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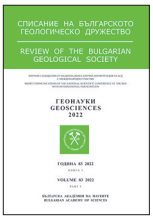

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Mineral deposit models in Bulgaria – basic principles, scope and classification scheme

Модели на минералните находища в България – основни принципи, обхват и класификационна схема

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Abstract. The necessity of development of mineral deposit models in Bulgaria, their basic principles and classification schemes are presented in the paper. Three types of models (descriptive, genetic, and quantitative) for each main deposit type are being developed by a uniform classification scheme of numerous geological, mineralogical, geochemical, industrial, and environmental characteristics and factors. These models will be used as a basis for metallogenic analysis of the ore productivity on the territory of Bulgaria by geological epochs, geodynamic settings, ore-forming systems and regions.

Keywords: mineral deposit modeling, descriptive model, genetic model, quantitative model, Bulgaria.

Introduction

The need for mineral deposit modeling in Bulgaria and the opportunity to be carried out at present are determined by the accumulation of a large amount of heterogeneous information from hundreds of deposits and occurrences, obtained as a result of the intensive prospecting, exploration and mining activity in the second half of the 20th century. On the metallogenic map of Bulgaria in M 1:1 000 000 are shown 187 ore deposits of 16 metals, barite and fluorite (Vassileff, Staikov, 1991). Adding to them the numerous deposits of industrial minerals, there is a significant information database on the national mineral resource potential.

In recent decades, mineral deposit data in Bulgaria have been summarized in a number of monographs on various deposit types (iron, lead-zinc, copper, gold, industrial minerals). However, the huge amount of summarized empirical data is accompanied by a language barrier and various ambiguous and contradictory genetic and classification interpretations. As a result, the mineral deposits in Bulgaria turn out to be difficult to recognize for the international economic geology science and practice, long working on the creation of coherent descriptive-interpretative mineral deposit models. For example: only 5 Bulgarian deposits (Elatsite – porphyry Cu; Varna – sedimentary Mn; Martinovo – Fe skarn; Malko Tarnovo and Strandzha – Cu skarn) are included in the world database of more than 3900 deposits, analyzed and summarized in Mineral Deposit Models (1986, and thereafter); or the large Phanerozoic Kremikovtsi IF-barite-polymetallic deposit of SEDEX type is still identified as “hydrothermal Fe replacement (metasomatic)” in a number of summary classification works (e.g., Dill, 2010). In my opinion, however, there are sufficient arguments (and data) to include many more Bulgarian deposits in the worldwide database, even as benchmarks for certain ore-forming systems and regions. In addition, the misinterpreted information can lead to insufficiently reasoned or even misleading future regional and local prospecting-exploration strategies and geological-economic assessments. Metallogenic models of all kinds are now considered as key to successful prospecting and exploration in the future (Pohl, 2022).

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All this determines the objective need for mineral deposit modeling on the basis of a unified system of representative characteristics, grouping into common types (in case of insignificant differences), highlighting the deposit formation trends in time and space, and identifying basic criteria for future prospecting-exploration works. In this sense, one of the main current goals of economic geology in Bulgaria should be to compile, analyze, synthesize and formalize the available information on the mineral deposits by a uniform scheme and to create comprehensive descriptive, interpretive and quantitative models of the major mineral deposit types. Work in this direction would allow enlargement of our knowledge on the basic elements of most productive ore-forming systems on the territory of Bulgaria and increasing the efficiency of future prospecting and exploration activities.

Mineral deposit modeling

On the problem of mineral deposit, modeling has been worked for a long time, in different directions and with different methodological approaches. Various models have been created at the local, regional, and global level – descriptive, genetic, classification, statistical, morphological, quantitative. The first summary publications (Genetic Models..., 1983; Eckstrand, 1984; Mineral Deposit Models, 1986; Krivtsov, 1989; Developments in…, 1992) show the undoubted benefits of the development of this sector of economic geology. The U.S. Geological Survey's approach to creating descriptive-quantitative models of most known mineral deposits in the world is becoming widespread (Mineral Deposit Models, 1986). Cox et al. (1986) defined mineral deposit models to be "systematically arranged information describing the essential attributes (properties) of a class of mineral deposits".

Based on the analysis of the different modeling approaches and the available information database, it was accepted that the modeling of mineral deposits in Bulgaria should cover 3 types of models for each main (or potentially perspective) deposit type: descriptive (empirical) model, interpretative (genetic) model, and quantitative (grade-tonnage) model (Fig. 1).

Descriptive models

A genetic-independent *scheme for classification* of mineral deposits in Bulgaria is adopted in the present work (after Mineral Deposit Models, 1986), based on the lithotectonic environment of host rock formation as a main empirical and easily recognizable geological element (Fig. 1A). Of course, it is clear that for epigenetic mineralizations there will always be a conflict between the lithotectonic settings of host rocks and that of the ore-forming processes. In this case, the expert assessment of the leading lithotectonic factors for ore formation is adopted.

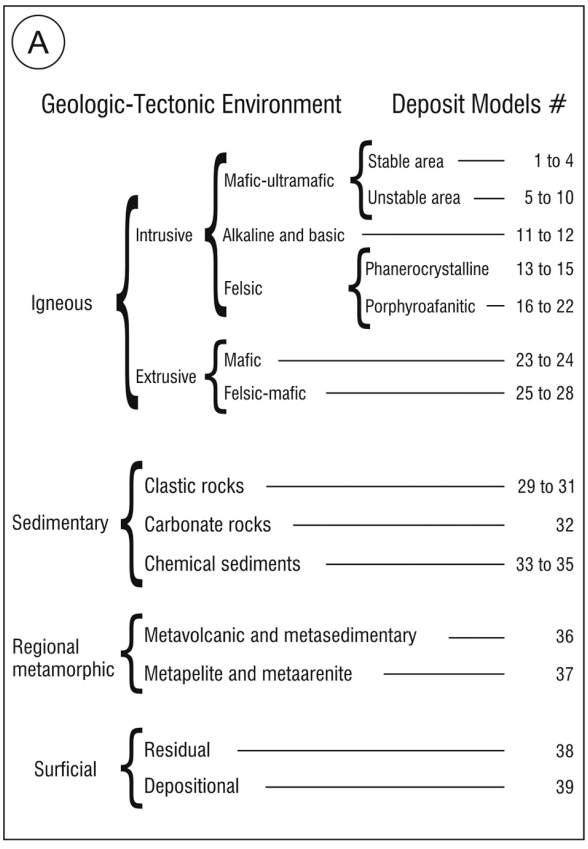
Mineral deposit *model names* must be short, without hypothetical genetic terms (e.g., hydrothermal-metasomatic, syngenetic, epigenetic, etc.), and based on: (*i*) the leading metal/mineral components (Pb-Zn, Cu-Au, Fe-Mn, barite, fluorite, etc.), and (*ii*) the specific and clearly recognizable geological characteristics (vein, porphyry, skarn, placer, volcanic-hosted, bedded, etc.). The second main feature in the model names (type locality derived from world class specific deposits), used in Mineral Deposit Models (1986), is not suitable for the Bulgarian deposits, since we can hardly associate them with, e.g. Appalachian Zn, Kipushi Cu-Pb-Zn, Comstock epithermal vein, etc. On the other hand, it is not advisable to give local names to our mineral deposit types that are not popular enough for the international economic geology community. The local and global names of analogous mineral deposit types will be mentioned in the section "Approximate Synonyms".

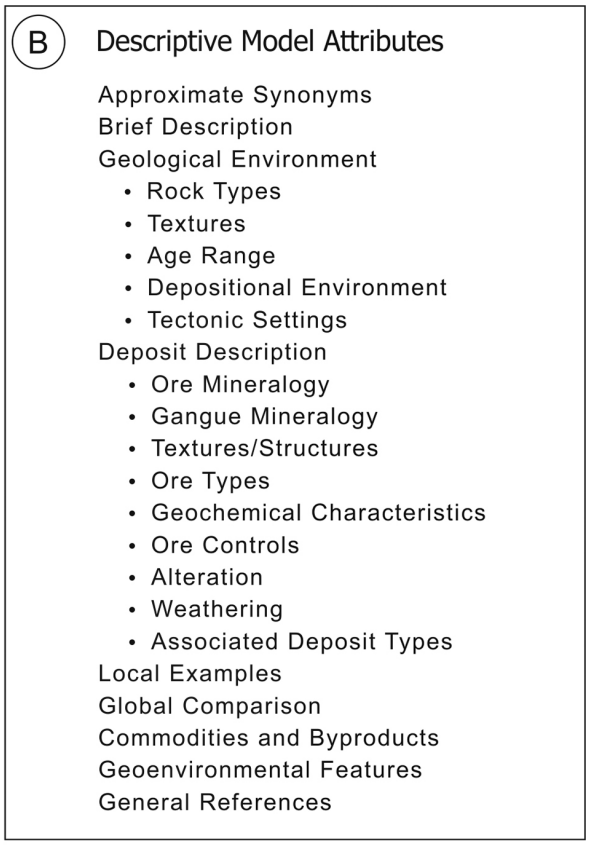
The *main body* of the descriptive models includes a concise description of the deposit types according to a unified scheme of over 50 main geological, mineralogical, geochemical, geophysical, industrial and environmental elements, grouped in several sections (approximate synonyms, brief description, geological environment, deposit description, local examples, global comparison, commodities and by-products, geoenvironmental features, general references) (Fig. 1B). If sufficient representative data are available for some deposit types, additional sections to the short list (e.g., prospecting-exploration criteria, mineral processing features, etc.) as well as additional elements to the main attributes (e.g., mineral assemblages/parageneses, zoning patterns, fluid inclusions, trace-element and isotope geochemistry, mine waste characteristics, etc.) will be introduced. An attempt will also be made to distinguish model subtypes of some mineral deposits, e.g. copper or lead-zinc deposits with and without precious metal mineralization.

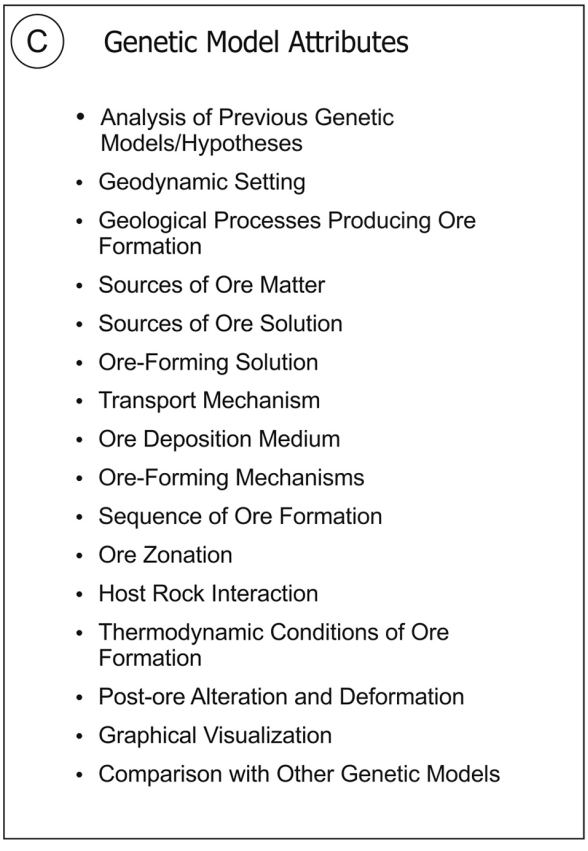
The main characteristics of the mineral deposit types will be accompanied by representative geological maps, diagrams, sections, photographs and other illustrative materials as well as by a list of general references.

Genetic models

The genetic (interpretative, mental, virtual) model of mineral deposit is the idea of development of a specific ore-producing mineral system, presented







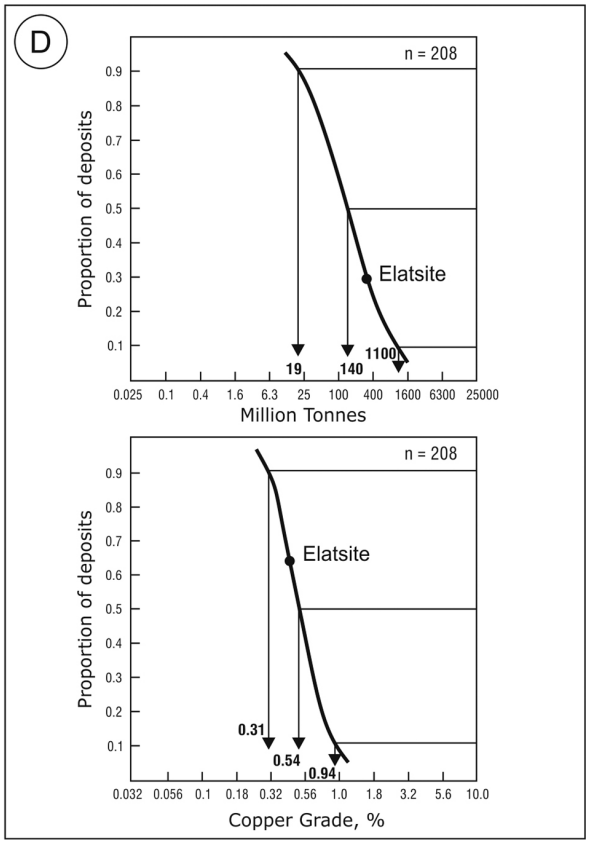


Fig. 1. Schemes of mineral deposit modeling in Bulgaria. *A*) Basic classification scheme (after Mineral Deposit Models, 1986); *B*) Short list of descriptive model attributes; *C*) General scheme of genetic model attributes; *D*) Grade and tonnage models of porphyry Cu deposits (after Mineral Deposit Models, 1986, Fig. 51-52, simplified).

in a simplified and easy-to-perceive form. This, in fact, "conceptual representation of mineral-forming systems in geoscientific terms" (Pohl, 2022) should be based on a maximum set of facts and data, not contradicting each other and interpreted in a logical construction. Genetic models are usually built on the summarized data of well-studied typical objects. A well-constructed integral scheme for describing the genetic model of ore deposits was developed by Ovchinnikov (1988) and adapted for the current mineral deposit modeling (Fig. 1C).

The model description of ore deposit formation will be preceded by a brief analysis of the hypotheses for its origin and the related arguments and will be finished by a comparison with other deposit models of the same type. The relevant genetically significant information will be used in a unified model scheme of basic elements of ore-forming processes (geodynamic setting, sources of ore matter and ore solution, transport mechanism, ore deposition medium and mechanism, alteration, etc.) (Fig. 1C). Based on all the data available so far, schematic or detailed (if possible) genetic ore-forming models will be built.

Quantitative models

Generally, the quantitative (grade-tonnage) models reflect various parameters of the mineral deposits (metal/mineral content, ore grade, reserves and resources, spatial metal/mineral distribution, etc.) in a graphical format in order to provide comparison with other deposits of the same type for resource assessment. The grade-tonnage models developed by the U.S. Geological Survey (Mineral Deposit Models, 1986, and thereafter) represent graphics with grade (cutoff metal/mineral content) or tonnage (reserves of ore/metal/mineral), on the horizontal axis, and cumulative proportion of deposits in the world, on the vertical one (Fig. 1D). The assessment of the range of their values with determination of averages, deviations and intercepts (90%, 50%, 10%) provides the necessary information for the selection of priority objects for prognosis, prospecting and exploration on the basis of their geological-economic significance.

The quantitative models of mineral deposits in Bulgaria are intended to include both a comparative characterization with similar deposits in the world and from different regions/ore fields in Bulgaria (if possible).

Summary and conclusion

Mineral deposit modeling in Bulgaria is planned to cover the development of 3 types of models (descriptive, genetic, and quantitative) for each deposit type by a uniform classification scheme of numerous geological, mineralogical, geochemical, industrial, and environmental characteristics and factors, corresponding to the modern modeling approaches in economic geology. Based on these models, a metallogenic analysis of the ore productivity on the territory of Bulgaria will be made by geological epochs, geodynamic settings, ore-forming systems and regions.

Mineral deposit modeling in Bulgaria can be used further in a number of scientific and applied fields, such as: theory of ore formation, metallogenic analysis, regional and local prognoses, prospecting and exploration, geological-economic assessment, mineral processing and mining.

References

Cox, D. P., P. B. Barton, D. A. Singer. 1986. Introduction. – In: *Mineral Deposit Models*, Cox, D. P, D. A. Singer (Eds.), U. S. Geol. Surv. Bull. 1693, 1–10.

Developments in Mineral Deposit Modeling, Bliss, J. D. (Ed.). 1992. – U.S. Geol. Surv. Bull. 2004, 168 p.; https://doi.org/10.3133/b2004.

Dill, H. G. 2010. The "chessboard" classification scheme of mineral deposits: Mineralogy and geology from aluminum to zirconium. – *Earth Sci. Rev*., *100*, 1–420; https://doi.org/10.1016/j.earscirev.2009.10.011.

Eckstrand, O. R. 1984. *Canadian Mineral Deposit Types: A Geological Synopsis*. Econ. Geol. Report, 36, Geol. Surv. Can., 86 p.; https://doi.org/10.4095/120000.

Genetic Models of Endogenous Ore Formations, Kuznetsov, V. A. (Ed.). 1983. Novosibirsk, Nauka, Vol. 1, 184 p., Vol. 2, 176 p. (in Russian).

Krivtsov, A. I. 1989. *Applied Metallogeny*. Moskow, Nedra, 288 p. (in Russian).

Mineral Deposit Models, Cox, D. P., D. A. Singer (Eds.). 1986. U. S. Geol. Surv. Bull. 1693, 379 p.; https://doi.org/10.3133/b1693.

Ovchinnikov, L. N. 1988. *Ore Deposits Formation*. Moskow, Nedra, 255 p. (in Russian).

Pohl, W. L. 2022. Metallogenic models as the key to successful exploration – a review and trends. – *Miner. Econ*., https://doi.org/10.1007/s13563-022-00325-3.

Vassileff, L., M. Staikov. 1991. Short metallogeny of Bulgaria. An explanatory note of the Metallogenic map of Bulgaria, 1:1 000 000. – *Rev. Bulg. Geol. Soc*., *52*, 2, 1–55 (in Russian with English abstract).