Unique ore complexes of sulfide dissemination zones in northeastern Asia

A.V. Volkov, A.A. Sidorov, I.N. Thomson
Department of Metallogeny, Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry, Russian Academy of Sciences, Staromonetnyi per. 35, Moscow, 119017 Russia

Abstract. Sulfide dissemination zones make up unique ore complexes. The genesis of large zones of fine-grained sulfide disseminations in terrigenous-volcanogenic sequences is presumably related to different processes ranging from hydrothermal-sedimentary to epigenetic processes related to deep-seated fluids. These zones have been insufficiently explored, although they serve as essential sources of ore materials for porphyry and vein deposits. The finely-disseminated sulfide minerals are enriched in various trace elements and are associated with inclusions of native metals (rare, noble, and other varieties). Therefore, systematic investigations of the mineral compositions of such zones for their geochemical characteristics are required. This is essential for solving questions of inherited mineralization and for identifying different sources of ore materials.

Keywords. Sulfide dissemination, genesis, sources, gold deposits, trace elements

1 Introduction

It has become increasingly evident that large ore-bearing zones are independent geological structures that have a prolonged evolutionary history that occasionally exceeds the duration of magmatic and tectonic cycles. The work of many investigators have revealed that metalliferous sedimentary and volcano-sedimentary sequences play an essential role in the formation of ore deposits. It is highly probable that gold mineralization in sedimentary sequences of the Verkhoyansk Complex is related to zones of finely-disseminated sulfide mineralization. Such zones are widespread in the Earth's crust and genetically diverse, but they have been poorly studied because of their low commercial significance. Zones with finely-disseminated sulfidization and nanoscale mineralization serve as a missing link in the concept of basic ore formations (Tomson et al. 1984; Sidorov 1998). Previously, researchers could not explain the relationship of separate ore-bearing (particularly, epithermal rootless) veins with other ore-bearing structures. Therefore, they believed that ore materials in veins were derived from a proximal intrusion or some deep-seated (subcrustal) fluids. Based on the method of hierarchical ore-formation analysis, we demonstrate that the mineral composition of zones with finely-disseminated mineralization in several districts mimics mineralogical types of poly- and monochronous ore-formation series (hereafter, ore complexes). At the same time, all members of a specific series are characterized by certain features of mineralogical-geochemical interrelations.

2 Types of ore-bearing zones

In the northwestern Pacific, one can distinguish at least four types of sulfidization zones and corresponding ore complexes (Table 1). Zones of finely-disseminated sulfidization zones in Mesozoic sandy-clayey terrigenous sequences, which are widespread at the base of volcanogenic belts and in perivolcanic districts, are best studied. For example, ore-bearing zones of the Okhotsk-Chukot volcanogenic belt (OCVB) are accompanied by an assemblage of large volcanogenic depressions (tectonomagmatic zones). These structures are occasionally confined to hidden fractures and are spatially associated with volcanic structures. Gold-sulfide zones with disseminated ores are confined to shear (dynamometamorphism) zones composed of dark gray siltstones with finely-disseminated pyrite and arsenopyrite. Within the ore bodies (or fields), one can also recognize veins and veinlets with base metal sulfide mineralization of the gold-rare metal, gold-silver, antimony, and mercury assemblages. At the same time, these assemblages make up independent deposits beyond the disseminated ore zones. Therefore, we include all ore associations mentioned above into a single ore complex type, with disseminated gold-sulfide deposits as the major member (Sidorov 1998).

The mineralogical-geochemical analysis of ore zones and sulfide concentrates revealed inhomogeneous concentrations of Au, Ag, Pb, Sn, Zn, Sb, and other elements in fine-disseminated sulfides. Weakly differentiated ore material is an efficient intermediate source for the more differentiated vein deposits in the ore complex considered above. Disseminated sulfidization zones of the hydrothermal-sedimentary pyritic ore type are not scrutinized in the present communication. Results of the study of the Goldstrike deposit (Emsbo et al. 2003) - one of the largest Carlin-type deposits in the world, where the Paleozoic sequence includes pre-ore disseminated mineralization that was probably remobilized at the ore stage - support our genetic model (Volkov and Sidorov 2001).

Vein-dissemination zones with pre-porphyry silver mineralization in the superimposed riftogenic Omsukchan Depression at the southern OCVB branch are of special interest. Consideration of data on the Ag-bearing province of the western Verkhoyansk region (Kostin et al. 1997) suggests the following conclusion: Like respective rocks in the western Verkhoyansk region, Permian sequences

Table 1: Major ore complexes, giant gold ore (Au-bearing) deposits, and their satellites in the northwestern sector of the Pacific ore belt.

Type of ore-bearing zone	Major ore complex	Examples of giant gold ore (Au-bearing) deposits	Types of gold deposits and their satellites
Disseminated As-bearing sulfides in terrigenous-carbonate sequences	Disseminated gold-sulfide	Maisk (Chukotka), Natalka (Magadan district), Nezhdaninsk (Yakutia)	Disseminated gold-sulfide, epithermal gold-silver, gold-quartz, and silver-base metal
Disseminated sulfide deposits in green tuffs and basalts	Massive sulfide porphyry copper	Peschanka (Chukotka), Lora (Magadan region)	Porphyry Cu, porphyry Cu-Mo, epithermal gold-silver, disseminated gold-rare metal, and skarn base metal
Disseminated base metal sulfide deposits in terrigenous-carbonate sequences	Disseminated silver-sulfide	Dukat (Magadan district), Prognoz, and Mangazei (Yakutia)	Epithermal gold-silver, silver-base metal, gold-rare metal, and tin-sulfide

of the Verkhoyansk Complex at the base of the Omsukchan Depression have been characterized by abundant disseminated silver-sulfide mineralization that probably served as the primary source of ore material for the Late Cretaceous volcanogenic Dukat deposit. In other words, based on certain genetic features of mineral assemblages in ores of the Mangazei and Dukat deposits, we have every reason to include the Mangazei-type deposits into the basic silver-sulfide formation of the regional polychronous ore complex. Lead isotope data also do not contradict our assumption (Sidorov et al. 2003). The rhodonite-rhodochrosite mineralization in the Dukat deposit can easily be explained by the regeneration of stratiform deposits in the Permian manganiferous siliceous-terrigenous-carbonate sequences that are widespread in the adjacent Kolyma region (Shpikerman 1998).

Tin-bearing sulfide zones in the Kavalerov ore district (Primorye) are restricted to perivolcanic structures of the East Sikhote Alin Volcanic Belt (ESVB) and are also very interesting. According to Tomson et al. (1984), sulfide and carbonaceous metasomatite zones are developed in Mesozoic terrigenous sequences of the folded ESVB base strata. Carbonaceous metasomatites are composed of black and dark gray fine-grained rocks including graphite stringers and low-crystalline carbonaceous material with rutile, ilmenite, sulfides, native metals, carbides and spinels. The ilmenite-carbonaceous metasomatite contains several native metals, such as iron, lead—tin alloy, aluminum, tin, iron-zinc alloy, wustite, cohenite (?), and osmiridium. Native metals and their alloys are also found as accessories in volcanic rocks of Primorye (Filimonova 1981). The study region incorporates several porphyry- and vein- type tin ore deposits coupled with numerous anomalies of tin and associated metals. Gold and mercury aureoles outline boundaries of the ore region.

The study of the porphyry Cu and related ore complexes revealed that they are occasionally related to pre-porphyry sulfidization zones or massive sulfide deposits. According to Sidorov (1998), V.S. Popov assigned such porphyry Cu deposits to the massive sulfide ore complex that serves as the transitional member between the massive sulfide and porphyry ore types (Sidorov 1998). Similarities in the ore-metasomatic columns of massive sulfide and porphyry Cu deposits have also been noted in Meyer (1981). New data on the possible source of material for the porphyry Cu deposits have been reported from the P'yagin Peninsula (northern Okhotsk region). The Lora deposit is confined to the domal Srednii Pluton in the internal zone of the OCVB. Rocks of the pluton are superimposed on Triassic-Late Jurassic island-arc rock complexes (Sidorov 1998). Xenoliths of these rocks were found in diorites of the Srednii Pluton located approximately 15 km south of the Lora porphyry Cu-Mo deposit. Based on an abundance of bornite and chalcopyrite disseminations (up to 50%) in these rocks, we suggest that such copper mineralization in volcanosedimentary basaltic rocks could serve as the source of material for the younger porphyry mineralization. The primary source could be represented by both cupriferous basalts and massive sulfide Cu deposits in island-arc rocks that subsequently served as the basis and source of Cu for the Cretaceous volcanoplutonic structures. The geochemical specialization of porphyry Cu ores also testifies to their genetic relationship with basaltic rocks, because Cu displays the highest positive correlation with Cr in stringer-disseminated ores from the granitoids. The Mo input is probably related to volcanoplutonic complexes of the granitoid series. At the same time, Sn- and W-bearing magmatic rocks also contributed some specific features to the porphyry Cu deposits.

3 Conclusions

The genesis of large zones of fine sulfide disseminations in terrigenous-volcanogenic sequences is presumably related to different processes ranging from hydrothermal-sedimentary to epigenetic (deep-seated fluid). These zones have been insufficiently explored, although they serve as essential sources of ore material for porphyry and vein deposits. Coupled with monochronous deposits of the porphyry Cu-Au-Sn series and other numerous satellite bodies, the sulfide dissemination zones make up unique ore complexes (polychronous ore-formation series). The finely-disseminated sulfides are enriched in various trace elements and associated with inclusions of native metals (rare, noble, and other varieties). Therefore, they should be systematically investigated for the mineral compositions of such zones for their geochemical character. This is essential for both solving the question of inherited mineralization and identifying different sources of ore materials.

Acknowledgements

This work was supported by the Russian Foundation for Basic Research, project nos. 03-05-64095, 03-05-64334, and 04-05-64359.

References

Emsbo P, Hofstra H, Launa EA (2003) Origin of high-grade gold ore, source of ore fluid components, and genesis of the Meikle and neighbouring Carlin-type deposits, northern Carlin trend, Nevada. Economic Geology 98: 1069-1105

Filimonova DG (1981) About a role of substance of volcanic host rocks in formation of preore, postmagmatic minerals of the Ducat ore field. Dokl. Akad. Nauk. 256: 962-965 (in Russian)

Kostin AV., Zaitsev AI, Shoshin VV (1997) The Silver-Bearing Province of Western Verkhoyansk Region, Yakutsk. (in Russian)

Meyer Ch. (1981) Economic Geology In: Skinner BJ (ed), Seventy-Fifth Anniversary Volume. Economic Geology Publication Company, 6-41

Shpikerman VI (1998) The Premesozoic Minerageny of Northeastern Asia, Magadan (in Russian)

Sidorov AA (1998) Ore Formations and Evolutionary-Historical Analysis of the Noble Metal Mineralization, Magadan (in Russian)

Sidorov AA Volkov AV, Dokl. Akad. Nauk, 374 (2003) About silver giants of Russia. Dokl. Earth Science 390: 516-518

Tomson IN, Sidorov AA, Polyakova OP, Polokhov VP (1984) Graphite-Ilmenite Mineralization in Ore Districts of the Eastern Soviet Union. Geol. Rudn. Mestorozhd. 6: 19-21

Volkov AV, Sidorov AA (2001) The Unique Gold Ore District of Chukotka, Magadan (in Russian)