On Minerogenetic Series: The Third Discussion

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Abstract: The minerogenetic (or metallogenetic) series of mineral deposits (called minerogenetic series for short) is an academic idea (concept) of studying minerogenetic characteristics in mineral deposit geology. It uses the views of systematology and mobilism to study mineralizing processes and naturally occurring mineral deposit assemblages formed in various stages of geological development in specific tectonic environments. The minerogenetic series is also a natural classification of mineral deposits. There are five hierarchical orders in the classification, with the minerogenetic series as the basic order and the core. The first order includes three categories: minerogenetic series association, minerogenetic series type, and minerogenetic series group. The second is the minerogenetic series, which is decomposed into three orders, i.e. the third, fourth, and fifth orders. The third is the minerogenetic subseries, the fourth is mineral deposit models (types), and the fifth is mineral deposits. Minerogenetic series is comparable to a certain extent metallogenic systems both in the research content and in their own research content. The study of minerogenetic series has both great theoretical significance and practical value for mineral prospecting. However, the study is still in its initial stage and a further study remains to be conducted.

Key words: concept of minerogenetic series, order, theoretic and practicable significance

Citation: Chen et al., 2020. On Minerogenetic Series: The Third Discussion. Acta Geologica Sinica (English Edition), 94(1): 1–9. DOI: 10.1111/1755-6724.14396

1 Introduction

In China's metallogenic research W. H. Wong was the first who used the term minerogenetic series. In his paper "On the Regional Distribution of Mineral Resources in China" published in 1920, he used this term to describe mineral deposit zonation in southern China. In 1974, in the study of Mesozoic volcanic-hosted iron deposits in the Nanjing-Wuhu area, Chen Yuchuan, Li Wenda et al. constructed the metallogenic model of the Nanjing-Wuhu iron deposit for various volcanic-related iron deposits and nonmetallic mineral deposits (Research Group of the Nanjing-Wuhu Program, 1978). This model puts emphasis on a set of genetically related mineral deposits formed by volcanic-dominated mineralizing processes in a regional geological setting, which have certain distribution characteristics in a space-time domain. This was an embryo of the concept of minerogenetic series to some extent. In 1975, in studying the types of iron deposits in China, Cheng Yuqi proposed that several interrelated types of iron deposit might occur simultaneously in an area and called them an iron deposit minerogenetic series (Cheng et al., 1976). In 1979, initiated by Cheng Yuqi, he, Chen Yuchuan, and Zhao Yiming wrote the paper "Preliminary Discussion on the Problems of Minerogenetic Series of Mineral Deposits", in which they formally proposed the concept of minerogenetic series. Therefore, if the study about minerogenetic series progressed from 1975 up to the present, it has had a history of 30 years. During this period, Cheng Yuqi, Chen Yuchuan, Zhao Yiming, and Song Tianrui again published "Further Discussion on the Problems of Minerogenetic Series of Mineral Deposits" in 1984; Zhai Yusheng and Qin Changxin wrote "On Minerogenetic Series and Mineralization Model" in 1987, which was listed as a reference book on ore deposits; Zhai Yusheng et al. published the monograph "Research on Metallogenic Series" in 1996; in 1998, under the direction of Cheng Yuqi the monograph "Preliminary Study on Minerogenetic Series in China" written by Chen Yuchuan, Pei Rongfu, Song Tianrui et al. was published and the English version of a paper about minerogenetic series was published in full in the Proceedings of the Ninth Quadrennial International Association on the Genesis of Ore Deposits (IAGOD) Symposium, which drew attention of mineral deposit geologists of other countries (Cheng et al., 1998). In 2000 Chen Yuchuan and Zhu Yusheng compiled and published maps of Precambrian, Paleozoic and Meso-Cenozoic minerogenetic series of China and their explanatory notes. Over 30 years, the state key-task projects in scientific and technological research, projects of the National Natural Science Foundation of China and geological survey and research projects of the former Ministry of Geology and Mineral Resources and Ministry of Land and Resources successively have carried out

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studies of minerogenetic series in the Nanling Mountains, Qinling Mountains, and middle and lower Yangtze River valley, on the northern margin of the North China platform, and in the Sanjiang area and Altay area (Chen, 1983; Chen et al., 1985, 1989, 1993; Chen and Mao, 1995; Wang and Chen, 1998; Wang et al., 2002). Various provinces and regions conducted studies of minerogenetic series and published a batch of monographs concerning areal, provincial and regional minerogenetic series. Especially, during 1988-1992, the former Ministry of Geology and Mineral Resources organized a basic research project of minerogenetic series (Chen Yuchuan and Zhai Yusheng were in charge of the project respectively), which achieved outstanding success. In 1999–2004, the China Geological Survey of the Ministry of Land and Resources organized and undertook a survey and integrated research project of "Metallogenic Systems of China and Regional Mineral Resource Potential Assessments". This project organized more than 200 scientists from 40 scientific research and teaching institutions and geological exploration departments and parties, including 7 academicians of the Chinese Academy of Sciences and the Chinese Academy of Engineering, to conduct a systematic and integrated study of the metallogenic characteristics of the whole country as well as various provinces and regions and yielded fruitful results. Among others, the study of minerogenetic series reached a new height and further improved the concept of minerogenetic series. Around China 214 minerogenetic series, 434 minerogenetic subseries, and 978 mineral deposit models (types) were established and the second-generation Precambrian, Paleozoic, Mesozoic and Cenozoic minerogenetic series map of China was compiled. The study and application of minerogenetic series have played a good role in promoting mineral resource survey and exploration. The research achievements of the second-round national-scale regionalization work with the minerogenetic series concept as the geological theoretical basis won the second-class award of the State Scientific and Technological Progress Prize.

The founder of minerogenetic series—Honorary President Cheng Yuqi of the Chinese Academy of Geological Sciences—passed away in 2002, and in order to commemorate his prominent contributions in establishing the concept of minerogenetic series and also in order to celebrate the 60th anniversary of the founding \f the People's Republic of China we wrote the paper "On Minerogenetic (Metallogenetic) Series: The Third Discussion" to summarize the major progress made in the study of minerogenetic series since the publication of "Further Discussion on the Problems of Minerogenetic Series of Mineral Deposits" in 1984.

2 Concept of Minerogenetic Series and Research Object

The minerogenetic series is an academic idea (concept) for studying the minerogenetic characteristics in mineral deposit geology. It uses the views of systematology and mobilism to study mineralizing processes and naturally occurring mineral deposit assemblages formed in various stages of geological development in specific tectonic environments. The minerogenetic series is also a natural classification of mineral deposits. Its main academic ideas are as follows: (1) mineral deposits are a component part of the geological environment, and mineralizing processes are a component part of geological processes that form the geological environment; (2) mineral deposits do not exist individually but exist as genetically related mineral deposit assemblages; (3) an assemblage of genetically related mineral deposits formed in a particular geological period or a particular stage of tectonic movement, in a particular tectonic unit and position, and in relation to a particular geological mineralizing process is called the minerogenetic series; (4) mineral deposits in a minerogenetic series have particular evolutionary characteristics and distribution characteristics in a time-space domain; (5) minerogenetic series formed successively in the same area show inheritance and evolution and might modify the early-formed minerogenetic series; (6) various minerogenetic series formed inside tectonic units involved in a tectonic cycle have particular evolutionary characteristics, distribution characteristic, and inherent relations and form a minerogenetic series group; (7) the same mineralizing processes in a similar tectonic environment and in different ages and areas may form similar minerogenetic series, but these minerogenetic series have their own features and form the minerogenetic series type; and (8) a minerogenetic series may be divided into five hierarchical orders (ranks): the first order includes three categories, minerogenetic series association, minerogenetic series type and minerogenetic series group; the second is minerogenetic series; the third is minerogenetic subseries; the fourth is mineral deposit models (types); and the fifth is mineral deposits.

The core of the minerogenetic series concept is that mineral deposits do not occur individually but occur in swarms and as different type groups, i.e. that they occur as assemblages of genetically related mineral deposits composed of mineral deposits that are of different origins, contain different useful minerals, and even belong to different geological formations (rock strata). Therefore the research object of minerogenetic series is mineral deposit assemblages in a time-space domain and their tempo-spatial structures, tectonic environments, formation processes, and evolutionary characteristics, as well as various relationships between mineral deposits. Through studies, exploration, and grasp of these objective characteristics, they are applied in guiding regional mineral prospecting, raising the mineral-prospecting efficiency, and further deepening our understanding of metallogenic characteristics.

3 Connotation and Classification of Minerogenetic Series

The minerogenetic series is a basic natural assemblage of mineral deposits in a time-space domain. They are "cells" of the mineral deposit world over the globe and form the global mineral deposit world. The minerogenetic series may be briefly defined as an assemblage of genetically related mineral deposits formed by particular mineralizing processes in the particular 4D time and space domains. Its connotation is as follows: the particular time domain refers to a particular stage of the geological history and generally refers to an active tectonic cycle or a relatively independent stage of tectonic movement; the particular space domain refers to a particular tectonic unit and generally refers to a tectonic unit involved by the above-mentioned tectonic movement, i.e. the tectonic environment related to mineralization, generally equivalent to a third-order tectonic unit or a tectonic unit spanning or included in an old tectonic unit; particular mineralizing processes refer to mineralizing processes occurring in this particular time-space domain; an assemblage of genetically related mineral deposits formed refers to a mineral deposit assemblage formed by particular mineralizing processes in the above-mentioned particular time and space domains, which have inherent genetic relation. The above-mentioned four factors form a minerogenetic series (Fig. 1), i.e. a physical entity of mineral deposit assemblages in a particular time-space domain. Therefore every minerogenetic series is the only mineral deposit assemblage entity, or we may say every minerogenetic series is a complete and also basic mineralizing system (here the concept of mineralizing system does not involve the late-stage of modification process proposed by Zhai Yusheng).

The research object of minerogenetic series is a set of genetically related mineral deposits in a 4D time-space domain and their tectonic environment related to mineralization, mineralizing processes and evolution, and tempo-spatial structures, and distribution characteristics of various types of mineral deposit, as well as their genetic relations.

The determination of a minerogenetic series should follow the law of nature, but an artificial boundary that comparatively accords with reality is always needed. A uniform approach should be set so as to facilitate study and idea exchange. The principle of the determination should correspond to the requirements of a definition and it is not advisable to set too short a time range. If we take a tectonic cycle as the time range, we mainly consider that this is a course of the regular activity of the crust and mantle, and within this time range tectonic and mineralizing processes are both controlled by unified mantle and crustal processes and are continuous geological processes. If we take a particular stage of a tectonic cycle as the time range, too many minerogenetic series will be distinguished, and additionally mineralizing processes in various time ranges are also genetically related and difficult to distinguish clearly. In consideration that the areal extent involved in a tectonic cycle is very large, that its activities occur to different degrees in different areas, and that there appear only some stages of activities in some tectonic belts, the time ranges of minerogenetic series in these tectonic belts are limited to some stages of activities of that tectonic cycle. With respect to the areal extent, the areas involved in the activities of a tectonic cycle are very large, in which tectonic units of varying size and related tectono-metallogenic units (metallogenic regions and belts) are formed. We distinguish five orders of metallogenic units: metallogenic domains, metallogenic provinces, metallogenic regions (belts), metallogenic subregions (subbelts), and ore fields. Neither too large a spatial extent nor too small a spatial extent involved in a minerogenetic series is suitable. It is advisable to use the areal extent involved in a third-order tectonic unit, i.e. the areal extent equivalent to a metallogenic region or belt. The principle for the determination of mineralizing processes is that: every minerogenetic series is constructed by a dominant mineralizing process. According to the conventional practice in the communities of mineral deposit geologists, mineralizing processes are classified into the magmatism-related mineralizing process, sedimentation-related mineralizing process, and metamorphism-related mineralizing process; in addition, the supergene mineralizing process is distinguished separately and the geofluid-related minerogenetic process (including minerogenetic series of temporarily uncertain origins) is also included. Some mineralizing series are formed simultaneously with other mineralizing processes, to which full attention should be given in the study and description of minerogenetic series.

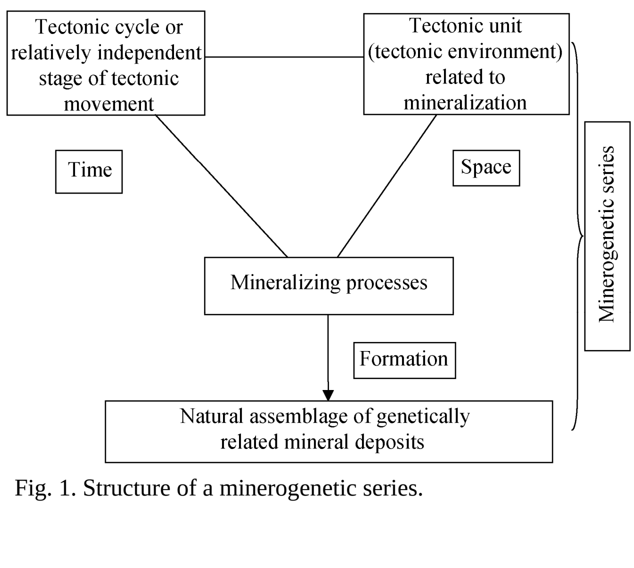

Fig. 1. Structure of a minerogenetic series.

4 Orders and Nomenclature of Minerogenetic Series

The minerogenetic series is divided into five hierarchical orders (Fig. 2). The first order includes three categories.

The first category: minerogenetic series association. It is an assemblage of minerogenetic series formed by different mineralizing processes. They may be classified into (1) the magmatism-related minerogenetic series association, (2) the sedimentation-related minerogenetic series association, (3) the metamorphism-related minerogenetic series association, (4) the supergene process-related minerogenetic series association, and (5) the geofluid-related minerogenetic series association (including minerogenetic series of temporarily uncertain origins). A minerogenetic series association formed by magmatism is an association made up of various minerogenetic series formed by volcanism (subaqueous or subaerial)- and

First order		Minerogenetic series group		Minerogenetic series association		Minerogenetic series type	
Second order				Minerogenetic series			
Third order				Minerogenetic subseries			
Fourth order				Mineral deposit model (type)			
Fifth order				Mineral deposits			

Fig. 2. Orders of minerogenetic series.

intrusion-related mineralization and associated with magmatic rocks of different compositions. A minerogenetic series association formed by sedimentation refers to that composed of various minerogenetic series formed by mechanical and chemical deposition processes in seas, rivers, and lakes in the geological past. A minerogenetic series association formed by metamorphism refers to that composed of various minerogenetic series formed by metamorphism of geologic bodies (including mineral deposits) due to dynamic and thermal processes within the crust. A minerogenetic series association formed by supergene processes refers to that composed of various minerogenetic series formed by physical and chemical actions on surface (and submarine) geological bodies exerted by the hydrosphere, atmosphere and gravitational attraction. A minerogenetic series associations formed by ore fluid processes refers to that composed of various minerogenetic series formed by contact metasomatism of ore fluids with country rocks and filling into country rocks, while ore fluids had no direct genetic relation to magmatism and metamorphism in the crust. For the time being, minerogenetic series of uncertain origins are also included in this association.

The second category: minerogenetic series type. A minerogenetic series type is made up of various similar minerogenetic series with some unique features of their own formed by the same kind of mineralizing processes in different ages, different areas, and similar tectonic environments. In the context of geological evolution, similar tectonic environments would appear in different geological periods, accompanied by the same kind of mineralizing processes, forming a set of mineral deposits (a minerogenetic series). Minerogenetic series of such kind formed in various geological periods show similarities to a great extent but have their own characteristics with respect to the geological periods when they occurred and so are different somewhat. For example, during the late stage of the Neoproterozoic Xuefengian tectonic cycle in northern Guangxi, China, an assemblage of large and medium-sized cassiterite-sulfide polymetallic deposits (e.g. the Baotan, Jiumao and other tin deposits and lead-zinc mineralization and gold mineralization in their surrounding areas) associated with the Xuefengian granite activity was formed. In this area, during the late stage of the Mesozoic Yanshanian tectonic cycle, an assemblage of superlarge cassiterite-sulfide polymetallic deposits (e.g. superlarge and large tin, lead, zinc, antimony, and silver deposits and copper and tungsten deposits in the Dachang ore belt) associated with late Yanshanian biotite granite activity was formed. The minerogenetic series of the two periods are of common mineralization nature and genetic type but differ somewhat in mineralization intensity and ore element composition, with the mineralization intensity of the latter being high and the ore elements, e.g. antimony, increasing. Over the globe, similar tectonic environments may also have formed in different areas in the same period of time, accompanied by the same type of mineralization, thus giving rise of a set of mineral deposits (a minerogenetic series). Minerogenetic series of this kind have similarities to a great extent in various areas but have the unique characteristics of the areas where they occur and thus differ somewhat. For example, polymetallic sulfide minerogenetic series were formed in tectonic environments of both modern mid-ocean spreading ridges and sea-floor spreading ridges. Sulfide polymetallic (Fe, Mn, Cu, Pb, Zn, Au, Ag, Ni, Co, etc) deposit assemblages were formed in the Pacific Ocean, Atlantic Ocean, Indian Ocean, and even the Okinawa Trough have the common nature but their ore element compositions and enrichment degrees are different (Wang et al., 2001). During the late Yanshanian tectonic cycle, cassiterite-sulfide polymetallic minerogenetic series associated with late Yanshanian biotite granite were formed in the Yangtze block southwest-margin tectonic belt of northern Guangxi, Xikang-Yunnan oldland (craton) margin tectonic belt, and Northern Guangdong oldland north-margin tectonic belt on the continent of China.

The third category: minerogenetic series group. The minerogenetic series group is an assemblage of various minerogenetic series formed in one metallogenic region (belt), the same tectonic cycle, different stages, and different tectonic environments. Because the activities of a tectonic cycle were regular, all stages of a tectonic cycle witnessed the formation of their unique tectonic environments and related mineralizing processes and minerogenetic series. Therefore tectono-metallogenic activities in various stages had some inherent and necessary relations, i.e., they should show regularity. So the assignment of these minerogenetic series to one group accords with the objective laws and the exploration into their tempo-spatial structure and evolutionary regularity will be conducive to guiding regional mineral prospecting. As various metallogenic regions (belts) have different histories of tectonic development and the tectonic environments kept in some metallogenic regions (belts) were relatively monotonous, no minerogenetic series group exists in those metallogenic regions (belts). However, the following case may also happen, i.e.: minerogenetic series formed in neighboring metallogenic regions (belts) are the product of activities of the same tectonic cycle and may form a minerogenetic series group straddling two or more metallogenic regions (belts). For example, several minerogenetic series were formed in the

Tianshan tectonic belt during the Hercynian tectonic cycle, which constitute a minerogenetic series group.

The second order of minerogenetic series is the minerogenetic series. As stated before, it is the core component part in minerogenetic series orders. We may also say, the minerogenetic series is an assemblage of genetically related mineral deposits (mineralizations) formed in a particular time range and area during the evolution of the earth and associated with particular mineralizing processes. The mineral resources earth (mineral deposit world) is comprised of numerous minerogenetic series, which are "cells" of the mineral resources earth. These "cells" may be grouped into an association, a type, and a group, and the "cells" themselves consist of minerogenetic subseries, mineral deposit models (types), and mineral deposits.

The third order of minerogenetic series is the minerogenetic subseries. It is a component part of a minerogenetic series. Some minerogenetic series occurred in a large tectonic region, formed in a relatively long period of time, and have very high mineralization intensity. On the other hand, tectonic conditions in different areas of the tectonic region are more or less different and mineralizing processes in these areas show some special characteristics besides common characteristics. The mineral deposit assemblages formed in these areas constitute subseries of a minerogenetic series. For example, the minerogenetic series of nonferrous metal, rare metal, rare earth metal, and uranium deposits related to Yanshanian granite in the Nanling region of China formed in the Mesozoic involves the Nanling tectonic belt, in which from east to west three secondary tectonic belts may be distinguished: the southern Jiangxi-northern Guangdong Caledonian uplift, southern Hunan-southeastern Guangxi Hercynian depression, and western Guangxi-northern Yangtze oldland margin depression. The whole minerogenetic series is characterized by a mineral deposit assemblage composed of tungsten, tin, lead, zinc, copper, antimony, arsenic, silver, gold, uranium, niobium, tantalum etc. However, the mineral deposit assemblage in each secondary tectonic belt has its dominant ore elements besides common ore elements and they show regular evolution from east to west. For example, in the southern Jiangxi-northern Guangdong area in the early and middle stages of mineralization, tungsten, tin, bismuth, molybdenum, copper, rare earth metals, niobium, and tantalum predominate in the mineral deposit assemblage; in the southern Hunan-eastern Guangxi area in the middle and late stages of mineralization, tungsten, tin, bismuth, molybdenum, lead, zinc, and rare earth metals are predominant; in the northwestern Guangxi area in the late mineralization stage, tin, lead, zinc, antimony, silver, and mercury are predominant; and the last-formed uranium deposits again mainly originated in the southern Jiangxi-northern Guangdong area. Therefore, four minerogenetic subseries may be distinguished correspondingly, which belong to the above-mentioned three secondary tectonic belts. These four minerogenetic subseries form a complete minerogenetic series in the Nanling region.

The fourth order of minerogenetic series is the mineral deposit model (type or style). The mineral deposit assemblage in a minerogenetic series consists of mineral deposit types formed by various similar minerals of the same origin. The representative mineral deposit of each mineral deposit type is the mineral deposit model. Each minerogenetic series consists at least of one or one more mineral deposit models.

The fifth order of minerogenetic series is the mineral deposit. It is the most basic component unit of a minerogenetic series. In an underexplored area a number of mineral localities and mineralization localities with mineral resource potential should be included in the research scope.

The naming of minerogenetic series should be standardized and the principle for the naming should both embody the main content and be as simple and clear as possible and also should facilitate enquiries. Therefore, using two forms of naming minerogenetic series simultaneously is preliminarily considered: one is naming using words, and the other is naming using numerical codes. Naming using words should reflect four elements: mineralization space, time, processes, and useful minerals. For space, the use of area names is suggested; for time, the use of tectonic cycles is suggested for minerogenetic series related to magmatism and metamorphism and the geologic age is used for minerogenetic series related to sedimentation and supergene processes; for minerals, mainly those that are mined as ore in a mineral deposit are expressed, and when there are several minerals, only those dominant ones are expressed. The examples are the minerogenetic series of nonferrous metal, rare metal, rare earth metal, and uranium deposits related to Yanshanian granite in the Nanling region and the minerogenetic series of Carboniferous sedimentary iron, aluminum, and clay deposits in Shanxi, Henan, Guangxi, and Guizhou. For numerical codes, we may explore different schemes. For example, we may use four-digit codes for expression. The first digit represents Chinese abbreviations of province, prefecture, or city; the second digit is the minerogenetic series association number that mineralizing processes belong to (magmatism is numbered 1, sedimentation 2, metamorphism 3, supergene processes 4, and ore fluid process and minerogenetic series of uncertain origin 5); the third digit is the geologic age (eight ages are distinguished: Archean is numbered 1, Paleoproterozoic 2, Mesoproterozoic 3, Neoproterozoic 4, Early Paleozoic 5, Late Paleozoic 6, Mesozoic 7, and Cenozoic 8); the fourth digit is the serial number of a minerogenetic series in a province, prefecture, or city.

5 Minerogenetic Series are a New Classification of Mineral Deposits—A Natural Classification of Mineral Deposits

The classifications of mineral deposits made by foreign and Chinese geologists may be summarized into two categories: genetic classification and commodity classification. The genetic classification includes several classification schemes, e.g. classification based on mineralization temperatures, classification based on mineralizing processes, and classification based on material sources. Outstanding research outcomes have been achieved in metallogenic research, and metallogenic specialization of magmatic rocks, metallogenic specialization of geological formations, and metallogenic specialization of tectonic environments were put forward. Especially increasing attention has been paid to controls of the tectonic environment on mineralization and various metallogenic systems are being established. The concept of minerogenetic series proposed by us in the 1970s just aims to study mineral deposit assemblages in various tectonic environments. Actually, conducting the classification of minerogenetic series is conducting the natural classification of mineral deposits. The basic unit ("cell") of this classification of mineral deposits is minerogenetic series and three categories are recognized: according to the genetic classification, minerogenetic series associations may be recognized; according to the classification of the tectonic cycle, minerogenetic series groups may be recognized; and according to the classification of the tectonic environment, minerogenetic series types may be recognized. The minerogenetic series itself consists of subseries, mineral deposit models, and numerous mineral deposits, as is shown in Fig. 3.

Minerogenetic series group	Minerogenetic series type	Minerogenetic series association
Minerogenetic series		
Minerogenetic subseries		
Mineral deposit model		
Mineral deposits		

Fig. 3. Natural classification of minerogenetic series.

6 Minerogenetic Series and Metallogenic Systems

There has been increasing interest in the study of metallogenic systems in the former USSR since the 1970s (especially in the 1980s) and in China since the 1990s. Two divergent views exist about the definition of metallogenic systems: one is that the full process of formation of mineral deposits and its products are a metallogenic system (Li, 1996; Zhai, 1997), and the other is that the process of formation of mineral deposits and process of their modification after their formation are a metallogenic system (Zhai, 1998). The two definitions have their own reasons. We are in favor of the first view. For the "system" is usually understood as a whole composed of things that have inherent relation; for example, in the "Cihai (a collection of Chinese words) it is interpreted as "a whole formed by combination of identical or similar things according to a certain order and inherent relation", and in the "Modern Chinese Dictionary" it is interpreted as "a whole composed of things of the same kind according to certain relation". Therefore the metallogenic system should be understood to be "a full process from the sources of ore materials through their migration and concentration to formation of mineral deposits, as well as the tectonic environment and its evolution during this process and final formation of a mineral deposit and mineralization assemblage". Actually, a metallogenic system consists of three parts: the mineralization-related tectonic environment and its evolution, mineralizing processes involving migration and concentration of ore materials, and product of mineralizing processes—mineral deposits, mineralizations, anomalies, and their tempo-spatial distribution. These belong to a whole of things that have inherent relation. On the other hand, the modification of mineral deposits after their formation and the status of their preservation are the product of processes of another metallogenic system. For the study of regional mineral deposits or mineral deposits a unified study of the two systems is very necessary, but assigning the two systems to one system does not agree with the concept of the "system" itself.

If we evaluate the minerogenetic series and metallogenic system from their concepts that we understand and accept, we may find that their research contents are consistent: both are designed to study the mineralization-related tectonic environment, mineralizing processes, and product of mineralization in a particular time-space domain and explore their formation, evolution, and tempo-spatial distribution characteristics. What is different is first that the metallogenic system that a minerogenetic series addresses has a particular time-space domain: a minerogenetic series is a metallogenic system in a particular time-space domain; a minerogenetic series group is a metallogenic system in a still larger time-space domain; a minerogenetic series type is a metallogenic system in which minerogenetic series of the same kind with similar tectonic environments are formed. The research scope of a metallogenic system is variable. The larger one may be global or a metallogenic system of a particular age, while the smaller one a metallogenic system in which a mineral deposit is formed. The metallogenic systems studied for minerogenetic series are specific ones, mainly those within the time and space domains of minerogenetic series orders and also those in a certain time range and tectonic environment. Secondly, in the study of minerogenetic series, importance is attached to the finally formed mineral deposit assemblage and its tempo-spatial distribution characteristics and mutual relation because those have the most direct relations to the guidance of mineral prospecting, exploitation, and utilization. Thirdly, what the minerogenetic series studies is also a natural classification of mineral deposits, while the study of the metallogenic system does not include this content. The comparison between minerogenetic series and metallogenic systems is shown in Table 1.

Although minerogenetic series and metallogenic systems have different research connotations, they have common research content; and it is very important to carry out these studies. Therefore there is no mutually exclusive problem in the research, and objectively there is not the question which contains which; on the contrary, we may study them together so as to improve their research.

7 Theoretical and Practical Significance of Minerogenetic Series Research

The study of minerogenetic series is of theoretical significance. First, through studies, the tempo-spatial

Table 1 Comparison between minerogenetic series and metallogenic systems

		Minerogenetic series	Metallogenic system
Common point	Research content	In a specific time-space domain, study the tectonic environment related to mineralization and mineralizing processes and evolution of a natural mineral deposit assemblage entity, and tempo-spatial structures and distribution characteristics of various types of mineral deposit and explore their origins and genetic relations	In a specific time-space domain, study the constraints for the formation of mineral deposits, mineralizing processes, and resulting mineral deposits, mineralizations, and anomalies
Different point	Research scope	Study in specific time-space domains of orders I, II, and III of minerogenetic series	Generally a metallogenic region or belt, which may either larger or smaller
	Other connotation of research	A new natural classification of mineral deposits	Not

positions of every mineral deposit and every natural mineral deposit assemblage may be determined, thus providing the tempo-spatial distribution of ore materials, compositional structures, and evolutional characteristics in an area and even the entire earth. Through studies of the compositions of ore materials in various ages, mineral deposit type associations, and their evolutionary characteristics in the time-space domain, it is possible to probe into the evolutionary processes and characteristics of the earth, e.g. the mantle and crustal processes and evolution of various layers of the earth.

The practicability of minerogenetic series research is very prominent. From the beginning of this research, we took the actual demand for guiding mineral prospecting as the objective. After 30 years of research, minerogenetic series research may provide guidance for mineral prospecting in the following three aspects: (1) One of the core ideas of the minerogenetic series concept is that mineral deposits exist as a mineral deposit assemblage, while such a mineral deposit assemblage is composed of mineral deposits of different ore minerals and different origins in a particular tectonic environment and shows certain characteristics with respect to regional distribution. This furnishes a theoretical basis for regional integrated mineral prospecting. (2) Proposing the term minerogenetic series types gives important guidance on mineral prospecting in areas where there are similar tectonic environments and similar mineralizing processes; similar mineral deposit assemblages may be found through an analog study, which provides science-based guidance on the determination of a target of mineral prospecting in a new area and the targets of prospecting for possibly omitted minerals. (3) The establishment of minerogenetic series groups suggests that a minerogenetic series may be formed in different tectonic environments in a tectonic cycle, which provides an idea for the arrangement of mineral prospecting in a large region.

Over nearly 30 years, the use of the concept of minerogenetic series by a number of geological institutions and departments in the mineral prospecting practice has seen success to different degrees and the idea and method of search for a certain anticipated type of mineral deposit in a minerogenetic series have been summarized (Chen and Chen, 1996; Han et al., 1996, 2004; Liu et al., 1996; Zhang et al., 1996; Luo et al., 2000; Feng and Wang, 2004; Li et al., 2005). When the former Ministry of Geology and Mineral Resources conducted the second-round national-scale metallogenic regionalization during 1992–1995, it used the concept of minerogenetic series as the main geological theoretical basis of metallogenic regionalization, and very good results were achieved in metallogenic regionalization and guidance on metallogenic prediction (Cheng, 1999).

8 Further Deepening Minerogenetic Series Research

Thirty years have passed since the presentation of the concept of minerogenetic series. Although during the 30 years considerable research has been performed, which has resulted in continuous improvement of the concept and steady expansion of the application scope, there is still a need to study many and more complex contents in this area and the scope involved is very large and even global. Therefore we must conduct and deepen the research continuously and persistently. With respect to geological research, the following main work should be done in the near term.

(1) Further improve the concept of minerogenetic series;

(2) Improve the establishment of minerogenetic series of various geologic ages around China;

(3) Further improve the division of main tectono-metallogenic environments throughout China and on that basis improve the establishment of minerogenetic series types around China;

(4) Improve the establishment of minerogenetic series groups around China;

(5) Improve the establishment of mineral deposit models of various minerogenetic series;

(6) Improve the compilation of maps of minerogenetic series of various main geologic ages;

(7) Improve and establish the minerogenetic lineages in China's main metallogenic regions (belts);

(8) Establish a database of research results of minerogenetic series;

(9) Carry out a deep-going study of minerogenetic series in key metallogenic regions (belts) step by step;

(10) Conduct minerogenetic series research in surrounding countries;

(11) Strengthen the study of metallogenic speciation of minerogenetic series and deepen the study of metallogenic speciation of a particular minerogenetic series formed by a particular tectonic setting, a particular mineral accumulation environment, and combination of particular host rocks and country rocks.

The following middle- and long-term research on minerogenetic series should be conducted.

(1) Further deepen the study of minerogenetic series in key metallogenic regions (belts);

(2) Study the establishment of global minerogenetic

series, minerogenetic series types, minerogenetic series groups, and minerogenetic lineages;

(3) Study the tempo-spatial structures and evolutionary characteristics of ore materials and mineral deposit assemblages in various geologic ages;

(4) Explore the constraint relations between the evolutionary characteristics of ore materials and earth evolution and then trace the evolutionary process of the earth.

With respect to applications in mineral prospecting, we should gradually improve and establish a computer system including the integrated information about minerogenetic series, theory and method of metallogenic prediction, and retrieval and prediction of minerogenetic series and raise the reliability and efficiency of the prediction progressively.

We hold that the study and exploration of minerogenetic series are currently still in an initial stage. However, this work is very significant, being an important branch in areas of mineral deposit geology and metallogenic research. We hope that more colleagues could participate in this research and apply the research results to mineral prospecting. We believe that through uninterrupted, persistent studies this scientific concept that originated in China will develop and make its own contributions to developing the theory on mineral deposit geology, giving impetus to mineral prospecting, and benefiting society.

Acknowledgements

This research was supported by the project “Nationwide Important Mineral Resource Potential Prediction, Evaluation and Integration”, the project “Integrated Study of Metallogenic Systems of China”, and the project “Assessments of Mineral Resource Potential in Important Metallogenic Regions and Belts in Western China” sponsored by China Geological Survey and the state key-task scientific and technological research project “Evaluation Technology and Demonstration Study of Dominant Mineral Resource Potential in Western China”.

Manuscript received Sept. 12, 2018
accepted Jun. 24, 2019
associate EIC: FEI Hongcai
edited by FEI Hongcai

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