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Study on Prospecting Indicators and Metallogenic Model of Alteration-Type Gold Deposits

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Abstract: The formation of structural alteration-type gold deposits is closely associated with tectonic activity and hydrothermal alteration processes. The accurate establishment of prospecting indicators and metallogenic models plays a crucial guiding role in mineral exploration. This paper systematically examines the material composition and formation conditions of structural alteration-type gold deposits, identifying three core categories of prospecting indicators: geological structures, mineral assemblages, and geochemical characteristics. By integrating the evolutionary behavior of metallogenic fluids, a metallogenic model characterized by "structural control of mineralization–fluid migration–alteration and mineralization" is established, and quantitative formulas for fluid metallogenic efficiency and alteration intensity are introduced to support the analysis. The results of this study can improve the accuracy of prospecting for this type of gold deposit and provide reliable theoretical and technical support for practical exploration activities.

Keywords: Structural alteration-type gold deposits; prospecting indicators; metallogenic model

Introduction

Structural alteration-type gold deposits represent one of the most important gold deposit types in China, with significant resource reserves and development value. Ore bodies of this type are commonly associated with specific structural zones and altered rock units, and exploration efficiency is often reduced due to the interference of complex geological conditions. At present, some exploration programs lack systematic prospecting indicators and metallogenic models, resulting in unclear target delineation and biased resource evaluation. In view of these issues, this study focuses on the key metallogenic elements of structural alteration-type gold deposits,

refines specific prospecting indicators, and constructs a targeted metallogenic model. Quantitative formulas are introduced to enhance the scientific rigor and practical applicability of the research.

1. Core Prospecting Indicators of Structural Alteration-Type Gold Deposits

1.1 Geological Structural Indicators: The Spatial Positioning Role of Ore-Controlling Structures

The formation and distribution of structural alteration-type gold deposits are strictly controlled by specific geological structural units, especially deep-seated major faults and their associated secondary faults, which constitute the migration pathways for ore-forming fluids and the spaces for mineral precipitation. Deep-

seated major fault zones are generally characterized by long extension distances and great cutting depths. They can connect deep and shallow crustal geological bodies, providing fundamental conduits for the upward migration of metallogenic fluids. Secondary faults are mostly developed along the margins of deep-seated major faults and are distributed in feather-like or branch-like patterns. The fracture spaces within these faults, as well as tectonic breccia zones, serve as key sites for mineral precipitation. The multi-stage nature of tectonic activity leads to complex internal structural variations within fault zones. Early-formed structural fabrics, modified by later tectonic events, commonly evolve into densely developed cleavage zones and schistose bands. In these areas, rock porosity and permeability are significantly enhanced, creating favorable conditions for the infiltration of metallogenic fluids and the enrichment of ore materials [1]. Moreover, at the contact zones between fault zones and surrounding rocks, pronounced lithological contrasts often occur. Such contrasts can cause abrupt changes in the physicochemical conditions of the fluids, thereby promoting the precipitation of gold from the fluids and the formation of ore bodies.

1.2 Mineral Assemblage Indicators: Indicative Significance of Alteration Minerals

The formation of structural alteration-type gold deposits is accompanied by intense hydrothermal alteration, and the presence of specific alteration mineral assemblages can directly indicate the occurrence and enrichment degree of gold mineralization. Pyrite is the most common gold-bearing mineral in this type of deposit, and its morphology, texture, and geochemical characteristics are closely related to gold enrichment. Coarse-grained cubic pyrite typically forms during the early stage of mineralization and generally exhibits a relatively low gold-bearing capacity. In contrast, fine-grained disseminated or framboidal pyrite is commonly formed during the main mineralization stage. Such pyrite contains abundant microfractures and lattice defects within the crystals, which provide favorable sites for the adsorption and enrichment of gold. Sericitization is one of the most typical alteration types in structural alteration-type gold deposits. Sericite is mainly produced by the hydrothermal alteration of feldspar and usually occurs

as flaky aggregates distributed in rocks near fault zones. The intensity and spatial extent of sericitization are generally positively correlated with the scale of gold mineralization. Silicification is also prominent during the mineralization process. Silica introduced by hydrothermal fluids precipitates within rock fractures to form quartz veins or silicified rocks. Quartz color may range from colorless and transparent to milky white; when quartz contains pyrite inclusions or exhibits a smoky-gray appearance, it often indicates the presence of nearby gold mineralization. In addition, alteration types such as chloritization and carbonatization also have important indicative significance. Chloritization commonly develops in the footwall of ore bodies, whereas carbonatization is more frequently observed along the margins of mineralized zones. The combined characteristics of these alteration mineral assemblages provide an effective basis for delineating the spatial extent of gold mineralization.

1.3 Geochemical Indicators: Quantitative Significance of Elemental Anomalies

Anomalous variations in geochemical characteristics constitute an important basis for identifying structural alteration-type gold deposits. Abnormal concentrations of gold and associated elements can accurately indicate the location and scale of mineralized bodies. Geochemical anomalies of gold typically manifest as continuous high-value anomaly zones, whose morphology and extension direction are commonly consistent with the strike of ore-controlling faults. Anomaly values generally decrease gradually from the center toward the margins, forming a distinct concentration gradient. Assemblages of associated elements exhibit significant indicative value. Elements such as arsenic (As), antimony (Sb), and mercury (Hg) often migrate together with gold in hydrothermal fluids and form synchronous geochemical anomalies in the vicinity of mineralized bodies. The anomalous ranges of these elements are usually broader than those of gold and therefore serve as effective indirect prospecting indicators. Anomalies of polymetallic elements such as copper (Cu), lead (Pb), and zinc (Zn) also show spatial associations with gold mineralization. In some gold-bearing zones, minor amounts of polymetallic sulfides may occur, resulting in localized high concentrations of these elements. In soil geochemical surveys, gold

concentrations exceeding five times the regional background value are generally considered anomalous. In rock geochemical analyses, gold contents greater than 1×10^{-6} indicate the presence of mineralization with potential industrial value [2]. Through the systematic collection and analysis of rock and soil samples, geochemical methods can rapidly delineate prospective exploration targets.

2. Construction of the Metallogenic Model for Structural Alteration-Type Gold Deposits

2.1 Sources and Evolution of Ore-Forming Fluids

Ore-forming fluids in structural alteration-type gold deposits exhibit multi-source characteristics, mainly including magmatic fluids derived from the deep crust, metamorphic fluids generated during metamorphic processes, and circulating fluids involving meteoric water. During magmatic activity, volatiles and ore-forming materials within magma chambers form magmatic fluids under high-temperature and high-pressure conditions. These fluids are enriched in gold, sulfur, and other metallogenic elements, and are characterized by high temperature and pressure. Regional metamorphism causes decomposition and recrystallization of minerals in rocks, releasing large amounts of ore-bearing fluids. Metamorphic fluids generally have relatively stable chemical compositions, enabling long-distance migration while transporting metallogenic materials. Meteoric water infiltrates deep underground along fault structures and subsequently mixes with magmatic and metamorphic fluids, forming mixed fluids with complex compositions. During the mixing process, the physicochemical properties of the fluids change, enhancing their capacity to dissolve and transport ore-forming elements. As ore-forming fluids migrate, decreases in temperature and pressure, together with interactions with surrounding rocks, lead to changes in pH and redox potential. These changes reduce the solubility of metallogenic components, causing gold to gradually precipitate from the fluids and form gold mineralization bodies.

2.2 Multistage Structural Ore-Controlling Mechanism

Tectonic activity plays a multistage controlling role in the metallogenesis of structurally altered rock–type gold deposits, closely influencing both the migration of ore-forming fluids and the precipitation of ore materials. During the pre-mineralization stage, the formation and development of deep-seated major faults provide primary migration pathways for ore-forming fluids. At this stage, tectonic activity is dominated by extensional faulting, and the internal space of fault zones continuously expands, creating favorable conditions for fluid accumulation. In the main mineralization stage, tectonic activity shifts to a compressional–transpressional regime. Fault zones undergo compressive deformation, resulting in intense rock fragmentation and alteration, and forming abundant tectonic breccias and fracture systems. These fractured zones become the principal sites for ore-forming fluid infiltration and mineral precipitation. The episodic nature of tectonic activity causes the mineralization process to exhibit a multistage character; each tectonic event triggers renewed fluid migration and superimposed enrichment of ore materials, leading to continuous enlargement of ore bodies and progressive improvement in ore grade [3]. In the post-mineralization stage, tectonic activity gradually weakens, and fault zones are filled by later-formed rocks or minerals. This infilling plays a protective role for the already formed ore bodies, preventing them from being subjected to weathering, erosion, and destruction.

2.3 Coupling Relationship Between Alteration and Mineralization and Its Quantitative Expression

A close coupling relationship exists between alteration and mineralization. Alteration processes not only modify the physical and chemical properties of rocks but also provide essential conditions for the precipitation of ore materials. This coupling relationship can be quantitatively analyzed using relevant formulas. When ore-forming fluids interact with surrounding rocks, mineral alteration is induced. Alteration increases rock porosity, creating space for the adsorption and precipitation of ore materials. The alteration intensity (SI) can be quantified based on the content and spatial distribution of alteration minerals, and is expressed as:

$$SI = \frac{\sum_{i=1}^{n}(C_i \times S_i)}{S_{total}} \times 100\%$$

where SI is the alteration intensity (%); C_i is the content of the i-th alteration mineral (%); S_i is the distribution area of the i-th alteration mineral (m²); S_{total} is the total area of the study region (m²); and n is the number of alteration mineral types. This formula

effectively reflects the overall intensity of alteration within the study area and provides a quantitative basis for evaluating mineralization potential.

Mineralization efficiency (ME) depends on the concentration of ore components in the ore-forming fluid, the migration velocity of the fluid, and the adsorption capacity of altered rocks. It can be expressed as:

$$ME = \frac{C_{gold} \times V_f \times K}{T \times P}$$

where ME is the mineralization efficiency kg/m³; C_{gold} is the concentration of gold in the ore-forming fluid (g/L); V_f is the migration velocity of the ore-forming fluid (m/s); K is the adsorption coefficient of altered rocks for gold (L/kg); T is the temperature of the ore-forming fluid (K); and P is the pressure of the ore-forming fluid (Pa). The magnitude of mineralization efficiency directly controls the grade and scale of ore bodies. This formula enables comparative analysis of metallogenic potential across different regions.

3. Application Synergy Between Prospecting Indicators and Metallogenic Models

3.1 Optimization of Exploration Workflow Through Integrated Multi-Indicator Identification

Exploration of structurally altered rock–type gold deposits should be based on the integrated identification of multiple prospecting indicators, establishing a three-level exploration workflow of "macroscopic–microscopic–geochemical" investigation. At the macroscopic scale, regional geological mapping is used to identify the spatial distribution characteristics of major deep-seated faults and their secondary fault systems, thereby delineating structurally favorable zones. Particular attention should be paid to fault intersections and bend zones, which are commonly key sites for the accumulation of ore-forming fluids. At the microscopic scale, rock samples are collected within these structurally favorable zones and examined under the microscope to identify the assemblages and spatial distribution of characteristic alteration minerals, such as pyrite and sericite, in order to determine the presence of mineralization indications [4]. At the geochemical scale, systematic rock and soil geochemical surveys are conducted in areas where anomalies are confirmed at the microscopic level, delineating the anomaly ranges of gold and associated elements and accurately locating

the spatial position of ore bodies. The coordinated application of this three-level exploration workflow can significantly enhance the efficiency and precision of prospecting, effectively avoiding exploration bias caused by reliance on a single indicator.

3.2 Target Area Optimization Guided by the Metallogenic Model

The metallogenic model provides systematic theoretical guidance for target area optimization of structurally altered rock–type gold deposits. Based on the metallogenic model of "structural ore control–fluid migration–alteration mineralization," an evaluation system for target area selection can be established. The evaluation system first focuses on the integrity and activity of ore-controlling structures, prioritizing fault zones with multi-stage tectonic activity and adjacent areas where secondary faults are well developed. These areas possess favorable fluid pathways and sufficient space for mineral precipitation. Secondly, the evolutionary characteristics of ore-forming fluids are analyzed. Through methods such as fluid inclusion thermometry and compositional analysis, the temperature and pressure ranges of ore-forming fluids are determined, and zones where abrupt changes in the physicochemical conditions of fluids occur are delineated. Finally, combined with the quantitative calculation results of alteration intensity and mineralization efficiency, the metallogenic potential of different areas is comprehensively scored. Areas with scores above 80 are defined as first-order targets, those scoring 60–80 as second-order targets, and those below 60 as prospective areas. Target area optimization guided by the metallogenic model enables targeted exploration, thereby reducing exploration costs.

3.3 Establishment and Implementation of a Dynamic Adjustment Mechanism

Prospecting indicators and metallogenic models of structurally altered rock–type gold deposits are not static and should be dynamically adjusted based on actual exploration data. During exploration, geological, mineralogical, and geochemical data should be regularly compiled and analyzed, and discrepancies between actual findings and theoretical models should be compared. When mismatches occur between prospecting indicators and the metallogenic model, the causes should be thoroughly

investigated. If discrepancies result from data errors, sampling and analytical work should be repeated; if they stem from model deficiencies, the parameters and processes of the metallogenic model should be adjusted based on new data. For example, in a certain exploration area, a negative correlation was observed between sericitization intensity and the scale of gold mineralization, which contradicted the original model. Further investigation revealed that late-stage hydrothermal overprinting had occurred in the area, resulting in the replacement of sericite by later minerals. Accordingly, the evaluation criteria for mineral assemblage indicators were revised, improving the applicability of the model [5]. The establishment and implementation of a dynamic adjustment mechanism ensure that prospecting indicators and metallogenic models maintain a high level of scientific rigor and practical relevance.

Conclusion

This study identifies three core prospecting indicators—geological structures, mineral assemblages, and geochemical characteristics—for structurally altered rock–type gold deposits, and clarifies their specific features and indicative significance. Based on the evolution of ore-forming fluids and mechanisms of structural ore control, a metallogenic model of "structural ore control–fluid migration–alteration mineralization" is established, with quantitative formulas for alteration intensity and mineralization efficiency introduced to enhance practical applicability. A three-level exploration workflow of "macroscopic–microscopic–geochemical" investigation and a metallogenic model–guided target area optimization approach are proposed, along with a dynamic adjustment mechanism for the prospecting system. The results provide systematic support for exploration of structurally altered rock–type gold deposits. Future studies may further improve accuracy and application value by integrating high-precision exploration technologies.

References

[1] Wang Bin, Zhou Mingling, Ding Zhengjiang, et al. Structural ore-controlling mechanisms and three-dimensional deep positioning prediction of altered rock–type gold deposits in northwestern Jiaodong Peninsula [J]. Earth Science Frontiers, 2025, 32(4): 140–154.

[2] Qi Yaogang, Meng Yong, Zhou Lin, et al. Characteristics and resource potential of structurally altered rock–type gold deposits in the East Kunlun metallogenic belt [J]. Gold Science and Technology, 2025, 33(3): 497–510.

[3] Zeng Qingdong, Wang Fengwei, Liu Fuxing, et al. New discovery of the Wulong altered rock–type gold deposit in the Liaodong gold province [J]. Acta Petrologica Sinica, 2025, 41(9): 2889–2896.

[4] Yang Xingke, Han Ke, He Hujun, et al. Intraplate orogenic-stage structural–alteration lithofacies mapping and prospecting model of the Changgou gold deposit, Hanyin gold field, South Qinling [J]. Geological Bulletin of China, 2020, 39(11): 1715–1725.

[5] Liu Xiaonian, Liang Longfei, Sun Weiguo, et al. Geological conditions and prospecting patterns of structurally altered rock–type gold deposits in southeastern Hubei [J]. World Nonferrous Metals, 2020(12): 60–61.