Ore Deposits of the U.S.S.R: Some Theoretical Aspects

by Vladimir I. Smirnov

This brief note reviews the Soviet scheme for classification of ore deposits. The author also summarizes their approach to metallogenic regimes and epochs, a subject dealt with at greater length in the following paper by D.V. Rundquist. Finally the author comments on the debate concerning global mineral resources, arguing strongly that mankind is not threatened by a shortage of minerals.

Classification of Ore Deposits

The genetic classification of ore deposits used in the U.S.S.R. differs somewhat from that adopted elsewhere. We recognize three series of deposits: endogenetic, exogenetic and metamorphogenetic. These are divided into groups, then classes and finally formations (Table 1).

The **endogenetic series** is subdivided into seven groups: magmatic, pegmatite, carbonatite, skarn, albitite-greisen, hydrothermal and pyrite. Included in the magmatic group are the Cu-Ni sulphide deposits of the liquid immiscibility (liquational) class, which occur on the Kola Peninsula (Pechenga) and Siberia (Norilsk), and the Siberian diamondiferous kimberlites and the Uralian chromites and titanomagnetites of the early magmatic (cumulate) class. The magmatic group also includes the larger chromite, titanomagnetite and apatite deposits of the Khibiny massif (Kola Peninsula) of the late magmatic (hysteromagmatic or fusional) class. The pegmatitic group embraces the micaceous and rare-metal deposits found in pegmatites of the crystalline Precambrian of Siberia, the Ukraine, and the eastern part of the Scandinavian shield.

Deposits of the carbonatite group, discovered mainly in the northwestern and eastern U.S.S.R. since 1950, include Fe, apatite, phlogopite, rare metals and rare earths. An extraordinary diversity is exhibited by the skarn group, which comprises iron ores in the Urals, Siberia and the Caucasus, W (scheelite) in Central Asia and the Far East, boron in the Caucasus and the Far East, and also Cu, Co, Sn and rare earths (Figs. 1, 2). The deposits in albitites and greisens form a special group containing rare metals such as Sn, W and Mo and found in Kazakhstan, Transbaikalia, the Far East and East Siberia.

Hydrothermal deposits in the U.S.S.R. are not subdivided on the basis of the temperature of the ore forming process, but rather into plutogenic, volcanogenic and amagmatic classes. These include ores of non-ferrous, rare, noble and radioactive metals known mainly in the Phanerozoic geosynclinal fold complexes of the Caucasus, the Urals, Central Asia, Siberia and the Far Northeast. Finally, the pyrite group comprises deposits of Cu, Pb and Zn associated with the geosynclinal ophiolites of the Urals, Rudnyi Altai, Caucasus and Central Asia.

The **exogenetic series** consists of three groups. The lateritic group is subdivided into residual and infiltrational deposits. Typical representatives of the residual variety are the Ni silicate ores in weathered Palaeozoic apodunite serpen-

tinities of the South Urals; lateritic bauxites are not characteristic of the U.S.S.R. In the infiltrational category are the peculiar deposits of native sulphur found in anhydrite-bearing carbonates of the Volga basin, in Central Asia and on the north slope of the Carpathians. The placer group is represented mainly by gold-bearing alluvial deposits (channel, valley, terrace and delta) of Quaternary age developed in the eastern U.S.S.R. Contemporary beach placers are not typical, but Palaeozoic and Tertiary analogues with ilmenite, rutile and zircon have been found in the southern and northern Soviet Union.

The sedimentary group comprises deposits of Fe, Mn and Al (bauxites). Sedimentary iron ores of Palaeozoic age occur in the Urals and Kazakhstan, of Jurassic age on the Russian and Siberian platforms, and of Neogene age on the Kerch Peninsula in the Crimea. Sedimentary Mn deposits of Palaeogene age are represented by the remarkable Chiatura deposits in the Caucasus (Fig. 3) and at Nikopol in the Ukraine. The most important bauxites are the Devonian ones in the Urals.

The **metamorphogenetic series** includes the large middle Proterozoic deposits of ferruginous quartzite in the Ukraine (Krivoi Rog) and on the Russian Platform (the Kursk Magnetic Anomaly). Also included in this series are the widely distributed, mainly micaceous pegmatites.

Metallogenic Epochs

The U.S.S.R. contains rock formations, geological structures and ore deposits formed at all stages of geological history, from the Archean to the Holocene (Smirnov, 1982). The two

Table 1: Genetic classification of ore deposits used in the U.S.S.R.

SERIES	GROUPS	CLASSES
Endogenetic	Magmatic	Liquid immiscibility (liquational)
		Early magmatic (cumulate)
		Late magmatic (fusional or hysteromagmatic)
	Pegmatitic	
	Carbonatite	
	Skarn	
	Albitite-Greisen	
Exogenetic	Hydrothermal	Plutogenic
		Volcanogenic
		Amagmatic
	Pyrite	
Exogenetic	Lateritic	Residual
		Infiltrational
	Placer	
Metamorphogenetic	Sedimentary	

Figure 1: En route to the Tyrnyaus Mo-W-Cu skarn deposits, 150 km NW of Ordzhonikidze in the Caucasus. (Photo by G. Leech)

Figure 2: Participants in the 1982 IAGOD excursion examining specimens in the Mukulan ore body of the Tyrnyaus field (Photo by G. Leech)

major events in the development of endogenous ore deposits were at 3800 Ma, when the magmatic and pyrite deposits of a basaltoid association and the metamorphogenetic pegmatites began to form, and 2500 Ma, when postmagmatic granitoid deposits first appeared. Typical representatives of the basaltoid association are magmatic deposits of chromite, titanomagnetite and Cu-Ni sulphides, whereas granitoid complexes are characterized by postmagmatic pegmatite, albite, greisen, skarn and hydrothermal deposits of non-ferrous, rare, noble and radioactive metals.

These ore deposits recurred later in geological time, basaltoid ores forming during phases of crustal tension and granitoid deposits during compressional cycles. The regular repetition of these pulses makes it possible to divide the history of ore formation into 10 metallogenetic epochs (Fig. 4, and see Fig. 4 of Rundquist, this issue of Episodes - Ed.). The Kolan (3800-2800 Ma) marks the onset of formation of the oldest endogenous deposits associated with greenstone belts and granite-gneiss domes. The Belomorian (White Sea) epoch, from 2800 to 2300 Ma, ago embraces the first half of the protogeosynclinal period and corresponds to the birth of the ancient geosynclines.

The Karelian (2300-1800 Ma) marks the peak and decline of the protogeosynclinal period, and the Gothian epoch (1800-1500 Ma) corresponds to an intergeosynclinal period with a temporary lull in active endogenous mineralization. A new period was then ushered in during the Grenvillian (1500-1000 Ma) when geosynclinal regimes were restored. Succeeding phases, the Baikalian (1000-600 Ma), the Caledonian (600-400 Ma), the Hercynian (400-250 Ma) and the Cimmerian (250-100 Ma) were distinguished by mature geosynclinal mineralization. Finally, the Alpine epoch (less than 100 Ma) is characterized by the cessation of geosynclinal activity leading to the development of rift tectonics controlling endogenous ore formation.

Throughout this long history, none of the endogenous groups experienced any pronounced qualitative changes, since magmatism recurred throughout. Basaltoid mineral associations formed from the outset of each phase or epoch to be succeeded by granitoid associations by the end. Representatives of the groups and classes of endogenous deposits formed throughout the entire span of crustal evolution, without any appreciable change from the early to the late epochs.

Environmental Regimes of Ore Formation

Endogenous deposits formed not only during the transformation of mobile geosynclines into stable platforms, but also in other geological environments. Four regimes can be distinguished: geosynclinal, platformal, transitional to oceanic, and oceanic. Each of these is marked by different degrees of magmatic differentiation and corresponding abundance of ore deposits, and their sequence corresponds to the series of decreasing magma-generating subcrustal systems proposed by V.V. Belousov (1976).

The geosynclinal regime (Fig 4) is distinguished by the most complete and comprehensive magmatic differentiation from ultrabasic to ultra-acidic rocks and by the most abundant mineralization. In the U.S.S.R., the full geosynclinal cycles of the Caledonides, Hercynides, Cimmerides and Alpides are

Figure 3: A close-up of the Chiatura manganese deposit of the south slope of the Caucasus about 150 km north of Tbilisi (Photo by G. Leech)

Figure 4: History of formation of endogenetic ore deposits.

represented by the following highly important magmatic formations and their associated endogenetic ore deposits:

- dunites with magmatic deposits of chromite and platinumoids,
- pyroxenites with magmatic deposits of titanomagnetites,
- plagiogranites with skarn deposits of Fe and Cu,
- basalt-liparites with pyrite deposits of Cu, Zn and Pb,
- granites with pegmatite, albitite and greisen ores of rare metals,
- granite porphyries with plutogenic hydrothermal deposits of non-ferrous, rare and noble metals,
- andesite-liparites with volcanogenic hydrothermal deposits also of non-ferrous, rare and noble metals.

The platformal regime is marked by less comprehensive magmatic differentiation. Within the Siberian platform and associated with Palaeozoic and Mesozoic tectonic and magmatic activity can be found:

- traps with magmatic Cu-Ni sulphide deposits,
- kimberlites that are locally diamondiferous,
- carbonatites with ores of Fe and rare metals,
- alkaline granites with hydrothermal deposits of non-ferrous metals, rare metals and Au.

Active continental margins are transitional from platformal to oceanic regimes. Their volcanic arcs are represented in the U.S.S.R. by the western margin of the Pacific Ocean, which is distinguished by more limited magmatic differentiation and a still narrower range of ore deposits. Associated with its basalt-andesite magmatism are mainly insignificant volcanogenic hydrothermal and pyrite deposits of non-ferrous metals. Finally, the oceanic regime of the Pacific with its primitive basalts bears only traces of pyrite mineralization.

A Comment on Global Mineral Resources

Metals are being extracted from the earth at ever increasing rates. For example, world Cu production more than doubled between 1960 and 1980, while in the same period Zn production increased by a factor of 1.85 and Pb production by 1.4. One would have thought that the metal reserves in mineral deposits would be sharply declining, but strange as it may seem this is not the case. On the contrary, reserves are increasing. As an illustration, whereas the global production of Cu grew by 3 million tons between 1960 and 1980, the total reserves increased by 280 million tons; the increase in reserves was thus 100 times greater than the growth in production. In the 1950s it was estimated that the reserves of copper would last for 30 years, until the 1980s. But the thirty years have already passed and the reserves are now good for another 55 years.

This paradox can be explained by the fact that the stock of commercially viable minerals is being continually increased by the discovery of new types of deposits that have, as a rule, lower concentrations of metals but greater reserves. For example, since the 1920s in the U.S.A. and the 1930s in the U.S.S.R., the small, rich vein deposits of Cu have been

replaced by the larger leaner Cu porphyries, whose share in both production and reserves is growing. Stratiform deposits have also been discovered, and pyritic deposits, which also contain large reserves of Cu at low concentrations, have become very important.

Moreover, at the beginning of the nineteenth century the concentration of Cu in mined ore was 10%, in 1890 it was 5%, in 1910 2%, in 1930 1.5% and in 1980 it dropped on occasion to 0.3%. Over the same period world Cu reserves increased by at least 400 million tons. Thus as Cu grades fell, the reserves grew to outstrip the increasing production of the metal.

In exploiting large ore deposits of low metal concentrations, the profitability of the mining operations has also increased. This is because the working of large masses of ore have made it possible to introduce new and more productive techniques of mining and primary processing, especially with the move away from underground to open-cast mining.

Of course only a small proportion of total metals available are found within the world's ore deposits; most are disseminated throughout ordinary rocks, as measured by their average abundance in the crust. For example, the clarkes for Zi, Cu, and Pb are 0.62%, 0.01% and 0.0016% respectively; these values are approximately 100 times lower than the average concentration of these metals in commercial ores. The reserves of such disseminated metals are vast. Thus the known reserves of Sn in all known ore deposits are only equal to the amount of Sn contained in 30 km³ of average rock. For Mo and Zn the equivalent volume is 200 km³ and for Cu 800 km³. Therefore by improving mining and processing techniques we will be able to extract ever increasing amounts of rock with declining metal concentrations, so that we will be able to meet all our needs for an infinitely long period of time. Mankind is certainly not threatened with a shortage of minerals.

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