasomatic zones or veins related to I-type granitoids. The orebodies consist of cassiterite–tourmaline–quartz or cassiterite–chlorite–quartz

associations and contain variable amounts of sulfides. The third group comprises tin deposits containing cassiterite and sulfides with the most complicated ore composition with abundant sulfides and sulfostannates accounting for 60–80% of the total ore mass. In some deposits, zinc, lead and silver dominate, whereas tin is sub-economic. The deposits of this group are generally associated with magmatic rocks of the Sikhote–Alin volcano-plutonic belt. The different associations are found together in the same districts and, locally, also in individual deposits. These are characterised by polychronous and polygeneticmineral systems, formed during long periods of time and in different tectonic settings. This testifies to changes in the many physico-chemical parameters of ore formation and, probably, of ore sources. We suggest that the complex mineral and element compositions of some of the ores were caused by the long-lasting composite tectono-magmatic processes.

Graupner T, Niedermann S, Rhede D, Kempe U, Seltmann R, Williams T & Klemd R 2010. Multiple sources for mineralizing fluids in the Charmitan gold(-tungsten) mineralization (Uzbekistan). *Mineralium Deposita* **45**: 667-682.
Abstract: Mineral assemblages present within the Charmitan gold(-tungsten) quartz-vein mineralization have been investigated for their cathodoluminescence behaviour, chemical composition and noble gas isotope systematics. This inventory of methods allows for the first time a systematic reconstruction of the paragenetic relationships of quartz, scheelite, sulphides and native gold within the gold mineralization at Charmitan and provides the basis to utilise noble gas data in the discussion of sources and evolution of ore-forming fluids. The vein quartz is classified into four generations based on microscopic and cathodoluminescence investigations. Scheelite II overgrows deformed scheelite I and has lower light rare earth element and higher intermediate rare earth element contents as well as higher strontium concentrations. Scheelite II is associated with the economic gold mineralization and formed during re-crystallization and re-precipitation of material which was partly re-mobilized from early scheelite I during infiltration of gold-bearing fluids. Early stage native gold inclusions are often associated with Stage 2 sulphides, scheelite II and bismuth tellurides and contain Ag (3.6–24.4 wt. %), Hg (≤ 1.0 wt. %), Fe (≤ 0.6 wt. %) and Bi (≤ 0.2 wt. %). Later stage electrum grains occur in association with Stage 3 sulphides and sulphosalts and contain Hg (<0.8 wt. %) and elevated Sb concentrations (up to 3.0 wt. %). Noble gas isotope data (3He/4He: 0.2-0.4 Ra) for hydrothermal ore fluids trapped in the gold-related sulphides and sulphosalts (Stage 2 pyrite and arsenopyrite; Stage 3 pyrite, sphalerite, galena and Pb sulphosalts) suggest that diverse fluid sources were involved in the formation of the Charmitan gold deposit. These data are indicative of a small, but significant input of fluids from external, deep-seated (mantle and possibly lower crust) sources. A decrease in the input of mantle helium and an increasing role of crustal helium from early to later stages of the mineralization is suggested by the measured 3He/4He and 40Ar*/4He ratios. Sulphides from ore veins in meta-sedimentary rocks contain higher portions of meteoric fluids than those in intrusive rock types as indicated by their lower 3He/36Ar ratios. The 3He/36Ar ratios in the meta-sedimentary rocks agree well with ratios typical of gold mineralizations in the Tien Shan gold province completely hosted by meta-sedimentary sequences, indicating intense fluid-wall rock interaction.

Hawkins T, Herrington R, Smith M, Maslenikov V & Boyce A 2010. The iron skarns of the Turgai belt, Northwestern Kazakhstan. *In Porter, T.M., (ed.), Hydrothermal Iron Oxide Copper-Gold & Related Deposits: A Global Perspective,* **v. 3** - *Advances in the Understanding of IOCG Deposits*; PGC Publishing, Adelaide, in press.
Abstract: The world-class Sarbai, Kachar and Sokolovsk iron ore deposits of the Turgai belt, in the Carboniferous Valerianovskoe arc of northwest Kazakhstan, contain an aggregate of more than 3 billion tonnes of mineable massive magnetite.

The Valerianovskoe arc is the possible westward extension to the South Tien Shan arc that is host to the giant Almalyk Cu-Au porphyry system in Uzbekistan. The magnetite bodies of the Turgai belt replace limestone and tuffs, and are distal to locally proximal to the contacts of gabbro-diorite-granodiorite intrusive complexes. Three main stages of alteration and mineralisation can be recognised at these deposits, namely: (1) pre-ore; (2) the main magnetite forming; and (3) post ore phases. The pre-ore stage is characterised by high temperature, metamorphic/metasomatic calc- and alumino-silicates. The main magnetite ore phase formed when hot, sulphur poor, acidic, iron-, silica- and aluminiumrich fl uids were structurally focused to dissolve and replace the dominantly limestone hosts. This was accompanied by a skarn assemblage gangue of epidote, calcic-pyroxenes, calcic-garnet and calcic-amphiboles, minor sulphide minerals and high fi eld strength element (HFSE)-bearing accessory minerals such as titanite and apatite. This magnetite-skarn mineralisation was followed by a late sulphide phase, when comparatively cooler fl uids, which produced distinctive and extensive alteration assemblages of sodium-rich scapolite, albite, chlorite and K feldspar, accompanied by chalcopyrite, pyrite and minor sphelarite and galena. The post-ore phase, is characterised by cross cutting barren veins composed of calcite, lesser albite and K feldspar, and minor quartz, and by widespread alteration comprising scapolite, albite and silica, which surrounds the deposit, and extends for several kilometers into the host rock. Many of the geological and mineralogical features of these deposits closely resemble those of IOCG deposits and provinces around the world.
However, as the copper sulphide mineralisation is sub economic, they may only be classified as either IOCG-style or IOCG-related deposits. Stable isotope (C, O, S) studies have been carried out on a range of sulphides, carbonates and silicates related to the mineralisation. Preliminary results from sulphides intergrown with magnetite support a magmatic source for the sulphur. Oxygen isotope data from associated silicates and iron oxides also support an igneous, or igneousrock equilibrated source for the mineralising fl uids. Carbon and oxygen isotope data from gangue carbonates suggest carbonate is derived from the interaction of igneous-derived or igneous-equilibrated fl uids with host limestones.

Kempe U, Seltmann R, Graupner T, Sergeev S A, Matukov D I, Kremenetsky A A 2010. Pb-Pb evaporation and U-Pb SHRIMP dating of zircon from Hercinian granitoids in the Muruntau area (Central Kyzyl Kum, Uzbekistan): implications and limitations. *Geochimica et Cosmochimica Acta*, in review.

Abstract: Dating of zircon from six granitoid rocks from the Muruntau area (Central Kyzyl Kum, Uzbekistan) by the Pb-Pb single grain evaporation and U-Pb SHRIMP methods yields consistent ages between 288 and 296 Ma which may be - at first glance - understood as intrusion ages of the granitoids. However, evaluation of data from comprehensive mineralogical and petrologic studies reveals that the U-Pb system of magmatic zircon is complicated by inheritance, new hydrothermal zircon growth, and secondary alteration with the latter causing direct and reverse U-Pb isotope discordance. There is good evidence that widespread albitisation of the granites is paralleled by formation of new, U-rich, hydrothermal zircon forming overgrowths and whole crystals. This implies that precise U-Pb SHRIMP dating of U-rich, undisturbed zircon at 290-294 Ma constrains the timing of hydrothermal alteration (albitisation) rather than that of magmatism. The intrusion age of the granites remains uncertain but should be somewhat older. Only a rough estimate of the intrusion age of about 293-320 Ma may be given. Extensive Au mineralisation found in the Muruntau area is similar in age but apparently somewhat younger.

Müller A, Herrington R, Armstrong R, Seltmann R, Kirwin D J, Stenina N G & Kronz A 2010. Trace elements and cathodoluminescence of quartz in stockwork veins of Mongolian porphyry-style deposits. *Mineralium Deposita*, **45**: 707-727.

Abstract: The combination of scanning electron microscope cathodoluminescence (SEM-CL), fluid inclusion analysis and high resolution electron probe microanalysis (EPMA) of Al, Ti, K, and Fe in vein quartz has yielded results permitting a greater understanding of the complex mineralisation of the Central Oyu Tolgoi and Zesen Uul porphyry-style deposits, southern Mongolia. These data demonstrate the relationship between quartz precipitation, dissolution and ore deposition as the mineralising fluid chemistry changed through time. Four major quartz generations are identified in the A-type veins from the stockworks of both the Central Oyu Tolgoi (OTi to OTiv) and Zesen Uul deposits (ZUi to ZUiv). Despite differences in the associated alteration and mineralisation style, the observed CL textures and trace element signatures of the quartz generations are comparable between deposits. The OTi and ZUi stage formed both the primary network of A-type veins and pervasive silicification of the host rock. Using the Ti-in-quartz geothermometer, crystallisation temperatures for OTi and ZUi of between 598 and 880ºC are indicated. The main stage of sulfide mineralisation was accompanied by the dissolution of pre-existing quartz (OTi and ZUi) and precipitation of a weakly luminescent generation of quartz (OTii and ZUii) with a low Ti content, reflected in a calculated temperature drop from approximately 700ºC to 340ºC in Central Oyu Tolgoi and 445 ºC in Zesen Uul. OTii and ZUii stage quartzes show high and variable Al concentrations. The next stage of quartz in both deposits (OTiii and ZUiii) forms a fine network of veins in cracks formed in pre-existing quartz. OTiii and ZUiii quartz contain measurable fluid inclusions of moderate salinity (3-17.1 wt.% NaCl eq.), entrapped in the temperature range 256 to 385ºC. OTiii and ZUiii are not related to any sulfide mineralisation. The final OTiv and ZUiv stages are characterised by quartz-calcite micro-breccias that penetrate the A-type veins. Based on the calculated entrapment temperatures, the OTiv/ZUiv stage crystallised between 212 and 335 ºC, and the quartz is characterised by elevated but variable Al and Fe contents. The CL and trace element signatures of the OTi to OTiii and ZUi to ZUiii stages of the two Mongolian porphyries show similar features to those observed in porphyry-style deposits from other regions. This suggests that a common sequence of quartz crystallisation occurs during the formation of early veins in many porphyry copper systems.

Prokopyev I R, Izokh A E, Borisenko A S, Naumov E A & Seltmann R 2010. Mineralogical and Geochemical Characteristics of the Maksut Copper-Nickel Deposit (Eastern Kazakhstan). *In:* Brown, G.H., Jugo, P.J., Lesher, C.M. and Mungall, J.E. eds. 2010. Abstracts, 11th International Platinum Symposium, 21-24 June 2010, Sudbury, Ontario, Canada; Ontario Geological Survey, Miscellaneous Release–Data 269.

Abstract: The Maksut copper-nickel deposit is located in Eastern Kazakhstan, in the Zaisan-Gobi folded zone, the northwestern branch of the Gobi-Tien Shan rift belt. This type of mineralization is widespread in Central Asia, especially in Western Mongolia and Northern China. The Maksut complex is a typical occurrence of mafic-ultramafic Early Permian magmatism and consists of two ore-bearing intrusions: the North and South Maksut massifs. The South Maksut massif has two intrusive phases. Massive sulfide Cu-Ni mineralization occurs in the bottom beds and contain inclusions of Pd-bearing minerals. The concentrations of Au, Ag, Pt, and Pd in the samples of magmatic rocks of the Maksut deposit were determined by scintillation spectral and atomic absorption analysis. From the contents of the main ore components, the ores of the Maksut deposit are relatively poor: Cu = 0.44%, Ni = 0.33%, Co = 0.017, but the scale of Cu-Ni sulphide mineralization is not yet fully estimated.

Seltmann R, Konopelko D, Biske G, Divaev F & Sergeev S 2010. Hercynian post-collisional magmatism in the context of Paleozoic magmatic evolution of the Tien Shan orogenic belt. *Journal of Asian Earth Sciences*, doi:10.1016/j.jseaes.2010.08.016.

Abstract: The Hercynian Tien Shan (Tianshan) orogen formed during Late Palaeozoic collision between the Karakum–Tarim and the Kazakhstan paleo-continents. In order to constrain timing of Hercynian postcollisional magmatism, 27 intrusions were sampled for U–Pb zircon dating along a ca. 2000 km – long profile in Uzbekistan and Kyrgyzstan. The samples were dated utilizing sensitive high resolution ion microprobe (SHRIMP-II). The obtained ages, together with previously published age data, allowed the timing of Hercynian post-collisional magmatism to be constrained and interpreted in the context of the Paleozoic magmatic evolution of the region. Apart from Hercynian post-collisional magmatism, two older magmatic episodes have been recognized, and the following sequence of events has been established: (1) approximately 10 Ma after cessation of continuous Caledonian magmatism a number of Late Silurian–Early Devonian intrusions were emplaced in the Middle and Northern Tien Shan terranes between 420 and 390 Ma. The intrusions probably formed in an extensional back arc setting during coeval subduction under the margins of Caledonian Paleo-Kazakhstan continent; (2) the next relatively short Late Carboniferous episode of subduction under Paleo-Kazakhstan was registered in the Kurama range of the Middle Tien Shan. Calc-alkaline volcanics and granitoids with ages 315–300 Ma have distinct metallogenic affinities typical for subduction-related rocks and are not found anywhere outside the Middle Tien Shan terrane west of the Talas–Farghona fault; (3) the Early Permian Hercynian post-collisional magmatism culminated after the closure of the Paleo-Turkestan ocean and affected the whole region across terrane boundaries. The post-collisional intrusions formed within a relatively short time span between 295 and 280 Ma. The model for Hercynian post-collisional evolution suggests that after collision the Tien Shan was affected by trans-crustal strike-slip motions which provided suitable conduits for ascending asthenospheric material and heat influx in the crust. This produced both granitoid magmas and hydrothermal fluid flow. As a result post-collisional intrusions and orogenic Au deposits, known in the region, formed coevally and were tectonically controlled; (4) between 240 and 220 Ma a Triassic thermal event affected the region resulting in resetting and growth of new zircon grains which is detected on a regional scale. Probably the influx of heat into the crust during the Triassic was tectonically focused and varied significantly in different terranes. In the region under investigation the Triassic thermal event was not accompanied by any significant magmatic activity. Thus, after cessation of Hercynian post-collisional magmatism ca. 280 Ma ago there was a long magmatically quiet period in the Tien Shan.

Seltmann R, Soloviev S, Shatov V, Pirajno F, Naumov E & Cherkasov S 2010. Metallogeny of Siberia: Tectonic, Geologic and Metallogenic Settings of Selected Significant Deposits. *Australian Journal of Earth Sciences* **57(5)**: 655–706. Appendix – Supplementary paper: data repository of large mineral deposits in Siberia, stored at http://nla.gov.au/nla.arc-25194

Abstract: Siberia has a prominent position in Russia, in terms of mineral resources and mineral production including copper, nickel, PGM's, uranium, molybdenum, tungsten, tin, manganese, gold, silver, lead, tantalum–niobium, rare earths, diamonds and many other mineral commodities. These resources are represented by a vast array of mineral systems and deposit styles in their respective terranes spanning the Precambrian and Phanerozoic geological history. These mineral systems include VHMS and SEDEX lead–zinc, orogenic gold, sediment- and shear-zone hosted to intrusive-related silver to silver-tin, alkaline gold to gold–uranium and uranium,

porphyry copper and copper–molybdenum, epithermal gold, gold–silver, silver, gold–antimony, mercury, uranium–fluorite, various granite-related deposits (W, Mo, Sn, Be, Ta, Co–Ni, etc.) including those associated with peralkaline granites (Nb–Ta–Zr–REE), skarn iron, lead–zinc, gold, tungsten, carbonatite tantalum–niobium, niobium–REE and REE, magmatic copper–nickel–PGM sulfide, PGM and mafic intrusion-hosted iron–titanium–vanadium deposits, and diamondiferous kimberlites. Some deposits are large and superlarge including the well-known Noril'sk nickel–copper–PGM and Udokan copper deposits, the Sukhoi Log, Olympiada, Nezhdaninskoe, Kubaka, Kupol gold deposits, the Dukat and Prognoz silver deposits, and the Yakutian diamondiferous kimberlites. Apart from the above-mentioned giant deposits, several others are poorly known and/or unknown to western geoscience. The study of these mineral systems can significantly contribute to our further understanding of the metallogeny of cratons and orogenic belts, orogenic collages, and anorogenic settings. This provides additions to, and further development of, existing classifications and geneticmodels ofmineral systems, allowing researchers to elucidate unknown or poorly studied mineral systems and styles found in Siberia, and to search for some other important styles that appear to be missing, although they are present in other regions with similar geological and tectonic settings.

Soloviev S G 2010. Iron oxide copper-gold and related mineralisation of the Siberian craton, Russia. 1 – Iron oxide deposits in the Angara and Ilim river basins, South-Eastern Siberia. *In Porter, T.M., (ed.), Hydrothermal Iron Oxide Copper-Gold & Related Deposits: A Global Perspective,* **v. 3** - *Advances in the Understanding of IOCG Deposits*; PGC Publishing, Adelaide, in press.

Abstract: The Angara and Ilim River Basins in Siberia incorporate several tens of signifi cant iron oxide concentrations known as the Angara-Ilim type deposits. They are associated with mafic igneous suites of the Permian-Triassic Siberian traps, and are represented by mineralised sub-vertical breccia pipes, likely diatreme-maars, extending for >1.5 to 2 km downward. These breccia pipes intersect tholeitic, calc-alkaline, mafic (dolerite) sills but incorporate younger basaltic dykes and stocks, which are possibly alkalic and exhibit a shoshonitic affinity. Gradual upward transition from massive basalts through porphyritic to vuggy and foamy varieties and finally to "tuffisites" cementing explosive breccias are observed. Two episodes of brecciation, hydrothermal alteration and mineralisation, divided by emplacement of the basaltic dykes, are distinguished. Specifically, the first (early) episode is expressed as brecciation of dolerites and sedimentary host rocks, followed by hydrothermal alteration of the breccias (prograde magnesian and calcic skarn to retrograde and hydrosilicate alteration) and mineralisation, including abundant magnetite. The second (late) episode occurred after, or contemporaneously with, the emplacement of basaltic dykes, associated "tuffisite" and intense "re-brecciation", and includes the formation of numerous massive magnetite, magnetite-apatite, and magnetite-calcite veins. The deposits are characterised by abundant magnesian and calcic skarns, with varying pyroxene/garnet ratios, intense retrograde and hydrosilicate (mostly chlorite-serpentine) alteration. All of these assemblages include magnetite, although it is especially abundant in association with chlorite and serpentine forming brecciated, disseminated and massive ores. Late massive magnetite (± apatite, calcite) veins crosscut the early assemblages and often contain "oolite" (concentric, spherulitic, ball-like) magnetite aggregations as well as magnetite-halite accumulations. Enrichment in sulphides (chalcopyrite, pyrite) is observed in the uppermost parts of some deposit.

Soloviev S G 2010. Iron oxide copper-gold and related mineralisation of the Siberian craton, Russia. 2 – Iron oxide, copper, gold and uranium deposits of the Aldan shield, South-Eastern Siberia. *In Porter, T.M., (ed.), Hydrothermal Iron Oxide Copper-Gold & Related Deposits: A Global Perspective,* **v. 3** - *Advances in the Understanding of IOCG Deposits*; PGC Publishing, Adelaide, in press.

Abstract: The Aldan Shield, part of the Siberian Craton, incorporates numerous iron oxide, copper, gold and uranium deposits formed during the Palaeoproterozoic and Mesozoic. These deposits are clustered within mineralised districts, and along major crustal lineaments across the shield, and include those with combinations of two or more of these metals. The period from 2.0 to 1.8 Ga during the Palaeoproterozoic, was especially productive for IOCG related apatite-iron oxide-REE, iron oxide [±apatite±copper] and copper-iron oxide-gold deposits, while evidence for the presence of signifi cant contemporaneous Au and U mineralisation is growing. These deposits are hosted by the Archaean-Palaeoproterozoic cratonic basement, with no direct relationship to the signifi cant contemporaneous anorogenic Palaeoproterozoic A-type igneous suites of the region. In contrast, during the Mesozoic, particularly from 150 to 130 Ma, major uranium and gold, and low grade copper concentrations were formed, but apparently only minor Fe oxide and no signifi cant IOCG related mineralisation. These younger deposits are mostly hosted in the Cambrian cratonic cover and/or along the cratonic basement/cover unconformity, and are closely associated with, or hosted by, small intrusives of potassic alkaline and transalkaline (with shoshonitic affi nities) to calc-alkaline rocks exhibiting similarities with those of both distal subduction-related and anorogenic igneous suites. The Palaeoproterozoic and Mesozoic deposits represent two temporally separated ore deposit assemblages involving copper, gold, iron oxides and uranium developed within similar, but not identical cratonic tectonic settings, and possibly with common metal sources in the lower crust. The older group included the development of IOCG mineralisation, the younger apparently did not, corresponding instead to “alkalic” porphyry- and epithermal-style deposits.

Soloviev S G 2010. Iron oxide (±copper, gold) and associated deposits of the Altai-Sayan orogenic system, South-Wastern Siberia, Russia. *In Porter, T.M., (ed.), Hydrothermal Iron Oxide Copper-Gold & Related Deposits: A Global Perspective,* **v. 3** - *Advances in the Understanding of IOCG Deposits*; PGC Publishing, Adelaide, in press.

Abstract – The Altai-Sayan orogenic system, located in the core of the Altaid orogenic collage of central Asia, hosts numerous iron oxide deposits, many of which contain substantial Au, Cu, apatite, fluorite, barite, REE and U concentrations. These deposits represent several styles of mineralisation that belong the IOCG association, namely, (1) proximal to distal metasomatic (skarn) and more distal scapolite-albite to chlorite-amphibole replacement; (2) stratabound magnetite-apatite occurring within volcanic sequences (Kiruna-type); and (3) carbonatites. Each of these styles corresponds to a different tectonic terrane and metallogenic epoch. The skarn and other replacement-type iron oxide (±Cu, Au) deposits are especially numerous in the Caledonian orogenic terranes of the Middle to Late Cambro-Ordovician, and occasionally Silurian, with minor mineralisation re-deposited (?) in the Devonian. They include deposits associated with (a) proximal contact skarns, localised in the immediate vicinity of related intrusives; (b) proximal to distal skarns, frequently well above large plutons, but occurring in zones where intrusive apophyses, small stocks and dyke swarms are present, in some cases related to breccia pipes or diatremes, or as flat-lying skarns and orebodies in shallow-dipping host lithologies; (c) proximal to distal albite-scapolite-rich alteration in fault zones, with only minor skarn; and (d) distal chlorite-amphibole-dominated accumulations, also within fault zones. Deposits of the two latter sub-types host the largest iron oxide concentrations, often containing

as much 500 to 700 Mt of iron ore. Stratabound magnetite (magnetite-hematite) and magnetite-apatite deposits are mostly found in Hercynian orogenic terranes, although older concentrations may locally occur in Caledonian domains. Devonian volcanic sequences exert a distinct stratigraphic control on these deposits, with gradual transitions from iron oxide-enriched alkalic volcanics (trachytes, etc.) to semi-massive and massive iron oxide mineralisation. Multi-stage formation of these deposits appears to be the most plausible explanation of their occurrence, with local re-deposition and enrichment of mineralisation related to the emplacement of younger plutons. Mesozoic (Cretaceous?) iron oxide-rich carbonatites emplaced in Caledonian and older terranes are of particular interest due to their possible relationships with potassic granites and strong enrichment in hematite, REE (bastnaesite, monazite, etc.), U (uraninite), barite, fluorite, apatite, locally magnetite and chalcopyrite.

Yakubchuk A 2010. Restoring the supercontinent Columbia and tracing its fragments after its breakup: A new configuration and a Super-Horde hypothesis. *Journal of Geodynamics* **50**: 166–175.

Abstract: Paleoproterozoic collisional (internal) and accretionary (external) orogens, additionally constrained by the matches between the Archaean granulite-gneiss and granite-greenstone terranes, are used to reconstruct the Mesoproterozoic supercontinent Columbia. The Archaean granulite-gneiss terranes occupy an axial position, forming the Archaean Super-Horde, traceable through almost all present cratons. Restored Columbia is a 30,000km long supercontinent, assembled by ca 1.85 Ga. There is no evidence of its breakup during the Mesoproterozoic, and it subsequently grew via external accretion until ca. 1.25 Ga. After 1.25 Ga, the Atlantica group of cratons was split from Columbia and rotated to collide with the remaining intact part of Columbia to produce the 1.0 Ga Grenville orogen, hence assembling the supercontinent Rodinia. At 1000–720 Ma, penetration of oceanic spreading centres into Rodinia between Siberia and the Australian cratons split the remaining part of Columbia into the Ur and Nena cratonic groups. Nena was then quickly rifted apart into Laurentia, Eastern Europe, and Siberia. Siberia started its drift from the present western edge of Laurentia towards Eastern Europe. This drift might have caused the separation from Nena of parts of the Palaeoproterozoic external orogen to form the Great Steppe superterrane, which later was assimilated into the basement of Neoproterozoic to Palaeozoic magmatic arcs with adjacent backarc oceanic basins, whose fragments are at present found inside the Central Asia supercollage. Simultaneously with Siberia, the remaining intact Ur began moving in the opposite direction around Atlantica. During this translation, Atlantica was fragmented into Congo–Tanzania, West Africa, Amazonia and Rio-de-la-Plata with opening of the internal Brasiliano oceanic basin and its subsequent suturing. This closure might have happened due to the arrival of Ur, whose Kalahari and India portions collided with Congo–Tanzania to produce the Damara and Mozambique orogens, welding Ur and Atlantica into Gondwana at 540–500 Ma.

2009

Konopelko D, Seltmann R, Biske G, Lepekhina E & Sergeev S 2009. Possible source dichotomy of contemporaneous post-collisional barren I-type versus tin-bearing A-type granites, lying on opposite sides of the South Tien Shan suture. *Ore Geology Reviews* **35**: 206–216.

Abstract: Two granitoid complexes in the eastern Kyrgyz Tien Shan, situated north and south of the Southern Tien Shan Suture, were studied. The suture formed as a result of the closure of the Turkestan Ocean and collision of the Tarim microcontinent in the south with the Middle Tien Shan in the north. The timing of collision is still disputed. The deformed calc-alkaline Terektinsky complex, situated immediately north of the suture, represents one of the largest shear-zone related intrusions in the Tien Shan (130 × 5–15 km in size). Small stocks of evolved A-type granites of the Inylchek complex, hosting economic tin mineralization, were emplaced immediately south of the suture opposite the Terektinsky complex. Two samples from the Terektinsky complex and 3 samples from three A-type stocks were collected for U–Pb zircon SHRIMP-II geochronology. The ages at 2σ level obtained for the Terektinsky complex north of the suture (294 + 5 Ma and 291 + 5 Ma) and ages of the small granite bodies south of the suture (299 + 4 Ma, 295 + 4 Ma, 289 + 6 Ma; Tashkoro, Inylchek and Maida'adir intrusions, respectively) are nearly identical, within error limits. They show that the Southern Tien Shan Suture in the eastern Kyrgyz Tien Shan had already formed by ~ 295 Ma, and had evolved into a transcrustal mega-shear zone controlling emplacement of granitoids. Geochemical distinction between the two magmatic systems is based on 10 original bulk and trace analyses of rocks from this study and on a large dataset extracted from previously published research and unpublished reports. Geochemically, the rocks of the Terektinsky complex comprise calc-alkaline (high potassium I-type) series while the granites of the Inylchek complex are typical A-type granites with an elevated alumina saturation index and higher boron contents compared to a “standard” A-type rapakivi granite. Contrasting metallogenic features of the two granitoid complexes south and north of the Southern Tien Shan Suture are defined by their sources: a fertile fore-arc complex, and/or passive margin sediments of Tarim to the south, and barren metamorphic Precambrian basement of the Middle Tien Shan to the north.

Moore K R, Wall F, Divaev F K & Savatenkov V M. 2009. Mingling of carbonate and silicate magmas under turbulent flow conditions: Evidence from rock textures and mineral chemistry in sub-volcanic carbonatite dykes, Chagatai, Uzbekistan. *Lithos* **110**: 65-82.

Abstract: The Triassic Chagatai Complex, Uzbekistan, comprises explosive pipes and dykes, dominantly of silicocarbonatite composition, with cross-cutting relationships indicating multi-stage emplacement. Although the dykes have been reported as diamond-bearing, they have not previously undergone detailed investigation in terms of their mineral chemistry or rock texture. The xenolith-rich dykes contain irregularly-shaped microscopic magmatic enclaves of silicate composition within carbonatite magma and corroded microphenocrysts with crystal overgrowths that record synmagmatic geochemical disequilibrium. Quench crystals of apatite and aegirine, and anhedral baryte, which formed after corrosion of apatite and magnetite microphenocrysts but prior to formation of crystal overgrowths and mantles, indicate contemporaneous rapid undercooling. The anhedral baryte formed as a by-product of an oxidising hydrous reaction from Ba-rich biotite and pyrite to chlorite. The rock and microphenocryst textures suggest that mingling between two magmas occurred and a post-minglingmineral assemblage, including baryte,

crystallised in a partially hybridised heterogeneous magma. An initial carbonatite mineral assemblage is identified as calcite+magnetite+apatite±augite±barium-rich biotite±melilite±pyrite. Changes in mineral chemistry of the carbonatite assemblage that are contemporaneous with the disequilibrium reaction textures suggest addition of a hydrous, Na–Si–Al-rich magma, and the mineral assemblage in the magmatic enclaves is similar to that of trachyte dykes in the Chagatai Complex. Using primarily rock textures and mineral chemistry, supported by mass balance calculations and isotope data, the silicate material is interpreted as a hydrous trachyte magma that had assimilated upper crustal material. The trachyte magma was entrained by carbonatite that was rapidly and turbulently ascending through the crust, shortly before emplacement as silicocarbonatite. The interpretation of magma mingling textures in the Chagatai Complex are unique amongst reported carbonatite occurrences: previously reported carbonate–silicate magma systems either formed globular textures or were interpreted as the products of assimilation of country rock only.

Müller A, Ihlen P M, Larsen R B, J Spratt & Seltmann R 2009. Quartz and garnet chemistry of South Norwegian pegmatites and its implications for pegmatite genesis. *Estudos Geológicos* **19(2)**: 20-24.

Pirajno F, Seltmann R, Cook N J & Borisenko A S 2009. **Special Issue: Intraplate magmatism and associated metallogeny in Central Asia, China and Siberia.** *Ore Geology Reviews* 35: 111–261. ISSN: 0169-1368.

Plotinskaya O Y, Groznova E O, Kovalenker V A, Novoselov K A & Seltmann R. 2009. Mineralogy and Formation Conditions of Ores in the Bereznyakovskoe Ore Field, the Southern Urals, Russia. *Geologiya Rudnykh Mestorozhdenii,* **51 (5)**: 414-443 [in Russian]. *Geology of Ore Deposits* **51**: 371-397.
Abstract: The Bereznyakovskoe ore field is situated in the Birgil'da–Tomino ore district of the East Ural volcanic zone. The ore field comprises several centers of hydrothermal mineralization, including the Central Bereznyakovskoe and Southeastern Bereznyakovskoe deposits, which are characterized in this paper. The disseminated and stringer–disseminated orebodies at these deposits are hosted in Upper Devonian–Lower Carboniferous dacitic–andesitic tuff and are accompanied by quartz–sericite hydrothermal alteration. Three ore stages are recognized: early ore (pyrite); main ore (telluride–base-metal, with enargite, fahlore–telluride, and gold telluride substages); and late ore (galena–sphalerite). The early and the main ore stages covered temperature intervals of 320–380 to 180°C and 280–300 to 170°C, respectively; the ore precipitated from fluids with a predominance of NaCl. The mineral zoning of the ore field is expressed in the following change of prevalent mineral assemblages from the Central Bereznyakovskoe deposit toward the Southeastern Bereznyakovskoe deposit: enargite, tennantite, native tellurium, tellurides, and selenides → tennantite–tetrahedrite, tellurides, and sulfoselenides (galenoclausthalite) → tetrahedrite, tellurides, native gold, galena, and sphalerite. The established trend of mineral assemblages was controlled by a decrease in fS_2, fTe_2, and fO_2 and an increase in pH of mineral-forming fluids from early to late assemblages and from the Central Bereznyakovskoe deposit toward the Southeastern Bereznyakovskoe deposit. Thus, the Central Bereznyakovskoe deposit was located in the center of an epithermal high-sulfidation ore-forming system. As follows from widespread enargite and digenite, a high Au/Ag ratio, and Au–Cu specialization of this deposit, it is rather deeply eroded. The ore mineralization at the Southeastern Bereznyakovskoe deposit fits the intermediate- or low-sulfidation type

and is distinguished by development of tennantite, a low Au/Ag ratio, and enrichment in base metals against a lowered copper content. In general, the Bereznyakovskoe ore field is a hydrothermal system with a wide spectrum of epithermal mineralization styles.

Seltmann R, Shatov V & Yakubchuk A 2009. Mineral deposits database and thematic maps of Central Asia, scale 1 : 1.5 million: ArcGIS 9.2, ArcView 3.2 and MapInfo 6.0(7.0) GIS packages. Explanatory Notes 143pp. Upgraded, updated and revised official release version. NHM London.

Abstract: Mineral Deposits Database and Thematic Maps of Central Asia, 1 : 1.5 Million Scale is a prime product of the Centre for Russian and Central Eurasian Mineral Studies (CERCAMS), Department of Mineralogy, Natural History Museum (NHM), London, that has been under steady development since 2002. Technical support was provided by a group of scientists from St. Petersburg and Moscow, Russia. The GIS package was produced under the IGCP Project 473 "GIS metallogeny of Central Asia" (2002-2008) and the International Association on the Genesis of Ore Deposits (IAGOD). The compilations benefited from cooperation, scientific contributions and logistical support from the IGCP-473 teams and project participants. The Central Asia GIS content includes: Topographic base map of Central Asia based on the topographic map of Kazakhstan and Middle Asia at 1.5M scale (1983) and the SRTM layer; Geologic thematic map layer 1.5M scale based on the Geological Map of Central Asia (scale 1:1.5M compiled for IGCP-473 by N. Afonichev & N. Vlasov, 2002); Mineral deposits thematic map layer showing the distribution of mineral deposits positioned on the geologic vector map at 1.5M scale (all materials in the metallogenic thematic map layer compilation have official, legal and public domain status); Gravimetric thematic map layer based on Gravimetric map of the USSR (scale 1:2.5M, Eds. P.P. Stepanov & M.A. Yanushevich); Anomalous Magnetic Field thematic map layer based on Map of Anomalous Magnetic Field of Russia, scale 1:5M (Ed. T.P. Litvinova); Polygon Linked - Lithological Attribution Database. The mineral deposits database includes information on the 1965 mineral deposits shown on the geologic thematic map layer. Each deposit contains information on its location (latitude and longitude, country and administrative region), mineral deposit type, major and minor mineral commodity, deposit size, geology, tectonic setting, age of host rocks and wallrock alteration, mineral composition of ore, orebody size and morphology, tonnage of ores and metal grades, references list, date of discovery etc. The database currently includes 608 full descriptions of mineral deposits (mainly of large and medium size) whereas the rest of the deposits from the database have a short description including deposit name, location (latitude and longitude), deposit type, major and minor mineral commodity, and deposit size. The product package includes a separate "Mineral Deposits Map of Central Asia" (in scales 1.5M and 2.5M), available in Corel Draw / PDF print format, a Demonstration Movie, and comprehensive Explanatory Notes.

Yakubchuk A S. 2009. Diamond deposits of the Siberian craton: Products of post-1200 Ma plume events affecting the lithospheric keel. *Ore Geology Reviews* **35**: 155-163.

Abstract: The Siberian craton was affected by more voluminous plume events during last 1200 Ma than any other craton on the Earth. These events produced many economically important deposits, of which the tectonic setting of diamond deposits and related alkaline magmatism is analysed in this paper. In space and time, they can be grouped into several subprovinces: Meso- to Neoproterozoic Yenisei–Sayan; Late Devonian to Early Carboniferous Vilyui; Permo-Triassic Tunguska; Late Jurassic Olenek; and Late Jurassic to Early Cretaceous Aldan.

Regardless of their age and subprovince affinity, the alkaline intrusions, including kimberlites, preferentially occur within the Archean granulite-gneiss terranes, forming a north–south-trending 'Central Horde', framed by Archean granite–greenstone terranes. These terranes in the basement of the Siberian craton constitute Tungus–Anabar and Aldan domains of similar composition, sinistrally offset for about 870 km. Despite such similarity, diamond deposits are discovered to date only in the Tungus–Anabar domain.

The seismic data show that the Central Horde in the Tungus–Anabar domain has a lithospheric keel, extending to a depth of greater than 250 km, whereas it is absent in the Aldan domain. At the surface, the Central Horde forms an uplift that controls lithofacies of Riphean to Cenozoic sedimentary basins in the Siberian craton, thus representing a long-lived and relatively stable feature, with storage of the diamonds in the subcontinental lithosphere at depth.

Previous direct dating of diamonds from different Siberian kimberlites indicated that they were formed in Archean to Paleoproterozoic times. The reconstructions suggest that, in Meso- to Neoproterozoic times, the Siberian craton might have formed part of the supercontinents Columbia and Rodinia. Within them, Siberian craton was attached by its northern edge to the present western margin of the North American craton, whereas the southern margin of Siberia might have been facing a present northern margin of Australia. Together, they were part of a very long supercontinent, and plotting of all presently globally known diamond deposits shows that they would all occur along its axis, mapping its then possibly single lithospheric keel, or a Super-Horde. After breakup of Rodinia, due to penetration of the spreading ridges between the Australian and Siberian cratons, Siberia was translated towards Eastern Europe for about 5000 km during 500 Ma. It was during this translation that it was periodically affected by Neoproterozoic to Mesozoic plumes, which delivered the diamonds to the surface into all subprovinces except Aldan.

Yakubchuk A S. 2009. Revised Mesozoic-Cenozoic orogenic architecture and gold metallogeny in the northern Circum-Pacific. *Ore Geology Reviews* **35**: 447- 454

Abstract: The orogenic collages of the northern Circum-Pacific between Japan and Alaska revealed an endowment of about 450 Moz Au in various deposit types and diverse Mesozoic–Cenozoic tectonic settings. The area consists of predominantly late Paleozoic to Cenozoic turbidite to island arc terranes as well as Precambrian cratonic terranes that can be grouped into the Kolyma–Alaska, Kamchatka–Aleutian, and Nipponide collages. The latter can be linked via the Mongol–Okhotsk suture with the late Paleozoic to early Mesozoic terranes in the Mongolides.

The early Yanshanian magmatic arc terranes in the fossil Kolyma–Alaska collage host copper–gold porphyry deposits, which have only recently received much attention. Exploration has revealed a large and growing gold endowment of more than 30 Moz Au in some individual deposits, with smaller role of epithermal deposits. This mineralization, formed at 140–125 Ma, is partly coeval with the collisions of magmatic arcs with the passive margin sequences of the Siberian craton and related granitoid magmatism. About 200 Moz of gold is known in the Kolyma–Alaska collage in the Mesozoic orogenic gold deposits and related Quaternary placers. The Central Kolyma, Indigirka, South Verkhoyansk, and North Chukotka subprovinces of the collage revealed an endowment of more than 10 Moz Au each. A similar and coeval event in the Mongolides in relation to the collision between Siberia and North China is largely reflected in still poorly dated intrusion-related gold deposits clustered along the Mongol–Okhotsk suture.

The overlapping Yanshanian magmatic arcs in Transbaikalia and northeast China and the Okhotsk–Chukotka magmatic arc in the Russian Far East stitch the Kolyma–Alaska collage with the Paleozoic Central Asian supercollage and adjacent cratons. While the Okhotsk–Chukotka arc reveals a relatively simple and broad oroclinal pattern, the Yanshanian arcs in Mongolia, and NE China form a tightly deformed giant Z-shaped feature that was bent in response to the southward movement of the Siberian craton and

northward translation of the Nipponides and North China craton to close the Mongol–Okhotsk suture in late Jurassic to Cretaceous times. The Yanshanian arcs host mostly small to medium-sized 100–70 Ma Au–Ag deposits, with the largest endowment discovered in the Baley district in Transbaikalia and at Kupol in the northern part of the Okhotsk–Chukotka arc. Some intrusion-related gold deposits were formed synchronously with this arc magmatism, with the largest known examples in the Tintina belt in Alaska formed at 104 and 93–91 Ma.
The Kamchatka–Aleutian collage is still evolving in front of the westward-subducting Pacific plate. It's late Cretaceous to Paleogene magmatic arc rocks form immature island arc terranes, extending from the Aleutian islands towards the Nipponides via Kamchatka peninsula, Kuril islands and eastern Sakhalin. However, in the Nipponides, the Sikhote–Alin portion of the magmatic arc overlaps the Mesozoic turbidite terranes. The oroclinal pattern of this more than 8000 km-long magmatic arc indicates its westward translation in agreement with the movement of the Pacific plate so that the arc is presently colliding with itself along the island of Sakhalin, a seismically active intraplate lineament and a boundary between the Nipponide and Kamchatka–Aleutian collages. This magmatic arc is usually interpreted to be of intra-oceanic origin, with subsequent docking to Asia from the south; however, presence of the Sea of Okhotsk cratonic terrane between Sakhalin and Kamchatka suggests that it may be rather considered as an external arc system that separated from the rest of Asia due to backarc spreading events, therefore, forming the most external arc system at the active margin with the Pacific plate. The subduction-related events in the collage produced numerous late Mesozoic to Cenozoic 1–3 Moz gold epithermal deposit in Kamchatka and Sikhote–Alin as well as Au–Cu porphyry deposits, with currently largest gold endowment in the pre-Tertiary Pebble Copper deposit in Alaska. The westward translation of the Kamchatka–Aleutian collage might have controlled the emplacement of this porphyry deposit, as well as up to 30 Moz into intrusion-related gold deposits at 70–65 Ma in the Kuskokwim belt, immediately north from the porphyry cluster.

Yusupov R G, Stanley C J, Welch M D, Spratt J, Cressey G, Rumsey M S, Seltmann R & Igamberdiev E. 2009. Mavlyanovite, Mn_5Si_3, a new mineral species from a lamproite diatreme, Chatkal Ridge, Uzbekistan. *Mineralogical Magazine* **73**: 43-50.
Abstract: Mavlyanovite, ideally Mn_5Si_3, is a new mineral from a lamproite diatreme close to the upper reaches of the Koshmansay river, Chatkal ridge, Uzbekistan. It occurs together with unnamed manganese siliciphosphide and manganese silicicarbide minerals in round to ovoid segregations, up to 10 cm in diameter, in volcanic glass. Segregations of hexagonal prismatic mavlyanovite up to 1-2 mm occur in interstices in the matrix and tiny inclusions (1-2 μm) of alabandite and khamrabaevite occur within mavlyanovite. It is opaque with a metallic lustre, has a dark-grey streak, is brittle with a conchoidal fracture and a near-perfect basal cleavage. VHN_{100} is 1029-1098 kg/mm^2 (Mohs hardness ~7). In plane-polarized reflected light, mavlyanovite is a pale-brownish-grey against the accompanying unnamed manganese silicicarbide (white). Reflectance values and colour data are tabulated. Average results of 19 electron microprobe analyses give Mn 70.84, Fe 6.12, Si 22.57, Ti 0.15, P 0.18, total 99.86 wt.% leading to an empirical formula of $(Mn_{4.66}Fe_{0.40})_{5.06}(Si_{2.91}Ti_{0.01}P_{0.02})_{2.94}$ based on 8 a.p.f.u. The calculated density is 6.06 g/cm^3, (on the basis of the empirical formula and unit-cell parameters from the structure determination). Mavlyanovite is hexagonal ($P6_3/mcm$) with a 6.8971(7), c 4.8075(4) Å, V 198.05(3) Å^3 and Z = 2. The structure has been determined and refined to R_1 = 0.017, wR_2 = 0.044, GoF = 1.16. Mavlyanovite is the naturally-occurring analogue of synthetic Mn_5Si_3 which is the parent aristotype structure of the Nowotny intermetallic phases studied extensively by the material-science community. It is also the Mn-dominant analogue of xifengite Fe_5Si_3. The mineral name honours Academician Gani Arifkhanovich Mavlyanov (1910-1988), for his contributions to the understanding of the geology of Uzbekistan.

2008

Förster H-J, Tischendorf G, Pälchen W, Benek R, Seltmann R & Kramer W 2008. Spätvariszischer Magmatismus. 257-296 & 500-510. In: W Pälchen & H Walter (eds.) *Geologie von Sachsen. Schweizerbart, Stuttgart* 2008. ISBN 987-3-510-65239-6. 537pp.

Goryachev N & Yakubchuk A 2008. Gold Deposits of Magadan Region, Northeastern Russia: Yesterday, Today, and Tomorrow. *SEG Newsletter* **74**: 9-15.

Müller A, Seltmann R, Kober B, Eklund O, Jeffries T E, & Kronz A 2008. Compositional zoning of rapakivi feldspars and coexisting quartz phenocrysts *Canadian Mineralogist* **46**: 1417-1442.
Abstract: The compositional zoning of plagioclase-mantled K-feldspar, defining the rapakivi texture, and of the associated quartz phenocrysts from the Paleozoic Land's End (U.K.) and Altenberg–Frauenstein (Germany) granites, and the Proterozoic Hammarudda (Finland) granite porphyry, has been investigated by laser-ablation – inductively coupled plasma – mass spectrometry, electron-probe micro-analyses, cathodoluminescence and thermal ionization mass spectrometry in order to investigate the formation of the rapakivi texture in two different eons. Recent analytical developments and the Ti-in-quartz geothermometer lead to interpretations of the trace-element zoning in quartz phenocrysts coexisting with rapakivi feldspars. There is an approximate coincidence with Ba-rich growth zones in plagioclase-mantled K-feldspar and Ti-rich zones in coexisting quartz phenocrysts. Both types of zoning indicate increasing temperatures of crystallization. The formation of the plagioclase mantles seems to be related to quartz-resorption events. The inferred temperature of crystallization increased after marginal resorption of quartz phenocrysts by about 82°C in the Altenberg–Frauenstein magma and 44°C in the Hammarudda magma, on the basis of the Ti-in-quartz geothermometer. The temperature increase is correlated positively with the crystallization of plagioclase mantles on the K-feldspar. The quartz phenocryst in the Land's End granite shows normal core-to-rim zoning of Ti (decreasing concentrations), indicating a gradual decrease in magma temperature. We contend that the increase in the quartz-crystallization temperature of >25°C after a resorption event is indicative for the interaction with mafic magma. Therefore, the interaction of a crystal-saturated granitic magma and a mafic magma is the driving force causing nucleation and crystallization of plagioclase on K-feldspar phenocrysts, even though the Pb isotope, Ba, Sr, and Rb zoning of the mantled K-feldspar phenocryst have not clearly recorded an interaction between granitic and mafic magmas. The frequency of rapakivi feldspars in the rock correlates with the portion of mafic magma involved in the mingling and mixing process. Isothermal decompression during adiabatic magma ascent may have contributed to the plagioclase mantle formation in the case of the Altenberg–Frauenstein and Hammarudda granites. The rare rapakivi feldspars in the Land's End granite developed during an early stage of magmatic evolution; as a result, tracing the conditions of formation of the rapakivi texture is speculative in that case.

Sinclair W D, Gonevchuk G A, Korostelev P G, Semenyak B I, Rodionov S M, Seltmann R & Stemprok M 2008, World tin-tungsten deposits (digital database version 3.21), World Minerals Geoscience Database Project, Geological Survey of Canada, accessible online at http://gdr.nrcan.gc.ca/minres/data_e.php.

Abstract: One of the main projects of the Working Group on Tin and Tungsten Deposits (WGTT) of the International Association on the Genesis of Ore Deposits (IAGOD) in recent years has been the compilation of a digital database of world tin-tungsten deposits. The principal compilers have been W.D. Sinclair, G.A. Gonevchuk, P.G. Korostelev, B.I. Semenyak, S.M. Rodionov, R. Seltmann and M. Stemprok. This database was completed in 2008 and made accessible online through the Geological Survey of Canada's Geoscience Data Repository (http://gdr.nrcan.gc.ca/minres/index_e.php). To display a plot of the deposits on a world map, one should click on the Mineral Deposits Web Map Server option on the Mineral Resources page, which will display a world map and a series of buttons at the top of the map. To display the tin-tungsten deposits, one should click the Select Layers button, select the Tin-Tungsten layer, and then click the Update Map button. To view the database itself, one should click the Launch GQuery button on the map page, click the Open button on the screen that appears, and then select World Tin-Tungsten Deposits from the drop-down menu. One can then display information on individual deposits, or deposit groups (districts). A hard copy map of the world displaying the distribution of tin-tungsten deposits is currently in preparation by the cartographic section of the GSC.

Stemprok M, Dolejs D, Müller A, Seltmann R 2008. Textural evidence of magma decompression, devolatilization and disequilibrium quenching: an example from the Western Krušné hory/Erzgebirge granite pluton. *Contributions to Mineralogy and Petrology* **155**: 93-109 & Supplement S1-S7.

Abstract: We report new occurrences of “two-phase” granitic textures from the Western Krušné hory/Erzgebirge pluton (central Europe) and use crystal-size distribution data and thermodynamic modeling to interpret their crystallization conditions. The two-phase texture consists of (1) early phenocrysts of quartz, plagioclase, K-feldspar and biotite, (2) medium-grained matrix of the same phases and (3) interstitial channels and patches of a late-stage, very fine-grained matrix. The porphyritic two-mica microgranites, which host two-phase textures, occur as minor intrusions in early low-F biotite granites or as marginal parts of evolved high-F Li-mica granites. Measurements of the crystal-size distribution of quartz revealed three grain populations: (1) early phenocrysts (0.5–3.0 mm) showing partial resorption by residual melt, (2) a medium-grained population of the equigranular rock matrix (0.05–0.50 mm) that experienced minor coarsening by subsolidus annealing and (3) a fine-grained population (<0.03 mm) in the interstitial channels and patches formed during rapid devolatilization; this quartz group shows no or poor grain coarsening. All samples exhibit similar fraction of the fine-grained population (44–52%) but proportions of phenocrysts to medium-grained matrix vary significantly. Thermodynamic modeling of liquidus equilibria and experimental data in the hydrous haplogranite system require: (1) ascent of a granitic suspension (15–25% phenocrysts) under H_2O-undersaturated conditions at 25–45 bar/°C and a cooling rate of 40 J/(g kbar) in order to produce partial resorption of quartz phenocrysts and continued growth of feldspar phenocrysts, followed by (2) emplacement as discrete intrusions or bodies along pluton roof accompanied by sudden devolatilization. At the onset of matrix nucleation, disequilibrium undercooling of 70–85°C was inferred from the presence of micrographic intergrowths of quartz and K-feldspar. The two-phase granites in the Western Krušné hory/Erzgebirge pluton and in the Southeast Asian batholith form compositionally narrow groups with high-silica and moderate volatile enrichments but they differ in peraluminosity and phosphorus concentrations.

Xiao W, Pirajno F & Seltmann R (eds.) 2008. **Geodynamics and metallogeny of the Altaid Orogen. Special Issue.** *Journal of Asian Earth Sciences* 32 (2-4): 77-300.

Yakubchuk A 2008. Re-deciphering the tectonic jigsaw puzzle of northern Eurasia. *Journal of Asian Earth Sciences* **32**: 82-101.
Abstract: Northern Eurasia consists of the East European, Siberian, North China, and Alai-Tarim cratons, fragments of the supercontinent Rodinia, and the orogens of the Baikalides, Timanides, Uralides, Altaids, and Mongolides. These can be collectively classified as the Central Asian supercollage. The Baikalides and Timanides host Meso- and Neoproterozoic magmatic arc terranes that were sutured with the adjacent East European and Siberian cratons in the end of the Neoproterozoic. The Paleozoic part of the supercollage consists of three almost synchronous and subparallel Neoproterosoic to Paleozoic magmatic arc and turbidite superterranes, as well as overlap assemblages, bent into the world's largest oroclines. Analysis of their structural pattern, supported by paleontological, lithological, and paleomagnetic data, indicates that these superterranes might have been produced via formation of arc–backarc systems at the margin of combined North China, East European and Siberian cratons and then deformed during Paleozoic westward-directed strike-slip translation between the clockwise rotating Siberian and eastward moving North China cratons. It is proposed that this development took place against the respective breakup of the above-mentioned cratons from the northern and southern margins of Eastern Europe in the Neoproterozoic, initially as a group of cratons called Nena, which reassembled in late Paleozoic to early Mesozoic times into Laurasia, part of the new supercontinent Pangea.

In Mesozoic–Cenozoic times, the subduction-related continental growth of northern Eurasia continued in the Nipponide, Kamchatka and Kolyma–Alaska orogenic collages of the northern Circum-Pacific, which consist of Paleozoic to Cenozoic turbidite to island arc superterranes and overlap assemblages, generally younging towards the Pacific oceanic plate and also severely oroclinally bent. It is proposed that terranes of the Kolyma–Alaska and Kamchatka collages were translated westward, dextrally relative to Siberia, whereas Nipponides were translated northward, relative to North China, similarly to the better constrained Mesozoic–Cenozoic reconstructions of southeastern Asia. The two groups of collages started to collide along the Mongol-Okhotsk suture zone in the south of the Siberian craton in the end of the Mesozoic and then continued to collide along the presently active plate boundary at the island of Sakhalin.

The proposed scenario suggests similarities in Paleozoic evolution of the Central Asian and Mesozoic–Cenozoic evolution of the northern Circum-Pacific supercollages, both possibly formed in response to westward subduction and related strike-slip translation of the (Paleo)-Pacific oceanic plates. The individual superterranes might have been consequently translated for as much as 4000–6000 km and oroclinally bent during such translation or/and rotation of the adjacent cratons.

2007

Alexander K, Herrington R, Kirk C & Chlup D 2007. Geology and mineralogy of the Shevchenko Lateritic Ni-Co deposit, Kazakhstan, in: Andrew, C.J. et al. (eds.) Proceedings of the ninth biennial meeting of the Society for Geology Applied to Mineral Deposits, Dublin, Ireland 20th-23rd August 2007, Irish Association of Economic Geology, Dublin, ISBN [0-950989-4-4] 1393-1396
Abstract: The Shevchenko deposit in western Kazakhstan, discovered by Soviet geologists and now controlled by Oriel Resources plc, contains a total resource of 104Mt @ 0.79% Ni. The deposit developed on ophiolites located in the Trans-Uralian Zone of the Urals, obducted onto the Kazakh continent during the Uralide Orogeny and deeply weathered in a number of stages up to the Tertiary. The deposit is dominated by nickeliferous smectites with subordinate nickel-bearing iron oxides and hydroxides. Weathering was variably developed on the serpentinites with deeper weathering controlled by distinct structural trends.

Doroshkevich A G, Wall F & Ripp G S 2007. Calcite-bearing dolomite carbonatite dykes from Veseloe, North Transbaikalia, Russia and possible Cr-rich mantle xenoliths. *Mineralogy and Petrology* **90**: 19-49.
Abstract: Carbonatites were discovered at Veseloe, North Transbaikalia, Russia in 2002. They are fluorapatite and calcite-bearing dolomite carbonatites and chemically classified as magnesiocarbonatites with high P, Ti, Cr and Ni. The Cr content in some parts of the Veseloe carbonatites is 3–4 times higher than average magnesiocarbonatite and results from the presence of partially resorbed polymineralic 3–5 mm diameter aggregates of Cr-rich minerals (magnetite, rutile, titanite, ilmenite, phengite, chlorite, chromite, titanite and talc). These aggregates may well be relict mantle xenoliths. They contain a rutile-magnetite intergrowth observed for the first time in nature and have compositions consistent with minerals from eclogite, kimberlite and mantle xenoliths. In the Veseloe carbonatites dolomite crystallized first, and then calcite, which is the inverse of the order of crystallization seen in most carbonatite complexes. Strontium isotope ratios are consistent with a Riphean mantle source. Carbon and O isotope ratios rule out some processes of alteration (metamorphic dehydration and high temperature hydrothermal alteration by meteoric waters) but do not plot in the accepted box for primary igneous carbonatite. Mineral geothermometers, inclusion measurements and the relict mantle xenoliths suggest petrogenesis by independent production of magnesiocarbonatite melt in the mantle rather than crustal differentiation of a carbonated-silicate parental melt.

Förster H-J, Gottesmann B, Tischendorf G, Siebel W, Rhede D, Seltmann R, Wasternack J 2007. Permo-Carboniferous subvolcanic rhyolitic dikes in the western Erzgebirge/Vogtland, Germany: a record of source heterogeneity of post-collisional felsic magmatism. *Neues Jahrbuch fuer Mineralogie, Abhandlungen* **183/2**: 123–147.
Abstract: In the western Erzgebirge/Vogtland of Germany, a suite of dikes of compositionally and texturally diverse, often K-rich high-Si rhyolites/porphyritic microgranites are evidence of igneous activities some 10 Ma after the major period of granite magmatism (325-318 Ma) in the early/middle Carboniferous (Namurian). Available geochronological data (305-295 Ma, from occurrences at Gottesberg and Jungfernsprung) suggest a middle/late Carboniferous (Stefanian) age for this episode of late-Variscan, post-collisional subvolcanic magmatism. Most rhyolites experienced variable degrees of high-and low-T alteration, such as greisenization, hematitization, sericitization, and argillitization, which disturbed and obscured the primary

abundances of many mobile trace elements (F, Li, Rb, Cs, Ba, Sr, Tl, Pb, U, Sn etc.). Several rhyolites seem to be intrinsically rich in Sn, W, and other ore elements, others received their enrichment in rare metals by superimposed greisenization. The Na(±Ca)-poor nature of superficially exposed rhyolites (<0.1 wt % Na_2O) is mainly ascribed to plagioclase alteration as a result of weathering. High-T, pervasive K-phyllic alteration, which caused enrichment in K and removal of Na, Ca, and Mg, may have operated in some rhyolites prior and additional to weathering. Irrespective of postmagmatic and exogenic overprinting, less-mobile elements conserving primary magmatic patterns and the Nd-isotope signatures indicate that generation of the rhyolites involved melting of a minimum of two geochemically and isotopically different (lower crustal) sources. According to Nd isotopes, the rhyolites form two distinct groups, with $\varepsilon Nd_{(300)}$ of −5.5 to −6.4 and −1.8 to −3.8, respectively, indicating the rocks are predominantly S-type and transitional I-S-type with respect to source lithology. Some rare-element rich rhyolites (Morgenröthe, Hahnewald) crossing the Eibenstock granite pluton display features in common with aluminous A-type granites and may be subvolcanic equivalents of shallowly intruded Li-F granites of the P-poor class. Contrasting Nd-isotope patterns imply that the rhyolites were derived from sources other than those of the granite plutons with which they are spatially associated.

Graupner T, Niedermann S, Seltmann R & Williams C T 2007. Ore formation in the Charmitan gold-quartz vein deposit (Uzbekistan): Constraints from mineralogical and noble gas data, in: Andrew, C.J. et al. (eds.*) Proceedings of the ninth biennial meeting of the Society for Geology Applied to Mineral Deposits, Dublin, Ireland 20th-23rd August 2007, Irish Association of Economic Geology, Dublin*, ISBN [0-950989-4-4] 577-579.

Abstract: Mineral assemblages present within four mineralization stages have been studied within the Charmitan gold-quartz vein deposit. Native gold inclusions often associated with sulphide minerals and, during the early stages, also with scheelite, contain Ag (7.8–24.5 wt. %), Hg (≤ 1.0 wt. %), Fe (≤ 0.6 wt. %), Cu (< 0.15 wt. %) and Bi (≤ 0.2 wt. %). Noble gas isotope data for hydrothermal ore fluids trapped in gold-related sulphides suggest that diverse sources were involved in the formation of the Charmitan gold system. The noble gas data are indicative of a small, but significant input of fluids from external, deep-seated (mantle and possibly lower crust) sources.

Herrington R, Boni M, Skarpelis N & Large D 2007. Palaeoclimate, weathering and ore deposits – a European perspective, in: Andrew, C.J. et al. (eds.) Proceedings of the ninth biennial meeting of the Society for Geology Applied to Mineral Deposits, Dublin, Ireland 20th-23rd August 2007, Irish Association of Economic Geology, Dublin, ISBN [0-950989-4-4] 1373-1376.

Abstract: Important European ore deposits, which are directly related to palaeo-weathering include bauxites, nickel laterites and supergene deposits of both copper and zinc. Current dating information for these deposits is incomplete but there is strong evidence of a clustering of all deposit types in distinct time periods with two major periods being the Cretaceous and Eocene-Miocene. Current palaeoclimate models further suggest that some of the bauxite and nickel laterite deposits may relate to warm temperate weathering periods rather than tropical conditions as is traditionally thought. A more holistic study of these diverse ore deposits linked to a better geochronology of the weathering process integrated into palaeoclimatic interpretations is needed to provide better models for their formation.

Konopelko D, Biske G, Seltmann R, Eklund O & Belyatsky B 2007. Hercynian post-collisional A-type granites of the Kokshaal Range, Southern Tien Shan, Kyrgyzstan. In: Special Issue IGCP project 510: A-type granites and related rocks through time. *Lithos* **97(1-2)**: 140-160.

Abstract: The Tien Shan (Tianshan) orogen formed during Late Palaeozoic collision between the Karakum–Tarim continent and the Paleo-Kazakhstan continent, a Caledonian component of the Altaid Collage. The Southern Tien Shan terrane represents an intensely deformed fold and thrust belt formed after the final closure of the Paleo-Turkestan ocean. In the Late Carboniferous–Early Permian the Tien Shan was affected by regionally developed diverse post-collisional magmatism. Post-collisional granites of the Kokshaal Segment (350 × 100 km), the easternmost segment of Southern Tien Shan in Kyrgyzstan, include some 20 post-tectonic intrusions varying in composition from biotite–hornblende rapakivi granite to biotite and topaz-bearing leucogranite. The granites are associated with coeval tholeiitic mafic rocks and with alkaline undersaturated syenites. The granites have a pronounced A-type affinity: they are metaluminous with high concentrations of $Na_2O + K_2O$, Rb, HFSE and high K_2O/Na_2O and Fe/(Fe + Mg) ratios, and comprise a single geochemical trend explained by fractionation of K-feldspar and hornblende. The U–Pb zircon SIMS ages of the Djangart, Uch-Koshkon, Mudryum and Kok-Kiya intrusions of the Kokshaal are 296 ± 4 Ma, 279 ± 8 Ma, 281 ± 2 Ma and 281 ± 3 Ma, respectively. The oldest age was obtained for rapakivi granites in the eastern part of Kokshaal while the leucogranites in its western part were dated at 280 Ma. This time span closely corresponds to known ages of post-collisional granitoids and related gold deposits of the Tien Shan. The granites have negative initial ε_{Nd} values (− 1.6 to − 6.9 at 280 Ma) and depleted mantle model ages of 1.05–1.43 Ga indicating a mixing of asthenospheric mantle and Precambrian crustal components. Precambrian Mesoproterozoic crust comprises the basement of the Tarim microcontinent underthrusted to the north beneath the sedimentary piles of Kokshaal. Mafic rocks associated with the granites may represent juvenile asthenospheric melts underplating the Tarim margin at the post-collisional stage and providing heat for generation of A-type granites from its Precambrian crust. Lithospheric plate-scale strike–slip shear zones that formed in the region subsequent to collision provided suitable conduits for ascending asthenospheric material.

On a regional scale, available Nd data for the Tien Shan show that most Paleozoic felsic rocks originated from Precambrian crustal sources. The Northern Tarim rocks, exposed in the Kokshaal Range, and rocks of the southern Paleo-Kazakhstan margin have similar Proterozoic depleted mantle model ages.

Konopelko D, Biske G, Seltmann R, Kiseleva M, Matukov D & Sergeev S 2008. Deciphering Caledonian events: Timing and geochemistry of the Caledonian magmatic arc in the Kyrgyz Tien Shan. *Journal of Asian Earth Sciences* 32: 131-141.

Abstract: In the Kyrgyz Tien Shan (also known as Tian Shan in literature) the Caledonian (Cambro-Silurian) intrusions comprise an extensive magmatic arc stretching from east to west for more than 1000 km. The characteristic feature of the arc is its relatively homogeneous composition of rock types over the whole structure. The Kichy-Naryn and Djetim intrusions presented in this study are slightly elongated in an east–west direction and occupy an area of ca. 100 km^2. The main rock types are diorite, granodiorite and granite. Geological and geochemical features of the Kichy-Naryn and Djetim intrusions demonstrate characteristics of I-type granite series. Rocks of the two intrusions define a continuous high-K calc-alkaline series. Diorite and granite of the Kichy-Naryn intrusion yielded early Silurian crystallisation ages of 436 ± 2 Ma (U–Pb, zircon). Diorite from pebbles in the conglomerate sampled close to the contact of the Kichy-Naryn intrusion yielded a significantly older early Ordovician crystallisation age of 466 ± 10 Ma. The obtained ages of 466 and

436 Ma match ages of two major regional magmatic pulses at ca. 435–440 and 460–470 Ma which took place during continuous subduction from the Cambrian to the Silurian. The amount of granites in the Northern Tien Shan, their prolonged history of formation and pronounced I-type geochemical characteristics suggest their formation in an Andean-type active margin environment.

Le Bas M J, Xueming Y, Taylor R N, Spiro B, Milton J A & Peishan Z 2007. New evidence from a calcite-dolomite carbonatite dyke for the magmatic origin of the massive Bayan Obo ore-bearing dolomite marble, Inner Mongolia, China. *Mineralogy and Petrology* **90**: 223-248.
Abstract: New data on Sr and Nd isotope composition and major and trace element distribution in dolomite-calcite carbonatite dykes at Bayan Obo are provided, and a Mid-Proterozoic age is deduced. The dykes and the neighbouring massive dolomite (H8) body have similar geochemical characteristics, interpreted to indicate a carbonatitic magmatic origin. The occurrence of riebeckite-bearing fenitized quartzites marginal to both dykes and H8 dolomite body, and the presence of xenoliths in the latter, supports this conclusion. Taken together with previously published stable isotope data, these data confirm a mantle-derived origin for the H8 body. The oxygen isotope composition of the dolomite and magnetite in the dykes is lower than that in the fine-grained dolomite. Oxygen data from samples of the coarse-grained dolomite host are either similar to the dykes or to the fine-grained type in agreement with their other geochemical characteristics. The carbonate-magnetite thermometric pairs of the fine-grained dolomite indicate a range of 350–540 °C, which is probably lower than that of the original main magmatic emplacement. This supports the distinction made between the original coarse-grained dolomite marble and dyke composition from the later fine-grained dolomite. Thus the large H8 dolomite is interpreted as a carbonatite intrusion that contains wall-rock xenoliths and caused fenitization of the hanging wall, foot wall and the xenoliths, and that the coarse-grained portions of the H8 marble are those portions that, in the Late Proterozoic to Palaeozoic, escaped recrystallization to fine-grained dolomite and subsequent REE-Fe mineralization.

Morelli R, Creaser R A, Seltmann R, Stuart F M, Selby D & Graupner T 2007. Age and source constraints for the giant Muruntau gold deposit, Uzbekistan, from coupled Re-Os-He isotopes in arsenopyrite. *Geology* **35(9)**: 795–798.
Abstract: The Muruntau gold deposit, Uzbekistan, is one of the largest gold deposits known worldwide, but its origin remains controversial. We used Re-Os arsenopyrite geochronology to precisely determine the age of main-stage gold mineralization at Muruntau to be 287.5 ± 1.7 Ma, which overlaps the emplacement of proximal post-tectonic granitoid magmatism. Additionally, we suggest that arsenopyrite growth may have occurred over an interval of at least 2 m.y. Os initial ratios derived from arsenopyrite were coupled with He isotopic data from fluid inclusions within arsenopyrite to constrain the source of ore metals and fluids. Muruntau arsenopyrite yields relatively unradiogenic initial Os (0.37 ± 0.27) and elevated $^{3}He/^{4}He$ ratios (0.23–0.33R_a) relative to purely crustal Os-He reservoirs. These data suggest the presence of a mantle-derived component in the ore system that was probably introduced during the generation of the granitoid magmas. These new timing and source constraints provide important new insight into the generation of this giant gold deposit, and they necessitate reexamination of genetic models for Muruntau and potentially other giant "orogenic gold" deposits worldwide.

Seltmann R, Borisenko A & Fedoseev G (Eds) 2007. **Magmatism and Metallogeny of the Altai and Adjacent Large Igneous Provinces with an Introductory Essay on the Altaids.** *IAGOD Guidebook Series 16.* CERCAMS/NHM, London 2007, 295p., ISBN 5-91220-008-6.

Abstract: This volume has been published as Volume 16 in the Guidebook Series of the International Association on the Genesis of Ore Deposits (IAGOD). Although it was prepared on the occasion of the International Symposium "Large Igneous Provinces of Asia, Mantle Plumes and Metallogeny", 13-16 August 2007, Novosibirsk, Russia, to serve as guidebook of field trips organised by the Institute of Geology and Mineralogy SB RAS, it represents rather a reference book than being just an excursion guide. The book consists of three parts:
Part A. "Metallogeny of the Southeastern Altai (Russia) and Northwestern Mongolia Ore District, Permian-Triassic Boundary", 2-12 August 2007;
Part B: "Permian–Triassic, Devonian, and Early Paleozoic Igneous Provinces of the Altai–Sayan Fold System (Kolyvan–Tomsk Fold Zone, Kuznetsk and Minusinsk Troughs, Kuznetsk Alatau)", August 17–25, 2007.
Part C: Essay "Eduard Suess and the Altaids: What is in a Name?" by Celâl Şengör and Boris Natal'in.

Slaby E S, Seltmann R, Kober B, Müller A, Galbarczyk-Gasiorowska L & Jeffries T 2007. LREE distribution patterns in zoned alkali feldspar megacrysts from the Karkonosze pluton, Bohemian Massif - implications for parental magma composition. *Mineralogical Magazine* **71(2)**: 193–217.

Abstract: The elemental compositions of zoned alkali feldspar megacrysts from the Karkonosze pluton have been analysed and Pb isotope ratios determined using LA-ICP-MS, EMPA and TIMS. The results are used to interpret the magmatic environments within which they crystallized. Growth zones in the megacrysts show fluctuating trace element patterns that reflect a systematic relationship between incompatible *LREE* and compatible Ba. Chemical gradients between zones in the cores and rims of the megacrysts are not accompanied by significant variation in initial Pb isotope composition. The nucleation and crystallization of the megacrysts is interpreted as having occurred in an environment of magmatic hybridization caused by mixing of mantle and crustal components in which effective homogenization of the Pb isotope composition preceded the onset of megacryst growth. The concentrations of *LREE* in alkali feldspar zones were used to reconstruct hypothetical melt compositions. Some of the zones appear to have crystallized in an homogenous magmatic environment having clear geochemical affinities with end-member magmas in the Karkonosze pluton, whereas others crystallized in heterogeneous domains of magma hybridization. With the exception of Nd, zones crystallized in more homogeneous magma show *LREE* fractionation under near-equilibrium conditions. Trace element abundances of megacrysts grown in dynamic, homogeneous magmatic environments of the Karkonosze pluton occasionally deviate from the predicted patterns and show *LREE* impoverishment.

Slaby E, Galbarczyk-Gąsiorowska L, Seltmann R & Müller A 2007. Alkali feldspar megacryst growth: Geochemical modelling. *Mineralogy and Petrology* **89**: 1-29

Abstract: Alkali feldspar megacrysts from the porphyritic Karkonosze granite (Western Sudetes, Poland) were formed during magma mixing. Barium concentrations in zoned crystals, a sensitive indicator of feldspar migration between coeval magmas, serve to reconstruct the crystallization path of the megacrysts. Based on geochemical data, a double mixing model for the formation of the porphyritic granite and for megacryst growth is constructed. The feldspar growth model supports megacryst nucleation and early crystallization in a hybridized crustal

magma of granodioritic composition. The growth model gives credibility of the choice of partition coefficients used in the modelling. Insights gained from mixing models based on whole rock composition and mineral zonation allow the recognition of various hybridization events that are reflected in a variety of megacryst crystallization paths within the pluton.

Smith M J, Coppard J, Herrington R J & Stein H 2007. The Geology of the Rakkurijärvi Cu-(Au) Prospect, Norrbotten: New Iron Oxide-Copper-Gold (IOCG) Deposit in Northern Sweden. *Economic Geology* **102**: 393–414.

Abstract: The Rakkurijärvi prospect consists of a group of mineralized magnetite and lithic breccias within the ca. 2.05- to 1.90-Ga Proterozoic supracrustal sequence of the Kiruna district, northern Sweden. Potentially economic grades of Cu and Au, largely in the form of chalcopyrite and other sulfide assemblages, are hosted in brecciated magnetite and metavolcanic rocks. The extent of the mineralization is currently open, both downdip and along strike. The deposit was discovered through an integrated geophysical and geochemical program focused on iron oxide-copper-gold (IOCG)–style mineralization. It is hosted by brecciated greenschist facies metavolcanic rocks within and adjacent to an east-northeast–trending shear zone. The dominant characteristics of the deposit are consistent with the IOCG class and include magnetite and lithic breccias hosted in a metavolcanic sequence, with matrices of albite, actinolite, and calcite surrounded by halos of sodic (albite-scapolite) and potassic (scapolite-K-feldspar-biotite) alteration. A distinctive accessory mineral assemblage includes apatite, titanite, and allanite. The paragenesis and textural evolution of the deposit includes early Na-rich alteration accompanying massive magnetite alteration. The Na-rich alteration is overprinted by potassic alteration (also associated with magnetite), although the paragenesis is complex and multiple generations of both sodic and potassic alteration are recognized. Alteration of lithic clasts to magnetite confirms a metasomatic origin, as opposed to an orthomagmatic origin, for the magnetite mineralization. Re-Os analyses of two separates of molybdenite intergrown with magnetite, interpreted as cogenetic with the sulfide assemblage, yield mineralization ages of 1853 ± 6 and 1862 ± 6 Ma.

Reconnaissance bulk-rock chemistry of the host volcanic rocks is consistent with an intermediate volcanic protolith, but much of the original character of the rocks is masked by albitization and incipient iron, sodic, and potassic alteration. The data also indicate significant element mobility during metasomatism and, in particular, the addition of Ti to the rock mass in biotite and as titanite. The compositions of secondary minerals are consistent with alteration and mineralization caused by highly saline fluids of relatively low F activity. The stable isotope characteristics of calcite, with $\delta^{18}O_{SMOW}$ ranging from 9.43 to 19.89 per mil and $\delta^{13}C_{PDB}$ ranging from –11.69 to +4.88 per mil, suggest that the fluids of the calcite and sulfide stage were derived from a magmatic source but had interacted extensively with local sedimentary and volcanic rocks.

Stanley C J, Jones G C, Rumsey M S, Blake C, Roberts A C, Stirling J A R, Carpenter G J C, Whitfield P S, Grice J D & Lepage Y 2007. Jadarite, $LiNaSiB_3O_7(OH)$, a new mineral species from the Jadar Basin, Serbia. *European Journal of Mineralogy* **19**: 575-580.

Abstract: Jadarite, ideally $LiNaSiB_3O_7(OH)$, is a new mineral species from the Jadar Basin, Serbia. It occurs as massive white aggregates, several metres thick, and is relatively free from inclusions and intergrowths; however, individual subhedral (tabular, elongate) to anhedral crystals rarely exceed 5–10 μm in size. It is associated with calcite, dolomite, K-feldspar, rutile, albite, ilmenite, pyrite, and fine-grained

muscovite. Searlesite, analcime, chlorite, and quartz have also been identified. Jadarite is translucent (opaque in masses) with a porcellanous lustre (masses), possesses a white streak, is brittle with a platy habit and has an uneven to conchoidal fracture. VHN_{200} is 390 (range 343–426) kg/mm^2. Mohs' hardness is 4–5. It shows weak pink-orange fluorescence under both short- and long-wave ultraviolet radiation. An infra-red adsorption spectrum is given and shows strong, sharp peaks at 3490 and 3418 cm^{-1} which indicates that water is present as (OH) only. Peaks at 1409 and 1335 cm^{-1} indicate the presence of BO_3 groups, and between 900 and 1180 cm^{-1} the probable presence of BO_4. In transmitted light, plates and grains of jadarite show twinning in some crystallites and for λ590 nm n_α = 1.536(± 0.001) and $n\gamma$ = 1.563(± 0.001). It is non-pleochroic, biaxial, and does not show parallel extinction. In plane-polarized reflected light, the mineral is dark grey with weak bireflectance, it is non-pleochroic and has abundant white internal reflections. Wet chemical analysis combined with CHN analyzer gave the following aggregate composition: Li_2O 7.3, Na_2O 15.0, SiO_2 26.4, B_2O_3 47.2, H_2O 4.3, total 100.2 wt.%. The empirical formula, based on 3B atoms per formula unit (*apfu*), is: $Li_{1.08}Na_{1.07}Si_{0.97}B_3O_{6.99}(OH)_{1.06}$. Jadarite is monoclinic ($P2_1/n$) with *a* 6.818(2), *b* 13.794(2), *c* 6.756(2) Å, ß 111.10(2)° *V* 592.8(2) Å^3 (*Z* = 4), alternatively ($P2_1/c$) with *a* 6.756(3), *b* 13.794(2), *c* 7.680(3) Å, ß 124.07(3) °, *V* 592.9(4) Å^3 and *Z* = 4. The measured density (Berman Balance) is 2.45 g/cm^3; calculated density is 2.46 g/cm^3 (on the basis of the empirical formula and unit-cell parameters refined from powder data). The six strongest X-ray powder-diffraction lines [d in Å(*I*)(*hkl*)] are: 4.666 (62) (120, 021), 3.180 (82) (200), 3.152 (74) (002), 3.027 (40) (221), 2.946 (100) (131), 2.241 (74) (3 11,151), The mineral name is for the locality in Serbia where it was discovered during mineral exploration of the Jadar Basin.

Zaccarini F, Thalhammer O A R, Princivalle F, Lenaz D, Stanley C J & Garuti G 2007. Djerfisherite in the Guli dunite complex, polar Siberia: A primary or metasomatic phase? *Canadian Mineralogist* **45**: 1201-1211.

Abstract: The uncommon sulfide djerfisherite, ideally $K_6(Fe,Cu,Ni)_{25}S_{26}Cl$, occurs in the dunite portion of the Guli complex, located in Polar Siberia, Russia. Distinctive features of the Guli complex are its considerable size, ~2000 km^2, making it the largest dunite–clinopyroxenite massif in the world, and its complicated geology. The exposed part is composed predominantly (60%) of variably serpentinized dunite. Melanocratic alkaline rocks cover about 30%, and other rock types, including melilitolite, ijolite, alkaline syenite and carbonatite, occupy less than 10% of the area. The sample with the most abundant djerfisherite is a coarse-grained phlogopite–magnetite-rich clinopyroxenite. Djerfisherite most commonly occurs in irregular patches of sulfide composed mainly of pyrrhotite accompanied by minor chalcopyrite and rare galena, in a matrix of Ti-bearing andradite, clinopyroxene, phlogopite, plagioclase, apatite and rare zircon, titanite and pyrophanite. It forms crystals generally less than 100 μm in size and occurs as irregular single-phase grains or it fills fissures of the silicate matrix and infiltrates phlogopite along its cleavage planes. We provide new data on the physical and crystallographic properties of djerfisherite. Its composition is characterized by an extensive substitution among Fe, Cu and Ni; their reciprocal substitutions are mainly controlled by the nature of the host rock. The djerfisherite from the Guli complex is Cu-rich and resembles that reported from alkaline rocks. This feature is consistent with the proposal that djerfisherite in the Guli complex crystallized as a primary mineral, during the late-stage fractionation of a highly alkaline melt portion, derived from successive fractional melting of an ascending mantle plume under metasomatic conditions.

2006

Chiaradia M, Konopelko D, Seltmann R & Cliff R A 2006. Lead isotope variations across terrane boundaries of the Tien Shan and Chinese Altay. *Mineralium Deposita* **41**: 411–428.

Abstract: The Muruntau gold deposit, Uzbekistan, is one of the largest gold deposits known worldwide, but its origin remains controversial. We used Re-Os arsenopyrite geochronology to precisely determine the age of main-stage gold mineralization at Muruntau to be 287.5 ± 1.7 Ma, which overlaps the emplacement of proximal post-tectonic granitoid magmatism. Additionally, we suggest that arsenopyrite growth may have occurred over an interval of at least 2 m.y. Os initial ratios derived from arsenopyrite were coupled with He isotopic data from fluid inclusions within arsenopyrite to constrain the source of ore metals and fluids. Muruntau arsenopyrite yields relatively unradiogenic initial Os (0.37 ± 0.27) and elevated $^{3}He/^{4}He$ ratios (0.23–0.33R_a) relative to purely crustal Os-He reservoirs. These data suggest the presence of a mantle-derived component in the ore system that was probably introduced during the generation of the granitoid magmas. These new timing and source constraints provide important new insight into the generation of this giant gold deposit, and they necessitate reexamination of genetic models for Muruntau and potentially other giant "orogenic gold" deposits worldwide.

De Boorder H, Zeylmans van Emmichoven & M J, Privalov V A. 2006. Distribution of Precambrian iron and gold deposits on the southwestern East European Platform reflected in underlying transcrustal structure and current river systems. *Ore Geology Reviews* **29**: 242–259

Abstract: The East European Platform is underlain by Archaean and Proterozoic complexes of the East European Craton. In the southwest these are locally exposed in the Ukrainian Shield and the Voronezh Massif on either side of the ca. 2000 km long ESE-striking late Palaeozoic Pripyat–Dniepr–Donets rift. Evaluation with Landsat imagery of 1:1,000,000 scale published maps of the Precambrian complexes [Zaritsky, A.I., Galetsky, L.S. (Eds.), 1992. Geology and Metallogeny of the Southwest of the East-European Platform Map Series, 1: 1,000,000, Ukrainian State Committee on Geology and Utilization of Mineral Resources, Kiev.] is largely obstructed by a cover of post-Palaeozoic sediments and soils of variable thickness. This obstruction is aggravated by an almost continuous patchwork of farmlands. However, analysis of the current drainage patterns in the Dniepr River basin and surrounding regions reveals a spatial coincidence of numerous stream courses and watersheds with previously inferred steep, transcrustal discontinuities of most probably Precambrian age. Transcrustal dislocations constituted important pathways for heat and fluids as is indicated by the distribution of a large proportion of assumed Early Proterozoic hydrothermal iron and gold deposits along them. This distribution is underpinned by the spatial coincidence of mineralization and elongate areas of highly irregular magnetization attributed to uneven distribution of hydrothermal magnetite in banded iron formation. In view of the extent of these dislocations, both vertically and laterally, the generation of hydrothermal fluid flow, emplacement of mantle-sourced magma and associated mineral potential away from banded iron formation complexes is likely. A second group of gold deposits, of Archaean age, is known to occur in association with still recognizable volcanic edifices in greenstone complexes. It is not known if and to what extent such Archaean gold deposits are related to these major transcrustal discontinuities. The kinematics and dynamics of these dislocations and pathways appear largely unknown and deserve high-priority investigation. The geological longevity of the transcrustal dislocation framework till the present day

inferred from the current drainage systems is corroborated, however, by repeated regional topographical levelling surveys.

Dolgopolova A, Weiss D, Seltmann R & Dulski P 2006. Tracing dust and Pb dispersal at the Orlovka Ta-W mining and ore processing site: insights from REE patterns and elemental ratios. *Journal of Hazardous Materials* **132**: 90-97.
Abstract: Different geological, technogenic and environmental samples from the Orlovka–Spokoinoe Ta–Nb–Sn–W mining site and ore processing complex in Eastern Transbaikalia (Russia), were analysed for Pb, Y, Zr, Hf and rare earth elements (REE) to assess the effect of dust and metal dispersal on the environment within the Orlovka–Spokoinoe mining site. Potential source material analysed included ore-bearing and barren granites, host rocks, tailing pond sediments, and ore concentrates. Lichens and birch leaves were used as receptor samples. The REE enrichment relative to chondrite, the extent of the Eu anomalies, the enrichments of heavy REE (HREE), and Zr/Hf and Yb/Y ratios suggest that tailings, barren granites, and metasedimentary host rocks are the main sources of dust in the studied mining environment. In addition, calculated lead enrichment (relative to host rocks) suggests that the environment is polluted with Pb. Our results clearly demonstrate the potential of REE patterns and elemental ratios as a reliable technique to trace dust and metals sources and dispersal within a confined mining area offering a new tool for environmental assessment studies.

Dolgopolova A, Weiss D, Seltmann R, Kober B, Mason T F D, Coles B & Stanley C J 2006. Use of isotope ratios to assess sources of Pb and Zn dispersed in the environment during mining and ore processing within the Orlovka–Spokoinoe mining site (Russia). *Applied Geochemistry* **21(4)**: 563-579.
Abstract: Element concentrations, element ratios and Pb and Zn isotope data are reported for different geologic samples (barren and ore-bearing granites and host rocks), technogenic products (ore concentrates and tailings) and biologic samples (lichens and birch leaves) from the Orlovka–Spokoinoe mining district, Eastern Transbaikalia, Russia, with the aim to trace the sources of Pb and Zn at a local level within the mining site. Lichens and birch leaves were used as receptors of contamination within the mining site. Pb/Zr and Zn/Zr values indicated Pb and Zn enrichment relative to host rocks. Zn isotope data of 15 geologic and 11 lichen samples showed different Zn isotopic signatures with the total range for the geologic suite of −0.4‰ to +1.2‰ and for lichens of +0.4‰ to +1.4‰ in δ^{66}Zn relative to Lyon JMC Zn standard. The source of isotopically heavy Zn within the Orlovka–Spokoinoe mining site could be potentially associated with long-range atmospheric aerosols that also contributed Pb to the studied mining site. Our results demonstrated that Zn isotopes might be used as new tools for Zn source assessment.

Müller A, Seltmann R, Halls C, Siebel W, Dulski P, Jeffries J, Spratt J, Kronz A 2006. The magmatic evolution of the Land's End pluton, Cornwall, and associated pre-enrichment of metals. *Ore Geology Reviews* **28**: 329-367.
Abstract: The peraluminous Land's End granite is one of the composite plutons forming the late-Variscan Cornubian batholith. The western part of the pluton hosts the Sn–Cu mineralisation of the St. Just mining district. The pluton consists of early megacrystic biotite (Mg-siderophyllite) granites and albite microgranites and younger Li-siderophyllite granites, and tourmaline granites together with fine-grained massive quartz–tourmaline rocks (MQT). Most of the granite varieties evolved by fractional crystallisation from a common crustal magmatic reservoir, apart from the albite microgranite, which has a different source. Trace element analyses of K-feldspar

megacrysts in the older biotite granites made using laser ablation ICP-MS reveal that the megacrysts were derived from moderately evolved sources and now reside in separate granite sub-stages with variable degrees of fractionation, so that equilibrium between phenocrysts and host no longer persists.
The younger granites show a strong in situ fractionation at the cm- to 100-m-scale, whereby boron-rich melts are concentrated in the apical parts of the individual intrusive units. Geological, textural and mineralogical data suggest that the tourmaline granites and MQT evolved mainly from fractionated Li-siderophyllite granites. Cathodoluminescence, trace element and melt inclusion studies of quartz from the MQT reveal that the MQT was formed during the transition from the magmatic to hydrothermal states from a mixture of immiscible phases. The Li-siderophyllite granites, tourmaline granites and MQT appear to be the immediate magmatic precursors from which the hydrothermal fluids responsible for the mineralisation in the St Just district originated.

Müller A, Thomas R, Wiedenbeck M, Seltmann R & Breiter K 2006. Water content of granitic melts from Cornwall and Erzgebirge: A Raman spectroscopy study of melt inclusions. *European Journal of Mineralogy* 18: 429–440.
Abstract: Melt inclusions (MIs) occurring in quartz of late-Variscan Sn-specialized granites from the Land's End pluton in SW England and from the eastern Erzgebirge volcano-plutonic complex in Germany were analyzed by Raman spectroscopy, secondary ion mass spectrometry and electron microprobe. Crystallized MIs were homogenized using cold-sealed autoclaves operating at 850°C and 2 kbar for 24 hours. The H_2O concentration of homogenized MIs from the Land's End granites determined by confocal Raman spectroscopy range between 1.5 and 5.4 wt.%. Several MIs from the Land's End granites contain a hypersaline fluid with 18.2 to 38.6 wt.% H_2O. Such mixed fluid and silicate-MIs are typical for magmas that were oversaturated in volatiles. The ratio of silicate glass/saline phase decreases with increasing degree of differentiation of the granite host. The H_2O content of MIs from the Niederbobritzsch granite, Schönfeld rhyodacite, Teplice rhyolite, Altenberg-Frauenstein microgranite and Schellerhau granite in the eastern Erzgebirge varies between 0.7 and 11.9 wt.%. The MIs from the volcanic rocks have more variable concentrations than the MIs from the granites. The high chemical discrepancies between MIs and whole rock suggest that the quartz phenocrysts in the Schönfeld rhyodacite were injected into a stratified magma chamber during the course of multiple recharge events at the chamber's base. MIs from granites from the eastern Erzgebirge do not contain hypersaline fluids, however they have F concentrations of up to 11.2 wt.%. The Li, Be and B contents of representative homogenized MIs were determined by SIMS. The light lithophile element ratios of MIs are constant for each magmatic province despite different fractionation degrees of the host rocks. MIs from rocks of the eastern Erzgebirge volcano-plutonic complex are relatively enriched in Li and Be, whereas MIs in granites of the Land's End pluton have higher B contents. The distinctive ratio of light lithophile elements of the silicate melt is also reflected in the light lithophile element ratio of the magmatic host quartz.

Plotinskaya O Yu, Kovalenker V A, Seltmann R & Stanley C J 2006. Te and Se mineralogy of the high-sulfidation Kochbulak and Kairagach epithermal gold telluride deposits (Kurama Ridge, Middle Tien Shan, Uzbekistan). *Mineralogy and Petrology* **87**: 187–207.
Abstract: The Late Paleozoic Kochbulak and Kairagach deposits are located on the northern slope of the Kurama Ridge, Middle Tien Shan, in the same volcanic structure and the same ore-forming system. Au–Ag–Cu–Bi–Te–Se mineralization is confined to veins and dissemination zones accompanied by quartz-sericite wall-rock

alteration. The tellurides, calaverite, altaite, hessite, and tetradymite are widespread at both deposits; at Kairagach selenides and sulfoselenides of Bi and Pb are common, while at Kochbulak Bi and Pb telluroselenides and sulfotelluroselenides are typical. The paragenetic sequence of telluride assemblages are similar for both deposits and change from calaverite + altaite + native Au to sylvanite + Bi tellurides + native Te, Bi tellurides + native Au, and, finally, to Au + Ag tellurides with time. These mineralogical changes are accompanied by an increase in the Ag content of native gold that correlates with a decrease in temperature, fTe_2 and fO_2 and an increase in pH.

Seltmann R, Cook N, Koneev R & Dolgopolova A (eds) 2006. Proceedings of the Field Workshop on Porphyry and Epithermal Deposits of the Chatkal-Kurama Region, Uzbekistan, 22-30 April 2006; CERCAMS-8. *The Natural History Museum*, 80 pp.

Seltmann R & Dolgopolova A (eds, English edition, 2006). **Uranium of Mongolia**. Translation of monograph by Yu.B. Mironov. NHM London, 2006, 230p., 22 tables, 29 figures, 63 references. ISBN 5-8198-0049-4 (soft-bound). ISBN 5-93761-078-4 (CD-ROM). *Printing House of VSEGEI St Petersburg, Russia 2006. © Centre for Russian and Central EurAsian Mineral Studies (CERCAMS), London, UK*

Annotation: General problems of geology, tectonics, and metallogeny of Mongolia are considered. The radiogeochemical and metallogenic subdivision of this territory with respect to uranium was carried out for the first time. The economic and prospective types of uranium ore mineralization are characterized and the uranium ore provinces and districts are outlined along with estimation of their possible uranium resources. The main attention is focused on the known and permissive uranium ore districts as targets for further geological exploration. The book is intended for a wide circle of geologists dealing with geological exploration of uranium deposits and study of uranium ore provinces and districts in Mongolia. The conclusions drawn in this book may be helpful in the decision making related to the development of mineral resources of Mongolia and particular provinces of this country. 22 tables, 29 figures, 63 references. Chapters: 1. Exploration of Uranium Ore Mineralization in Mongolia, 2. Geotectonics, 3. Mineral Resources of Mongolia: Principal Features, 4. Distribution of Radioactive Elements in Rocks, 5. Types of Uranium and U-Bearing Mineralization, 6. Uranium Ore Districts and Permissive Districts, 7. Estimation of Uranium Resources in Mongolia, Conclusions, References.

2005

Armstrong R, Kozelj D & Herrington R**,** 2005 - The Majdanpek Cu-Au Porphyry Deposit of Eastern Serbia: A Review; in Porter, T.M. (Ed.), Super Porphyry Copper & Gold Deposits: A Global Perspective; PGC Publishing, Adelaide, **2**: 453-466.
Abstract: The approximately 1000 Mt @ 0.6% Cu, 0.3-0.4 g/t Au Majdanpek porphyry copper is the most northerly deposit within the Timok Magmatic Complex (TMC) which also hosts the exploited Bor and producing Veliki Krivelj deposits. Slightly older, but similar magmatic rocks southeast of the region host the significant porphyry-high sulphidation mineralisation at Elatsite and Chelopech in neighbouring Bulgaria. Similar porphyry deposits are also known in Romania, across the Danube river to the north of Majdanpek. The TMC igneous rocks show clear evidence of crustal contamination and thus likely relate to an eastward dipping subduction zone beneath a continental margin located to the west. Mineralisation is related to sparse and narrow north-south trending andesitic dykes dated at 83 Ma. These dykes intrude along a north-south trending fracture zone cutting Proterozoic and Palaeozoic metamorphic rocks, and Jurassic limestones. Extrusive facies of the TMC are rare at Majdanpek, although they are common farther to the south of the region. Mineralisation is typically developed as stockworks, the bulk of which are actually within the metamorphic aureole of the andesitic dykes. There are also numerous skarns and replacement bodies flanking the intrusives, while more distal replacement bodies are found in the Jurassic limestones. The highest copper grades relate to K-silicate alteration and zones of strong silicification. Mo grades are very low throughout the deposit, while the Cu%:Au g/t ratio is approximately 2:1. PGEs occur as minor phases accompanying the copper mineralisation and are recovered at the smelter. Significant supergene upgrading is recorded in an oxidation blanket that was 25 m thick in the north and covered the deposit.

Brooks S J, Udachin V & Williamson B J 2005. Impact of copper smelting on lakes in the southern Ural Mountains, Russia, inferred from chironomids. *Journal of Paleolimnology* **33:** 229-241.

Chiaradia M, Konopelko D, Seltmann R & Cliff R 2005. Lead sources in ore deposits and magmatic rocks of the Tien Shan and Chinese Altay; in Mao, J.W., et al., (Eds.), Mineral Deposit Research: Meeting the Global Challenge, Proceedings of the Eighth Biennial SGA Meeting, Beijing, China, 18-21 August, 2005; Springer, pp. 1301-1304.
Abstract: The Altaid orogen consists of Paleozoic subduction-accretion complexes and magmatic arcs as well as narrow Precambrian basement slivers which were accreted, consolidated and then deformed during Paleozoic collisions and subsequent Alpine-Himalayan deformations between the East European craton in the West, the Siberian craton in the East, and the Alai-Tarim and Karakum microcontinents in the South. The Altaids are the site of abundant plutonism and host some of the largest gold deposits in the world, especially of the orogenic gold type. Over 100 new lead isotope data show that each one of the Altaid domains investigated is characterized by distinct lead isotope signatures and that there is an W-E Pb isotope gradient suggesting a progressive transition from a continental crust environment in the west (Western Tien Shan) to an almost 100% juvenile (mantle-derived) crust environment in the east (Chinese Altay). Our data indicate also the locally extensive presence of old continental crust at the base of the Tien Shan east of the Talas-Farghona fault but not west of it. The lead isotope signatures of the ore deposits follow closely those of the magmatic and basement rocks of the host

domains suggesting that no unique reservoir has been responsible for the gold concentration in this orogen.

Dolgopolova A, Seltmann R, Stanley C, Weiss D, Kober B & Siebel W 2005. Isotope systematics of ore-bearing granites and host rocks of the Orlovka-Spokoinoe mining district, Eastern Transbaikalia, Russia. In Mao, J.W., et al., (Eds.), Mineral Deposit Research: Meeting the Global Challenge, Proceedings of the Eighth Biennial SGA Meeting, Beijing, China, 18-21 August, 2005; Springer, pp.747-750.
Abstract: Pb, Rb and Sr isotope data are reported for the Khangilay, Orlovka and Spokoinoe granite massifs and their host rocks in the Orlovka-Spokoinoe mining district, Eastern Transbaikalia, Russia. Pb isotope analyses indicate a common Pb source for all three granite massifs reflecting a homogenous source melt from which all magmatic members evolved. Pb isotope systematics identify two possible scenarios for the source of Li-F granites: 1) a crust-mantle source where a mixture of MORB and continental-derived material were brought together in an orogenic environment; and 2) a type II enriched mantle source where subducted continental material could have been strongly implicated in volcanic suites. New Rb-Sr isotope age data yield a 143.8±4.2 Ma age for barren granites of the Orlovka and Khangilay massifs.

Gerel O, Amar-Amgalan S, Oyungerel S & Myagmarsuren 2005. Granitoids and related mineralization of Mongolia: petrochemistry and mineral deposits GIS. in Mao, J.W., et al., (Eds.), Mineral Deposit Research: Meeting the Global Challenge, Proceedings of the Eighth Biennial SGA Meeting, Beijing, China, 18-21 August, 2005; Springer, pp. 1313-1316.
Abstract: Granitoids occupy the main part of Mongolia's territory forming elongated Phanerozoic accreted belts. The major deposits and occurrences in Mongolia are associated with granitoids and their interpretation plays key role for mineral deposit assessment.
The GIS database and compilation is being constructed in MapInfo 6.5 and contains a digitally compiled thematic maps linked to Geologic map of Mongolia, Tectonic map of Mongolia and Mineral Deposit map of Mongolia at 1:1,000,000 scale. The major layers are: Granitoid distribution map at the scale of 1:500,000 and 1:200,000 with topography and major tectonic units, major towns, roads, railroads, likes and rivers. Database contains tables with description of plutons and complexes, which includes area, host rocks, age, and contact metamorphism, petrographic description of major phases of granitoid plutons and complexes, dikes, postmagmatic alteration.
Geochronological data and major trace and isotopic data of each pluton are shown in separate tables. The GIS compilation provides maps of large regions showing granitoid belts. Granitoid interpretation includes chemical classification, tectonic discrimination, magma source, origin of granitoids and evolution of granitic magmatism trough the time. Also location of major mineral deposits and mineralization associated with accreted belts and interpretation of this relation will be done. An example of maps and interpretation is demonstrated for the Southeast Mongolia. Output of project will be: Granitoid magmatism map on the scale of 1:500,000.

Golovanov I M, Seltmann R & Kremenetsky A A 2005. The Porphyry Cu-Au/Mo Deposits of Central Eurasia: 2. The Almalyk (Kal'makyr-Dalnee) and Saukbulak Cu-Au Porphyry Systems, Uzbekistan; in Porter, T.M. (Ed.), Super Porphyry Copper & Gold Deposits: A Global Perspective; PGC Publishing, Adelaide, **v. 2**: 513-523.

Abstract: The Almalyk porphyry Cu-Au system of eastern Uzbekistan encompasses the giant ore deposits at Kal'makyr (2.5 Gt @ 0.38% Cu, 0.5 g/t Au) and Dalnee (2.8 Gt @ 0.36% Cu, 0.35 g/t Au). The Sarycheku orebody (200 Mt @ 0.5% Cu, 0.1 g/t Au) is part of the Saukbulak porphyry Cu-Au system, some 18 km to he south. Both systems are associated with the second, Middle- to Late-Carboniferous, pulse of magmatic activity within the Devono-Carboniferous Valerianov-Bel'tau-Kurama volcano-plutonic belt that is the main element of the Middle Tien Shan terrane in Central Asia. Previous K-Ar dating of the ore-related porphyry intrusive and the mineralisation has returned ages in the range of 310 to 290 Ma, whereas recent U-Pb zircon dating reported for the intrusive sequence in the Almalyk district partially overlaps in the range of 320 to305 Ma, with ore-related porphyries 315 to 319 Ma. Mineralisation at both Kal'makyr and Dalnee is predominantly in the form of stockworks with lesser disseminations, and is associated with Late Carboniferous quartz monzonite porphyry plugs intruding earlier dioritic and monzonitic intrusive rocks of the same magmatic complex. The orebodies take the form of a cap like shell developed above and draped over the flanks of the related quartz monzonite porphyry stock.The dominant hosts to ore are the monzonite and diorite wall rocks, with the quartz monzonite porphyry only containing ore in its outer margins, surrounding and/or overlying a barren core. The focus of stockwork development is fracturing related to both the intrusive contact of the porphyry stock and to crosscutting faulting. Alteration comprises an early K-silicate phase followed by albite-actinolite and peripheral epidote-chlorite-carbonate-pyrite propylites, overprinted by an abundant phyllic episode which is closely related to the final distribution of the ore. Associated mineralisation commenced with barren quartz-hematite veining,followed by quartz-magnetite, quartz-pyrite-molybdenite-chalcopyrite with the bulk of the contained gold,quartz-carbonate-polysulphide with lesser gold, then by zeolite-anhydrite, and finally carbonate and barite veining. Subsequent oxidation and uplift developed a layer of oxide ore, a limited leached cap and supergene sulphide enrichment, largely in zones of fault related fracturing.

Graupner T, Kempe U, Wall V J, Seltmann R, Köhler S & Shatov V 2005. Mass transfer during alteration and Au precipitation at Muruntau: Alteration behaviour of different rock types. In Mao, J.W., et al., (Eds.), Mineral Deposit Research: Meeting the Global Challenge, Proceedings of the Eighth Biennial SGA Meeting, Beijing, China, 18-21 August, 2005; Springer, pp. 1317-1320.
Abstract: Results from petrographic microscopy, scanning electron microscopy (SEM), and Rietveld analysis indicate intense hydrothermal alteration processes for those pelitic and psammopelitic metasedimentary rocks of the Variegated Besapan, which occur within the Muruntau ore field. However, whereas significant input of ore-bearing hydrothermal fluids into the psammopelitic rock types and strong transfer of components from the fluid to these rocks is indicated by mass transfer calculations, these calculations yield a significantly smaller transfer of components to the rocks for pelitic rock types. Alteration reactions in the psammopelitic rock types at Muruntau are strongly controlled by the infiltration of orebearing hydrothermal fluids. The variable alteration behaviour has significantly contributed to an accumulation of higher contents of gold in the psammopelitic rocks, compared to the pelitic rocks.

Herrington R, Achmedov N A & Charter W J 2005. The Khandiza Zn-Pb-Cu-Ag VMS deposit: Part of a new 'Bathurst District' in southern Uzbekistan? In Mao, J.W., et al., (Eds.), Mineral Deposit Research: Meeting the Global Challenge, Proceedings of the Eighth Biennial SGA Meeting, Beijing, China, 18-21 August, 2005; Springer, 615-618.
Abstract: The Lower Carboniferous Khandiza VMS deposit is located in southeast Uzbekistan close to the border with Tajikistan. Currently awaiting development by

Marakand Minerals Limited ("Marakand"), the deposit comprises more than 14 Mt of resource grading 7.2% Zn, 3.5% Pb, 0.9% Cu, 130g/t Ag and 0.4 g/t Au. The deposit is hosted in Lower Carboniferous (Visean) rhyolite and dacite extrusives and pyroclastics, closely associated with a rhyolitic subvolcanic system.. Geochemistry suggests the volcanics show both tholeiitic and calc-alkaline affinity, consistent with being forming in a rifted continental margin above the south-facing active destructive plate margin to the north of the Paleotethys Ocean. The sulphides form multiple lenses of massive banded ore with sulphidecemented clastic volcanic breccias and footwall disseminations. Mineralogy of the sulphides is fairly simple comprising sphalerite, galena, chalcopyrite and pyrite with minor sulphosalts. Silver reports to sulphosalts and galena as well as other minor silver-rich sulphide phases. Minor gold appears to be paragenetically late. The Khandiza region has many features comparable to the Bathurst district of Canada where rifting at a supra-subduction continental margin is responsible for generating the host volcanics to deposits such as the Brunswick 12 deposit. In southern Uzbekistan, Khandiza is the only VMS deposit that has so far been well explored. A further 34 mineral occurrences and base metal anomalies have been identified, all associated with volcanics, and warranting further exploration. 12 of these targets are within 10km of Khandiza itself, and associated with the Chornova volcanic complex.

Herrington R J, Armstrong R N, Yakubchuk A, Seltmann R, Shatov, V, Gerel O, Koval P & Berzina A 2005. Analysis of magmatic belts of Mongolia utilising a new combined geology map and petrochemistry GIS product. p. 53–62, in: Seltmann R., Gerel O., Kirwin D.J. (Eds.) *Geodynamics and metallogeny of Mongolia with a special emphasis on copper and gold deposits*. SEG-IAGOD Field Trip, 14–16 Aug. 2005, 8th Biennial SGA Meeting. IAGOD Guidebook Series 11: CERCAMS/NHM London, 225.

Abstract: The objectives of the article are to provide a revised geodynamic framework and tectonic interpretation of key magmatic arcs in Mongolia with the potential of linking the evolution of magmatic arcs to metallogeny by combining in a GIS product available maps with mineral deposit databases. The described GIS product includes terrane maps, consisting of a series of time slices describing the spatial distribution of different terrane types with a georeferenced set of spreadsheets containing whole rock geochemical data of granitoids, and some volcanics for the major arc successions. The system is highly flexible, compiled in ARC and MapInfo formats with databases simply compiled in the form of Excel spreadsheets converted to DBF formats.

Herrington R, Maslennikov V, Zaykov V, Seravkin I, Kosarev A, Buschmann B, Orgeval J-J, Holland N, Tesalina S, Nimis P and Armstrong R 2005. Classification of VMS deposits: Lessons from the South Urals. *Ore Geology Reviews* **27**: 203-237.

Abstract: VMS deposits of the South Urals developed within the evolving Urals palaeo-ocean between Silurian and Late Devonian times. Arc-continent collision between Baltica and the Magnitogorsk Zone (arc) in the south-western Urals effectively terminated submarine volcanism in the Magnitogorsk Zone with which the bulk of the VMS deposits are associated. The majority of the Urals VMS deposits formed within volcanic-dominated sequences in deep seawater settings. Preservation of macro and micro vent fauna in the sulphide bodies is both testament to the seafloor setting for much of the sulphides but also the exceptional degree of preservation and lack of metamorphic overprint of the deposits and host rocks. The deposits in the Urals have previously been classified in terms of tectonic setting, host rock associations and metal ratios in line with recent tectonostratigraphic classifications. In addition to these broad classes, it is clear that in a number of the

Urals settings, an evolution of the host volcanic stratigraphy is accompanied by an associated change in the metal ratios of the VMS deposits, a situation previously discussed, for example, in the Noranda district of Canada.
Two key structural settings are implicated in the South Urals. The first is seen in a preserved marginal allochthon west of the Main Urals Fault where early arc tholeiites host Cu–Zn mineralization in deposits including Yaman Kasy, which is host to the oldest macro vent fauna assembly known to science. The second tectonic setting for the South Urals VMS is the Magnitogorsk arc where study has highlighted the presence of a preserved early forearc assemblage, arc tholeiite to calc-alkaline sequences and rifted arc bimodal tholeiite sequences. The boninitc rocks of the forearc host Cu–(Zn) and Cu–Co VMS deposits, the latter hosted in fragments within the Main Urals Fault Zone (MUFZ) which marks the line of arc-continent collision in Late Devonian times. The arc tholeiites host Cu–Zn deposits with an evolution to more calc-alkaline felsic volcanic sequences matched with a change to Zn–Pb–Cu polymetallic deposits, often gold-rich. Large rifts in the arc sequence are filled by thick bimodal tholeiite sequences, themselves often showing an evolution to a more calc-alkaline nature. These thick bimodal sequences are host to the largest of the Cu–Zn VMS deposits. The exceptional degree of preservation in the Urals has permitted the identification of early seafloor clastic and hydrolytic modification (here termed halmyrolysis sensu lato) to the sulphide assemblages prior to diagenesis and this results in large-scale modification to the primary VMS body, resulting in distinctive morphological and mineralogical sub-types of sulphide body superimposed upon the tectonic association classification.
It is proposed that a better classification of seafloor VMS systems is thus achievable using a three stage classification based on (a) tectonic (hence bulk volcanic chemistry) association, (b) local volcanic chemical evolution within a single edifice and (c) seafloor reworking and halmyrolysis.

Herrington R J, Puchkov V N & Yakubchuk A S 2005. A reassessment of the tectonic zonation of the Uralides: implications for metallogeny. In: McDonald I, Boyce A J, Butler I B, Herrington R J & Polya D A (Eds). Mineral Deposits and Earth Evolution. *Geological Society*, London, Special Publications **248**:153-166.
Abstract - This paper reviews the current model for the structural zonation of the 'oceanic' Urals and shows that only its westernmost Sakamara, Tagil and Magnitogorsk zones reveal the presence of thrust structures, whereas in the East Uralian megazone and Trans-Uralian zone, the classic zonation rather reflects late- or post-collisional granitic welding and strikeslip displacement of the orogen for 100-300 km. This sinistral strikeslip displacement is shown to be responsible for the current lens shaped structure of the individual zones in the Urals.
Restoration of the individual zones into their pre-strikeslip fault positions suggests that the Urals contains only two magmatic arcs, one in the west and one in the east. The western Tagil Magnitogorsk immature arc hosts a variety of chromite, Alaska-type PGE and major VMS deposits whilst the eastern Valerianovka arc effectively stitches together the Kazakh Tien Shan structures and is host to important copper-gold and giant iron (+copper) skarn deposits.
The geodynamic evolution of the Urals commences with the immature Tagil Magnitogorsk magmatic arc in the Late Ordovician where data supports eastward directed subduction below the oceanic back-arc basin that existed in the rear of the Kazakhstan Tien Shan arcs. In the later Palaeozoic, these arcs collided with each other and were together thrust onto the East European craton. Syncollisional granitoid intrusions welded the magmatic arcs, which were soon displaced into presently observed fragments along the post-collisional orogen-parallel strikeslip faults.

Herrington R J, Zaykov V V, Maslennikov V V, Brown D & Puchkov V N 2005a. Mineral deposits of the Urals and Links to Geodynamic Evolution, in: Hedenquist et al. (eds.), *Economic Geology* **100th Anniversary Volume**: 1069-1095.

Abstract: The Urals form the geographic divide between Europe and Asia and represent one of the major metal producing regions of Russia, particularly for iron, copper, zinc, nickel, aluminum, and gold. 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 the assembly of Pangea at the site of collision between the East European, Siberian, and Kazakh cratons where subduction led to oceanic arcs in the west through the Silurian to the Devonian and a continental arc in the east from the Devonian to the Carboniferous. Proterozoic sediment-filled rifts on the margin of the East European craton host giant epigenetic deposits of magnesite and siderite, with minor fluorite and base metals, and the sequences are intruded by major mafic dikes that host significant titanomagnetite and chromite resources. Silurian oceanic-arc complexes in the Sakmara allochthon host giant chromite deposits and some arc-related VMS deposits, and the Magnitogorsk and Tagil intraoceanic volcanic arcs host economically significant VMS deposits. The arcs collided with the East European craton during ocean closure, and postcollision intrusion of zoned gabbro-granite plutons into the arcs resulted in the formation of magnetite skarns. The suture zone between the arcs and the craton hosts small epigenetic gold deposits. East of these arcs, the East Uralian zone comprises a complex, fault-bounded collage of early Paleozoic rift sequences, volcanic arcs, and intrusions and marks the continent-continent collision between the East European craton and its accreted arc assemblage and the Kazakh craton. Rocks of the East Uralian zone are intruded by at least two postaccretionary granitoid suites, one of which is spatially and genetically linked to major orogenic gold deposits that are located along transcrustal shear zones; the other consists of arclike porphyritic andesites that host porphyry copper occurrences. The Trans-Uralian zone lies east of the East Uralian zone and is underlain by rocks of the Kazakh continental margin, in at least its eastern part. The Valerianovka continental magmatic arc, developed on the Kazakh continent, hosts undeveloped porphyry copper deposits and giant magnetite bodies. The Urals were exhumed and partially eroded during latest Paleozoic time. Deep weathering from the Mesozoic to the present resulted in the development of a number of significant lateritic deposits, auriferous gossans, bauxites, and shallow-marine iron deposits.

Orgeval J-J, Guerrot C, Tessalina S G, Bourdon B, Zaykov V, Buley C, Bushmann B, Herrington R & Taylor R 2005. Lead isotopic systematics of Urals massive sulphide deposits. In Mao, J.W., et al., (Eds.), Mineral Deposit Research: Meeting the Global Challenge, Proceedings of the Eighth Biennial SGA Meeting, Beijing, China, 18-21 August, 2005; Springer, pp. 667-670.

Abstract: The isotopic composition of lead from a total of 53 samples of galena from 18 VHMS deposits shows a range between 17.437 and 18.111 for 206Pb/204Pb; 15.484 and 15.630 for 207Pb/204Pb and 37.201 – 38.027 for 208/204Pb. The results show a systematic trend with the leads of the Sibay, Barsuchiy Log and Djusa deposits being most radiogenic by comparison with those of Bakr-Tau and Oktiabrskoe which are the least radiogenic deposits. The Bakr-Tau and Oktiabrskoe deposits occur within most primitive fore- arc rocks at the lower part of the Baymak-Buribay formation, which contain lavas of boninitic affinity. The Sibay, Barsuchiy Log and Djusa deposits are found in intra- and back-arc setting and are hosted by a sequence of bimodal tholeiites. The deposits in “arc” settings such as the Balta-Tau, Gai and Alexandrinka deposits occupy an intermediate position. This trend is explained in term of mixing between mantle wedge and continental blocks.

Plotinskaya O Yu, Kovalenker V A, Rusinov V L & Seltmann R 2005. Oscillatory zoning in goldfieldite from epithermal gold deposits. *Doklady Earth Sciences* **403-5**:799-802.

Plotinskaya O Yu, Rusinov V L, Kovalenker V A & Seltmann R 2005. Oscillatory zoning in goldfieldite as a possible indicator of it's formation conditions. Bulgarian Academy of Sciences, *Geochemistry, Mineralogy and Petrology* **43**: 142-147.

Seltmann R, Gerel O & Kirwin D J (Eds.) 2005. **Geodynamics and metallogeny of Mongolia with a special emphasis on copper and gold deposits.** *IAGOD Guidebook Series vol. 13:* CERCAMS NHM London, 225p., 172 figs., 29 tables. ISBN 5-8198-0075-3.

Abstract: This volume has developed from an excursion guidebook that was initially prepared for the international workshop "Geodynamics and Metallogeny of Mongolia" that has been held in Ulaanbaatar, 30 July-1 August 2003, with a one-week follow-up expert field trip to Oyu Tolgoi and some adjacent deposits and exploration targets in the South Gobi. Increasing interest in the geology of Cu-Au and other mineral deposits of Mongolia has encouraged the editors to produce the present updated, largely revised and expanded book that includes supplementary chapters on other famous deposits such as the giant Erdenet Cu-Mo porphyry system and the Boroo gold deposit. This monograph represents simultaneously the guidebook of the SEG-IAGOD fieldtrip "Copper and Gold deposits of Mongolia" visiting the Oyu Tolgoi, Erdenet and Boroo deposits (14-16 August 2005). The trip took place as pre-conference excursion related to the 8th Biennial SGA Meeting in Beijing/China (18-21 August 2005). We hope that these data published under the auspices of the IGCP-473 project will prove helpful in understanding the geology and metallogeny of Mongolia.

Seltmann R & Porter T M 2005. The Porphyry Cu-Au/Mo Deposits of Central Eurasia: 1. Tectonic, Geologic & Metallogenic Setting and Significant Deposits; in Porter, T.M. (Ed.), Super Porphyry Copper & Gold Deposits: A Global Perspective; PGC Publishing, Adelaide, **v. 2**: 467-512

Abstract: 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 over an interval of almost 5000 km across central Eurasia, from the Urals Mountains in Russia in the west, to Inner Mongolia in north-eastern China, to the east. These deposits were formed during a range of magmatic episodes from the Ordovician to the Jurassic. They are associated with magmatic arcs within the extensive subduction-accretion complex of the Altaid and Transbaikal-Mongolian 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.

The development of these collages commenced when slivers of an earlier Proterozoic subduction complex accreted to the palaeo-Tethys Ocean margin of the combined Eastern Europe and Siberian cratons were rifted from the main cratonic mass. These slivers were the contiguous Karakum and Altai-Tarim micro-continents, which became separated from the main cratonic mass by oceanic spreading that

created the Khanty-Mansi back arc basin. Subduction of the palaeo-Tethys Ocean beneath these micro-continents and the adjacent back-arc basin produced the overlapping late Neoproterozoic to early Palaeozoic Tuva-Mongol and Kipchak magmatic arcs. Contemporaneous intra-oceanic subduction within the back-arc basin from the Late Ordovician produced the parallel Urals-Zharma magmatic arc, and separated the main Khanty-Mansi back-arc basin from the inboard Sakmara marginal sea. By the Late Devonian the Tuva-Mongol and Kipchak arcs had amalgamated to form the Kazakh-Mongol arc which extended over the whole palaeo-Tethys Ocean margin of the combined cratonic mass, while magmatic activity continued on the Urals-Zharma arc. During the mid Palaeozoic the two main cratonic components of the proto-Asian continent, the Siberian and Eastern European cratons, began to rotate relative to each other, “drawing-in” the two sets of parallel arcs to form the Kazakh Orocline between the two cratons. During the Late Devonian to Early Carboniferous, the Khanty-Mansi back-arc basin began subducting beneath the oroclinally infolded outer island arc mass to form the Valerianov-Beltau-Kurama arc. At the same time the palaeo-Pacific Ocean began subducting below the Siberian craton to form the Sayan-Transbaikal arc, which expanded by the Permian to become the Selanga-Gobi-Khanka arc which for a period was continuous with the Kazakh-Mongol arc. By the Mid to Late Permian, as the Kazakh Orocline had continued to develop, both the Sakmara and Khanty-Mansi back-arc basins had been closed and the collage of cratons and arcs were sutured by accretionary complexes. During the Permian and Triassic the North China craton approached and docked with the continent, closing the Mongol-Okhotsk sea (an embayment on the palaeo-Pacific margin) to form the Mongolian Orocline. Subduction and arc building activity on the palaeo-Pacific Ocean margin continued to the Mid Mesozoic as the Indo-Sinian and Yanshanian orogenic cycles.
Significant porphyry Cu-Au/Mo and Au-Cu deposits were formed during the: Ordovician in the Kipchak arc (e.g. Bozshakol Cu-Au in Kazakhstan and Taldy Bulak porphyry Cu-Au in Kyrgyzstan); Silurian to Devonian in the Kazakh-Mongol arc (e.g. Nurkazgan Cu-Au in Kazakhstan; Taldy Bulak-Levoberezhny Au in Kyrgyzstan); Devonian in the Urals-Zharma arc (e.g. Yubileinoe Au-Cu in Russia); Devonian in the Kazakh-Mongol arc (e.g. Oyu Tolgoi Cu-Au, and Tsagaan Suvarga Cu-Au, both in Mongolia); Carboniferous in the Kazakh-Mongol arc (e.g. Kharmagtai Au-Cu in Mongolia, Tuwu-Yandong Cu-Au in Xinjiang, China; Koksai Cu-Au, Sayak skarn Cu-Au, Kounrad Cu-Au and the Aktogai Group of Cu-Au deposits, all in Kazakhstan); Carboniferous in the Valerianov-Beltau-Kurama arc (e.g. Kal’makyr-Dalnee Cu-Au and Kochbulak epithermal Au, both in Uzbekistan; BenqalaCu-Au in Kazakhstan); Late Carboniferous to Permian in the Selanga-Gobi-Khanka arc (e.g. Duobaoshan Cu-Au in Inner Mongolia, China); Triassic in the Selanga-Gobi-Khanka arc (e.g. Erdenet Cu-Mo in Mongolia); and Jurassic in the Selanga-Gobi-Khanka arc (e.g. Wunugetushan Cu-Mo in Inner Mongolia, China).In addition to the tectonic, geologic and metallogenic setting and distribution of porphyry Cu-Au/Mo mineralisation within central Eurasia, a description of the setting, geology, alteration and mineralisation recorded at each of the deposits listed above is included within this paper.

Seltmann R, Shatov V, Guriev G, Yakubchuk A & Dolgopolova A 2005. GIS package on mineral deposits database and thematic maps of Central Eurasia in Mao, J.W., et al., (Eds.), Mineral Deposit Research: Meeting the Global Challenge, Proceedings of the Eighth Biennial SGA Meeting, Beijing, China, 18-21 August, 2005; Springer, pp. 1331-1334.
Abstract: The GIS (Geographic Information System) Central Asia is composed of spatially referenced geographical, geological, geophysical, geochemical and mineral deposit thematic layers, and their respective attribute data. It is issued to establish insights in the regions mineral potential and its past and future mining activities.

Subsequently, the information system is further exploited to derive new rules between the different attribute information in their relation to mineral deposit information and the special distribution of the deposits.

Yakubchuk A S 2005. Geodynamic evolution of accreted terranes of Mongolia against the background of the Altaids and Transbaikal-Mongolian collages; in, Seltmann, R., Gerel, O. and Kirwin, D.J., (Eds.), Geodynamics and Metallogeny of Mongolia with a Special Emphasis on Copper and Gold Deposits: SEG-IAGOD Field Trip, 14-16 August 2005, 8th Biennial SGA Meeting; *IAGOD Guidebook Series* **11**: CERCAMS/NHM, London; pp. 13-24.

Abstract: Mongolia occupies parts of the Altaid and Transbaikal-Mongolian orogenic collages of Neoproterozoic-Paleozoic rocks located between the East European, Siberian, North China and Tarim cratons. The “pre-stitch” assemblages consist of only three oroclinally bent Neoproterozoic-Early Paleozoic magmatic arcs (Kipchak, Tuva-Mongol and Urals), separated by sutures of their former backarc basins from each other and adjacent cratons. The pre-stitch assemblages in the core of Mongolia are Neoproterozoic to Paleozoic intra-arc, backarc, magmatic arc and accretionary terranes and Precambrian cratonal terranes. The cratonal terranes of Central Mongolia separate the two collages.

This study proposes that major cratons and smaller cratonal terranes in the basement of magmatic arcs of both collages may represent fragments of the super-continent Rodinia that existed 1.0-0.7 Ga ago. In the Late Proterozoic was a major breakup of Rodinia into presently known cratons. The combined Tuva-Mongol and Kipchak arcs and then the Urals arc might be rifted off united Eastern Europe-Siberia to produce the Paleo-Asian, Khanty-Mansi and Sakmara backarc oceanic basins respectively.

In Mongolia, there are remnants of the Tuva-Mongol and Kipchak arcs. The latter is located in the South Gobi. The geodynamic evolution of Mongolia can be explained through the opening of backarc basins, followed by clockwise rotation of Siberia with respect to Eastern Europe that started in the Ordovician. This resulted in arc-arc, intra-arc and arc-craton collisions. After this episode, the overlap assemblages formed above the extinct Kipchak and Tuva-Mongol arcs. This process continued in the Middle Paleozoic until the Early Permian with several episodes of oroclinal bending, strike-slip duplication and reorganization of the magmatic arcs to produce the new Kazakh-Mongol arc, extending from Central Asia to Mongolia that welded the extinct Kipchak and Tuva-Mongol arcs.

In the Transbaikal-Mongolian collage there were two episodes, in the Devonian – Early Carboniferous and in the Middle Carboniferous to Early Triassic that respectively produced the Sayan-Transbaikal and Selenga-Gobi-Khanka magmatic arcs facing the Paleo-Pacific Ocean. Final amalgamation of the Altaids took place in the Late Paleozoic – Early Traissic, but overlapping magmatic arcs continued to evolve in the Middle Triassic to Middle Jurassic in Transbaikalia-Mongolia against the background of northward drift of North China and related oroclinal bending of the Selenga-Gobi-Khanka arc. The oroclinal bending ultimately resulted in collision of the present eastern part of the arc with the Siberian craton to form the Mongol-Okhotsk suture zone. This collage was welded by the Late Jurassic-Early Cretaceous (Yanshanian) magmatism that developed along the eastern coast of Asia.

Since the Late Cretaceous, a system of intra-plate continent-scale conjugate northwest-trending and northeast-trending strike-slip faults developed in Asia in response to the southward propagation of the Siberian craton with subsequent offset of some tectonic belts for as much as 70 to 700 km. The India-Asia collision rejuvenated some of these faults.

Yakubchuk A S & Nikishin A M 2005. Russia. pp 456-473 Vol IV. In: Encyclopedia of Geology edited by Selley R C, Cocks L R M & Plimer I R, published by Elsevier Academic Press. 5 volumes. 3, 200 pages.

Yakubchuk A S, Shatov V V, Kirwin D, Edwards A, Tomurtogoo O, Badarch G & Buryak V A 2005. Gold and base metal metallogeny of the Cemtral Asian Orogenic Supercollage. *Economic Geology* **100th Anniversary Volume**: 1035-1068.

Abstract: The Central Asian supercollage consists of the Baikalides, Timanides, Altaids, and Mongolides. They are located between the Eastern European, Siberian, Karakum, Tarim, and North China cratons. The metallogenic evolution of the Central Asian supercollage took place within the framework of the supercontinent cycle, between the breakup of the supercontinent Rodinia at the end of the Neoproterozoic and reassembly of the supercontinent Pangea by the end of Paleozoic to early Mesozoic times. The abundant mineral deposits that are present in this region formed in major pulses, coinciding with episodes of oroclinal bending within the supercollage. The Baikalides and Timanides formed through the opening and subsequent closing of back-arc basins between the major cratons and adjacent island arc terranes prior to ca. 600 Ma. The Baikalides host large, epigenetic, Broken Hill-like Pb-Zn and world-class orogenic Au deposits within the ancient passive margin sedimentary sequences.

During Neoproterozoic to early Paleozoic times, Siberia was located north of Eastern Europe so that the Timanides-Baikalides and then the Mongolides and Altaids formed along the active margin of the Pacific Ocean. At this stage, volcanogenic massive sulfide (VMS), porphyry, and intrusion-related Au deposits were formed. During the middle Paleozoic, Siberia was rotated clockwise relative to Eastern Europe. The Mongolide superterranes were shifted along the continental margin of Siberia to the seaward side of the Altaids. In both collages, new overlapping magmatic arcs that host porphyry and VMS deposits were formed.

In the middle to late Paleozoic, the continuing rotation of Siberia, dextral strike-slip movement of the Mongolide terranes relative to the Altaids, and northward drift of the North China, Tarim, and Karakum cratons from Gondwana caused oroclinal bending and collisions between the magmatic arcs and adjacent cratons. At this stage, porphyry, skarn, and epithermal deposits were generated in the overlapping arcs, whereas sedimentary- hosted base metal deposits were formed in the back-arc basins.

By the end of the Paleozoic, the Altaid collage was amalgamated and then separated by the Trans-Eurasian late-collisional strike-slip fault system into the Altai-Mongol and Kazakhstan-Khingan domains. Movement along this fault sinistrally displaced terranes and metallogenic belts of the two domains by as much as 1,000 km. As a result of these collisional and translational events, the prolific gold endowment of the Tien Shan, Urals, eastern Kazakhstan, and Lena orogenic Au provinces was established.

The Mongolides were amalgamated by the middle Mesozoic, after southward movement of Siberia toward the North China craton. This collision assembled the Central Asian supercollage and produced the Mongol-Okhotsk province of orogenic Au deposits. After this event, the Yanshanian arcs, which developed along the eastern margin of Asia, stitched all cratons and collages as they appear today. These arcs host epithermal Au deposits in eastern Russia, and Carlin-like Au ores in association with more alkalic back-arc magmatism.

2004

Bykadorov V, Fedorenko O, Korobkin V, Mazurov A, Rafailovich M, Seltmann R & Smirnov A 2004. The tectonics and minerageny of the Urals, South Tian-Shan and Southern Altay. *32nd International Geological Congress, Florence, Italy*, **215-3**: 994.

Dolgopolova A, Seltmann R, Kober B, Weiss D, Stanley C J & Dulski P 2004. Geochemical characteristics and lead isotope systematics of highly fractionated Li-F enriched amazonite granites and related host rocks of the Orlovka-Spokoinoe mining district, Eastern Transbaikalia (Russia). *Applied Earth Science (Transactions of the Institution of Mining and Metallurgy B)* **113:** 83-99.
Abstract: Element concentrations and Pb isotope data are reported for the Khangilay, Orlovka and Spokoinoe granite massifs and their host rocks in the Orlovka-Spokoinoe mining district, Eastern Transbaikalia, Russia. The aim of the paper is to characterize the evolution trends and geochemical features of the Khangilay pluton and the Orlovka and Spokoinoe deposits and to study the genesis of the three granite massifs by examining fluid-rock and crust-mantle interaction in the evolution of granitoid magmatism. Zr/Hf, Y/Ho and Rb/Sr demonstrate that all three granite bodies show a continuous fractionation history from parental biotite-muscovite granites of Khangilay to highly evolved ore-bearing amazonite granites of Orlovka. Khangilay and its derivates Spokoinoe and Orlovka represent different evolution stages. REE patterns of the amazonite granites of Orlovka show a stronger Eu anomaly and more apparent REE tetrad effects in comparison with the less evolved granites of Khangilay. Pb isotope analyses indicate one common Pb source for all three granite massifs reflecting a homogenous source melt from which all magmatic members generated. Based on Pb isotope systematics two possible scenarios for the source of Li-F granites are proposed: 1) a crust-mantle source where a mixture of MORB and continental-derived material were brought together in the orogenic environment; and 2) type II enriched mantle source where subducted continental material could have been strongly implicated in volcanic suites.

Dolgopolova A, Weiss D J, Seltmann R, Stanley C J, Coles B & Cheburkin A K 2004. Closed-vessel microwave digestion technique for lichens and leaves prior to determination of trace elements (Pb, Zn, Cu) and stable Pb isotope ratios. *International Journal of Environmental & Analytical Chemistry*, **84:** 889-899.
Abstract: A reliable and robust procedure using closed-vessel microwave digestion of lichens and leaves for precise and accurate determination of trace elements (Pb, Zn and Cu) and stable Pb isotope ratios is presented. The method was developed using certified reference material CRM 482 Pseudovernia furfurea (Lichens), NIST 1515 (Apple Leaves) and NIST 1547 (Peach Leaves) and tested on lichens from a mining site in Russia. A mixture of 3mL of HNO3, 3mL of H2O2, 2mL of H2O and 0.8mL of HF ensured complete sample dissolution with 100_5% recovery for Pb, Zn and Cu at a maximum temperature of 210_C and pressure of 350 psi. The amount of HF and microwave pressure significantly influenced Pb, Zn and Cu recovery. Comparison between EMMA-XRF and ICP-AES showed a good correlation between Pb, Zn and Cu concentrations. Using the newly developed digestion method, Pb isotopes in lichens from the mining site were determined with an internal precision better than 0.02%.

Gerel O & Seltmann R 2004. Geodynamics and Metallogeny of Mongolia - An IGCP-473 Workshop in Ulaanbaatar and Expert Field Trip to the South Gobi. Conference Report. *Episodes - Journal of International Geoscience* **27**: 32-36.

Graupner T, Kempe U, Seltmann R & Shatov V 2004. Genesis of the giant Muruntau gold deposit (Uzbekistan): new data and old questions. *32nd International Geological Congress, Florence, Italy*, **215-5/6**: 994.

Abstract: Since the discovery of gold at Muruntau (Central Kyzylkum desert) in 1958, there has been ongoing discussion on the genesis, timing and source(s) of the gold. During the two last decades, the deposit became the subject of focused studies leading to accumulation of new, high quality data. A review of published articles, however, shows that fundamental problems of the deposit formation remain controversial. It is obvious that the main Au mineralisation was generated by a quite large hydrothermal system. Nevertheless, it is still under discussion what was the heat source driving the system (metamorphic, granite-, or mantle-related). There is also no widely accepted view on the source(s) of the gold whether deep-seated, granite-related, or remobilised from wall rocks (possibly from black shales) or from an older, low-grade hydrothermal mineralisation. Published Mesozoic versus Palaeozoic ages of the gold mineralisation are controversially discussed. A review of available data indicates a change in the tectonic regime during the evolution of Muruntau. Early, low-grade "flat" veins were deformed and boudinaged in a ductile regime during intense regional thrusting. In contrast, "steep" high-grade veins and stockwork veinlets formed originally in an open space regime and were later involved in intense brittle deformation (brecciation). No signs of crack-and-seal behaviour were found for the ore veins. High-grade gold was deposited from dilute CO2-rich high temperature (above 400C) fluids in the veins and within the wall rocks during the first formation period of the stockwork system. Dominant wall rock alteration at this stage was microclinisation. This event may be dated at 270-280 Ma (Rb-Sr and Sm-Nd data). Later brittle vein deformation resulted in generation of local ore shoots. The focus of further research should be directed at the relationship between mineralisation and magmatism. Some published age data suggest a time gap between granite magmatism and ore formation. A link to the intrusion of mafic dikes cannot be excluded. However, the absolute age of the magmatism is poorly constrained and granites in the region are not characterised in an appropriate manner. We suggest that progress in the understanding of the genesis of the Muruntau deposit may be reached by more detailed characterisation of late- to post-collisional Hercynian granite magmatism in the region.

Halls C, Seltmann R, & Dolgopolova A 2004. **Atlas of mineral deposit models of the Republic of Kazakhstan.** English edited version of compilation by Bespaev Kh A, Miroshnichenko L A (Eds.). Almaty, Kazakhstan, 142 pp.

Annotation: The Atlas presents geological-genetic models for the main deposit types of Kazakhstan, including deposits of metallic and non-metallic mineral resources (ores, diamonds, and industrial minerals), and fuel and energy resources (hydrocarbons and uranium deposits). The geological models developed by Kazakh geologists are based on examples from studied deposits and ore fields. The applied principles and methodologies to construct these models utilize complex information in order to predict the parameters and scales of accumulation and conditions of formation of the mineral resources. Models permit a focused approach to be used in metallogenic analysis, prognosis and prospecting of deposits. The Atlas is designed for a broad range of specialists dealing with the study, exploration and evaluation of deposits, and will also be of great use to geology students.

Kempe U, Graupner T, Goetze J & Seltmann R 2004. Zircon and monazite alteration in the Muruntau granite (Muruntau, Uzbekistan): a natural analogue for hydrothermal alteration of nuclear waste forms. *32nd International Geological Congress, Florence, Italy*, **215-16**: 996.

Abstract: A granite body (Murun granite) was discovered close to the giant Muruntau gold deposit (Uzbekistan) in a deep drill hole below 4005 m and traced down to the bottom of the hole at 4294 m. Several samples from the borehole were investigated by optical microscopy (OM), cathodoluminescence microscopy (OM-CL), and scanning electron microscopy (SEM). The Murun granite is an equigranular syenogranite. According to whole rock analysis, it is high in silica and alkalis (SiO2 75.4 wt. %; Na2O 4.2 wt. %; K2O 4.3 wt. %), depleted in CaO and FeO, very low in MgO, TiO2, P2O5, Ba, and Sr, and displays a pronounced negative Eu anomaly. Contents of U (29 ppm) and Th (28 ppm) are high. The rock is strongly altered with orthoclase transformed to microcline. Several alteration processes were discovered in plagioclase resulting in pure albite containing tiny inclusions of calcite, muscovite, and fluorite. Biotite is transformed to chlorite and muscovite. Important accessories are zircon, monazite, some uraninite, and fergusonite. Secondary calcite, pyrrhotite, pyrite, chalcopyrite, and synchisite-röntgenite intergrowths develop intensely near the granite contact. Primary magmatic zircon with normal growth zoning is altered to U- and Hf-rich zircon (up to 4 wt. % UO2 and 6 wt. % HfO2) during albitisation. A second alteration developed mostly within the core of the crystals and along certain growth zones resulting in a U decrease (down to 1-2 wt. % UO2). In more intensely altered grains, tiny pores occur together with intergrowth of thorite-coffinite, xenotime, and uraninite. Euhedral monazite crystals show oscillatory growth zoning and sector zoning mostly caused by variations in Th concentration. Th is incorporated by coupled substitution of huttonitic type ($Y^{3+} + P^{5+} \leftrightarrow Th^{4+} + Si^{4+}$). The Th content reaches up to 37 wt. % ThO2 (typical values vary around 6-15 wt. % ThO2). In altered monazite, a decrease in Th and Si was found. Inclusions of thorite-coffinite occur within the altered areas of the grains. Strongly altered monazite appears xenomorphic and homogeneous in BSE images. U-rich zircon and Th-rich monazite may be regarded as natural analogues of high-loaded nuclear waste forms with zircon and monazite structure. The study on the Murun granite demonstrates that, in such a case, U and Th may be remobilised from zircon and monazite under certain hydrothermal conditions. Significant portions, however, are again fixed immediately in secondary thorite-coffinite and uraninite.

Kempe U, Seltmann R, Graupner T, Wall V J, Matukov D & Sergeev S 2004. SHRIMP U-Pb zircon dating of Hercynian granite magmatism in the Muruntau gold district (Uzbekistan). In: Khanchuk A I, Gonevchuk G A, Mitrokhin A N, Simanenko L F, Cook N J & Seltmann R (Eds.) 2004. Metallogeny of the Pacific Northwest: Tectonics, Magmatism and Metallogeny of Active Conteninental Margins. *Proceedings of the Interim IAGOD Conference, Vladivostok, Russia.* 1-20 September 2004. Vladivostok, DALNAUKA: 2004, 719pp. ISBN 5-8044-0470-9, pp 210-213.

Abstract: First results of precise U-Pb zircon dating of Hercynian granite magmatism in the vicinity of the giant Muruntau gold deposit are reported. Three samples of three different granite facies (porphyritic coarse-grained melanocratic; porphyritic coarse-grained leucocratic and medium-grained leucocratic granites) were taken from outcrops in the North Tamdynskii granite about 31 km to the northwest of Muruntau. The geological setting and petrographic characteristics of these samples, as well as other data, indicate that at least two postcollisional granite types are distinguishable within this area. However, both types yield SHRIMP U-Pb ages around 290 Ma apparently indistinguishable from each other within the limits of error. Detailed studies of the rocks and zircons contained within show significant signs of alteration

that also affected the U-Pb system of the zircon. Strongly altered parts of zircon grains yield 206Pb/238U ages down to 20 Ma, with apparently concordant ages until about 260-250 Ma. The ages defined for the three samples (287.5±1.4 Ma; 293.3±2.1 Ma; and 289.3±3.6 Ma) should therefore be treated as minimum ages. Further isotope investigation on other granite intrusions or dikes present in and around the Muruntau deposit is in progress.

Khanchuk A I, Gonevchuk G A, Mitrokhin A N, Simanenko L F, Cook N J & Seltmann R (Eds.) 2004. **Metallogeny of the Pacific Northwest: Tectonics, Magmatism and Metallogeny of Active Conteninental Margins.** *Proceedings of the Interim IAGOD Conference, Vladivostok, Russia.* 1-20 September 2004. Vladivostok, Dalnauka, 719pp. ISBN 5-8044-0470-9.

Khanchuk A I, Gonevchuk G A & Seltmann R (Eds.) 2004. **Metallogeny of the Pacific Northwest (Russian Far East): Tectonics, Magmatism and Metallogeny of Active Continental Margins.** *Guidebook for the Field Excursions in the Far East of Russia*: September 1-20, 2004**.** Published by Dalnauka Publishing House, IAGOD Guidebook series 11, Vladivostok, 2004, 176 p., 122 figs., 29 tables. (ISBN 5-8044-0464-4).

Khanchuk A I, Gonevchuk G A & Seltmann R 2004. Preface p 3-4. In: Khanchuk A I, Gonevchuk G A & Seltmann R (Eds.) Metallogeny of the Pacific Northwest (Russian Far East): Tectonics, Magmatism and Metallogeny of Active Continental Margins. IAGOD Guidebook series 11, Dalnauka Publishing House, Vladivostok, 176 p. (ISBN 5-8044-0464-4).

Lein A Y, Maslennikov V V, Maslennikova S P & Spiro B 2004. Sulfur and carbon isotopes in the black smoker hydrothermal vent ecosystems of the Ural paleoocean *Geochemistry International* **42:** 668-681.
Abstract: The isotopic compositions of sulfide minerals and organic carbon (C_{org}) from the biomorphic ore of black smokers in the South Ural paleocean were studied. The $\delta^{34}S$ values of sulfide minerals from pseudo-morphs after vestimentiferas, mollusks, and polychaetas vary from –3.5 to +3.5‰. These values characterize the sulfur isotopic composition of hydrogen sulfide from hydrothermal solutions in the Devonian ocean and testify to the catastrophic burial of the ancient bioherms studied, which retained the pseudomorphous ore texture and prevented their posthydrothermal alteration. The organic carbon of sulfidized organisms from ancient hydrothermal biological communities is enriched in ^{13}C by 2–10‰ relative to the C_{org} of pre-Carboniferous sedimentary rocks. This supports the presence of chemoautotrophic organic matter in the biomorphic sulphide ore studied. It was demonstrated that kerite and kerite-like segregations typical of South Ural ore were produced by the metamorphism of biomass of ancient microbial mats.

Mao J, Konopelko D, Seltmann R, Lehmann B, Chen W, Wang Y, Eklund O & Usubaliev T 2004. Postcollisional age of the Kumtor gold deposit and timing of Hercynian events in the Tien Shan, Kyrgyzstan. *Economic Geology* **99:** 1771-1780.
Abstract: We report here $^{40}Ar/^{39}Ar$ whole-rock and sericite data for host-rock (sericite-quartz altered rock) and gold ore (pyrite-quartz-feldspar-carbonate) from the giant Kumtor gold deposit in the Tien Shan fold and thrust belt of Kyrgyzstan, one of the largest orogenic gold belts on Earth. Plateau ages for whole-rock samples of

sericite-quartz altered rock and sericite-bearing gold ore are 285.5 ± 1.2 and 288.4 ± 0.6 Ma. Sericite concentrates gave plateau ages of 284.3 ± 3.0 (host rock) and 285.4 ± 0.2 (ore) Ma. The age of mineralization is slightly younger than a U-Pb zircon age of 296.7 ± 4.2 Ma obtained for the postcollisional Djangart granite, about 80 km southeast of Kumtor, and slightly older than two published U-Pb ages of 268 ± 1 and 280 ± 9 Ma on a postcollisional granite intrusion about 10 km west of Kumtor. These ages also overlap with data from the other major gold deposits of the 2,000-km-long southern Tien Shan fold and thrust belt. The ages define a late Paleozoic event of gold mineralization related to regional-scale fluid flow and granite magmatism controlled by transcrustal shear zones during the postcollisional stage.

Morelli R M, Creaser R A & Seltmann R 2004. Rhenium – Osmium geochronology of arsenopyrite from the giant Muruntau Au deposit, Uzbekistan. In: Khanchuk A I, Gonevchuk G A, Mitrokhin A N, Simanenko L F, Cook N J & Seltmann R (Eds.) 2004. Metallogeny of the Pacific Northwest: Tectonics, Magmatism and Metallogeny of Active Conteninental Margins. *Proceedings of the Interim IAGOD Conference, Vladivostok, Russia.* 1-20 September 2004. Vladivostok, Dalnauka: 2004, 719pp. ISBN 5-8044-0470-9, pp 510-513.

Abstract: We report here the initial results of Re-Os arsenopyrite geochronology for the giant Muruntau gold deposit, Uzbekistan. Re-Os isotope analyses were performed on nine arsenopyrite samples drilled from five different spot locations on an individual hand specimen from a stockwork veinlet from the Muruntau open pit. The $^{187}Re/^{188}Os$ ratios for the arsenopyrite range up to high values of ~ 6000, with correspondingly highly radiogenic Os ($^{187}Os/^{188}Os$ ~ 30). The Re contents range up to a few tens of parts per billion (ppb) with common Os abundances ranging up to ~ 100 parts per trillion ^{192}Os. The nine analyses, when regressed together, yield a Re-Os isochron age of 286±5 Ma (2σ uncertainty, Model 3; MSWD = 5), interpreted to represent the age of arsenopyrite formation, and by proxy, gold mineralization at Muruntau. This age overlaps consistent ages determined by K-Ar, Rb-Sr and most recently U-Pb SHRIMP isotope methods that were reported for post-collisional granitoids in the Muruntau region and were interpreted as minimum intrusion ages. The Re-Os arsenopyrite age for ore deposition at Muruntau overlaps the age previously determined from scheelite (279±18 Ma), but is older than ages determined for alteration mineralogies and lithologies using the Rb-Sr and Ar-Ar methods at Muruntau. The age overlap between Muruntau ore deposition and local felsic magmatism allows for a possible association between the large accumulation of hydrothermal gold mineralization at Muruntau and magmatism.

Seltmann R, Armstrong R & Dolgopolova A 2004. Mineral resource assessment of Eurasian ore provinces through CERCAMS, the Centre for Russian and Central Asian Mineral Studies (NHM London, UK). *32nd International Geological Congress, Florence, Italy*, **136-10**: 620.

Seltmann R & CERCAMS team. 2004. First U-Pb zircon SHRIMP and Re-Os arsenopyrite dating of granitic magmatism and gold mineralization from the Muruntau district and implications on Muruntau-style deposits. Plenary lecture (IAGOD keynote address). In: Khanchuk A I, Gonevchuk G A, Mitrokhin A N, Simanenko L F, Cook N J & Seltmann R (Eds.) 2004. Metallogeny of the Pacific Northwest: Tectonics, Magmatism and Metallogeny of Active Conteninental Margins. *Proceedings of the Interim IAGOD Conference, Vladivostok, Russia.* 1-20 September 2004. Vladivostok, Dalnauka: 2004, 719pp. ISBN 5-8044-0470-9, pp 23-24.

Seltmann R, Shatov V, Yakubchuk A, Lehmann B, Jingwen M, Fedorenko O, Isakhodjaev B, Nikonorov V & Minaev V 2004. Mineral deposit types of Central Asia: new exploration models based on modern geodynamic background (IGCP-473 progress report). *32nd International Geological Congress, Florence, Italy*, **215-1**: 993.
Abstract: The ore-bearing belts of the Central Asian region s.s. (Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan) host over 2500 known mineral deposits of variable size, age and type. Large areas of Central Asia were explored during Soviet times when important deposits were discovered. Earlier, metallogenic studies were based on largely fixistic geodynamic views. In addition, many deposits were typified according to standards, which significantly differ from internationally accepted ore classification or exploration models. The current study, carried out in the framework of the IGCP-473 project (2002-2006) and coordinated through the Centre for Russian and Central Asian Mineral Studies (CERCAMS), aims to develop a unified metallogenic-geodynamic model of Central Asia and the adjacent territories of China, Mongolia and Russia. This GIS-based approach integrates the currently available as well as new data in order to unify the geotectonic units of Central Asia and their mineral inventory. The metallogenic evolution as seen against the background of crustal growth during accretionary orogeny has led to the definition of the main mineral deposit types and resulting exploration models. Although orogenic (mesothermal) gold deposits represent the world's best examples of this type, the preliminary analysis of Kumtor, Muruntau and similar deposits with orogenic features shows that their regional tectonic setting has similarities to Carlin-style gold mineralization. If this interpretation is valid then the spatial association of gold and mercury belts of the Southern Tien Shan indicates a complex erosion-controlled spectrum of ore deposits in the Tien Shan gold province with shallow Hg-Sb mineralization and deeper gold (-tungsten). The ongoing studies should help to define the controlling parameters for ore formation in the Central Asian metallogenic belts as a prerequisite to characterize and classify main gold-bearing deposit types, including meso- to epithermal transitional and unconventional types, such as IOCG (Olympic Dam) and Carlin-style. Major ore deposits are to be expected in the extension of the known metallogenic belts under moderate sedimentary cover of the Meso-Cenozoic basins such as in the Urals - Tien Shan transition zone. These regions of low exploration maturity with respect to metal exploration have great potential with invaluable information from hydrocarbon exploration and mapping surveys.

Spiro B, Weiss D J, Purvis O W, Mikhailova I, Williamson B, Udachin V & Coles B J 2004. Pb isotopes in lichen transplants - transient records of diverse sources around the Karabash smelter, Urals, Russia. *Environmental Science and Technology* **38:** 6522-6528.
Abstract: Transplants of the lichen *Hypogymnia physodes*, which is relatively tolerant to SO_2 and heavy metals, were deployed for 3 months over a 60 km long SW−NE transect centered on a highly polluting Cu smelter and its adjoining town of Karabash, southern Urals, Russia. The abundance of ^{206}Pb, ^{207}Pb, ^{208}Pb, and ^{204}Pb were determined by MC-ICP-MS. The measurement of ^{204}Pb revealed critical features, which would otherwise remain concealed: (i) The precise isotope ratios referenced to ^{204}Pb allowed several different sources to be resolved even within the small area covered: (a) the obvious pollutant source of the Karabash Cu smelter; (b) two dispersed sources, likely to include soil with lower and different contributions of thorogenic and uranogenic lead; and (c) one anthropogenic source with higher contribution of ^{235}U derived Pb. (ii) In part of the transect, the Pb isotope composition changed while the Pb concentrations remained the same. This indicates that the Pb content of the transplantation material from the background site was largely replaced

and that the transplants provide a transient record reflecting a continuous accumulation and loss of environmental Pb, probably mainly in the form of extracellular particles. Overall, the method of lichen transplantation coupled with Pb isotope ratio determinations proved effective in assessing the usefulness of lichens in biomonitoring and in resolving different sources of atmospheric deposition.

Wall F 2004. Kola Peninsula: minerals and mines. *Geology Today* **19 (6)**, November-December 2003: 206-211.
Abstract: Numerous world class mineral deposits made the Kola Peninsula a 'Mecca' for mineralogists and key economic deposits make it one of Russia's most important industrial area. For geologists there is the challenge of explaining how this situation has come about.

Wall F & Zaitsev A N 2004. Phoscorites and Carbonatites from Mantle to Mine: the key example of the Kola Alkaline Province. *Mineralogical Society Bulletin* **3-9**.
Abstract: The Kola Peninsula, Russia, is one of the world's most extreme, where the most important concentrations of ultrabasic, alkaline rocks and carbonatites are found. Many of the carbonatites occur in association with apatite, magnetite, silicate rocks called phoscorites, which are key to understanding how carbonate-bearing magmas travel from mantle to the crust and how they behave on cooling. Most of the phoscorites are found to be concentrated at six complexes in Kovdor, Vouriyari, Sokli and Turiy Mys plus the Afrikanda ultrabasic complex. Analysis of the minerals most important in understanding the petrogenesis of the Kola rocks revealed presence of REE, Zr, Nb, PGE and sulphide minerals in various concentrations.

Wall F & Zaitsev A N (Eds.) 2004. **Phoscorite and Carbonatite: mantle to mine the key example of the Kola Alkaline Province**. *The Mineralogical Society Series,* #10. ISBN 0903056224. 498 pp.
Abstract: This book on the rocks of the Kola Peninsula, Russia, makes a major new contribution to our knowledge of one the worldís most extreme, and thus important concentrations of ultrabasic, alkaline rocks and carbonatites. Many of the carbonatites occur in association with apatite, magnetite, silicate rocks called phoscorites, which are key to understanding how carbonate-bearing magmas travel from the mantle to the crust and how they behave on cooling. Phoscorites are also of prime economic importance as sources of phosphate, iron ore, baddeleyite, copper and Platinum Group Elements (PGE). Fourteen chapters provide new data, discussions and interpretations by European and North American experts on Kola and include summaries of literature previously only available in Russian. Topics include: Timing of the Kola alkaline magmatism; Mineralogy, geochemistry and petrogenesis of six complexes at Kovdor, Sokli, Sallanlatvi, Afrikanda,Vuoriyarvi and Turiy Mys; Three chapters on REE, Zr, Nb, PGE and sulphide minerals; Introductions to the Kola Alkaline Province and phoscorites; A review of stable isotope data and resulting petrogenetic interpretations; A petrogenetic interpretation in the context of a mantle plume; A comprehensive review chapter on economic deposit.

Wall F & Zaitsev A N 2004. Rare earth minerals in Kola carbonatites. pp 341-373 in: Phoscorite and Carbonatite: mantle to mine the key example of the Kola Alkaline Province. *The Mineralogical Society Series,* #10 edited by Wall F & Zaitsev A N.

Wall V J, Graupner T, Yantsen V, Seltmann R & Hall G C 2004. Muruntau, Uzbekistan: a giant thermal aureole gold (TAG) system. In J. Muhling et al (eds) SEG 2004: Predictive Mineral Discovery Under Cover; Centre for Global Metallogeny, The University of Western Australia, Publication No. **33:** 199-203.

Abstract: Muruntau, with gold production and resources exceeding 3000 tonnes at an average grade >2 g/t, is the largest gold deposit known outside the Witwatersrand and the subject of a vast literature, mainly by Russian and Uzbek workers. We examine the nature and evolution of the Muruntau auriferous system, developing genetic and exploration targeting models. These are based on our new work in 2003-2004, and previous work on the Muruntau mine, its surrounds and deep drillholes, as well as geochemical, grade-distribution and petrological data that have been integrated with regional geology and geophysics.

Webster J, Thomas R, Förster H-J, Seltmann R & Tappen C 2004. Geochemical evolution of halogen-enriched granite magmas and mineralizing fluids of the Zinnwald tin-tungsten mining district, Erzgebirge, Germany. *Mineralium Deposita* **39:** 452 - 472.

Abstract: We remelted and analyzed crystallized silicate melt inclusions in quartz from a porphyritic albite-zinnwaldite microgranite dike to determine the composition of highly evolved, shallowly intruded, Li- and F-rich granitic magma and to investigate the role of crystal fractionation and aqueous fluid exsolution in causing the extreme extent of magma differentiation. This dike is intimately associated with tin- and tungsten-mineralized granites of Zinnwald, Erzgebirge, Germany. Prior research on Zinnwald granite geochemistry was limited by the effects of strong and pervasive greisenization and alkali-feldspar metasomatism of the rocks. These melt inclusions, however, provide important new constraints on magmatic and mineralizing processes in Zinnwald magmas.

The mildly peraluminous granitic melt inclusions are strongly depleted in CAFEMIC constituents (e.g., CaO, FeO, MgO, TiO_2), highly enriched in lithophile trace elements, and highly but variably enriched in F and Cl. The melt inclusions contain up to several thousand ppm Cl and nearly 3 wt% F, on average; several inclusions contain more than 5 wt% F. The melt inclusions are geochemically similar to the corresponding whole-rock sample, except that the former contain much more F and less CaO, FeO, Zr, Nb, Sr, and Ba. The Sr and Ba abundances are very low implying the melt inclusions represent magma that was more evolved than that represented by the bulk rock. Relationships involving melt constituents reflect increasing lithophile-element and halogen abundances in residual melt with progressive magma differentiation. Modeling demonstrates that differentiation was dominated by crystal fractionation involving quartz and feldspar and significant quantities of topaz and F-rich zinnwaldite. The computed abundances of the latter phases greatly exceed their abundances in the rocks, suggesting that the residual melt was separated physically from phenocrysts during magma movement and evolution.

Interactions of aqueous fluids with silicate melt were also critical to magma evolution. To better understand the role of halogen-charged, aqueous fluids in magmatic differentiation and in subsequent mineralization and metasomatism of the Zinnwald granites, Cl-partitioning experiments were conducted with a F-enriched silicate melt and aqueous fluids at 2,000 bar (200 MPa). The results of the experimentally determined partition coefficients for Cl and F, the compositions of fluid inclusions in quartz and other phenocrysts, and associated geochemical modeling point to an important role of magmatic-hydrothermal fluids in influencing magma geochemistry and evolution. The exsolution of halogen-charged fluids from the Li- and F-enriched Zinnwald granitic magma modified the Cl, alkali, and F contents of the residual melt, and may have also sequestered Li, Sn, and W from the melt. Many of these fluids contained strongly elevated F concentrations that were equivalent to or greater than

their Cl abundances. The exsolution of F-, Cl-, Li-, ± W- and Sn-bearing hydrothermal fluids from Zinnwald granite magmas was important in effecting the greisenizing and alkali-feldspathizing metasomatism of the granites and the concomitant mineralization.

Williamson B J, Mikhailova I, Purvis O W & Udachin V 2004. SEM-EDX analysis in the source apportionment of particulate matter on Hypogymnia physodes lichen transplants around the Cu smelter and former mining town of Karabash, South Urals, Russia. *The Science of the Total Environment* **332:** 139-154.

Abstract: Scanning electron microscopy with energy-dispersive X-ray analysis (SEM-EDX) of particulate matter on lichen transplant thalli (Hypogymnia physodes) was assessed as a complementary technique to wet chemical analysis for source apportionment of airborne contaminants. Transplants (2 month exposure) stationed in the Cu smelter and former mining town of Karabash were compared with those from a control site 30 km south. Particulate matter in Karabash samples (715 analyses) showed higher levels of S, Pb, Cu, Sn and Zn compared with the control (598 analyses). Complex element associations among the particles confounded detailed mineralogical identifications, and therefore a simplified particle classification scheme was devised for source apportionment. Karabash samples contained high levels of particles classified as mining-related (MRP), and these were also identified in control samples, indicating wide spatial dispersion from the smelter and highlighting the sensitivity of the method. It was noted that MRP <2.5-μm diameter were poorly represented on lichen surfaces suggesting this may limit the usefulness of Hypogymnia transplants as proxies when assessing human health impacts from airborne particulates. Analyses of the lichen thallus surface (away from surface particulates) revealed high levels of Cu, Zn, Fe and Pb associated with organics in the Karabash samples compared with the control, with a proportionate loss of K, interpreted as being due to a stress-related increase in cell membrane permeability. This type of analysis may provide a novel SEM-EDX-based method for assessing lichen vitality. The techniques developed are presented and further implications of the study are discussed.

Williamson B J, Udachin V, Purvis O W, Spiro B, Cressey G & Jones G C 2004. Characterisation of airborne particulates in the Cu smelter and former mining town of Karabash, South Ural Mountains of Russia. *Environmental Monitoring and Assessment*, **98:** 235-259.

Abstract: Airborne total suspended particulates (TSP), dusts from smelter blast furnace and converter stacks, and filtrates of snow melt waters have been characterised in the Cu smelter and former mining town of Karabash, Russia. TSP was collected at sites up- and downwind of the smelter and large waste and tailings dumps (Oct. 2000 and July 2001). Methods for particle size, mineralogical and elemental determinations have been tested and described, and a new PSD-MicroSOURCE™ XRD technique developed for the mineralogical analysis of microsamples on filter substrates. TSP in downwind samples has a mean equivalent spherical diameter of 0.5 μm (s.d. = 0.2) and was found to be 100% respirable. The main element of human health/environmental concern, above Russian maximum permitted levels (1 μg m-3, average over any time period), was Pb which was measured at 16-30 μg m-3 in downwind samples. Individual particulates mainly consisted of complex mixtures of anglesite (PbSO4), Zn2SnO4 and poorly ordered Zn sulphates. From experimental and theoretical considerations, a high proportion of contained Pb, Zn, Cd and As in this material is considered to be in a readily bioavailable form. Chemical and mineralogical differences between the TSP, stack dusts and snow samples are discussed, as well as the implications for human and regional environmental health.

Yakubchuk A 2004. Architecture and mineral deposit settings of the Altaid orogenic collage: a revised model; *Journal of Asian Earth Sciences* **23:** 761-779.
Abstract: The Altaids are an orogenic collage of Neoproterozoic-Paleozoic rocks located in the center of Eurasia. This collage consists of only three oroclinally bent Neoproterozoic-Early Paleozoic magmatic arcs (Kipchak, Tuva-Mongol, and Mugodzhar-Rudny Altai), separated by sutures of their former backarc basins, which were stitched by new generations of overlapping magmatic arcs. In addition, the Altaids host accreted fragments of the Neoproterozoic to Early Paleozoic oceanic island chains and Neoproterozoic to Cenozoic plume-related magmatic rocks superimposed on the accreted fragments. All these assemblages host important, many world-class, Late Proterozoic to Early Mesozoic gold, copper-molybdenum, lead-zinc, nickel and other deposits of various types.

In the Late Proterozoic, during breakup of the supercontinent Rodinia, the Kipchak and Tuva-Mongol magmatic arcs were rifted off Eastern Europe-Siberia and Laurentia to produce oceanic backarc basins. In the Late Ordovician, the Siberian craton began its clockwise rotation with respect to Eastern Europe and this coincides with the beginning of formation of the Mugodzhar-Rudny Altai are behind the Kipchak arc, These earlier arcs produced mostly Cu-Pb-Zn VMS deposits, although some important intrusion-related orogenic Art deposits formed during arc-arc collision events in the Middle Cambrian and Late Ordovician.

The clockwise rotation of Siberia continued through the Paleozoic until the Early Permian producing several episodes of oroclinal bending, strike-slip duplication and reorganization of the magmatic arcs to produce the overlapping Kazakh-Mongol and Zharma-Saur-Valerianov-Beltau-Kurama arcs that welded the extinct Kipchak and Tuva-Mongol arcs. This resulted in amalgamation of the western portion of the Altaid orogenic collage in the Late Paleozoic. Its eastern portion amalgamated only in the early Mesozoic and was overlapped by the Transbaikal magmatic arc, which developed in response to subduction of the oceanic crust of the Paleo-Pacific Ocean. Several world-class Cu-(Mo)-porphyry, Cu-Pb-Zn VMS and intrusion-related Au mineral camps, which formed in the Altaids at this stage, coincided with the episodes of plate reorganization and oroclinal bending of magmatic arcs. Major Pb-Zn and Cu sedimentary rock-hosted deposits of Kazakhstan and Central Asia formed in backarc rifts, which developed on the earlier amalgamated fragments. Major orogenic gold deposits are intrusion-related deposits, often occurring within black shale-bearing sutured backarc basins with oceanic crust.

After amalgamation of the western Altaids, this part of the collage and adjacent cratons were affected by the Siberian superplume, which ascended at the Permian-Triassic transition. This plume-related magmatism produced various deposits, such as famous Ni-Cu-PGE deposits of Norilsk in the northwest of the Siberian craton.

In the early Mesozoic, the eastern Altaids were oroclinally bent together with the overlapping Transbaikal magmatic arc in response to the northward migration and anti-clockwise rotation of the North China craton. The following collision of the eastern portion of the Altaid collage with the Siberian craton formed the Mongol-Okhotsk suture zone, which still links the accretionary wedges of central Mongolia and Circum-Pacific belts. In the late Mesozoic, a system of continent-scale conjugate northwest-trending and northeast-trending strike-slip faults developed in response to the southward propagation of the Siberian craton with subsequent post-mineral offset of some metallogenic belts for as much as 70-400 km, possibly in response to spreading in the Canadian basin. India-Asia collision rejuvenated some of these faults and generated a system of impact rifts.

Yakubchuk A S & Nikishin A M 2004. Noril'sk–Talnakh Cu–Ni–PGE deposits: a revised tectonic model. *Mineralium Deposita* **39**: 125–142.
Abstract: The Noril'sk mining district is located at the northwest margin of the Tunguska basin, in the centre of the 3,000·4,000 km Siberian continental .ood basalt (CFB) province. This CFB province was formed at the Permo-Triassic boundary from a superplume that ascended into the geometric centre of the Laurasian continent, which was surrounded by subducting slabs of oceanic crust. We suggest that these slabs could have reached the core–mantle boundary, and they may have controlled the geometric focus of the superplume. The resulting voluminous magma intruded and erupted in continental rifts and related extensive flood basalt events over a 2–4 Ma period.

Cu–Ni–PGE sulphide mineralization is found in olivine-bearing differentiated mafic intrusions beneath the flood basalts at the northwestern margin of the Siberian craton and also in the Taimyr Peninsula, some 300 km east of a triple junction of continental rifts, now buried beneath the Mesozoic–Cenozoic sedimentary basin of western Siberia. The Noril'sk-I and Talnakh-Oktyabr'sky deposits occur in the Norill'sk–Kharaelakh trough of the Tunguska CFB basin. The Cu–Ni–PGE-bearing mineralized intrusions are 2–3 km-wide and 20 km-long differentiated chonoliths. Previous studies suggested that parts of the magma remained in intermediate-level crustal chambers where sulphide saturation and accumulation took place before emplacement. The 5–7-km-thick Neoproterozoic to Palaeozoic country rocks, containing sedimentary Cu mineralization and evaporites, may have contributed additional metal and sulfur to this magma.

Classic tectonomagmatic models for these deposits proposed that subvertical crustal faults, such as the northeast-trending Noril'sk–Kharaelakh fault, were major trough-parallel conduits providing access for magmas to the final chambers. However, geological maps of the Noril'sk region show that the Noril'sk–Kharaelakh fault offsets the mineralization, which was deformed into folds and offset by related reverse faults, indicating compressional deformation after mineralization in the Late Triassic to Early Jurassic. In addition, most of the intrusions are sills, not dykes as should be expected if the vertical faults were major conduits. A revised tectonic model for the Noril'sk region takes into account the fold structure and sill morphology of the dominant intrusions, indicating a lateral rather than vertical emplacement direction for the magma into final chambers. Taking into account the fold structure of the country rocks, the present distribution of the differentiated intrusions hosting the Noril'sk-I and Talnakh–Oktyabr'sky deposits may represent the remnants of a single, >60 km long, deformed

and eroded palm-shaped cluster of mineralized intrusions, which are perceived as separate intrusions at the present erosional level. The original direction of sill emplacement may have been controlled by a northeasttrending paleo-rise, which we suggest is present at the southeastern border of the Noril'sk–Kharaelakh trough based on analysis of the unconformity at the base of the CFB. The mineralized intrusions extend along this rise, which we interpret as a structure that formed above the extensionally tilted block in the metamorphic basement. Geophysical data indicate the presence of an intermediate magma chamber that could be linked with the Talnakh intrusion. In turn, this T-shaped flat chamber may link with the Yenisei–Khatanga rift along the northwest-trending Pyasina transform fault, which may have served as the principal magma conduit to the intermediate chamber. It then produced the differentiated mineralized intrusions that melted through the evaporites with in situ precipitation of massive, disseminated, and copper sulphide ore. The Noril'sk–Kharaelakh crustal fault may not relate to mineralization and possibly formed in response to late Mesozoic spreading in the Arctic Ocean.

Zaitsev A N, Sitnikova M A, Subbotin V V, Fernandez-Suarez J & Jeffries T E 2004. Sallanlatvi complex - a rare example of magnesite and siderite carbonatites. Pp 201-245 in *The Mineralogical Society Series,* #10 edited by Wall F & Zaitsev A N.

Zaraisky G P, Balashov V N & Seltmann R 2004. Oscillation phenomena at magmatic crystallization: role of devolatilization. *Geological Society of America Abstracts with Programme* **36 (5):** 378.
Abstract: The two component haplogranite melt crystallization model is proposed. The new model takes into account the thermodynamic interaction with fluid components (H_2O, NaF) and combine it with non-equilibrium model of H_2O loss-and-gain by melt during crystallization. The numerical application is developed for simplified working system: alb – qtz – NaF – H_2O. The process of crystallization takes place in dyke belonging to upper part crystallizing granite system. The model of fluid release is based on the scheme which includes the input of dissolved H_2O by magma convection, the accumulation of H_2O in melt due to crystallization, the reversible transfer of H_2O between magmatic melt and vapor (fluid) phase, the autocatalytic irreversible stage of this transfer and the vapor buoyancy escape out of system. The autocatalysis of devolatilization is conditioned by the pair collisions of vapor (fluid) bubbles. Mineral crystallization and the buoyancy process have the "viscous" activation energy (450 kJ/mole) and the kinetics of bubbles forming has the diffusion activation energy (60 kJ/mole). The calculations reveal the wide region of kinetic parameters with oscillation regime of melt degassing. The changes of H_2O concentration, the temperature and the rates of mineral crystallization get the oscillation character. The variation in H_2O concentration dissolved in melt produces a swing motion of eutectic position in phase diagram and causes rhythmic crystallization of mineral components. At the initial water content in melt 4.4% and at fluorine content 4-6% the oscillation of H2O concentration are in the range 1.6-2.8%. For 4% of F in melt the temperature oscillation focused around of 740 ^{0}C, and for 6% of F – around of 690 ^{0}C. A comparison of the model patterns with the natural samples of line rocks from Etyka and Orlovka (Transbaikalia) shows a principal relevance of model.

2003

Armstrong R N, Yakubchuk A, Herrington R J & Seltmann R 2003. Accreted magmatic belts of Mongolia and their ore potential - A new GIS product. pp8-11. In: Herrington R, Gerel O, Seltmann R & Kirwin D (eds) 2003. Geodynamics and Metallogeny of Mongolia. Proceedings of a workshop in Ulaanbaatar, 31 July - 1 August 2003. *Mongolian Geoscientist* **21:** 73pp.

Belogub E V, Novoselov C A, Spiro B & Yakovleva B A 2003. Mineralogical and S isotopic features of the supergene profile of the Zapadno-Ozernoe massive sulphide and Au-bearing gossan deposit, South Urals. *Mineralogical Magazine* **67:** 339-354.
Abstract: The profile of the supergene zone of the Zapadno-Ozernoe massive sulphide Cu-Zn deposit differs from the classic model (Emmons, 1917) in that it includes a prominent dark sooty subzone rich in secondary sulphides. This subzone is situated above residual pyrite sands, which overlie the massive sulphide body and below quartz-baryte leached sands. It contains a diverse mineral assemblage which consists of secondary sulphides such as galena, sphalerite, metacinnabar, Se-bearing pyrite–dhzarkenite series, tiemannite, native Au, native S and native Se, and unidentified sulphosalts of Ag and Hg. The very light S isotope composition of the secondary sulphides (lowest values $\delta^{34}S = -17.2$‰ VCDT) in comparison with primary pyrite ~0‰ and baryte +18.4‰ is indicative of bacterial sulphate reduction. The overlying oxidized part of the supergene column contains minerals of the jarosite–beudantite–segnitite series. The maximum concentrations of Au, up to 150 ppm, occur in the lower part of the profile. The atypical structure, mineral assemblage and S isotope composition of the secondary sulphides in the dark layer of the supergene profile are indicative of particular geochemical conditions due to the existence of a stagnant water body that gave rise to intense bacterial activity, in turn controlled by fluctuations in the redox boundary.

Graupner T, Kempe U, Seltmann R, Isakhodjaev B A & Golovanov I M 2003. Geological, mineralogical and geochemical criteria for an exploration model for the Muruntau orogenic gold deposit, Uzbekistan. pp184-186. In: Akhmedov N A (ed) 2003. *Problems of ore deposits and maximizing the prospecting efficiency*. Proceedings of International Scientific-Technical Conference in Tashkent, 21-24 October 2003. Publ. IMR: 470pp.

Graupner T, Seltmann R, Williams C T, Wilkinson J J & Kim M 2003. Morphology, distribution and chemistry of Au and associated minerals in sulphide-poor and sulphide-rich orogenic Au deposits of the Southern Tien-Shan: A microscopic, cathodoluminescence and microprobe study. pp339-342. In: Akhmedov N A (ed) 2003. *Problems of ore deposits and maximizing the prospecting efficiency*. Proceedings of International Scientific-Technical Conference in Tashkent, 21-24 October 2003. Publ. IMR: 470pp.

Herrington R, Gerel O, Seltmann R & Kirwin D (eds) 2003. Geodynamics and Metallogeny of Mongolia. Proceedings of a workshop in Ulaanbaatar, 31 July - 1 August 2003. *Mongolian Geoscientist* **21:** 73pp.

Herrington R, Williamson B, Udachin V. & Spiro B, 2003. MinUrals: Mineral resources of the Urals – Origin, development and environmental impacts. Pp 39-43. In: Akhmedov N A (ed) 2003. Problems of ore deposits and maximizing the prospecting efficiency. Proceedings of International Scientific-Technical Conference in Tashkent, 21-24 October 2003. Publ. IMR: 470pp.

Konopelko D, Biske G, Belyatsky B, Eklund O & Seltmann R 2003. Hercynian post-collisional magmatism of the SE Tien Shan, Kyrgyzstan: timing and metallogenic potential. pp10-15. In: Geodynamic Processes and Metallogeny of Chinese Altay (Altai) and Tianshan. Extended Abstracts, International Field Symposium in Urumqi, Xinjiang, China: 9-21 August 2003: 78pp.
Abstract: Four post-collisional intrusions of the Kokshaal range in the SE Tien Shan, Kyrgyzstan formed as a result of two regional magmatic pulses at 296 Ma and 280 Ma. The intrusions crosscut folded Late Palaeozoic rocks and post-date the main stage of deformations in the region. The ages of the two magmatic pulses bracket with the ages of the "orogenic" gold deposits of the Southern Tien Shan and define specific post-collisional stage of magmaism and mineralization.

Konopelko D, Mao J, Du A, Piatkov A, Biske G & Seltmann R 2003. Re-Os age of molybdenite from the Sarytau tungsten deposit and timing of Hercynian events in the Bukantau mountains, central Kyzylkum, Uzbekistan. pp379-380. In: Akhmedov N A (ed) 2003. *Problems of ore deposits and maximizing the prospecting efficiency*. Proceedings of International Scientific-Technical Conference in Tashkent, 21-24 October 2003. Publ. IMR: 470pp.

Leistel J M, Augé T, Bourgeois B, Bretteville V, Coste B, Lerouge C, Orgeval J J, Koroteev V, Ivanov K S, Sazonov V N, Maslennikov V, Zaykov V, Telenkov O Udachin V, Tesalina S, Belenki A, Williamson B, Herrington R, Spiro B, Purvis O W, Dubbin W, Brooks S, Buschmann B, Bourdon B, Omenetto P, Nimis P, Tatarko N, Puchkov V, Salikhov D, Seravkin I, Kruglov V, & Ignatieva M 2003. MinUrals: Mineral resources of the Urals - Origin, development and environmental impacts, INCO : International Scientific Cooperation Project (1998-2002), Contract number: ICA2-CT-2000-10011, Final Report (Covering the period from 1 September 2000 to 31 August 2003), 55pp. (Plus 3 Appendices).

Leistel J M, Augé T, Bourgeois B, Bretteville V, Coste B, Lerouge C, Orgeval J J, Koroteev V, Ivanov K S, Sazonov V N, Maslennikov V, Zaykov V, Telenkov O Udachin V, Tesalina S, Belenki A, Williamson B, Herrington R, Spiro B, Purvis O W, Dubin W, Brooks S, Buschmann B, Bourdon B & Omenetto P 2003. MinUrals: Mineral resources of the Urals - Origin, development and environmental impacts, pp 37-40 in: Eliopoulis et al. (eds.) *Mineral Exploration and Sustainable Development*, Millpress ISBN 90 77017 77 1.
Abstract: The European MinUrals project is focusing on the South Urals mining sector, in order to improve local socio-economic conditions, through: 1) The reinterpretation of the geodynamics of South Urals and of the different types of ore deposits and the development of tools for mineral exploration (new geophysical and geochemical technology). The convergence setting and the formation of arc, fore-arc and back-arc systems explain the volcano-sedimentary and structural features. This geodynamic setting largely controls the distribution and characteristics of the different types of mineralisation; 2) The evaluation of local mining-related risks to the

environment, with a development of methodologies for assessing and reducing the environmental impact and localizing areas of high metal potential/low environmental constraints. Three pilote sites were investigated: Sibay and Uchaly (with mining installations), and Karabash (with mining installations and smelter); 3) The implementation of a Geographical Information System taking into account the mineral potential and the environmental constraints that, through data ranking and combining the key parameters of the areas with high metal potential and environmental constraints, will enable the production of a Mineral Potential and Environmental Constraints Map of the South Urals; 4) The elaboration of recommendations for a suitable environmentally aware mining-industry legislation, based on a comparison with the European legislation, to be adressed to the Commission on the demarcation of powers and subjects between the federal government, governments of the subjects of the Russian Federation and local authorities.

Mao J, Du A, Seltmann R & Yu J 2003. Re-Os ages for the Shameika porphyry Mo deposit and the Lipovy Log rare metal pegmatite, central Urals, Russia. *Mineralium Deposita* **38**: 251–257.
Abstract: The ages for pegmatite rare metal and beryl (emerald) deposits, as well as porphyry Mo deposits in the Hercynian Uralide orogen, are not well known. Five molybdenite samples from the Lipovy Log pegmatite Ta-Nb-Mo deposit and 11 molybdenite samples from the Shameika porphyry Mo deposit were selected for Re-Os dating. Both mineral occurrences are spatial-temporally associated with the Adui composite granite pluton, a well-known rare metal-related granite intrusion. A Re-Os isochron age of 262.0±7.3 Ma was obtained for the Lipovy Log pegmatite Ta-Nb-Mo deposit. The Shameika porphyry Mo deposit, associated with the Malyshevo leucogranitic stock and surrounding hornfels, provided isochron ages of 273±5 and 282±6 Ma, for two groups of molybdenite (within stock and within hornfels). All of these Re-Os ages are consistent with presumed Hercynian ages for the granite intrusions, formed in a post-collisional setting within the Uralide orogen.

Mao J W, Goldfarb R J, Seltmann R, Wang D H, Xiao W J & Hart C (Eds.) 2003. **Tectonic Evolution and Metallogeny of the Chinese Altay and Tianshan**. *IAGOD Guidebook Series* **10:** 286pp. ISBN 5-93761-052-0.

Mao J W, Goldfarb R J, Seltmann R, Wang D H, Xiao W J & Hart C 2003. Preface. In: Mao J W, Goldfarb R J, Seltmann R, Wang D H, Xiao W J & Hart C (Eds., 2003) Tectonic Evolution and Metallogeny of the Chinese Altay and Tianshan. *IAGOD Guidebook Series* **10:** 1-5.

Mao J W, Seltmann R & Goldfarb R J 2003. Mineral Resources of Chinese Altay and Tianshan: Metallogeny and Related Tectonic Processes - A Field Workshop of the IGCP-473. Conference Report. *Episodes - Journal of International Geoscience* **27:** 28-32.

Maslennikov V V, Maslennikova S P, Large R, Danyushevsky L V & Herrington R J 2003, The trace element zonation in vent chimneys from the Silurian Yaman- Kasy VHMS deposit in the Southern Ural, Russia: insights from laser ablation inductively coupled plasma mass-spectrometry (LA-ICP-MS), pp151-154 in: Eliopoulis et al. (Eds.) Mineral Exploration and Sustainable Development, Millpress ISBN 90 77017 77 1.

Abstract: The combination of high sensitivity ICP-MS and Nd-YAG UV laser ablation was utilised to determine the distribution of trace elements (Mn, Tl, As, Pb, Au, Ag, Bi) within the Silurian black smoker vent chimneys from Yaman-Kasy copper-zinc-massive sulphide deposit in the Southern Urals. The study has shown systematic distribution patterns within the chimneys for two groups of trace elements. Group 1 elements (Mn, As, Pb, Ag and Au) are enriched in colloform pyrite in the outer-most section of the chimney wall. This enrichment probably results from rapid precipitation of colloform pyrite under low temperature conditions. Pyrite euhedra, which result from the recrystallization of colloform pyrite toward the inner wall, are depleted in the Group 1 elements. Group 2 elements (Bi, Ag and Au) are enriched in chalcopyrite along the boundary between the chalcopyrite inner wall and the sphalerite filled central conduit, where Bi, Ag, Au, Pb tellurides have been precipitated in a zone of strong temperature gradients. The main zone of chalcopyrite within the central inner wall is depleted in Group 2 elements, probably due to the high temperature of formation which is unsuitable for telluride precipitation. Generally, trace element concentrations of chimneys increase with the decrease in chalcopyrite content from pyrite-chalcopyrite- to marcasite-chalcopyritesphalerite- to marcasite-quartz-rich chimneys, due to decrease in temperature and increase in Eh of the black smoker fluids.

Maslennikov V V, Ayupova N R, Herrington R J & Danyushevsky L V 2003, Implication of halmyrolysis in migration of REE during formation of ferruginous sedimentary rocks in Uzelga massive sulphide deposits, Southern Urals (Russia), pp147-150 in: Eliopoulis et al. (Eds.) Mineral Exploration and Sustainable Development, Millpress ISBN 90 77017 77 1.
Abstract: Ferruginous sedimentary rocks associated with the Devonian Uzelga VHMS deposits of the southern Urals formed by cold seawater interaction (halmyrolysis) of hyaloclastic material with intercalated carbonates and sulphides. These units have been previously interpreted as either “jasperites”, “gossanites” and “umbers”. They have been investigated using REE geochemistry in both bulk samples and laser ablation inductively coupled plasma mass-spectrometry. In carbonate-rich hyaloclastic sediments the REE contents decrease in the following order: hyaloclastites → partially hematitized hyaloclastites → hematite-quartz aggregates. The REE contents in jasperites are therefore always much lower than in primary hyaloclastites. The REE patterns in most gossanites and umbers were preserved with the exception of any pronounced negative Ce anomalies. The REE-behaviour is dependent on the presence of anion complexes available during seawater/ rock interaction. The presence of $CO3^{2-}$ and $HCO3^{-}$ in carbonate-bearing hyaloclastites promotes the formation of soluble carbonate REE-complexes and the migration of the REE into the subalkaline seawater during interaction of seawater with carbonaceous hyaloclastites.

Purvis O W, Chimonides P J, Jones G C, Mikhailova I N, Spiro B, Weiss D J & Williamson B J 2003/4. Lichen biomonitoring near Karabash Smelter Town, Ural Mountains, Russia, one of the most polluted areas in the world. *Proceedings of the Royal Society London* B **271:** 221-226, 03Pb0978.1-03Pb0978.6.
Abstract: Biogeochemical signatures were investigated in transplanted and native lichens near a major pollution source using sensitive multi-element chemical analysis. Transplants were established across a 60 km transect centred on the smelter town of Karabash, Ural Mountains, Russia. Statistically significant trends in element concentrations were recorded, some below one part per million. Fine metal particles are accumulated from pollution aerosols. Prolonged exposure may lead to cellular damage and enhanced accumulation or element loss. 206Pb:207Pb isotope ratios are similar to those associated with airborne particles in Europe and Russia; an

outlier near Kyshtym with a lower ratio indicates a source with a higher 235U: 238U ratio. The method is discrete, sensitive, able to detect short-term pollution episodes and useful for understanding element cycling, which is of critical importance for human and environmental health.

Seltmann R, Akhmedov N K, Isakhodjaev B A, Golovanov I M, Shatov V & Yakubchuk A 2003. Re-assessment of the mineral potential of Central Asia with special focus on the Republic of Uzbekistan. pp34-37. In: Akhmedov N A (Ed.) 2003. *Problems of ore deposits and maximizing the prospecting efficiency*. Proceedings of International Scientific-Technical Conference in Tashkent, 21-24 October 2003. Publ. IMR: 470pp.

Seltmann R, Armstrong R, Herrington R & Williamson B (Eds.) 2003. **Geodynamics and metallogeny of Mongolia with a special emphasis on Cu-Au porphyry systems.** Proceedings of the CERCAMS-III Mongolia Exploration Workshop, NHM London, 19-20 May 2003. Abstracts and Power Point Presentations CD-Rom.

Seltmann R, Graupner T, Klemd R, Kempe U & Shatov V 2003. Criteria for an exploration model for Muruntau style deposits. Report on Commissioned Research Project for CRC*pmd and Placer Dome Minerals Inc. CERCAMS NHM London, Dec. 2003. 93pp. and CD-Rom (Map and Data Depository Appendix).

Shatov V V, Seltmann R & Moon C J 2003. The Yubileinoe porphyry Au(-Cu) deposit, the South Urals: Geology and alteration controls of mineralization. pp379-382. In: Eliopoulos D G et al. (Eds.) 2003. *Mineral Exploration and Sustainable Development*. Proceedings 7th Biennial SGA Meeting, Athens, 24-28 August 2003. Millpress Rotterdam, 2003: **Vol. I-II**, 1272pp.
Abstract: Based on results of combined petrographical and geochemical mapping of hydrothermally altered rocks of the Yubileinoe Au (-Cu) deposit area, the sequence of hydrothermal activity events have been reconstructed. Such an approach made it possible to determine the geochemistry of alteration zones related both to the mineralized granite porphyry stock and to pre-granitic volcanic and sedimentary units. The results can be used to evaluate the ore potential for alteration haloes associated with hiddengranite porphyry stocks within the study area.

Udachin V, Williamson B J, Purvis O W, Spiro B, Dubbin W, Brooks S, Coste B, Herrington R J & Mikhailova I 2003. Assessment of environmental impacts of active smelter operations and abandoned mines in Karabash, Ural Mountains of Russia. *Sustainable Development* **11:** 1-10.
Abstract: Industrialization in the former USSR caused widespread environmental damage, which is graphically illustrated in the South Urals mining region of west-central Russia. One of the most heavily polluted areas is the town of Karabash and its surrounding area, which has abandoned mines and a large active copper smelter close to its centre. The area is affected by effluents and gaseous and particulate emissions from the smelter, acid drainage from abandoned mines and leachates and dusts from waste dumps and tailings dams. This article outlines the methodologies employed under a 3 year instrumental- and bio-monitoring assessment of mining-related impacts in Karabash, designed to be sensitive to the natural setting and specific political, sociological and economic situation in the Ural mountains. The results of the preliminary, planning stage of the project are presented and discussed.

Yakubchuk A, Seltmann R & Shatov V 2003. Tectonics and metallogeny of the western part of the Altaid orogenic collage. In: Mao J W, Goldfarb R J, Seltmann R, Wang D H, Xiao W J & Hart C (Eds.) Tectonic Evolution and Metallogeny of the Chinese Altay and Tianshan. Proceedings Volume of the International Symposium of IGCP-473 in Urumqi and Guidebook of the Field Excursion in Xinjiang, China: August 9-21, 2003. *IAGOD Guidebook Series* **10:** 7-16.

Abstract: The Paleozoic Altaid orogenic collage occurs between the East European and Siberian cratons, in the north, and Karakum, Tarim, and North China pre-1 000 Ma cratons, in the south. In the western part of the collage is the Kazakhstan orocline. The outer part of the Altaid orogenic collage includes the Paleozoic magmatic arcs of the Urals–Rudny Altai and Paleozoic accretionary complexes extending from the southern Tien Shan through the Trans-Urals into the Irtysh–Zaissan zone. In its core there are several generations of Vendian to Late Paleozoic magmatic arcs of Kazakhstan, often with pre-1 000 Ma metamorphic basement, and Junggar–Balkhash accretionary complexes. Fragments of all of these units occur in Xinjiang, but the Junggar–Balkhash accretionary complexes, extending to southern Mongolia and northeastern China, dominate. On the northern flank they are bounded by Neoproterozoic to Late Paleozoic tectonic units of Altai, Sayan, and Mongolia, which also represent several generations of arc magmatism. The pre-1 000 Ma metamorphic units in the basement of magmatic arcs could have been rifted off the East European and Siberian cratons. Kinematically, the oroclinal structure can best be explained through the clockwise rotation of Siberia relative to Eastern Europe during the Middle and Late Paleozoic. This conclusion is supported by the paleomagnetic data. The rotation caused several collisional episodes of the arcs, both with each other and with the cratons. Metallogenically, the western part of the Altaid collage hosts major Au, Cu, Pb–Zn, W–Mo and other deposits of different types which can be grouped into metallogenic belts, some of which extend to Xinjiang. The formation of VMS, porphyry and epithermal deposits in the magmatic arcs and Pb–Zn to W–Mo deposits in the backarc setting coincides with episodes of oroclinal bending, whereas each collisional episode coincides with the formation of orogenic gold deposits. The largest of these deposits formed during the final amalgamation of the collage in the accretionary complexes of the Tien Shan and Eastern Kazakhstan provinces, but almost no orogenic gold mineralization formed in the Junggar–Balkhash accretionary complex.

Zhang X C, Spiro B, Halls C, Stanley C J & Yang K Y 2003. Sediment-hosted disseminated gold deposits in SW Guizhou, PRC: Their geological setting and origin in relation to mineralogical, fluid inclusion and stable isotope characteristics International Geology Review 45.

Abstract – The sediment-hosted disseminated gold deposits in Southwest Guizhou, People's Republic of China (PRC) are located in faults on the flanks of anticlines or domes in clastic sedimentary rocks of Late Permian to Middle Triassic age on the southwestern edge of the Yangtze Paraplatform. Lamprophyres crop out in the vicinity of the gold deposits. Mineralization in the area coincides with belts of weak Bouguer gravity and magnetic anomalies. The Lannigou and Yata deposits, described in detail in the present study, together with Baidi, are situated in the southeastern domain where mineralization was emplaced in fine turbidites of basinal facies of Middle Triassic age. The structures guiding this mineralization are high-angle reverse faults on domes or anticlines. To the northwest, the Getang deposit is one of a group of deposits, including Zimudang, Sanchahe, Dayakou, and Xiongwu, which were emplaced in silicified breccias in impure carbonates or marls of Upper

Permian to Lower Triassic platform facies. They are controlled by low-angle and bedding-parallel faults on anticlines.

The clastic sedimentary host rocks are rich in illite and organic matter. Mineralization takes the forms of pervasive silicification, veinlets of quartz and disseminated auriferous arsenic-bearing pyrite and arsenopyrite, veins of quartz and calcite, and veinlets of realgar, cinnabar and stibnite. Gold is mainly associated with arsenic-rich pyrite. The main stage gold mineralization in pyrite is accompanied by pervasive silicification of host rocks. The Permian Emeishan basalts, widely distributed in the northwestern area, contain high average gold contents and may have been the primary source of the gold in the sediment-hosted deposits in SW Guizhou. Arsenic, antimony and mercury show a pattern of distribution similar to that of gold in country rocksand host rocks. Gold is found mainly in pyrite and partly in illite. Analysis of samples from the Lannigou deposit by high-resolution electron-probe microanalysis (EPMA) revealed that gold occurs in zones of intermediate arsenic content (3-5 wt%) on pyrite rims. It is deduced that gold probably occurs as discrete submicron-sized particles rather than as a charged Au species in a coupled diadochic substitution with arsenic in the pyrite structure.

The auriferous fluids at the Lannigou and Yata deposits are shown to be CO_2-rich (Xco_2>0.05) and of low salinity (<5 wt% equiv. NaCl) with relatively high homogenization temperatures (mainly 240 to 300 ^{0}C) and were probably trapped under high confining pressures (1.5 to 2.3 kb). They are not typical epithermal fluids. At Lannigou, the $d^{34}S_{VCDT}$ values of sulphides range from +8.4 to +12.5‰, the $d^{13}C_{VPDB}$ of carbon in calcite ranges from -0.1 to -3.6‰, and the $d^{18}O_{VSMOW}$ of quartz and calcite are mainly around +17.6 and around +25.8‰ respectively. At Getang, the isotopic compositions of hydrothermal minerals are in the range $d^{34}S_{VCDT}$ of -14.3 to +4.4‰ for sulphides, $d^{13}C_{VPDB}$ of -3.2 to -0.6‰ for calcite and $d^{18}O_{VSMOW}$ of +14.0 to +15.3‰ for calcite and quartz. These isotope analyses show that sulphur was probably derived mostly via the marine reservoir from the sedimentary country rocks, though part of the sulphur in the Getang deposit could be from altered or weathered basalt. Most of the carbon in the hydrothermal fluids was probably derived from the dissolution of carbonates in sedimentary rocks, though decarbonation reactions caused by low-grade metamorphism at deeper levels could have contributed some of the CO_2. The original hydrothermal fluids responsible for the gold mineralization are deduced to have formed by burial metamorphism at depths of 6-8 km with addition of meteoric water through deep fractures. Mineralization probably took place when fluids concentrated at near lithostatic pressures in permeable clastic horizons deconpressed as they were released along structural channelways during the Yanshanian tectonic cycle when impermeable shale cover sequences were breached. Mixing between evolved formation water/burial metamorphic water and meteoric waters was an important process during the late stage of the hydrothermal evolution. The tectonic setting, structural control, hydrothermal alteration, and ore and gangue mineral assemblages of the deposits in SW Guizhou show many features in common with those of the Carlin-type gold deposits in Nevada, USA, though the host rocks, relationship to igneous rocks and the timing of mineralization are different.

2002

Fedkin A, Seltmann R, Bezmen N & Zaraisky G 2002. Experimental testing of line rocks in Li-F granites: evidence from superliquidus experiments with F and P added. *Bulletin of the Czech Geological Survey* **77-2**:113-125. ISSN 1210-3527.
Abstract: New experimental data on the simulation of layered textures typical of some highly evolved granites are presented. In the experiments, low-evolved and high-evolved granite systems were compared, both doped with F and F+P. Most of the runs exhibit zones of quartz crystallization within a chemically heterogeneous granite glass. The experiment using typical material from the Li-F-P-rich Podlesí granite stock (Krušné hory Mts., Czech Republic) as a starting charge, with added F and P, resulted in discrete microlayering. In the quenched glass, rhythmically alternating thin (5–10 μm) bands either enriched or depleted in alumina occurred. The experimental result simulates natural analogs of granitic line rocks, which occur locally in the Podlesí stock as well as in the Orlovka and Etyka granite massifs, Eastern Transbaikalia (Russia).

Herrington R J, Armstrong R N, Zaykov V V, Maslennikov V V, Tessalina S G, Orgeval J-J & Taylor R N A 2002. Massive sulfide deposits in the South Urals: Geological setting within the framework of the Uralide orogen. In: *Mountain building in the Uralides: Pangea to Present,* Geophysical Monograph **132**, American Geophysical Union: 155-182.
Abstract: The south Urals is host to more than 80 Paleozoic volcanic-hosted massive sulfide (VMS) deposits developed in four distinct metallogenic zones. From west to east these are: the Sakmara zone, Main Uralian fault zone, and the east and west Magnitogorsk zones. In the Sakmara zone, the chemistry of host volcanic suites is consistent with development of the zone in a Silurian oceanic arc. The Main Uralian fault marks a line of paleosubduction and contains VMS deposits similar to those formed in modern mid-ocean ridge settings. The Magnitogorsk zones contain VMS deposits formed in a Devonian fore-arc, arc and inter-arc or proto-back arc setting. The earliest volcanics of the Magnitogorsk zone, the Baimak-Buribai formation, form a boninitic fore-arc sequence, evolving later to more calc-alkalic volcanics with evidence for a contribution from subducted slab to the volcanics. Later, and farther east of the subduction suture, a rifted, more mature arc setting formed where the Karamalytash formation volcanics developed in an inter-arc or proto-back arc setting. The Karamalytash formation shows little evidence of contribution from subducted sediment to the melt. Stratigraphically overlying the Baimak-Buribai formation, and partly time equivalent to the Karamalytash formation, is the Irendyk formation. The Irendyk formation is VMS-poor, but contains abundant epiclastic volcanosediments and epithermal-like gold-barite deposits, indicative of shallower sea conditions. The Irendyk formation appears to form a long linear geographic feature, perhaps marking the line of an emerging arc sequence behind which the Karamalytash formation developed in a rift. Previous authors suggest that the west and eastern Magnitogorsk zones developed as separate arcs, but the arc-like volcanics in the east Magnitogorsk zone may simply indicate the migration of the volcanic arc eastwards as the East European craton approached the Main Uralian fault.

Herrington R J, Smith M, Maslennikov V V, Belogub E & Armstrong R N 2002. A short review of Palaeozoic hydrothermal magnetite iron-oxide deposits of the South

and Central Urals and their geological setting. In: *Porter T.M. (ed.), Hydrothermal Iron Oxide Copper-Gold & Related Deposits: A Global Perspective*, **2**, pp. 243-253, PGC Publishing, South Australia, ISBN 0-9580574-1-9.
Abstract: The Urals orogen represents the site of Palaeozoic ocean development which developed into a zone of arc development, arc-continent collision, continent-continent collision and post-orogenic collapse. The orogen is host to a number of world-class VMS deposits in the Silurian to Devonian arc sequences but in addition is host to highly significant iron oxide deposits of both hydrothermal and orthomagmatic origin. The hydrothermal ores are developed in Palaeozoic belts associated with rift-related dominantly mafic, largely subaerial alkaline volcanism intruded by comagmatic stocks a varying ages from the Late Silurian to Early Carboniferous. Volcanism, sedimentation and mineralisation all seem to be controlled by major N to NNE trending structures. Much of the mafic volcanic sequence shows hematisation, evidence of early oxidation of the lava-tuff packages. Mineralisation comprises massive and disseminated magnetite bodies with elevated REE and ubiquitous accessory apatite. The deposits can be huge, in the case of the Carboniferous Kachar deposit in Kazakhstan reserves of over a billion tonnes of >45% Fe are defined. Some of the bodies are true contact skarns developed at the contact between intrusive bodies and volcano-sediments which include limestones. Other bodies, including the giant Kachar deposit are distal to any possible related intrusions and are developed within regionally extensive scapolite alteration zones. A regionally consistent pattern of early feldspar+-biotite alteration followed by ore-stage pyroxene-garnet-scapolite followed by late hydrous silicate-carbonate alteration is repeated throughout the Urals. Regionally extensive scapolitisation is common in most of the belts. Base metals are common in the deposits, often appearing late in the paragenetic sequence, with some bodies having almost economic copper grades (0.6% Cu) with significant precious metals.

Kogarko L N, Williams C T & Woolley A R 2002. Chemical evolution of loparite through the layered, peralkaline Lovozero complex, Kola Peninsula, Russia. *Mineralogy and Petrology* **74:** 1-24.
Abstract: Lovozero, the largest of the world's layered peralkaline intrusions, includes gigantic deposits of Nb + REE-loparite ore. Loparite became a cumulus phase after crystallisation of about 35% of the 'Differentiated complex', and its compositional evolution has been investigated through a 2.35km section of the intrusion. The composition of the cumulus loparite changes systematically upwards through the intrusion with an increase in Na, Sr, Nb and Th and decrease in REE and Ti. This main trend of loparite evolution records differentiation of the peralkaline magma through crystallisation of 1600m of the intrusion.
The formation of the loparite ores was the result of several factors including the chemical evolution of the highly alkaline magma and mechanical accumulation of loparite at the base of a convecting unit. At later stages of evolution, when concentrations of alkalis and volatiles reached very high levels, loparite reacted with the residual melt to form a variety of minerals including barytolamprophyllite, lomonosovite, steenstrupine-(Ce), vuonnemite, nordite, nenadkevichite, REE,Sr-rich apatite, vitusite-(Ce), mosandrite, monazite-(Ce), cerite and Ba,Si-rich belovite. The absence of loparite ore in the "Eudialyte complex" is likely to be a result of the wide crystallisation field of lamprophyllite, which here became a cumulus phase.

Konopelko D, Biske G, Belyatsky B, Eklund R & Seltmann R 2002. Geochronology and geochemistry of Hercynian post-collisional granitoid complexes of the eastern part of the South Tien-Shan. In: F. Mitrofanov (Ed.). *Geology and geoecology* -

Proceedings XIIIth Young Scientist Conference, Apatity, Russia, 19-22 November 2002. **Vol. 1**: Geology, Petrology and Geochronology, Ecology: 61-65.

Abstract: The Tien-Shan belt formed during the late Paleozoic collision of Kazakhstan and Tarim paleocontinents. Shortly after the culmination of the collision voluminous post-collisional granitoid intrusions invaded the whole region regardless to the position of the Hercynian structural units. In the eastern Hercynian Tien-Shan some 25 intrusions with distinct A-type affinities have been formed.

Zircons from four major intrusions of the region were dated by U-Pb SIMS method utilizing ion microprobe Cameca 1270 in NHM, Stockholm and two magmatic pulses at 295 Ma and 280 Ma were established. When few discordant analyses were excluded from calculations the concordant ages for the four intrusions were calculated as following: Dzhangart 296.7±4.2 Ma, n=8, MSWD=0.69; Mudrjum 282.0±1.2 Ma, n=12, MSWD =4.1; Kok-Kiya 278.9±1.3 Ma, n=7, MSWD =0.08; Uchkoshkon 279±8.1 Ma, n=3, MSWD =4.9. All calculations were made using the program Isoplot/Ex v. 2.05 (Ludwig, 1999). Thus, it was established that the granitoids of the two age groups formed during two magmatic pulses with the age difference between the pulses outside the analytical error limits. $e_{Nd(315)}$ values from seven samples representing granites of both age groups range between –2.39 and –5.62 indicating a significant input of Precambrian crustal component. This matches well the current knowledge of the eastern Tien-Shan as a collage of microcontinents with Precambrian basements.

Seltmann R, Yakubchuk A & Shatov V 2002. Mineral Potential of Central Asia: What Do We Know? In: Mineral Potential of Asia – An MMAJ Forum. CD-Rom with Power Point Presentations and Proceedings abstract publication. Metal Mining Agency of Japan.

Abstract: The Central Asian republics of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan intend to redefine their role both in the CIS and Asian markets, developing the mineral and energy resource potential of their national economies. The landlocked location of the Central Asian mineral provinces causes high infrastructure costs. Most transport routes are traditionally through Russia. One possible alternative is a Silky Way railroad project.

The mining industry in these five transition-economy countries plays an important role. In the past, the region served as a major metal provider for the FSU. Mineral products account for 1/3 to 1/2 of national GDPs from exports of gold (3.4 percent of the world's production in Uzbekistan (1996) and significant amount in Kyrgyzstan), ferrochrome (20 percent of the world's production in Kazakhstan), copper, lead, zinc, molybdenum, tungsten, niobium, tantalum, uranium, mercury, and antimony. In Turkmenistan, which focuses on the energy sector, and Tajikistan, processing imported bauxite with cheap hydroelectric power means that the mining industry plays a subordinate role. This is despite significant mineral resources of gold, silver, and copper in the Tajik Tien Shan and the Pamirs.

Most ore deposits are confined to the Altaid orogenic collage, located between the East European and Siberian cratons and smaller Precambrian slivers. Several generations of arc magmatism contributed primarily to the ore potential of the Stans: Vendian to Early Paleozoic, Middle Paleozoic to Early Carboniferous, Early Carboniferous to Permo-Triassic. In the Mesozoic, there were several post-collisional magmatic events. The resulting tectonic-metallogenic belts are confined to the Kipchak arc, Kazakh-Mongol arc and its back-arc rifts, Valerianov-Beltau-Kurama arc, South Tien Shan – East Urals – Irtysh-Zaissan suture, Mugodzhar-Rudny Altai arc, and Sakmara suture.

The region is among the world's major Au producers. It hosts giant (>10 M oz) and medium to large orogenic (mesothermal) Au deposits of Muruntau, Kumtor, Bakyrchik, controlled by the South Tien Shan – East Urals – Irtysh Zaissan suture,

granite-related Vasilkovskoe, Bestobe, Zholymbet deposits in the Kipchak arc, and Berezovskoe, Kochkar, Yubileinoe granite-related deposits in the Mugodzhar-Rudny Altai arc. Kochbulak, an important Au-Ag epithermal deposit, and low-grade hypogene Cu-porphyry deposits, with Au, Mo, and PGE by-products (Kounrad, Kalmakyr-Dalnee, Nurkazgan), are related to mid-late Paleozoic magmatic arcs of the region. The world-class Dzhezkazgan sediment-hosted Cu deposits are associated with Carboniferous red-bed aquifers. PGE mineralization occurs in black shale-hosted deposits (Muruntau) and in the porphyries (Bozshakol). Pb-Zn (Ag-Cu-Au) deposits (Maikain, Mizek, Tekeli, Shalkiya, Rudny Altai) are of different ages and types (VMS, sedex, sediment-hosted), with major production from Rudny Altai. Chromium deposits in Paleozoic ophiolites occur in the Kazakh Urals, related to the Sakmara suture (Kempirsai). Granite-related rare metal (Sn, W, Mo, Nb, Ta, REE) mineralization occurs in late-orogenic greisens, stockworks, skarns and pegmatites in Kazakhstan and Kyrgyzstan (Akchatau, Batystau, Verkhnee Kairakty, Aktiuz, Kalba). Significant U and V deposits of various types are present in Kazakhstan, Kyrgyzstan and Uzbekistan.

Regardless of the success of prospecting and exploration activities during Soviet time and since the 1990s, the region is still underexplored. This is a function of the complex geodynamic setting of this vast territory, exceeding the size of Europe, and is also related to continuing financial and legal difficulties. However, there are several operating mines with western investment. Despite the exploration maturity, this region is still able to generate new targets, especially in areas previously restricted or where attention is focussed under the Mesozoic-Cenozoic cover. Reassessing the conventional models of known deposits, such as mercury deposits of Kyrgyzstan or Fe-skarn deposits of the Torgai depression, can potentially lead to recognition of new deposit types. There is significant potential to develop known discoveries, such as lateritic nickel deposits in Kazakhstan.

Yakubchuk A 2002. The Baikalide-Altaid, Transbaikal-Mongolian and North Pacific orogenic collages: a similarity and diversity of structural patterns and metallogenic zoning. In: D. Blundell, F. Neubauer, A. von Quadt (eds) *The Timing and Location of Major Ore Deposits in an Evolving Orogen*, Geological Society Special Publication **204**: p. 368.

Abstract: The Baikalides-Altaid, Transbaikal-Mongolians and North Pacific orogenic collages consist of several oroclinally bent magmatic arcs separated by accretionary complexes and ophiolitic sutures located between the major cratons. The tectonic patterns of these collages are principally similar as they were formed as a result of rotation of the surrounding cratons and strike-slip translation along the former convergent margins.

The Altaid and North Pacific collages have principally the same distribution of metallogenic belts. In particular, the middle-late Palaeozoic belts of porphyry and epithermal deposits in the Altaids occupy the same position as the Mesozoic-Cenozoic metallogenic belts of the North Pacific collage. The Ural platinum belt occupies similar position tothe belt of platinum-bearing intrusions in Alaska. Major mineralizing events producing world-class intrusion-related Au, Cu-(Mo)-porphyry and VMS deposits in the Altaids. Formation of major porphyry, epithermal and Alaska-type PGMdeposits took place simultaneously with oroclinal bending. The tectonic setting of the orogenic gold deposits in the Tien Shan and Verkhoyansk-Kolyma provinces, hosting world-class hardrock gold deposits, is also similar, especially the distribution of their gold endowments. Major orogenic gold deposits occur within the sutured backarc basins. The craton-facing passive margin rock sequences, initially formed within backarc basins and now entrapped within such oroclines, represent favorable locations for emplacement of orogenic gold deposits.

Yakubchuk A S, Cole A, Seltmann R & Shatov V V 2002. Tectonic setting, characteristics, and regional exploration criteria for gold mineralization in the Altaid orogenic collage: The Tien Shan province as a key example. *Society of Economic Geologists,* Special Publication **9**: 177-201.

Abstract: The Paleozoic Altaid orogenic collage occurs between the East European and Siberian cratons, in the north, and Karakum, Tarim, and North China pre-1000 Ma cratons, in the south. In the western part of the collage is the Kazakhstan orocline. The outer part of the Altaid orogenic collage includes the Paleozoic magmatic arcs of the Urals – Rudny Altai and Paleozoic accretionary complexes extending from the southern Tien Shan through the Trans-Urals into the Irtysh-Zaissan zone. In its core there are several generations of Vendian to late Paleozoic magmatic arcs of Kazakhstan, often with pre-1000 Ma metamorphic basement, and Junggar-Balkhash accretionary complexes. Fragments of all of these units occur in Xinjiang, but the Junggar-Balkhash accretionary complexes, extending to southern Mongolia and northeastern China, dominate. On the northern flank they are bounded by Neoproterozoic to late Paleozoic tectonic units of Altai, Sayan, and Mongolia, which also represent several generations of arc magmatism.

The pre-1000 Ma metamorphic units in the basement of magmatic arcs could have been rifted off the East European and Siberian cratons. Kinematically, the oroclinal structure can best be explained through the clockwise rotation of Siberia relative to Eastern Europe during the middle and late Paleozoic. This conclusion is supported by the paleomagnetic data. The rotation caused several collisional episodes of the arcs, both with each other and with the cratons.

Metallogenically, the western part of the Altaid collage hosts major Au, Cu, Pb-Zn, W-Mo and other deposits of different types which can be grouped into metallogenic belts, some of which extend to Xinjiang. The formation of VMS, porphyry and epithermal deposits in the magmatic arcs and Pb-Zn to W-Mo deposits in the backarc setting coincides with episodes of oroclinal bending, whereas each collisional episode coincides with the formation of orogenic gold deposits. The largest of these deposits formed during the final amalgamation of the collage in the accretionary complexes of the Tien Shan and Eastern Kazakhstan provinces, but almost no orogenic gold mineralization formed in the Junggar-Balkhash accretionary complex.

Zaitsev A N, Demény A, Sindern S & Wall F 2002. Burbankite group minerals and their alteration in rare earth carbonatites - source of elements and fluids (evidence from C-O and Sr-Nd isotopic data). *Lithos*, **62:** 15-33.

Abstract: Following from previous work in which burbankite carbonatites were described as transition environment pegmatites, this paper examines the source and evolution of the magma and fluids from which such carbonatites formed at Khibina and Vuoriyarvi. The work forms part of the recent INTAS-funded Kola project. It shows that REE-rich magmas and fluids are derived from the same carbonatitic source in each complex but that the complexes have different source signatures. In order to model the radiogenic isotopes in terms of mantle end members at least 3, possibly 4 components are now needed to produce the variation recorded on the Kola Peninsula.

2001

Mordberg L E, Stanley C J & Germann K 2001. Mineralogy and geochemistry of trace elements in bauxites: the Devonian Schugorsk deposit, Russia. *Mineralogical Magazine* **65-1**: 81-101.

Abstract: Processes of mineral alteration involving the mobilization and deposition of more than 30 chemical elements during bauxite formation and epigenesis have been studied on specimens from the Devonian Schugorsk bauxite deposit, Timan, Russia. Chemical analyses of the minerals were obtained by electron microprobe and element distribution in the minerals was studied by element mapping. Interpretation of these data also utilized high-resolution BSE and SE images. The main rock-forming minerals of the Vendian parent rock are calcite, dolomite, feldspar, aegirine, riebeckite, mica, chlorite and quartz; accessory minerals are pyrite, galena, apatite, ilmenite, monazite, xenotime, zircon, columbite, pyrochlore, chromite, bastnaesite and some others. Typically, the grain-size of the accessory minerals in both parent rock and bauxite is from 1 to 40 m. However, even within these rather small grains, the processes of crystal growth and alteration during weathering can be determined from the zonal distribution of the elements. The most widespread processes observed are: (1) Decomposition of Ti-bearing minerals such as ilmenite, aegirine and riebeckite with the formation of 'leucoxene', which is the main concentrator of Nb, Cr, V and W. Crystal growth can be traced from the zonal distribution of Nb (up to 16 wt.%). Vein-like 'leucoxene' is also observed in association with organics. (2) Weathering of columbite and pyrochlore: the source of Nb in 'leucoxene' is now strongly weathered columbite, while the alteration of pyrochlore is expressed in the growth of plumbopyrochlore rims around Ca-rich cores. (3) Dissolution of sulphide minerals and apatite and the formation of crandallite group minerals: 'crandallite' crystals of up to 40 m size show a very clear zonation. From the core to the rim of a crystal, the following sequence of elements is observed: CaBaCePbSrNd. Sulphur also shows a zoned but more complicated distribution, while the distribution of Fe is rather variable. A possible source of REE is bastnaesite from the parent rock. More than twelve crandallite type cells can be identified in a single 'crandallite' grain. (4) Alteration of stoichiometric zircon and xenotime with the formation of metamict solid solution of zircon and xenotime: altered zircon rims also bear large amounts of Sc (up to 3.5 wt.%), Fe, Ca and Al in the form of as yet unidentified inclusions of 1-2 m. Monazite seems to be the least altered mineral of the profile. In the parent rock, an unknown mineral of the composition (wt.%): ThO2 - 54.8; FeO - 14.6; Y2O5 - 2.3; CaO - 2.0; REE - 1.8; SiO2 - 12.2; P2O5 - 2.8; total - 94.2 (average from ten analyses) was determined. In bauxite, another mineral was found, which has the composition (wt.%): ThO2 - 24.9; FeO - 20.5; Y2O5 - 6.7; CaO - 2.0; ZrO - 17.6; SiO2 8.8; P2O5 - 5.4; total - 89.3 (F was not analysed; average from nine analyses). Presumably, the second mineral is the result of weathering of the first one. Although the Th content is very high, the mineral is almost free of Pb. However, intergrowths of galena and pyrite are observed around the partially decomposed crystals of the mineral. Another generation of galena is enriched in chalcophile elements such as Cu, Cd, Bi etc., and is related to epigenetic alteration of the profile, as are secondary apatite and muscovite.

Reyf F G, Seltmann R & Zaraisky G P 2001. The role of magmatic processes in the formation of banded Li,F-enriched granites from the Orlovka tantalum deposit, Transbaikalia, Russia: Microthermometric evidence. *Canadian Mineralogist* **38:** 915-936.

Abstract: Quartz- and topaz-hosted melt, fluid, and mineral micro-inclusions have been studied to shed light on the origin of the massive and banded Li,F-enriched granites that host the Orlovka tantalum deposit, in Transbaikalia, Russia. Certain quartz and topaz grains, similar to most of the others in their morphology and

structure, contain primary or secondary melt inclusions (or both), suggesting that these rocks are of magmatic origin. Their textural features are assumed to stem from different regimes of cooling of parental melts, as indicated by morphological peculiarities of rock-forming minerals. From thermometric and analytical studies of the melt and fluid inclusions, it follows that the Li,F-enriched granites were formed from melt that was enriched in F (~4 wt%) and H2O (~6 wt%), contained CO2 in addition to H2O (mole fractions are ~0.08 and ~0.92, respectively), and had unusually low viscosity (~50 Pa•s at 660°C). The existence of quartz crystals that contain melt inclusions and columbite–tantalite microcrystals in the same growth-zones suggests that the melt became tantalite-saturated during early stages of crystallization at the top of the intrusion and late in the crystallization sequence at lower levels. With regard to results of model calculations, the uppermost position of the most Ta-rich melt in the pluton is considered to be caused by the removal of interstitial residual melt from deeper parts of the magmatic body and emplacement into a previously solidified crystalline carapace rather than by crystal settling.

Seltmann R & Jenchuraeva R (eds) 2001. **Paleozoic geodynamics and gold deposits in the Kyrgyz Tien Shan.** *IAGOD Guidebook Series 9*, London: Natural History Museum 102p.

Shatov V V, Cole A, Seltmann R. & Yakubchuk A 2001. Metallogeny of gold in the Tien Shan and Urals Paleozoic fold belts: a GIS-based approach. In *Mineral deposits at the beginning of the 21st century,* A. Piestrzynski *et al*., eds., Swets & Zeitlinger Publishers Lisse, pp. 489–492.

Yakubchuk A S, Seltmann R, Shatov V V & Cole A 2001. The Altaids: Tectonic Evolution and Metallogeny. *SEG Newsletter* **46**: 7-14.
Abstract: The review paper comprises the first publication from the NHM Mineralogy Department's Centre for Russian and Central Asian Mineral Studies. The Altaids are one of the largest and most economically important of the crustal blocks of the Eurasian landmass. They host large numbers of ore deposits, many of world class, including gold, copper-molybdenum, lead-zinc, and nickel. The rich metal endowment of the Altaids is a result of a prolonged and complex history of crustal growth and deformation. The paper describes the development of the Altaids in relation to the diverse and widespread mineralisation they contain.

Zaykov V V, Maslennikov V V, Zaykova E V & Herrington R J 2001. Ore formation and ore-facies analysis of massive sulphide deposits of the Urals paleoocean. *Miass: Urals Branch of the Russian Academy of Sciences* 315pp ISBN 5-7691-1234-4 (in Russian with English abstract).
Resume: This monograph contains the compiled results of the Russian perspective of joint NHM-IMIN (Russian partners) research since 1995 into the massive sulphide deposits of the south Urals. The book documents characteristics of the deposits and host rocks within the Uralide orogen, proposing models for the environment of formation, early diagenesis and subsequent preservation of the deposits.

2000

Balashov V N, Zaraisky G P & Seltmann R 2000. Fluid-Magma Interaction and Oscillatory Phenomena during Crystallization of Granitic Melt by Accumulation and Escape of Water and Fluorine. *Petrology* **8:** *505-524* [English language translation of *Petrologiya* **8:** 563-585]

Cole A. & Seltmann R 2000. The role of granitoids during Variscan orogenic gold mineralization in the Tien Shan and Ural mountain belts of central Eurasia. *Documents du BRGM* 297: 110-111.

Gonevchuk V G, Seltmann R & Gonevchuk G A 2000. Tin mineralization and granites of the main ore districts of Central Amur region, Russian Far East, pp. 113-125.In: A. Kremenetsky, B. Lehmann & R. Seltmann (eds): Ore-Bearing Granites of Russia and Adjacent Countries. IAGOD Monograph Series (ISBN 58198-0002-8) IMGRE Moscow. 371 pp.

Kremenetsky AA, Beskin SM, Lehmann B & Seltmann R 2000. Economic geology of granite-related ore deposits of Russia and other FSU countries: an overview, pp. 3-60 In: A. Kremenetsky, B. Lehmann & R. Seltmann (eds): Ore-Bearing Granites of Russia and Adjacent Countries. IAGOD Monograph Series (ISBN 58198-0002-8) IMGRE Moscow 371 pp.

Kremenetsky A, Lehmann B & Seltmann R (eds) 2000. **Ore-Bearing Granites of Russia and Adjacent Countries.** *IAGOD Monograph Series (ISBN 58198-0002-8),* IMGRE Moscow 371 pp.

Mordberg L E, Stanley C J & Germann K 2000. Rare earth element anomalies in crandallite group minerals from the Schugorsk bauxite deposit, Timan, Russia. *European Journal of Mineralogy* 12: 1229-1243.
Abstract: Two generations of crandallite [$AB_3(XO_4)_2(OH)_6H_{0\ or\ 1}$ - where A = Ca,Ba,Sc,Pb,Bi,REE,Th, B= Al,Fe,Ga, and X= P,As,S,Si,C] from the Schugorsk bauxite deposit were distinguished by electron probe microanalysis. The first formed under oxidizing conditions in a neutral to slightly alkaline environment and has significant cerium depletion. The second formed under reducing conditions and a more alkaline environment and is enriched in samarium. Crandallite minerals have a broad distribution in bauxitic and lateritic profiles of different origins and will have different REE profiles depending on the Eh-pH conditions during weathering. They can thus be used as environmental indicator minerals.

Seltmann R, Koroteev V, Fershtater G & Smirnov V (Eds.) 2000. **The eroded Uralian Paleozoic ocean to continent transition zone: Granitoids and related ore deposits.** IGCP-373 International Field Conference in the Urals, Russia, 18–30 July 2000. *IAGOD Guidebook Series 8*. Natural History Museum, London: 102 p.

Shatov V V, Plyushchev E V, Belova V N, Russkikh S S & Seltmann R 2000. Alteration Controls on Localization of Scheelite Stockwork Mineralization in the Verkhnee Qairaqty Deposit Area, Central Kazakhstan. pp 373–387 in *Geodynamics and Metallogeny: Theory and Implications for Applied Geology*. (*N. V. Mezhelovsky, A. F. Morozov, G. S. Gusev, V. S. Popov eds.) Moscow.*