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THE REGIONAL AND LOCAL CONTROLS ON GOLD AND COPPER MINERALISATION IN CENTRAL ASIA AND KAZAKHSTAN.

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Abstract – Large and giant scale copper-porphyry and gold deposits of different genetic styles were discovered in the countries of Central Asia as a result of many years of intensive exploration. The most economically important deposits are of the mesothermal Au and Cu-Au porphyry type, and tend to have distinctive geotectonic position in volcanic-plutonic belts of active continental margins (Cu-Au porphyry) or to be related to collisional granitoids in passive continental margins (mesothermal Au). Giant and large scale deposits demonstrate particular geological settings of these mineralisation styles.

Introduction

As a result of intensive exploration between the 1930s and 1990s, many major metallogenic provinces and deposits were found in the USSR, including the territory of Central Asia and Kazakhstan (Figure 1). In the 1990s, following the breakup of the USSR and the formation of the independent Kazakhstan and the states of Central Asian - Uzbekistan, Kirgizstan, Tadjikistan, western based mining companies became increasingly interested in the potential of these deposits, and many entered into joint ventures with local organisations for the purpose of bringing the deposits into production, or modernising existing operations.

The active interest in the Central Asian and Kazakhstan copper-gold porphyry and gold mesothermal mineralization was connected with the high intensity of gold discoveries during the 30 years period in Uzbekistan and adjacent countries, with the existence of giant deposits – Muruntau (mesothermal gold) and Kal'makyr-Dalnee (copper-gold porphyry) and with the high summary potential of both metals (Tables 1 & 2). The purpose of this paper is to briefly outline the geological character and regional geological setting of the gold and copper-gold metallogenic provinces and major deposits, as a guide to further exploration.

Geological setting of gold and copper-gold mineralization

The territory of Central Asia and Kazakhstan is the part of Central Asian fold belt that was formed by the progressive convergence and collision of the Siberian continent with the North Chinese, Tarim, Karakum, Tadzhik and Kazakhstan-North Tian Shan ancient massifs and was completed by the end of the Palaeozoic (Figure 2). The ancient blocks that are known within

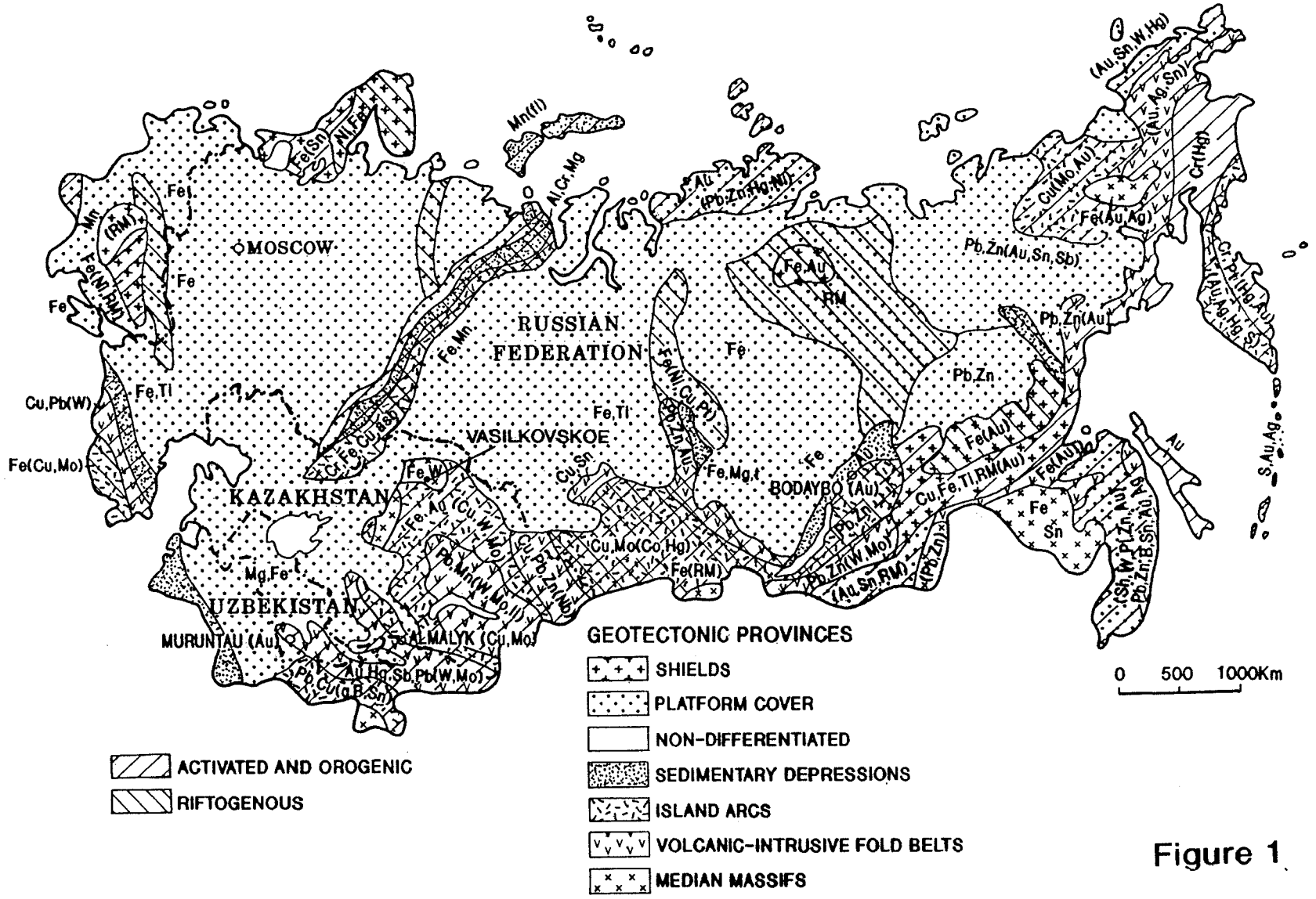


Figure 1

TYPES OF MINERAL PROVINCES AND SUBPROVINCES OF THE USSR

the territory at present, form a U-shaped pattern convex to the northeast and are regarded as parts of a single Kazakhstan - North Tien Shan Precambrian Massif that was reworked by the Early Palaeozoic deformation. Ophiolite and island arc assemblages are typical of the area inside the U-shaped region and in the boundary zone that separates Tian Shan from the Pamirs and Tadzhik depression (Zonenshain et. al., 1990).

The Devonian continent-margin volcanic belt divides the eastern segment of the Central Kazakhstan-North Tian Shan continent into northern and southern parts. The northern part is underlain by a continental crust that already existed by the end of Devonian. The southern part represents a fore-arc volcanic-intrusive zone of Late Palaeozoic accretion. The fore-arc domain was covered and outlined by the Carboniferous-Permian volcanic-intrusive belt (Fig. 2).

Table 1 - Reserves and Grades of Central Asian Mesothermal Au Deposits

Country, metal	Deposit name	Grade, g/t / Moz	Year of discovery
Uzbekistan, Au	Tamdybulak	4.0 / 2.0	1955
Uzbekistan, Au	Muruntau	2.0 / 200	1958
Tadjikistan, Au	Taror	4.3 / 3.2	1959
Tadjikistan, Au	Jilau	1.1 / 3.6	1959
Uzbekistan, Au	Besopantau	2.5 / 5.0	1960
Uzbekistan, Au	Myutenbai	1.9 / 20	1961
Uzbekistan, Au	Kokpatas	3.5 / 20	1965
Uzbekistan, Au	Zarmitan	10 / 8.0	1967
Uzbekistan, Au	Balpantau	1.5 / 2.7	1968
Uzbekistan, Au	Turbai	1.3 / 4.0	1969
Uzbekistan, Au	Daugiztau	4.0 / 6.0	1971
Kirgizstan, Au	Kumtor	3.6 / 23	1972
Uzbekistan, Au	Upper Kumar	6.0 / 9.6	1974
Uzbekistan, Au	Amantaitau	3.0 / 6.0	1980
Uzbekistan, Au	Triada	3.0 / 3.0	1985
Uzbekistan, Au	Adjibugut	1.5 / 3.0	1994
Kazakhstan, Au	Bakyrchik	9.0 / 12.5	1953
Kazakhstan, Au	Vasilkovskoe	4.5 / 12.0	1966
Kazakhstan, Au	Bestyube	? / 4.8	
Kazakhstan, Au	Suzdalskoe	7.0 / 3.0	
Kazakhstan, Au	Yubileinoe	7.0 / 2.1	
Kazakhstan, Au	Stepnyak	3.0 / 2.0	
Kazakhstan, Au	Akbakai	18.5 / 1.0	1968
Kirgizstan, Au	Dzheruy	6.3 / 2.4	
Kirgizstan, Au	Taldybulak	7.5 / 2.5	

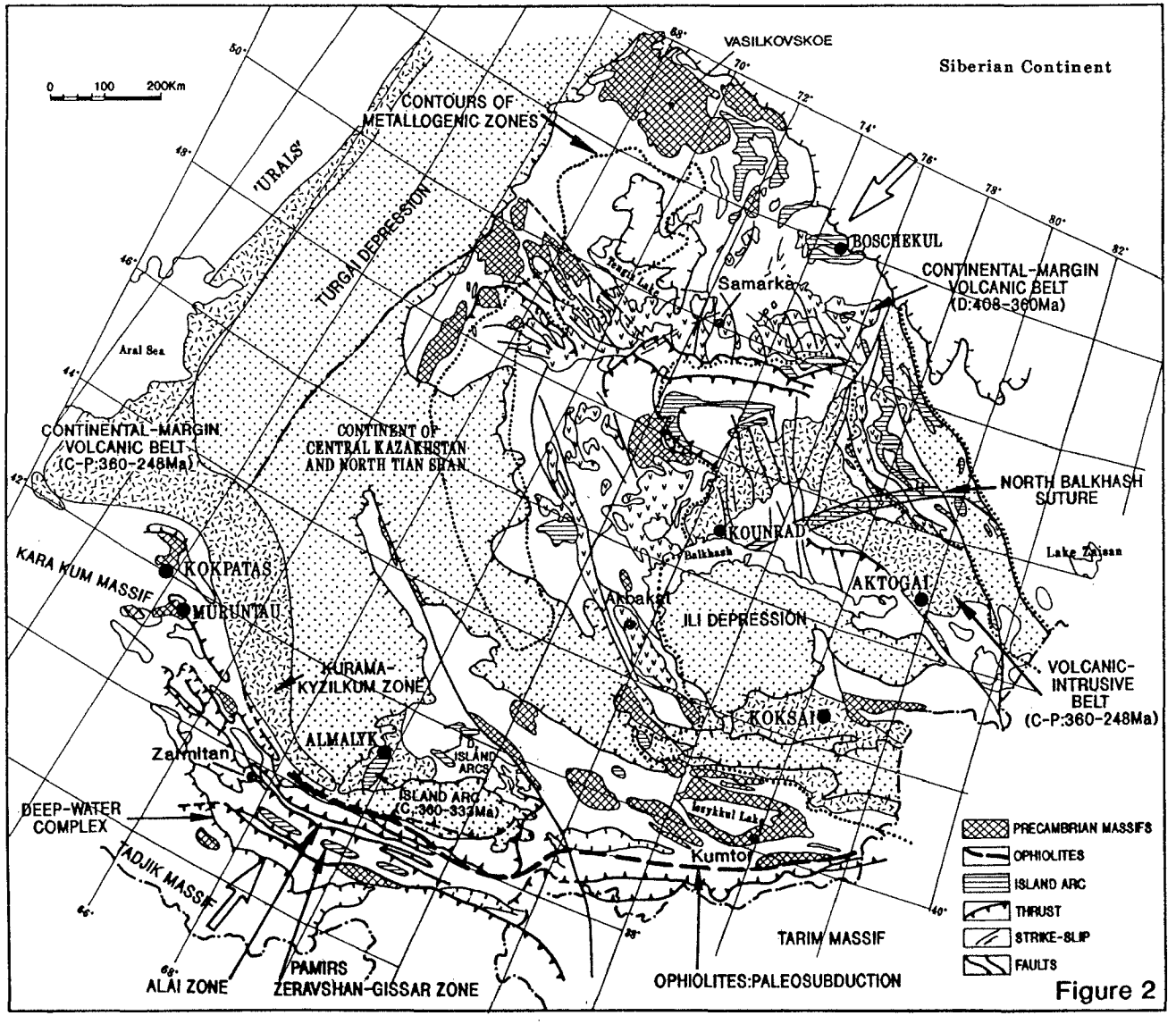


Figure 2

TECTONIC SCHEME WITH METALLOGENIC PROVINCES AND ZONES OF CENTRAL ASIA

Table 2 - Reserves and Grades of Cu and Porphyry Cu-Au Deposits

Country	Deposit & style	Cu Resources, Mt	Grade, Cu / Au g/t
Kazakhstan	Zheskazgan, stratiform	35	1.5% Cu
	Aktogai-Aiderly, porphyry	12.5	0.39 % Cu
	Kounrad, porphyry	2.0	0.7 % Cu
	Samarka, porphyry	3.0	1.5% / 0.5 g/t
	Chatyrkul-Zaisan, Iron-oxide	2.0	3.5% / 0.5 g/t
	Koksai, porphyry	1.7	0.55% / 0.12 g/t
	Irisu, iron-oxide	1.4	0.5% / 0.3 g/t
	Boschekul, porphyry	1.3	0.7% / 0.3 g/t
	Karabas, porphyry	1.0	0.5 % Cu
Uzbekistan	Kalmakyr-Dalnee, porphyry	20	0.5% / 0.3 g/t
	Kuzata, porphyry	6.0	0.85% Cu
	Kauldy, porphyry	5.5	0.5 % Cu
	Balykty, porphyry	3.0	0.34 % Cu

Four metallogenic provinces are recognised for the Kazakhstan-North Tian Shan continent (Fig. 3, contours of metallogenic zones shown on Fig. 2; Semenov et. al., 1968):

The Kazakhstan Province underlies the northern part of the continent where the basement is composed of pre-Devonian continental crust. The rocks are Precambrian and Early Palaeozoic massifs and Cambrian to Silurian island arcs, continental and marine sedimentary sequences and ophiolites. Several styles of Au mineralization occur in the province: quartz vein-stockwork, sulphide polymetallic, porphyry copper-gold, skarn copper-gold and others. The first and most important, exemplified by mineralization in the Vasilkovskoe deposit in the Precambrian Kokchetav massif, is quartz vein-stockwork. Gold at Vasilkovskoe is associated with bismuth and arsenic. An intrusive complex of gabbro-diorite (497-575 Ma) and hornblende-biotite granodiorite (456-468 Ma) hosts the mineralisation. The complex is regionally controlled by the junction of two regional faults (Gold deposits..., 1996).

Cu-Mo porphyry deposits of several ages occur also within the Kazakhstan province. The Boschekul deposit, associated with a multiphase (diorite porphyry, granodiorite-porphyry, syenite-porphyry) dyke of Cambrian age intrudes into a porphyrite-sandstone-siltstone sequence of the same age (Fig. 3, Table 2). Another example is the recently discovered Samarskoe copper-gold porphyry deposit. Deposits of this type occur within the Devonian continental-margin volcanic belt.

The Ordovician volcanic basement of the belt is considered to be one of the major sources of Au in Samarka-type deposits (Shuzhanov, pers. communication). According to the most recent studies of the deposit, a Lower Devonian stock of granodiorite-porphyry

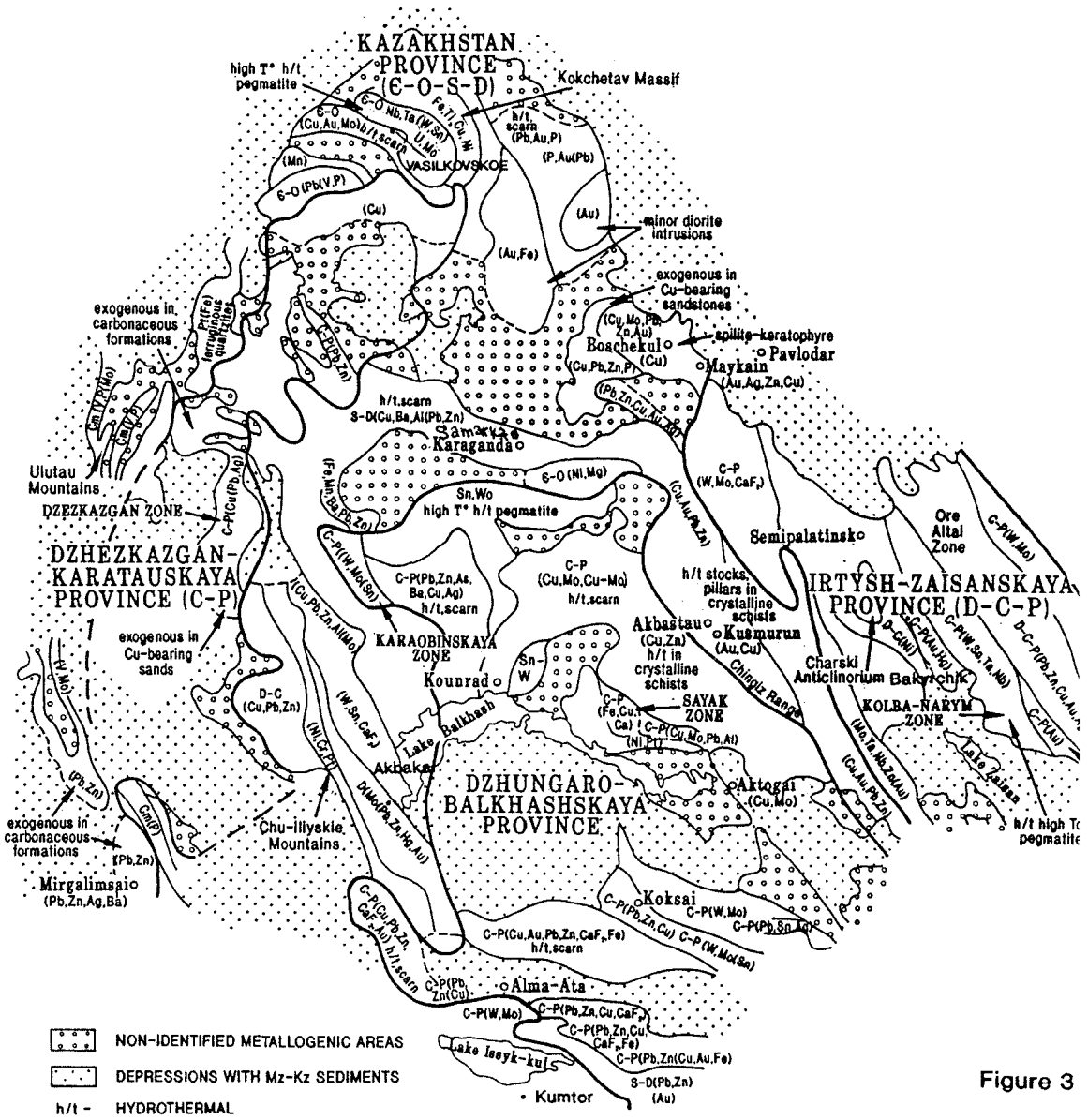


Figure 3

METALLOGENIC PROVINCES OF EASTERN KAZAKHSTAN

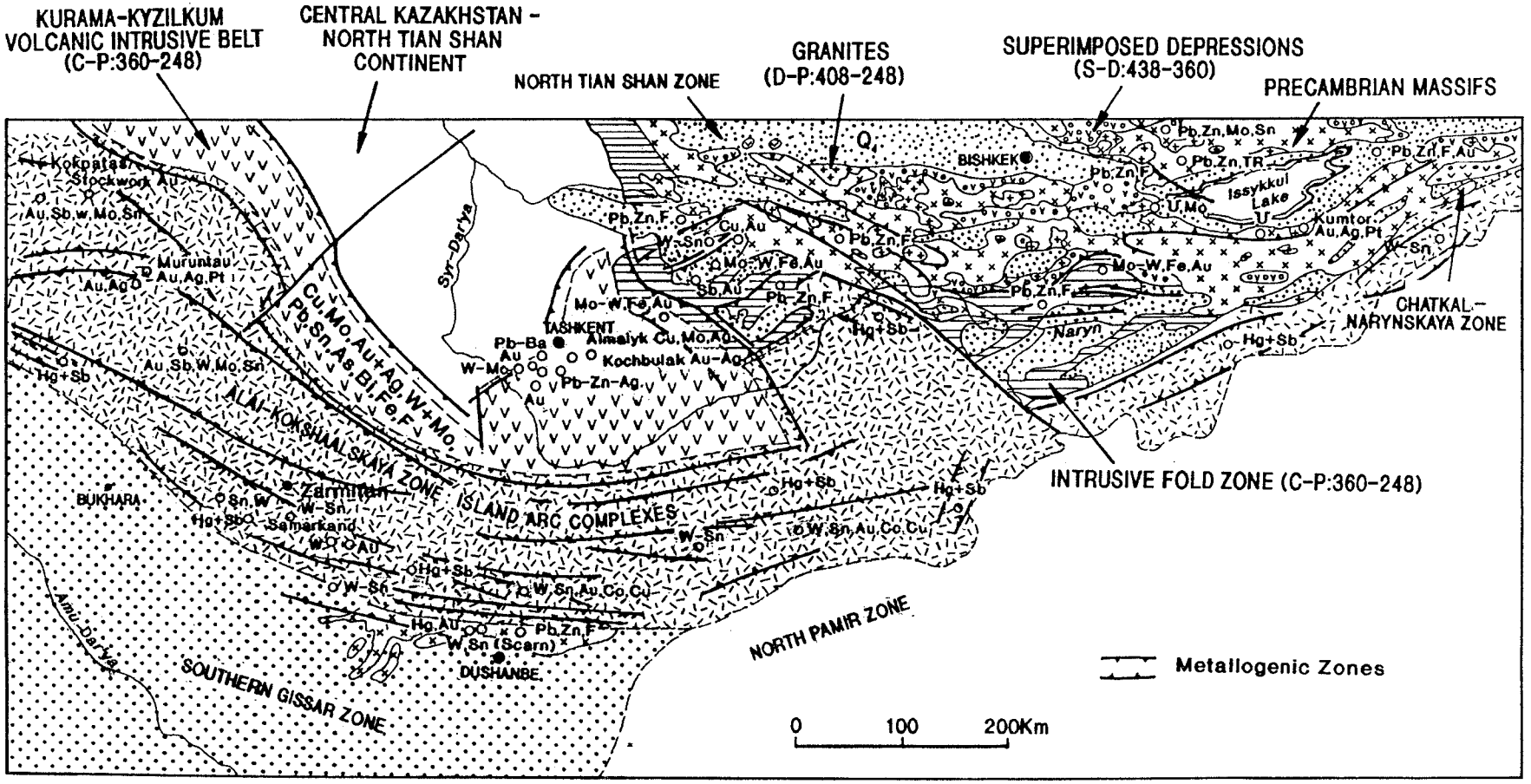
intrudes a quartz-diorite batholith of Upper Silurian-Lower Devonian age. Vein and disseminated mineralization occurs mainly in a pre- to syn-ore intrusive breccia, but also along contacts between breccia and granodiorite-porphyries, as veinlets in quartz diorite and along the contact of the intrusive complex with tuffs of andesite-basalt composition. Intense potassic alteration is prominent. Zones of intense silicification – silica caps or "secondary quartzites" are closely associated with the ore, and have been used as guides for prospecting.

In addition to gold and porphyry deposits, there are multiple occurrences of Ba, Cu, Pb-Zn, Mo and fluorite mineralization associated with the Devonian continental-margin volcanic belt in the Kazakhstan province.

The Dzhungaro-Balkhashskaya province (Fig. 3) comprises the accretionary terrain that lies to the south of the Kazakhstan province. The province is famous for its Cu-Mo deposits, as exemplified by Kounrad and Aktogai. Both deposits occur in the Carboniferous-Permian volcanic-intrusive belt which superimposes and outlines the fore-arc domain of the Late Palaeozoic accretion (Fig. 2). The Kounrad deposit is associated with an eroded central volcanic-intrusive complex composed of andesite-basalt and basalt, overlain by quartz porphyry and felsite flows. The volcanic suite is intruded by stocks and dykes that are apophyses of the Kounrad granitoid batholith which outcrops to the south from the deposit. The Cu-Mo mineralization is mostly hosted in a granodiorite-porphyry stock that was emplaced into the strato-volcanic vent. The large-scale Aktogai-Aiderly Cu-porphyry deposit is hosted by the Koldar multistage gabbro-diorite-granite complex of Late Carboniferous age that was emplaced in a horst-like uplift and volcanic rocks. Mineralization is controlled by the explosive breccia connected with the ore-bearing granodiorite-porphyry stock (Zvezdov et. al., 1993).

The Irtysh-Zaisan Province comprises a sequence of accretionary island arcs and passive continental margin sedimentary sequences. It contains major volcanogenic-sulphide Cu-Pb-Zn-Ba deposits of the Ore Altai zone, small magmatic Cr deposits, greisen Mo-W deposits and vein Au mineralization of the sulphide-W type which is genetically connected with small intrusions of diorite and granodiorite. The most famous gold deposit of the province, Bakyrchik, and the associated deposits of the Bakyrchik ore field, are controlled by a regional-scale thrust fault zone. Mineralization is vein and disseminated pyrite and arsenopyrite with free gold, and is hosted by a Middle Carboniferous sandstone-shale sequence intruded by lamprophyre dykes. The morphology of the gold-sulphide-polymetallic ore bodies is described as sub-vertical echelon-like mineralised zones (Gold deposits..., 1996, Metallogeny..., 1980).

The Tian-Shan Province lies on the northern edge of the Karakum-Tarim and Tadjik micro-continents. It includes Uzbekistan and the other countries of Central Asia, and is bounded to the north by the Kazakhstan-North Tian Shan ancient massif (Fig. 2 and 4). The northern part of the province, near Lake Issykkul, the *North Tian Shan* zone, is underlain by Precambrian massifs. It is mainly characterised by Pb-Zn, Au, Ag, Mo, Sn mineralization. However, within it the large Kumtor Au-Ag-Pt vein-stockwork system deposit also occurs, hosted by carbonaceous terrigenous volcanic rocks of Proterozoic or Palaeozoic age. Mineralization is associated with strong hydrothermal alteration controlled by faults. Native Au occurs mainly in pyrite but also in quartz, carbonate, feldspar and scheelite (Nikonorov, 1993).



METALLOGENIC ZONES OF TIAN-SHAN

Figure 4

The southern part of the Tian-Shan Province is called the *Kurama-Kyzylkum volcanic-intrusive belt* and is of island arc origin (Mossakovski, 1975), where collision granitoids are also known. This belt embraces the Almalyk region, with the giant Kal'makyr-Dalnee Cu-Au porphyry deposits, a large-scale Pb-Zn-Ag skarn, and the Kochbulak epithermal Au-Ag deposit, as well as other Au occurrences associated with volcanic sequences. The Cu-Au porphyry deposits are controlled by large faults that subdivide the Almalyk region into structural blocks. Other important ore controls are a large scale north-west-trending fault, an appropriate level of erosion, and hybridisation among the ore-bearing intrusions (Sokolov, 1995). The porphyry deposits are associated with granodiorite porphyry stocks that intrude a syenite to diorite batholith.

The Alai-Kokshal, or South Tian Shan, which includes the Central Kyzylkum metallogenic province, occurs immediately to the south of the Kurama-Kyzylkum belt, just north of the northern edge of the Karakum-Tarim continental block. The zone is underlain by black flysch and Early Devonian-Middle Carboniferous limestones of reef-origin. The sequence was deposited in the Cambrian-Middle Carboniferous on a passive continental margin. An Ordovician-Devonian island arc of calc-alkaline volcanics (andesites and basaltic andesites) was accreted to this margin, and then the entire assemblage was overprinted by a Late Carboniferous-Permian magmatic arc and a series of granitoid intrusions which were related to the collision of the Tadjik and other continental fragments lying to the south of the zone.

Gold is the dominant metal, although a wide variety of other metals deposits occur in the province. Au deposits are typically of the mesothermal type; the largest examples are Muruntau and Kokpatas with several other smaller deposits Amantaitau, Daugiztau, Adjibugut, Zhauldas and others that occur along the 80 km zone to the south-west from Muruntau (Table 1). They are hosted by metamorphosed carbonaceous terriginous sequences of Late Proterozoic to Silurian age. Mineralization is of two mineralogical types: gold-quartz (Muruntau), and gold-quartz-sulphide (Amantaitau, Daugiztau and Kokpatas). Adjibugut has mineralization that is transitional between the Au-quartz and Au-sulphide types.

The position of a deposit in the vertical section of the ore-generating system determines the type of hydrothermal alteration and the mineralogical composition of the ore zones. Au-arsenopyrite mineralization at the Zhauldas deposit is accompanied by quartz-biotite alteration and is hosted by Teskazgan formation (late Proterozoic-early Cambrian); Au-quartz-pyrite zones of the Amantaitau deposit in green Besopan (Ordovician-Silurian) are accompanied by quartz-sericite-carbonate alteration; Au-quartz-pyrite and Au-sulphide zones (transitional type of mineralization) in Besopan are exposed together with quartz-sericite-pyrite (berizites) alteration (Adjibugut deposit); similar alteration is typical for Au-sulphide Besopan-hosted mineralization (Daugistau deposit); argillisation connected with Au-Ag mineralization in Besopan (Vysokovoltnoe deposit). Quartz-vein stockwork ore bodies of the Zarmitan gold deposit are hosted by the late Carboniferous gabbro-syenite-grano-syenite batholith which intruded the Silurian quartz-mica shales, sandstones, siltstones regional sequence (Bortnikov et. al., 1996).

Conclusions

The Central Asian and Kazakhstan mesothermal Au and Cu-Au porphyry provinces are associated with several kinds of geological setting and geotectonic environments. Gold-bearing granitoid batholiths occur in Proterozoic-Devonian continental crust terrains of an ancient massif and are controlled by regional and local junctions (Vasilkovskoe, Kazakhstan).

The position of the mesothermal gold province in Uzbekistan is connected with the accretion of a volcano-plutonic arc to a passive continental margin and the influence of assumed deep-seated granodiorite batholiths on the formation of wallrock hosted gold deposits (Muruntau and other deposits of the region).

One of the primary regional controls on Cu-Au porphyry deposits is their position in volcanic-plutonic arcs and an association with intrusion centred base and precious metal systems (Samarskoe, Kounrad) or with granitoid batholiths (Aktogai in Kazakhstan; Kal'makyr-Dalnee in Uzbekistan).

The near surface position of the Precambrian volcanogenic basement in volcanic-intrusive belts and "silica cap"-specific alteration associated with ore, can both be considered as the features controlling ore in the Devonian continental-margin volcanic belt in Kazakhstan. In the majority of cases, the mineralised provinces, regions and ore-bearing granitoid batholiths are controlled by the junctions of regional and local faults, and zones of crushing in host volcanic and sedimentary sequences along batholith contacts.

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