Metallogenic Effect of Transition of Tectonic Dynamic System*

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ABSTRACT: Tectonic dynamic system transition, one of the main factors in metallogenesis, controls metallogenic fluid movement and ore body location in orefields and on an ore deposit scale (mainly in the continental tectonic setting), and even the formation and distribution of large-scale deposit clusters. Tectonic dynamic system transition can be classified as the spacious difference of the tectonic dynamic system in various geological units and the temporal alteration of different tectonic dynamic systems. The former results in outburst of mineralization, while the latter leads to the metallogenic diversity. Both of them are the main contents of metallogenic effect of tectonic dynamic system transition, that is, the alteration of dynamic system, the occurrence of mineralization, and the difference of regional tectonic dynamic system and metallogenic diversity. Generally speaking, the coupling of spatial difference of tectonic dynamic system and its successive alternation controlled the tempo-spatial evolution regularity of mineralization on a larger scale. In addition, the analysis of mineralization factors and processes of typical ore deposits proved that the changes of tectonic stress field, the direct appearance of tectonic dynamic system transition, may lead to the accident of mineralization physical-chemical field and the corresponding accidental interfaces were always located at ore bodies.

KEY WORDS: tectonic dynamic system transition, metallogenic diversity, interface mineralization.

The metallogenic system is a complex system characterized by temporal outburst and spatial diversity. The transition of the tectonic dynamic system, one of the principal factors in metallogeny, is closely related to ore-forming process (mainly under the continent tectonic settings) and controls the formation and distribution of large deposit clusters, the movement and localization of ore-bearing fluid in the orefield and on an ore deposit scale. The transition of the tectonic dynamic system can be classified as the spacious difference of tectonic dynamic system in various geological units and the temporal alternation of different tectonic dynamic systems. The former can lead to the bursting and intermittent mineralization, while the latter may initiate the diversity of mineralization. Both of them are two important aspects of mineralization effects of the transition of the tectonic dynamic system, that is; ① in the same geological unit, the alteration of different tectonic dynamic systems can trigger the occurrence of massive mineralization; ② during the same geological period, the difference of tectonic dynamic system in various geological units leads to the multiplicity of mineralization. Moreover, the mineralization mechanism is an important aspect for the research into the mineralization effect of the
transition of tectonic dynamic system. The analysis of mineralization factors and ore-forming process of typical ore deposits showed that the changes in tectonic stress field could lead to the accident of metallogenic physical and chemical field. And the accident interface usually matches the location of an ore body. And this mineralization regularity is called “interface mineralization”.

**TRANSITION OF TECTONIC DYNAMIC SYSTEM AND OCCURRENCE OF METALLIZATION**

The “metallogenic outburst in the Yanshan period” in the eastern part of China is initiated by such large disturbances as the thinning of lithosphere, adjustment of thermo, mass and density structure in lithosphere, and transition of geotectonical pattern (Deng et al., 1999). The direct representation of the tectonic dynamic system transition is the changes in regional stress field. Accompanied by the directional change in the principal compressive stress from NWW-SEE to NE-SW, intense magmatic action and mineralization occurred in North China plate in Jurassic-Cretaceous. In South China, the formation of W, Sn, REE ore deposits arose from remelting granitic magmatic action in the middle and late Yanshan movement. Research showed that the remelting related to faults occurred in the late period when the tectonic stress was turning from NW to NE-NNE (Zhai et al., 2003; Mao and Wang, 2000; Lü et al., 1999; Wan and Zhu, 1996; Lü and Kong, 1993). The Jiaodong deposit cluster, located on the eastern margin of the North China craton, is the outgrowth of the “metallogenic outburst in the Yanshan period”. The tectonic dynamic system has experienced transitions for many times since Mesozoic in Jiaodong ore deposit cluster (Deng et al., 1999; Miao et al., 1997) from passive continental margin (230 – 150 Ma) to shearing continental margin (150 – 110 Ma), and finally to active continental margin where the active continental margin converted from oblique subduction (110 – 45 Ma) to obverse subduction (45 Ma). The tectonic system transition was a basic force to activate, transport and accumulate the crust-mantle ore-forming materials in the shallow crust. Generally speaking, in the early shearing and compressional state, the ore-forming fluid components and rock compositions reacted with and converted to each other; while in the late shearing and extensional state, hydrothermal fluid started to precipitate, resulting in metasomatism and mineralization. The analysis of cleavage, petrofabric, fossil stress and strain in orefields and ore deposits included in Jiaodong deposit cluster, such as Linglong, Jiaojia orefield and Xiadian gold ore deposit shows that the tectonic stress field experienced a great change in the early and middle mineralization epochs (Lü et al., 1999; Lü and Kong, 1993). This change is concordant with regional stress field influenced by the plate movement. In Linglong gold deposit, the change in tectonic stress field showed its synchronism with fluid pulsation otherwise, indicating that the regular transition of tectonic stress field controlled fluid pulsation. In addition, the multi-stage mineralization also showed approximately periodical regular pattern (Fig. 1).

![Figure 1. Transition of tectonic stress field and tectonics-fluid pulse in Linglong gold ore deposit (after Zhao et al. (1996) and Deng (1998)).](image-url)

**DIFFERENCE OF TECTONIC DYNAMIC SYSTEM AND METALLOGENIC DIVERSITY**

Controlled eventually by tectonic dynamic processes, the metallogenic system can be classified as extensional, compressional, slip, uplift, subsidence, macroscopic ductile-shear and meteor-impact structural metallogenic systems. The different stress conditions, geothermic gradients, tectonic styles, rock formations, magmatic actions and metamorphisms in each structural metallogenic system may lead to the movements of different fluids, and, as a result, lead to different types of mineralizations, giving rise to the metallogenic diversity. Moreover, the spatial transition belt (also called tempo-spatial transition domain) between different tectonic metallogenic systems is the priority mineralization situation (Zhai et al., 1999). For example, with the oceanic trench dive and compressing, formed the collision superimposed type gold deposit; with the basin extension and depression, developed the sedimental strata-bounded gold deposits and in the volcano and
island arc region where there is the transition belt between extensional and compressing conditions, the endogenous gold deposit occurred easily (Deng et al., 2001). The representative types of transition belt include the domain between ductile and brittle dynamic systems and the conjunction between continental and oceanic lithospheres. The temperature in the domain between ductile and brittle dynamic systems ranges from 250 to 300 °C and the corresponding pressure from 0.1 to 0.3 GPa (Zhai et al., 1997), which are the optimum conditions of enrichment and deposition of metallogenic elements. This domain is also the transition zone from closed system to open system, favorable for the metallization, too (Deng et al., 2001). The conjunction belt between continental and oceanic lithosphere—the paleocontinental margin shows more favorable factors for metallogeny. The mutual matches between metallogenic factors, including the abundance of metallogenic mass, syntaxis of polygenetic metallogenic fluid, long-time activity of macroscopic structure, high thermal abnormality, interaction between mantle and crust, manifold geological settings and lengthy mineralization history, induce greatly the enrichment of metallic elements (Zhai et al., 2003).

It should be emphasized that massive intraplate metallization may occur in a single tectonic system for the persisted intense stress action. Yet in the secondary mineralization scale (such as among different orefields in a deposit cluster, even among different ore deposits in an orefield), the fluid features and water-rock reactions vary in their different tectonic locations, temperature-pressure conditions. In addition, the local inhomogeneity of other geological conditions, favorable for metallization, takes on the secondary diversity in the meantime (Xu et al., 1998; Yang and Zhang, 1996).

**TRANSITION OF TECTONIC STRESS FIELD AND INTERFACE METALLIZATION**

The metallogenic mechanism of the transition of tectonic dynamic system is the fluid physical movement and the chemical reaction in water-rock system under special conditions, presenting directly the variation of physical and chemical parameters during mineralization. A typical gold orefield—Jiaojia orefield in Jiaodong deposit cluster is systematically studied to explain the relationship between the transition of regional tectonic stress field and the variance of metallogenic physical-chemical parameters. The change in the tectonic stress field in this orefield is accordant obviously with that in the whole deposit cluster (Figs. 2, 3). That is, the regional stress field was in a ductile compressional and shearing state before metallization (230—150 Ma), in a brittle shearing and extensional state in the early metallization stage (150—135 Ma), in a brittle shearing and extensional state during the main metallogenic stage (135—110 Ma).
Ma), and in a pressing and shearing state again after metallization (110—65 Ma). The value of stress in the main metallogenic stage was less than that before metallization. The direction of the maximum stress is NW-SE in the early metallogenic stage, and the values of principal compressing stress, shearing stress, energy, moving potential and cracked coefficient decrease from the middle of the main fault belt to its sides; but the value of the maximum stress is always high in the places where the secondary faults develop. However, during the main metallogenic stage, the direction of principal compressive stress is NE-SW, and the values of principal compressive stress, shearing stress, energy and moving potential increase from the middle of the fault belt to the sides. Therefore, the stress field was transforming from a strong compressional state to a weak shearing and extensional state during metallogenic period in Jiaojia orefield. It is in the weak place of rock physical interface that Au-rich sulfides and crevice-Au are easy to deposit from metallogenic fluid, that is, the gold mineralization occurs in the temporal-spatial transiting interface between the shearing and compressional state and the shearing and extensional state. This mineralization regularity also occurs on the secondary deposit scale, such as in the Xiadian gold deposit (Deng et al., 1998).

The research into the mineralization in the same orefield demonstrates that the transition interface of drastic stress decrease is in agreement with that of the multiform metallization physical and chemical parameters that experienced a sudden change (Fig. 4), indicating that the transition of tectonic stress field leads to the readjustment of the structure of metallogenic physical and chemical field and the formation of a unified physical and chemical interface, where occurred multiform alterations and metallizations.

**DISCUSSION**

1) Both the above-mentioned spatial difference and temporal alternation of tectonic dynamic system controlled the tempo-spatial evolution regularity of metallization on the ore deposit cluster-orefield-deposit scale. Generally speaking, the coupling of the temporal and spatial changes of tectonic dynamical system can constrain the metallization on a larger scale. For example, based on the supercontinent evolution, the geological evolution and metallization on the global scale can be divided into three periods (Kerrich, 1992): ① the period of unstable crust in Archean (2 600 Ma) when massive sulfide deposits formed in volcanic rocks, gold deposits in metamorphic rock and nickel deposit in komatite; ② the geological period of stable continent in Proterozoic era (2 600—600 Ma) when metallization showed great diversity and the Pb-Zn deposits were related to extension-rift basin was widely developed; ③ the Phanerozoic (after 6 00 Ma). With the formation of
Pangea. Many Pb, Zn, Cu mineralization bodies occurred in intraplate extensional basin. With the decomposition of Pangea, Au deposit and leguminous chromite deposit occurred in island arc or extensional basin.

(2) Although the effect of the transition of tectonic dynamic system on fluid metallization is discussed in the paper, it should be pointed out that the feedback action of fluid on the tectonic evolution is still very important. For example, the insertion of fluid and the change in fluid compositions may also affect the physical properties of the rocks, leading to the tectonic stress diversity (Wawrzyniec et al., 1999).

(3) The general regularity of mineralization effect of the tectonic system transition is preliminarily summarized above, but it is still needed to obtain its common model. Detailed research on some typical deposit clusters in the following two aspects is expected: (1) the main types and temporal-spatial structure of transition of tectonic dynamic system; (2) the physical-chemical mechanism of interaction among tectonic transition, geofluid movement and mineralization.

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REFERENCES CITED


