Preliminary Study on the Characteristics of Ductile Shear Zone Type Gold Deposit

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Abstract. The ductile shear zone type gold deposit is a very important type of gold deposit. For the study of metallogenic characteristics of ductile shear zone, the development is extremely rapid, and there are already quite mature research methods and relatively complete research contents. This paper mainly focuses on the structural characteristics, fabric characteristics of the shear zone, the relationship between the deformation of the shear zone and mineralization, the relationship between gold deposits and shear zones, the geochemical characteristics of the shear zone gold deposits, the metallogenic model and the future. The research direction has been made a simple narrative.

1. Introduction
The ductile shear zone, also known as the ductile fault, is a band-like spreading, high strain zone developed at a certain depth of the earth's crust, and is a two-layer structure in which the surface brittle fault forms a fracture to the deep extension of the crust and the surface brittle fracture Mode [1].

Sibson [2] and Ramsay [3] first published the classic theory of the ductile shear zone, that is, it is a strip-shaped, high-strain zone that develops to a certain depth in the earth's crust. Almost at the same time, Boyle [4] first proposed the ductile shear zone type gold deposit in 1979, the type of gold deposit associated with the ductile shear zone. Since then, the theory and application of the ductile shear zone and the study of the shear zone type gold deposit have made great progress. It is not only found that the altered mylonite type gold deposit is related to the ductile shear zone, but also a considerable amount of original The gold deposits classified into quartz veins are also related to ductile shear zones, and a number of shear zone gold deposits have been found based on shear band theory. At the same time, progress has been made in the study of the ore-forming mechanism and ductile shear deformation of the ductile shear zone on the migration and enrichment of ore-forming elements.

At present, the research on ductile shear zone type gold deposits has achieved fruitful results at home and abroad, and the relationship between ductile shear zone and gold mineralization has been studied in depth. In China, Ding Shijiang [5], Yu Mingxu [6] and other systems studied the relationship between
ductile shear zone and gold mineralization; Wang Henian et al. [7], Wang Liandeng et al. [8] studied ductile shear and gold ore. The relationship between the chemical periods, etc.; Qu Yajun [9] studied the types of gold deposits in the ductile shear zone and related prospecting indicators; Chen Berlin et al. [10] studied the types of tectonic deformation and gold mineralization in the ductile shear zone. Type relationship; Li Xiaofeng et al. [11] studied the relationship between ductile shear zone and gold deposit from time and space and genesis; Rattenbury et al. [13] systematically studied ductile shear and gold mineralization stage. The relationship between etc.

The shear zone not only controls the spatial distribution of the gold deposit, but also is a favorable channel for the migration of gold-bearing fluids. In addition, the shearing action causes gold mineralization and enrichment, which is an important mechanism for the formation of gold deposits. From the composition of the gold-containing shear band, there are both ductile shear bands, superimposed brittle-ductile shear bands, and even brittle shear bands. Therefore, shear-band gold deposits have complex structures and rock deformations of different types of rocks, and have significant features in geochemistry and metallogenic models [14].

2. Shear band fabric characteristics
The more common microscopic structures in the ductile shear zone are mainly (not necessarily all visible in a ductile shear zone) micro-pleats, mainly micro-pleats or structural lens bodies formed by shearing forces. Often composed of mineral particles oriented, more common in quartz veins; rotating eyeballs, lens bodies and pressure shadows, generally by relatively rigid minerals (such as plagioclase) and some coarse-grained minerals (such as quartz) The rotation and elongation that occur are oriented along the direction of the vertical stress, and the minerals (such as sericite) that are easy to comb are often concentrated at the ends of the eyeball or lens body into a tail-like pressure shadow; the mineral stretching line, More common is the tensile line structure composed of quartz and quartz aggregates; dislocation phenomenon, minerals in the strong ribbed lithification center, a large number of dislocations can be seen under transmission electron microscopy, and the dislocation phenomenon becomes weak outward; quartz The wire-drawing structure, in the sillimanite grain, visible quartz core, its wire drawing structure is obvious, the orientation is roughly parallel with the SC band; kink phenomenon, the kink phenomenon of mica minerals is often seen under orthogonal microscope, and the performance is mostly cleavage Bending, in the shape of "S"; subgranular, as in the larger quartz particle profile, forming near-granular polygonal sub-particles, sometimes further recrystallization causes the sub-particle boundaries to disappear, but can still be identified; Recrystallization, mostly developed in mylonite, its expression is also diverse, but the general trend is that the initial stage is mainly granulation, healing and reorientation by recrystallization; in addition, there are nuclear raft structures, SC Structures such as faceting are also common. The above microscopic structure can reflect the deformation characteristics of the ductile shear zone at different deformation stages from the microscopic scale, and the activation, migration, enrichment and precipitation of the ore-forming elements under different deformation stages and different deformation characteristics will also Different characteristics are presented, so by studying the microstructure, it can help to understand the metallogenic process of this type of gold deposit [15].

3. Deformation characteristics of shear zone and metallogenic relationship
The deformation in the ductile shear zone is multi-stage, and the early deformation is mostly plastic or ductile deformation. With the ductile shearing action, it gradually transforms into ductile-brittle deformation and brittle deformation. Various microstructures are formed at different stages of deformation, such as the mineral phase does not change during the early deformation process, but only changes in mineral structure, morphology and particle size. In the mylonite with low degree of deformation, the minerals mainly produce wavy extinction, deformation marks, deformed strips and mechanical twins. These structures can well reflect the temperature and pressure conditions of rock deformation. Liu Tiebing et al. [16] through rock deformation experiments and studies on natural
mylonite show that the deformation of rock under different temperature and pressure conditions can form different microstructures. For example, if the biotite is in the condition of green schist facies (when the temperature is low), the deformation is mainly a simple open kink, and with the increase of temperature and pressure conditions, the kink becomes sharp and narrow, under the condition of high green schist facies. (When the temperature is high), a large amount of recrystallization begins to occur. The appearance and transformation of the above microscopic structures reflect certain ore-forming environments and deformation characteristics. More importantly, in the process of ductile deformation, it is often accompanied by fine granulation, pressure dissolution, fluid action, metamorphism, and differentiation. Structural decomposition, tectonic metamorphism and alteration, etc., which have important effects on the activation, migration, enrichment and precipitation of ore-forming elements, such as fine granulation, enhance the activity and permeability of rocks, and provide for ore-bearing fluids. Channel, pressure dissolution is an important driving force for the activation and precipitation of mineral elements Au. The fluid action can accelerate the migration and exchange of material components in the strain system. The metamorphic reaction can release SiO₂, CO₂, H₂O, Au, Fe from the surrounding rock. Components such as Cu, S, Pb, and Zn constitute a hydrothermal fluid. Xu Xuechun [17] shows that with the degeneration and metamorphism of the ductile shear deformation process, the gold-bearing ductile shear zone can be degraded and metamorphosed by the green schist facies and corresponding mineral combinations, such as biotite (green)+ Muscovite + quartz + feldspar, and gold elements are obviously enriched in strong degenerate metamorphic belts. Zhang Xiaodong et al.’s research shows that due to the deep toughness deformation, the chemical position of Au can be increased, causing it to break away from the original mineral or rock occurrence sites, and with Ag, Pb, Zn, Cu and other mineralization elements and Si, The components such as K, Na, and H₂O are activated and differentiated to form a mineral-containing hydrothermal fluid to change the chemical composition of the original rock.

Studies have shown that the nature of tectonic deformation has a close relationship with the migration and enrichment of ore-forming materials. For example, Chen Bolin [10] shows that with the change of the deformation type in the ductile shear zone, the enrichment of ore-forming materials the degree is also different. It is generally believed that in the early stage of ductile shearing, the deformation is mainly ductile deformation due to the high temperature and pressure conditions in the deep part. In the process, micro-cracks, C-facets, and lattice dislocations and grain boundary slips are often formed. At this time, the ore-forming materials are activated and preliminarily enriched, but they are not enough for mineralization. With the progress of ductile shearing and changes in temperature and pressure conditions, the deformation gradually transforms into ductile-brittle and brittle, and each formed in the early stage. The microscopic structure has also been expanded into fissures, fragmentation zones, etc., providing space conditions for the further enrichment of ore-forming materials, and the process of entering the tough-brittle and brittle zones from the ascending ore-bearing hydrothermal fluid in the deep ascending. It continuously activates the ore-forming materials in the extracted ore source layer and superimposes it with the previous enrichment to further increase the enrichment level, thereby providing a sufficient material source for mineralization.

4. Metallogenic mode

There are many disputes about the metallogenic model of ductile shear zone type gold deposits. Many scholars have proposed corresponding metallogenic models from different aspects. Among them, the “three-stage” model proposed by Bonnemaison [18] has the greatest impact. The main point of this model: in the early stage of ductile deformation, the structural deformation and hydrothermal erosion become the main, and the disseminated gold mineralization of toxic sand and sulfide is formed on the mylonated lithological surface, which makes the Au element preliminary rich. The ore bodies formed generally do not have industrial value. In the mid-term tough-brittle deformation stage, the initial Au element does not exist as an independent mineral, but exists in the form of a complex, which is only enriched at the edge of the arsenopyrite crystal. The insidious milky-white quartz veins are located in or near the early ductile shear zone. Elements of Bi, W, Mu, or Sn may be symbiotic in this vein, and some
of them become new mineralization during the re-activity of the structure. The carrier, but in general inherits the mineralization in the early stage and reactivates the enrichment to form a gold deposit. This phenomenon is reflected in the enrichment phase in the mid-stage and forms an independent natural gold for the first time. In the late stage of brittleness, reticular quartz veins are formed, and different grades of gold are formed in different mineralized forms. This model played a very positive role in the mineralization prediction and prospecting work of the early ductile shear zone type gold deposits, and found more large gold deposits. However, with the research on the metallogenic model of ductile shear zone type gold deposits and the actual mining of specific deposits, it is gradually found that the metallogenic model has many problems that cannot be explained or even deviated from the facts, such as ductile shear zone type gold deposits. The "block gold" that often appears in the middle. Therefore, many scholars have begun to study their relationship between the ductile shear zone and gold mineralization in specific deposits, and then proposed their own metallogenic model.

Fu Shanling et al. [15] considered that the mineralization of ductile shear zone type gold deposits can be divided into four stages: the activation stage of ore-forming elements. During the early ductile deformation process, the rocks are in a high temperature, high pressure and high chemical position. In the overall compression state, strong plastic deformation occurs, and a large amount of H₂O and CO₂ are released from the rock-forming minerals, and a strong water-rock reaction occurs with the surrounding rock to form a medium-high temperature alteration zone, but in the process, The permeability and solubility of the rock increase, and the gold element in the mineral dissociates into the fluid to form the ore-bearing hydrothermal fluid. However, since the rock at this time is in a high pressure state and there is no obvious crack, the gold-containing fluid does not. It is possible to make a large-scale migration, so it constitutes a temporary, nearly closed circulation system, and the ore-forming elements produce a large-scale activation. During the migration and enrichment stage of ore-forming elements, when the shear zone starts to transform toughness, some micro-cracks are often induced in the rock, and a high fluid pressure gradient is established to promote the gold-bearing fluid along the shear zone. The micro-cracks rise and the intermediate temperature alteration occurs, which further strengthens the Au element migration from the mineral source layer, and finally enriches the Au element in the ore-bearing hydrothermal fluid in the ductile shear zone. During the sedimentation and mineralization stage of ore-forming elements, as the ductile shearing progresses, the ductile deformation is transformed into a ductile-brittle deformation. Due to partial release of stress or reduction of burial depth, the early microfractures begin to expand, making the temperature Gradient, pressure gradient, chemical position, etc. are also significantly reduced, resulting in the reaction of fluid with surrounding rock, and the Au element is precipitated to form a gold deposit, but the gold grade formed at this time is still relatively low, not enough to form Large-scale gold nugget; in the later stage of superimposed transformation, the brittle deformation occurred in the later stage of ductile shearing formed brittle fracture zone or fracture zone, providing a channel and deposition site for further enrichment of gold elements, such as along ductile shear The intrusive hydrothermal activity promotes the further activation and migration of Au in the ductile shear zone. The ductile shear zone formed in the early stage only serves as a channel for the ore-bearing fluid, and the ductile-brittle zone and brittle fracture zone or fracture zone formed in the later stage become a good ore-bearing structure. Due to the multi-cycle nature of the tectonic movement, the activity of the ductile shear zone will also be multi-stage, so the multi-stage ductile shearing activity will inevitably lead to the multi-stage nature of the migration and enrichment process of the Au element. The superposition of stacks provides sufficient ore-forming materials to form rich and large gold deposits.

5. Prospects for research on characteristics of ductile shear zone gold deposits

1. Systematic study of the main rock-forming mineral combinations and their deformation characteristics in the mylonite, calculating the stress-strain parameters of the shear-deformed rock, and clarifying the stress-strain environment in the ductile shear zone.

2. Systematic study of the migration mechanism of the major elements and the stress-sequencing of activation transfer under the action of natural strong shear stress in the ductile shear zone: although the
migration of macroscopic elements in the underground fluids, especially the thermal fluids, is quite consistent understanding, but due to the addition of strong strain conditions, the geochemical properties of the elements have been changed. The current understanding is not uniform. On the contrary, this is mainly due to the systematic comparative study of rocks of different deformation grades; As a research object, the tape cutting is an in-depth systematic study on the rheological characteristics of ductile shear zone and rock geochemistry, and explores the activation and migration of rock chemical composition in the process of occurrence, development and evolution of ductile shear zone. The formation of ductile shear zone mylonite is related to the mechanism of change of elements (isotopes).

(3) Systematically study the changes of trace chemical composition and rare earth elements in the process of shear deformation, discuss the activation and migration of trace elements in rocks under strong deformation conditions, and explore the dynamic control of trace element migration, including the distribution of rare earth elements. The stress constraint and the chemical behavior of strain mineral lattice change and its constraints on the migration of deformed rock elements in the strain process.

(4) Theoretically explore the causal relationship between component activation, transfer and stress (strain) in rock under natural strong shear strain conditions, and provide a theoretical scientific basis for further exploration of the role of dynamic diagenesis (metallogenesis) in ductile shear zone. To provide a scientific basis for the formation and evolution of the ductile shear zone in the middle and lower crust (such as the enrichment of ductile shear zone gold), and to provide theoretical and experimental results for diagenesis and metallogenic geochemistry under ductile shear deformation. In accordance with.

(5) Modern analytical techniques such as in-situ analysis of laser isotope and laser ICP-MASS analysis techniques to study the activation and migration of elements and isotopes of rocks (minerals) in the deformation domain, and to reveal the elemental activation during the process of mylonization. The migration mechanism provides an important role in providing higher quality geochemical evidence.

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