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GEOCHEMICAL CHARACTERISTICS OF ORE FORMING FLUIDS IN SHEAR ZONE HOSTED ARCHEAN GOLD DEPOSITS

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太古代剪切带金矿床成矿流体的地球化学特征

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摘要 就剪切带金矿床的成矿热液流体的组成、稳定同位素和微量元素特征而言,很难对成矿流体的来源下明确结论。成矿流体有四种可能来源:变质的、岩浆的、地幔排气的、下地壳麻粒岩化和深循环地下水的来源。前三种来源有地球化学证据,因而不能完全排除其可能性。第四种来源因为它与剪切带流体为低盐度、高压这一特征相矛盾而尚未被大多数科学工作者所接受。同一矿床或同一地区的成矿流体的同位素均一化提供的证据说明均一化发生在成矿流体进入剪切带之前,也就是说,在剪切带之下存在均一的流体带。与剪切带动力作用最密切相关的成矿流体的物理化学参数是温度、压力和相态。流体相分离是剪切带成矿流体的普遍特征,它能反映剪切带对金矿化的控制。流体是剪切带活动性和成矿作用的介质,流体地球化学特征的研究是对成矿流体和成矿元素的来源有较好认识的重要途径之一。在研究剪切带和成矿之间的联系中认识成矿物质来源是非常重要的。如果没有成矿物质来源,甚至在最有利的构造环境,如流体活动和矿质沉淀的化学环境,也不会发生成矿作用。剪切带流体记录有两种方式:一是由流体与围岩间相互反应形成的蚀变矿物组合;另一是蚀变矿物和脉石矿物中的流体包裹体。它们是剪切带流体的地球化学特征研究的主要对象。

关键词 成矿流体 剪切带 太古代金矿床
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地球化学

1 INTRODUCTION

What is a fluid? This paper is concerned with fluids and therefore incumbent upon us to state what mean by this term. Any object which flows we call it fluid. We are all familiar with classification of material as solids, liquids and gases. Liquids and gasses are

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both called fluids. Solids and fluids continually metamorphose or deform over short or relatively long periods of time and it is often difficult to draw an exact boundary between the two states, and under certain conditions rocks and glaciers flow. In the geological process, we will focus attention on the rheological properties of a system, that is concerned with how things flow or deform under some applied force or stress, specially we concern the liquids, gases and magmas.

To understand why ore deposits form where they do, it is first necessary to understand the nature of ore-component transporting media, which in almost all cases are liquid, gas, and magma. Whether the ores are magmatic, more or less distantly related to magma, associated with metamorphic process, or related only to groundwaters and sedimentary basin brines etc. are all intimately associated with the movement of fluids.

But not all fluids are ore forming fluids only that containing ore-components we define it as ore forming fluids. For the purpose of closer investigation, the potential ore forming fluids can be divided into 8 categories: (1) silicate-dominated magmas or derived oxide, carbonate, sulfide-rich magmatic liquids, (2) water-dominated hydrothermal fluids that separate from magmas, (3) meteoric waters, those that have passed through the atmosphere, and when they filter into ground become groundwater, (4) seawater, (5) formation waters (connate water) trapped in pore spaces in sediments or enter it later on, (6) fluids associated with metamorphic process, (7) mine water and (8) hydrothermal fluids derived from modern seafloor vents, and from thermal springs. Any of the aqueous fluids may be hot or cold and be deep-seated or occur near the surface. It heated and liquid, each aqueous fluid would be considered a hydrothermal fluid because this term refers to any hot, watery fluid, without regard to origin.

Various attempts have been made to understanding the ore forming fluids associated with Archean lode gold deposits (Brown, 1995, Ho et al. 1990, Lu and Chi, 1994, Lu et al. 1995). This paper deals with the ore forming fluids associated with shear zones in the Archean terrain and to study their composition, characteristics, and possible mechanism to form these deposits.

2 MAJOR COMPOSITIONS OF FLUIDS AND THEIR INVOLVEMENT IN ALTERATION REACTIONS

Fluids in shear zones are different in composition with their geological setting, sources and minerogenetic types. In this paper the focus is placed on the fluids related to gold mineralization in Archean greenstone shear zones. Fluid inclusion and altered mineral assemblage data show that there are some similarities in composition of ore fluids producing gold deposits in Archean greenstone belts in various parts of the world. The fluids are predominated by SiO_2 , H_2O , CO_2 , K, Na, Ca, Mg, Cl as well as CH_4 , H_2S , N_2 etc. Listed in table 1 are the characteristics of fluid inclusions from gold deposits in some Archean greenstone belts. It can be seen from the table that the salinity of ore forming fluids is generally lower than 10% w (NaCl), CO_2 is usually and important component of the ore fluids, with a density of $0.7 \sim > 1.0 \text{ g/cm}^3$. Alteration and fluid inclusion studies

of the Linglong deposit in Shandong province, China indicate that the ore fluid is chemically predominated by SiO_2 , H_2O , CO_2 , Na, K, Ca and Cl, with the CO_2 density being $0.65 \sim 1.01 \text{ g/cm}^3$ and the salinity ranging from $2\% \sim 19\% w(\text{NaCl})$ (mostly within the range of $2\% \sim 12\%$), and contains a small amount of CH_4 . These characteristics are similar to those of ore fluids for gold deposits in other Archean greenstone belt.

Table 1 Fluid inclusion data for some lode gold deposits in Archean greenstone belts

Ore deposit	Fluid inclusion data	Possible ore-forming mechanism from fluid inclusion evidence	Reference
Red Lake gold deposit, Ontario, Canada	Primary $\text{H}_2\text{O}-\text{CO}_2$ inclusions, the density of CO_2 high, $\text{CO}_2/\text{H}_2\text{O}$ highly variable, T_h (homogenization temperature) $110 \sim 360^\circ\text{C}$; aqueous inclusions (liquid inclusions) with a low salinity of $4\% w(\text{NaCl})$ equip.; T_h about 350°C	Probably fluid immiscibility, i. e., separation of CO_2 - and H_2O -rich solution-phase fluid from $\text{H}_2\text{O}-\text{CO}_2$ fluid	Brown and Lacinaite, 1986
McIntyre-Hollinger gold deposit, Ontario, Canada	Primary $\text{H}_2\text{O}-\text{CO}_2$ inclusions with $3\% \sim 24\%$ (mole) CO_2 , $T_h = 220 \sim 385^\circ\text{C}$, CO_2 density $0.46 \sim 0.78 \text{ g/cm}^3$; CO_2 and $\text{CH}_4-\text{CO}_2-\text{H}_2\text{O}$ inclusions also observed, in graphite-bearing quartz veins also observed CH_4 inclusions; of course, aqueous inclusions also present	Probably fluid immiscibility; pressure = $(350 \sim 500) \times 10^5 \text{ Pa}$ during precipitation, buffer solution QFM	Smith et al., 1984
Hollinger gold deposit, Ontario, Canada	Primary $\text{H}_2\text{O}-\text{CO}_2$ inclusions, $\text{CO}_2/\text{H}_2\text{O}$ highly variable, with 6% (mole) CO_2 , salinity $1\% \sim 4\% w(\text{NaCl})$ equip., $T_h = 225 \sim 355^\circ\text{C}$, CO_2 density 0.65 g/cm^3 , minor CH_4	Phase separation	Wood et al., 1986
O'Brien gold deposit, Ontario, Canada	Primary $\text{H}_2\text{O}-\text{CO}_2$ inclusions, $\text{CO}_2/\text{H}_2\text{O}$ relatively constant, $T_h = 210 \sim 380^\circ\text{C}$	Early fluid homogenous, late fluid heterogenous, i. e., phase separation	Krupka et al., 1977
Sigma gold deposit, Quebec, Canada	Secondary $\text{H}_2\text{O}-\text{CO}_2$ inclusions, density $< 10\% w(\text{NaCl})$ equip., with $15\% \sim 30\%$ (mole) CO_2 , $T_h = 285 \sim 395^\circ\text{C}$; secondary H_2O inclusions, density $15\% \sim 34\% w(\text{NaCl})$ equip., $T_h = 60 \sim 295^\circ\text{C}$; in the same fissure CO_2 inclusions also observed in addition to the above-mentioned two types of inclusions	Fluid immiscibility	Ho et al., 1987

Table 1. (continued)

Yilgarn Block gold mine. Western Australia	Primary H ₂ O-CO ₂ inclusions. CO ₂ /H ₂ O constant 20%~30% (mole) CO ₂ . salinity < 2% w (NaCl) equip., T _h = 200~390 °C; aqueous and CO ₂ inclusions coexisting in later miarolitic minerals	Part of the early fluid immiscible, late fluid heterogenous	This work
Norbeau mine. Quebec. Canada	Aqueous and CO ₂ inclusions coexisting. daughter minerals occasionally observed. T _h = 250~350 °C, salinity mostly less than 10% w (NaCl) equip., aqueous inclusions dominant	Probably phase separation	This work
Tadd gold deposit. Quebec. Canada	Aqueous and H ₂ O-CO ₂ inclusions coexisting with minor amounts of CO ₂ inclusions in the same fissure, coexistence of CO ₂ inclusions and aqueous inclusions particularly common; in the altered zone inclusions present in groups from altered minerals into early quartz (Fig. 3B)	Phase separation or interaction between fluid and country rock	This work
Sigma gold deposit. Quebec. Canada	Aqueous and H ₂ O-CO ₂ inclusions together with CO ₂ inclusions occurring in the same fissure, or in quartz coexisting with native gold and pyrite (Fig. 3A)	Phase separation	This work
Linglong gold deposit. Shandong. China	Aqueous, H ₂ O-CO ₂ , H ₂ O-CO ₂ -CH ₄ and CO ₂ inclusions distributed at the major stages of gold deposition (quartz-pyrite stage and quartz- polymetallic sulfide stage); inclusions distributed in a complicated pattern, within the same fissure, CO ₂ inclusions found coexisting with aqueous inclusions, or various types of inclusions occurring in different fissure. N ₂ content high in some individual inclusions	Phase separation, i. e., separation of CO ₂ and CO ₂ -CH ₄ - H ₂ O and aqueous solution from H ₂ O- CO ₂ fluid	This work

Similarities in major composition of fluids in shear zones make it impossible to distinguish fluids of different origins. However, the alteration zone is an important marker of fluid activity in a shear zone, which resulted from the interaction between fluids and rocks in the shear zone and on both sides of it. The typical alterations associated with gold mineralization in shear zones include silicification, carbonatization (especially ferrodolomitization), albitization, chloritization and pyritization, but they are variable with changes in geological setting and deposit style. To be exact, the factors affecting the types of alteration include: (1) the composition of protolith; (2) the permeability of and water/rock ratio in the rocks in shear zones and on both side of them; and (3) temperatures and pressure conditions for fluids and surrounding mediums in addition to the major compositions of fluids themselves.

In the case of small amounts of fluids, the control of protolith composition over the altered mineral assemblage appears particularly important. Five major types of rock assemblages are recognized in greenstone belts: (1) mafic volcanic intrusive rocks; (2)

komatiites; (3) banded iron formations; (4) argillo-sedimentary rocks; and (5) felsic intrusive rocks (Colvine et al. 1988). All these rocks have experienced a greenschist facies metamorphism. Different alteration types and alteration processes would be noticed when a shear zone cuts through different rock assemblages. Listed in table 2 are the reaction equations for several principal rocks and fluids. It can be seen clearly that in case fluids are similar in composition (dominantly $\text{CO}_2 + \text{H}_2\text{O}$) but different kinds of minerals are involved in rock/fluid reaction, different resultant would be produced. Some of the resultant are the intermediate products and could further react with the fluids. Alteration reaction usually proceeds step by step, and with decrease of minerals in the protoliths and intermediate products the altered minerals would gradually increase. This process may be reflected in alteration zonation of the shear zone. For example, the Tadd gold prospect in the Chibougamau area in the northern part of the Abitibi greenstone belt is possessed of the following mineral assemblages in going from the interior of the shear zone outwards:

Zone A2: (far away from the shear, not altered)	chlorite, calcite, and magnetite.
Zone A3:	chlorite, ankerite, and sericite.
Zone A4:	ankerite, fuchsite, and chlorite.
Zone A5: (near the shear strongly altered)	ankerite, sericite, and pyrite.

Evidently, chlorite and calcite would be gradually replaced by ankerite and sericite. As can also be seen from table 2, a considerable number of the resultant contain quartz, ankerite and sericite which are the main components of vein-shaped ore bodies in the shear zone hosted gold deposits (Roberts, 1987), and also are the most commonly seen minerals and alteration types in alteration zones.

Alteration is related not only to the composition of the protolith, but also to the permeability of the rock within a shear zone and on both sides of it. Generally speaking, the permeability of the rock within the shear zone and its vicinity is higher than that for away from it. Therefore, shear zones are favorable not only to fluid activity, but also to the replacement of the protolith by fluids. It is worth while pointing out that alteration reaction between fluids and country rocks not only led to changes in composition of the protolith, but also caused changes in the composition and physicochemical properties of fluids themselves. Meanwhile, there is a possibility to promote the precipitation of ore forming materials.

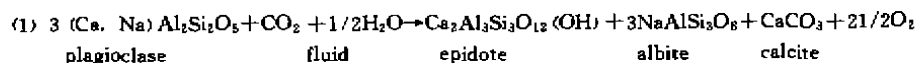
3 STABLE ISOTOPIC CHARACTERISTICS OF FLUIDS

Although the major compositions of fluids in shear zones and their alteration reactions can serve as an important indicator of whether there have occurred hydrothermal activities in shear zones and whether they are related to mineralization (Guha et al., 1991), they are unable to serve as an indicator of fluid sources. Studies on fluid inclusions and modern geothermal system provided strong evidence suggesting that the fluids with the above mentioned major components may be magmatic fluids, metamorphic fluids, deeply recycling surface water (excluding highly saline brines in equilibrium with the country rocks), fluids resulting from mantle degassing and granulitization, or mixed fluids of various origins. Unlike the granite type W-Sn deposits or submarine massive sulfide

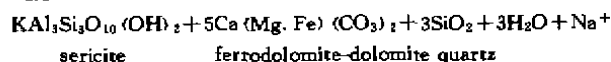
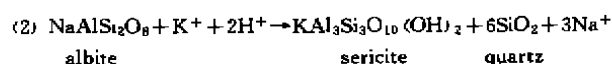
Table 2 The processes of alteration reaction when shear zones cut through different rocks

1. Protoliths are mafic volcanic rocks and intrusives

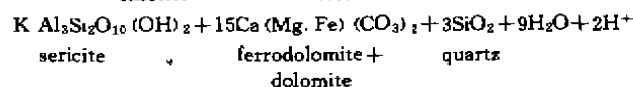
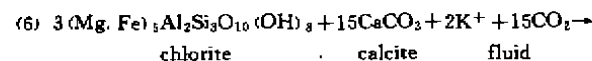
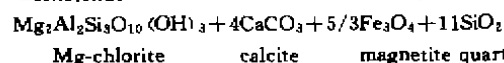
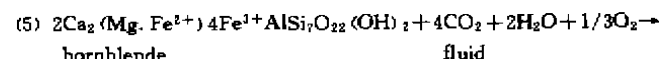
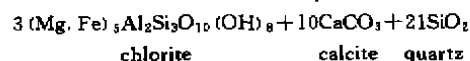
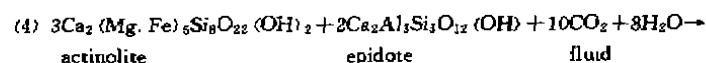
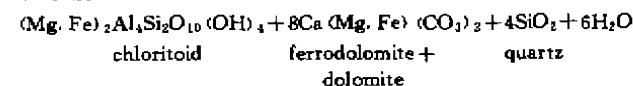
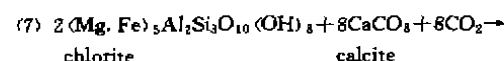
Decomposition of plagioclase



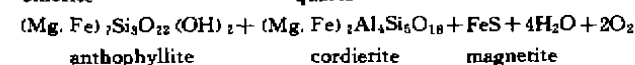
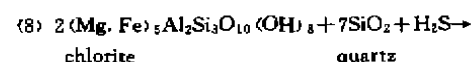
Hydration reaction of albite



Decomposition of water-bearing mafic minerals

Formation of chloritoid under high CO₂ content condition

Sulfurization of chlorite



I. Protoliths are ultramafic rocks

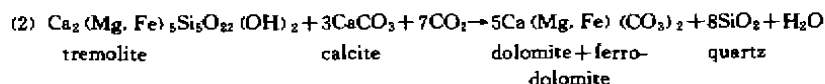
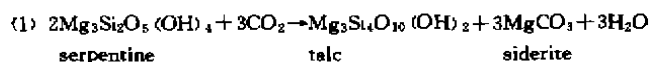
Decomposition of water-bearing Mg-Fe silicates under high CO₂ content condition

Table 2. (continued)

Carbonatization and dewatering

$$(3) \quad \text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2 + 3\text{CaCO}_3 + 3\text{CO}_2 \rightarrow 3\text{CaMg}(\text{CO}_3)_2 + 4\text{SiO}_2 + 2\text{H}_2\text{O}$$

talc calcite dolomite quartz

Formation of anothite and biotite under relatively high-grade metamorphism conditions

$$(4) \quad 4\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2 + (\text{Mg, Fe})_5\text{Al}_2\text{Si}_3\text{O}_{10}(\text{OH})_2 + 2\text{K}^+ \rightarrow 2(\text{Mg, Fe})_7\text{Si}_6\text{O}_{22}(\text{OH})_2 +$$

talc chlorite tremolite

$$2\text{KAl}(\text{Mg, Fe})_3\text{Si}_2\text{O}_{10}(\text{OH})_2 + 6\text{H}_2\text{O} + 2\text{H}^+$$

biotite

III. Protoliths are oxide-silicate iron formations

$$(1) \quad 7\text{Fe}_3\text{O}_4 + 24\text{SiO}_2 + 3\text{H}_2\text{O} \rightarrow 2\text{Fe}_7\text{Si}_8\text{O}_{22}(\text{OH})_2 + 31/2\text{O}_2$$

magnetite quartz grunerite

$$(2) \quad \text{Fe}_3\text{O}_4 + 6\text{H}_2\text{S} + \text{O}_2 \rightarrow 3\text{FeS}_2 + 6\text{H}_2\text{O}$$

magnetite pyrite

$$(3) \quad \text{Ca}(\text{Mg, Fe})(\text{CO}_3)_2 + 2\text{H}_2\text{S} + 1/2\text{O}_2 \rightarrow \text{FeS}_2 + \text{CaMg}(\text{CO}_3)_2 + \text{CO}_2 + 2\text{H}_2\text{O}$$

ferrodolomite pyrite dolomite

$$(4) \quad (\text{Fe, Mg})_7\text{SiO}_{22} + \text{KAl}_3\text{Si}_3\text{O}_{10}(\text{OH})_2 + 2\text{CaCO}_3 + 3\text{H}_2\text{S} \rightarrow$$

grunerite sericite calcite

$$\text{KCa}_2(\text{Mg, Fe})_4\text{Al}_3\text{Si}_4\text{O}_{22}(\text{OH})_2 + 3\text{FeS} + 5\text{SiO}_2 + 4\text{H}_2\text{O} + 2\text{CO}_2$$

tschermakite pyrrhotite quartz

$$(5) \quad (\text{Mg, Fe})_5\text{Al}_2\text{Si}_3\text{O}_{10}(\text{OH})_2 + \text{KAl}_3\text{Si}_3\text{O}_{10}(\text{OH})_2 + 3\text{SiO}_2 + 2\text{Ca}(\text{Fe, Mg})(\text{CO}_3)_2 + \text{O}_2 \rightarrow$$

chlorite sericite quartz dolomite

$$(\text{Fe, Mg})_3\text{Al}_2\text{Si}_3\text{O}_8 + \text{KCa}_2(\text{Mg, Fe})_4\text{Al}_3\text{Si}_4\text{O}_{22}(\text{OH})_2 + 4\text{H}_2\text{O} + 4\text{CO}_2$$

garnet tschermakite

IV. Protoliths are granitic rocks

$$(1) \quad 4(\text{Na, K})\text{AlSi}_3\text{O}_8 + 2\text{H}^+ \rightarrow \text{NaAlSi}_3\text{O}_8 + \text{KAl}_3\text{Si}_3\text{O}_{10}(\text{OH})_2 + 6\text{SiO}_2 + 2\text{Na}^+$$

alkaline albite sericite quartz

feldspar

$$(2) \quad 40(0.9\text{NaAlSi}_3\text{O}_8 + 0.1\text{CaAl}_2\text{Si}_2\text{O}_6) + 2\text{KAl}_2(\text{Mg, Fe})_{25}\text{Si}_{25}\text{O}_{10}(\text{OH})_2 + 6\text{H}_2\text{O} + 4\text{CO}_2 + 2\text{K}^+ \rightarrow$$

plagioclase biotite

$$34\text{NaAlSi}_3\text{O}_8 + 4\text{KAl}_3\text{Si}_3\text{O}_{10}(\text{OH})_2 + (\text{Mg, Fe})_5\text{Al}_2\text{Si}_3\text{O}_{10}(\text{OH})_2 + 4\text{CaCO}_3 + 4\text{SiO}_2 + \text{Na}^+$$

albite sericite chlorite calcite quartz

deposits, ore deposits in shear zones have no well defined ore forming material sources. For this reason, stable isotopic research is one of the indispensable approaches to identifying the origins of ore fluids in shear zones, though this approach is far from maturity at present.

3.1 CARBON ISOTOPES

The carbon isotopic composition data for ore fluids are mostly developed from carbonate minerals of hydrothermal origin (especially ankerite and pyrite). The carbon isotopic fraction between carbonate minerals and hydrothermal solutions is dependent on temperature, Eh , pH and other factors (Ohmoto and Rye, 1979). In the range of Eh for the precipitation of ore forming materials for the most majority of gold deposits in shear zones $\delta^{13}\text{C}$ dolomite = $\delta^{13}\text{C}$ fluid at the temperatures from 270 to 350 °C; $\delta^{13}\text{C}$ calcite - $\delta^{13}\text{C}$

fluid = +1‰ at 300 °C. No experimental data are available on carbon isotopic fraction between ankerite and fluids. It is estimated that the data are similar to those for calcite (Kerrick, 1989). Therefore, the carbon isotopic composition of carbonate minerals of hydrothermal origin could approximately represent that of fluids.

It shows that the variations of $\delta^{13}\text{C}$ in carbonate minerals of hydrothermal origin from the major gold mineralized provinces, gold deposits or orebodies in the Abitibi greenstone belt of Canada and the Yilgarn block of Australia in comparison with those of carbonate minerals of regional alteration and submarine hydrothermal alteration origins. It can be seen that the carbonate minerals associated with gold deposits have $\delta^{13}\text{C}$ values ranging from -9‰ to +2‰ mostly within the range of -7‰~0‰.

The $\delta^{13}\text{C}$ values of individual minerogenetic provinces or individual deposits vary cover a much narrower range than those of the whole greenstone belt or carbonate minerals of regional alteration and submarine hydrothermal alteration origins. The Abitibi greenstone belt is a most typical example. In the Kirkland Lake area $\delta^{13}\text{C}$ values vary from -2.0‰ to -4.5‰ in the east Malartic area, -6.8‰~-5‰ in the Sigma deposit, -6‰~-5‰ and in Lamarque deposit, -4.5‰~-6.5‰. Such small scale variations in $\delta^{13}\text{C}$ could be caused by changes in physicochemical conditions of the sedimentary environments (e. g. temperature, *Eh*, pH, fluid phase separation, etc.) rather than the mixing of fluids of different origins. So it follows that in a region or a deposit where $\delta^{13}\text{C}$ varies over a narrow range the ore fluids may come from a relatively homogeneous fluid reservoir, while from one region to another, if $\delta^{13}\text{C}$ values are highly variable, it may be said with certainty that the fluids are of multiple source.

Now there has been no unity in thinking concerning the relationship between carbon isotopic composition and fluid source. It is generally accepted that mantle derived CO_2 has a $\delta^{13}\text{C}$ value of about -5‰ (Ohmoto and Rye, 1979), but in consideration of the heterogeneity of the mantle and the incorporation of carbon into the mantle and meteorites through recycling (as indicated by the great variation range of $\delta^{13}\text{C}$ values from -30‰ to >50‰, this assumed $\delta^{13}\text{C}$ value of -5‰ could necessarily be held (Ohmoto, 1986). According to the carbon isotopic compositions of mid-ocean ridge basalt glass, carbonate and diamond, it has been suggested a $\delta^{13}\text{C}$ value of -6‰~+2‰ for mantle derived CO_2 . The carbon isotopic composition of crust source CO_2 is uncertain. According to Ohmoto and Rye, the average $\delta^{13}\text{C}$ of crustal igneous rocks, metamorphic rocks and sedimentary rocks was calculated to be -5.5‰. Hoefs (1987) considered that the average $\delta^{13}\text{C}$ of crustal rocks is -7‰. As can be seen clearly, it is impossible to take only one measure to distinguish mantle derived from crust derived carbon (Ohmoto, 1986). As a matter of fact, the $\delta^{13}\text{C}$ values of crustal rocks vary over a wide range. For example, the $\delta^{13}\text{C}$ values of carbonate minerals (of non alteration origin) from volcanic rocks in Archean greenstone belts range approximately from -8.5‰ to -0.5‰ (Kerrick, 1986) while those of Archean marine carbonate minerals are within the range of -2‰~+3‰. Evidently, fluids released from different protoliths or those in different proportions in response to metamorphism or magmatism would be different in their carbon isotopic compositions. That is to say, it is impossible to distinguish whether fluids are either mantle derived or metamorphic or magmatic in origin merely on the basis of the $\delta^{13}\text{C}$ values

of fluids in any shear zone. So the fact that the $\delta^{13}\text{C}$ values of ore fluids in the above mentioned Archean gold deposits fall mostly within the range of -7‰ could by no means provide reliable information about fluid sources. Even if a certain mining district or a deposit with a narrow range of $\delta^{13}\text{C}$ variations is taken into specific consideration, a diversity of explanations could by no means be avoided for fluid origins. For example, Spooner et al. (1987), based on the fact that the $\delta^{13}\text{C}$ values ($-33\text{‰} \sim +0.4\text{‰}$) of Hollinger McIntyre gold deposit are similar to those of the Mink Lake Mo-Au deposit known to be of magmatic hydrothermal origin ($-3.0\text{‰} \sim +1.5\text{‰}$), considered that the former deposit also is of magmatic hydrothermal origin. As for the $\delta^{13}\text{C}$ value of about -3.0‰ , there may be other three explanations: (1) mantle derived (Colvine et al. 1988); (2) derived from the reworking (metamorphism) of carbonatized magnetite-rich ultramafic rocks (McNaghron et al. 1988); and (3) derived from a homogeneous fluid reservoir in which fluid can be derived from various types of crustal rocks (Kerrick, 1987).

It is shown that the problem of fluid sources can not be solved merely on the basis of carbon isotopic data. But the fact that individual regions or deposits are relatively homogeneous in $\delta^{13}\text{C}$ lends support to such a point of view that the ore fluids for gold deposits in shear zones were derived from a carbon isotopic homogenized fluid reservoir. This fluid reservoir may be either a magmatic intrusive mass or a region where mantle derived or metamorphically derived or multiple sources (considerably homogeneous) fluids were relatively accumulated.

3.2 OXYGEN AND HYDROGEN ISOTOPES

The oxygen and hydrogen isotopic composition data of fluids were mainly developed respectively from quartz and water bearing hydrothermal altered minerals, which were calculated under the estimated temperature (e. g. through fluid inclusion thermometry) conditions in terms of the mineral/water isotopic fraction equation and also can be worked out by directly determining fluid inclusions. The $\delta^{18}\text{O}$ values of quartz veins in gold deposits in several Archean greenstone belts and those of inclusion fluids, with the $\delta^{18}\text{O}$ values of fluids being lower than those of quartz by about $4\text{‰} \sim 7\text{‰}$.

The $\delta^{18}\text{O}$ values of ore forming fluids for gold deposits in greenstone belts lie between $+3\text{‰}$ and $+10\text{‰}$, corresponding to those of quartz veins between $+9\text{‰}$ and $+16\text{‰}$. Such is the case for the Linglong gold deposit in China. This variation range is of world scale. If a certain greenstone belt or a region or a deposit in the greenstone belt is taken into specific consideration, the variation range of $\delta^{18}\text{O}$ values would be much smaller. Take the Abitibi greenstone belt for example, most $\delta^{18}\text{O}$ values are within the range of $+12.5\text{‰} \sim +15.0\text{‰}$ (quartz) against a range of $+9\text{‰} \sim +11\text{‰}$ for quartz from the central eastern parts of the belt. Another example is the Sigma gold deposit whose $\delta^{18}\text{O}$ values range from $+9\text{‰}$ to $+11\text{‰}$ (quartz, Kerrich, 1989).

Systematic oxygen isotopic studies of quartz from quartz veins within a shear zone and hydrothermal quartz from the alteration zones on both sides as well as of quartz from unaltered rocks in going further outwards indicate that the $\delta^{18}\text{O}$ values of hydrothermal quartz have nothing to do with the composition of the country rocks and this is consistent with the high permeability and large water/rock ration in the shear zone, suggesting that

the $\delta^{18}\text{O}$ values of ore fluids calculated from those of quartz may reflect the oxygen isotopic composition of the fluid source and the small scale variation of $\delta^{18}\text{O}$ of fluids in the same deposit may result from temperature variation and fluid phase separation, independent of the mixing of multiple sources fluids. Therefore, like carbon isotopes, oxygen isotope data may imply that ore fluids in an individual deposit or in shear zones of a region were derived from a relatively homogeneous fluid reservoir.

The hydrogen isotope data are less available than the oxygen isotope data. The δD values of ore fluids for the Archean gold deposits in Canada were estimated at $-30\text{‰} \sim -70\text{‰}$, about -56‰ for the Archean gold deposits in Austria; -62.6‰ for the Sidaogou gold deposit in China; and $-62\text{‰} \sim -93\text{‰}$ for the Linglong gold deposit in China.

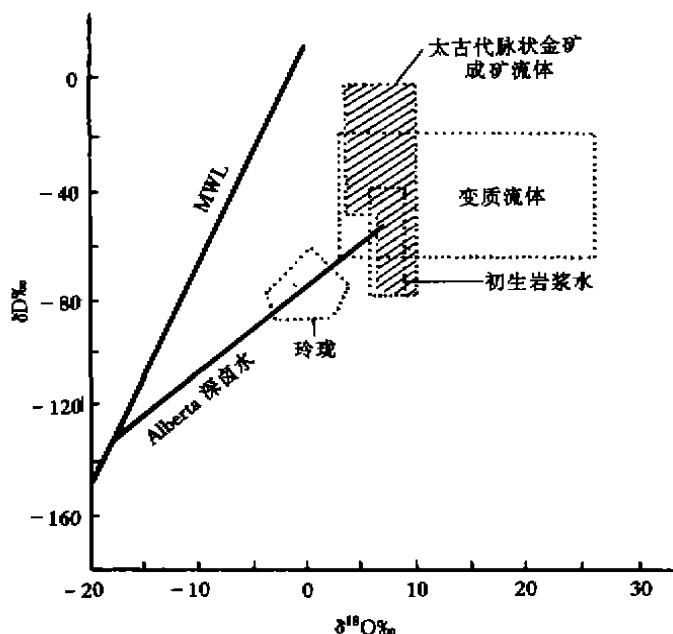


Fig. 1 $\delta\text{D}-\delta^{18}\text{O}$ variation range of ore forming hydrothermal fluids for the Archean shear zone hosted gold deposits, the relationship between primary magmatic water and metamorphic water and $\delta\text{D}-\delta^{18}\text{O}$ variation range of the Linglong gold deposit

图1 太古代剪切带金矿床成矿热液流体的 $\delta\text{D}-\delta^{18}\text{O}$ 变化范围, 原生岩浆水和变质水之间的关系以及玲珑金矿床 $\delta\text{D}-\delta^{18}\text{O}$ 变化范围 (data from Kerrich, 1989 and Lu, 1991)

As seen in the $\delta^{18}\text{O}-\delta\text{D}$ diagram (Fig. 1), ore fluids for the Archean vein type gold deposits, metamorphic water and primary magmatic water all fall almost within the same area, indicating that ore fluids in a shear zone may be either metamorphic or magmatic fluids. It is impossible to distinguish metamorphic fluid from magmatic fluid merely on the basis of oxygen and hydrogen isotope data (Kerrich, 1989). Formation brines derived from deep recycling surface water and cogenetic water in sedimentary rocks may have the same $\delta^{18}\text{O}-\delta\text{D}$ range as metamorphic water or primary magmatic water (e. g. brine from Alberta, Fig. 1). However, the salinity of this kind of brine must be extremely high, in discrepancy with the observed low salinities of fluid inclusions.

3.3 SULFUR ISOTOPES

The sulfur isotopic composition of ore fluids can be deduced from the $\delta^{34}\text{S}$ values of sulfide minerals. The $\delta^{34}\text{S}$ of sulfides depends on the total $\delta^{34}\text{S}$ as well as temperature, E_h , pH, etc. In case the oxidizing condition is lower than the $\text{CO}_2/\text{H}_2\text{S}$ boundary, the $\delta^{34}\text{S}$ of sulfide minerals can, to a first approximation, represent that of ore fluids (Ohmoto and Rye, 1979).

It can be seen that the $\delta^{34}\text{S}$ values for pyrite and pyrrhotite from the selected Archean lode gold deposits of Canada and Western Australia (including the sulfur isotopic composition data of sulfides from the Linglong, Hetai, Sidaogou and other gold deposits of China) are mostly within the range of $0\text{‰} \sim +6\text{‰}$, although some gold deposits have slightly lower values, for example, the $\delta^{34}\text{S}$ values of the Golden Mile gold deposit of Australia are within the range of about $-8\text{‰} \sim -2\text{‰}$ and those of the Canadian Arrow gold deposit, $-13\text{‰} \sim -6\text{‰}$.

For the fluids with $\delta^{34}\text{S} = 0\text{‰} \sim +6\text{‰}$ it is generally accepted that they were derived either from magmas or from leaching or desulfication of the crystallized igneous rocks because the $\delta^{34}\text{S}$ values of Archean igneous rocks are mostly around zero (Colvine et al. 1984). However, desulfication of sulfides in hydrothermal sediments may give rise to a $\delta^{34}\text{S}$ range of $0\text{‰} \sim +6\text{‰}$. For example, the Archean hydrothermal metamorphic sedimentary rocks of Superior province have $\delta^{34}\text{S}$ values ranging from -6‰ to $+8\text{‰}$ with a mean values of $+2.5\text{‰}$ (Strauss, 1986). As for either igneous rocks or hydrothermal sedimentary rocks, their desulfication would be accompanied by metamorphism.

Therefore, like carbon, hydrogen and oxygen isotopes, sulfur isotopes are also able enough to distinguish magma derived fluids from metamorphically derived fluids. At the same time, ore fluids derived from mantle degassing should not be ruled out.

4 TRACE ELEMENT CHARACTERISTICS OF ORE FORMING FLUIDS

From the above discussions, it can be seen that it is hard to distinguish fluids of magmatic origin from those of metamorphic origin to use stable isotopes. Moreover, ore fluids of other origins could not be ruled out. So ever increasing interest has been aroused in the study of trace elements in ore fluids.

Kerrick (1986) chose the lithophile elements K, Rb, Sr, Ba, Li, and Cs and S/Se ratios as the source tracers of hydrothermal fluids producing gold deposits in shear zones because these elements were subjected to regular variations during the processes of magmatic evolution, with some differences from those encountered during metamorphism. Such differences would be reflected in trace element characteristics of the products of hydrothermal alteration in the shear zones. Alteration zones in gold deposits in the most majority of the shear zones are characterized as being rich in K and S, which makes it possible to use the lithophile elements and S/Se ratios as the source tracers of hydrothermal ore fluids.

Generally speaking, shear zone hosted gold deposits are characterized as being rich in the lithophile elements, in sharp contrast to the country rocks (in the Archean greenstone belts mafic and ultramafic rocks are the dominant country rocks). This characteristic feature is taken as one of the important lines of evidence for "magmatic hydrothermal origin" or "granulitization hydrothermal origin" as magma hydrothermal solutions are characterized as being rich in lithophile elements and granulites (especially Archean granulites) are characterized by obvious depletion in lithophile elements, which is

considered as a manifestation of "removal of lithophile elements" during granulitization. These "removed" lithophile elements together with H_2O , CO_2 , etc. would become the components of gold ore fluids as result in the enrichment of lithophile elements in gold deposits.

However, if we analyze the distribution regularities of individual lithophile element and their correlations with one another, we can find much in conflict with the viewpoints

of "magmatic origin" or "granulitization origin". Fig. 2 is a diagram showing the correlations among the lithophile elements in the Kerr Addison gold deposit in the western part of the Abitibi greenstone belt.

The host rocks of this deposit are ultramafic rocks, of which the protolith is characterized as being depleted in lithophile elements. So the lithophile element characteristics of the mineralized and altered rocks have almost not been affected by the protolith and hence can truly reflect the characteristics of ore forming hydrothermal fluids. At a glance of Fig. 3, it can be seen clearly that K is well correlated with Rb and Ba but poorly with Sr, Cs, Tl and Li. Actually, the contents of Cs and Tl are always low, without and change with varying K content and alteration, generally within the range

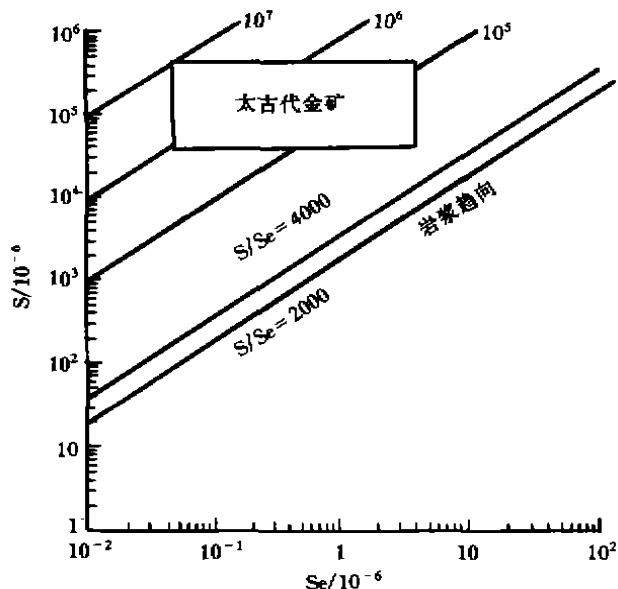


Fig. 2 Correlation diagram of some lithophile elements in the Kerr Addison gold deposit in the Abitibi greenstone belt

图2 Abitibi 绿岩带 Kerr Addison 金矿床
某些亲石元素的相关图
(after Kerrich, 1989)

of $(1\sim2) \times 10^{-6}$ or so, nearly approaching the limit of detection. The content of Li is $(5\sim120) \times 10^{-6}$, showing no correlation with K content. According to Kerrich (1989), gold deposits in Archean greenstone belts are commonly possessed of the characteristics described above, i.e., the elements K, Rb and Ba are of linear enrichment and K/Rb and K/Ba ratios approach or exceed the average crustal values (285 and 51 respectively, Fig. 3). As Cs is not enriched, the K/Cs ratio is greatly in excess of the average crustal value (9130).

These characteristics are in strong conflict with magma derived hydrothermal solution. K/Rb, K/Li, K/Cs and K/Tl ratios in the tending to decrease progressively with the evolution of magma, precisely lower than the average crustal values, just against the variation trend of Rb/Sr and K/Ba ratios which are remarkably higher than the average crustal values. These features are also in discrepancy with the "granulitization origin" as Cs should be more significantly depleted than Rb and K while Ba should be more slightly depleted than K if the depletion of large ion lithophile (LIL) elements took place during

the process of granulitization. Hydrothermal solution produced in this way should be characterized as being low in K/Rb and K/Cs but high in K/Ba. As a matter of fact, the actual case is just the opposite. Kerrich (1989) considered that metamorphic hydrothermal fluids resulting from amphibolite facies metamorphism may possess the above described characteristics.

The use of S/Se ratios as a tracer of ore forming hydrothermal fluid is based mainly on their similar behavior during the process of magmatic evolution and S/Se ratios in chondrites and mantle source magmas are generally within the range of 2000~4000. In the

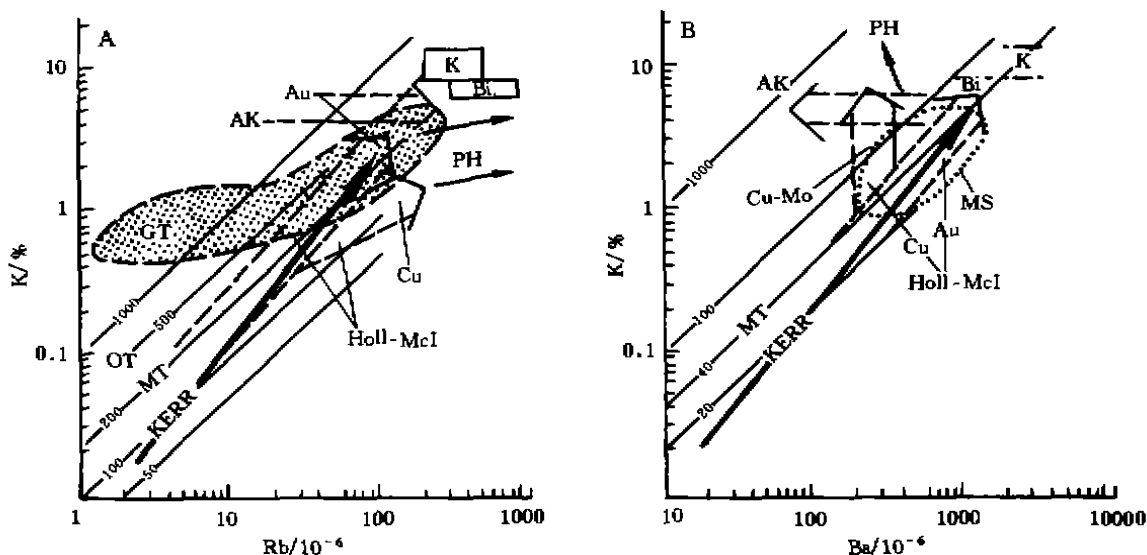


Fig. 3 K-Rb (A) and K-Ba (B) diagrams of some magmatic, metamorphic and metallogenic systems

图3 某些岩浆的、变质的和成矿的系统 K-Rb (A) 和 K-Ba (B) 关系图

MT—general trends; OT—oceanic tholeiite; PH—pegmatite hydrothermal fluid; AK—Ackley granite, New Foundland (variation trend of differentiated granite with Mo or Sn, W mineralizations).
GT—granulite trend; MS—metamorphic rocks field; KERR—potash alteration zone in the Kerr Addison gold deposit; Holl-McI—potash alteration zone in the Hollinger-McIntyre gold deposit; Au, Cu, Cu-Mo-Au, Cu, and Cu-Mo mineralization blocks in Hollinger-McIntyre gold deposit and their trends; Bi—biotite field; K-K—Feldspar field
(after Kerrich, 1989)

supergene process Se is more active than S^{6+} and hence S/Se ratios in all sedimentary rocks and the whole crust are higher than those in the mantle.

At present, the reliable data are almost unavailable on S/Se ratios in shear zone hosted gold deposits. However, according to Kerrich's preliminary results, the ratios are significantly greater than 2000~4000. The Canadian Arrow gold deposit in the Abitibi greenstone belt, for example, has S/Se ratios ranging from 50000 to 100000. As rocks in the Archean greenstone belts are considered as the intrusive rocks (tonalite, trondhjemite and granodiorite) associated with gold mineralization, i. e., the result of melting of basaltic rocks and lamprophyre—an indicator of the relationship between gold mineralization and mantle processes is a more typical mantle source magmatic rock, both

of them should have low S/Se ratios. For this reason, the fact that gold deposits have high S/Se ratios could lend support to the hypotheses of "magma hydrothermal origin" or "mantle degassing origin".

As viewed from the major composition and stable isotopic and trace element characteristics of ore forming hydrothermal solution for gold deposits in shear zones as discussed above, it can be seen that there has been no unity in thinking on the source of ore fluids of four possible sources: metamorphism derived; magma hydrothermal; mantle degassing and lower crustal granulitization derived hydrothermal fluids and deep recycling groundwater. The former three hypotheses are more or less supported by their respective geochemical evidence and thus could not be completely ruled out, but the forth has not commonly accepted. That is because oxygen isotopic homogenization and high $\delta^{18}\text{O}$ values require a sufficiently long duration of recycling of surface water at depth and this would inevitably lead to the formation of highly saline brines, precisely in conflict with the fact that fluids in shear zone are low in salinity. On the other hand, the fluids are high in pressure, which is inconsistent with the model of surface water recycling. Trace element characteristics also provide strong evidence against the hypotheses of magma hydrothermal origin and mantle degassing granulitization hydrothermal origin. But it should be noted that the trace element data are limited at the present time and little experimental evidence has been developed for the partitioning between hydrothermal solutions and minerals. The possibility of mixing of fluids of different origins could not be ruled out because different geological processes (magmatism, metamorphism, mantle-degassing granulitization) would be probably controlled by regional shear zones. The isotopic homogenization of fluids for the same deposit or the same region provides strong evidence suggesting that such a process of mixing would occur before fluids found their way into a shear zone, i. e., there exists a homogeneous fluid reservoir beneath the shear zone.

5 PHYSICOCHEMICAL FEATURES OF FLUIDS

The physicochemical features of fluids include temperature, pressure, *Eh*, pH, phase state, etc., of which temperature, particularly pressure and phase state are most closely related to the kinetic process of shear zones.

Fluid inclusion studies of 16 shear zones hosted gold deposits demonstrated that the homogenization temperatures are generally within the range of 200~400 °C (Table 1). Much research work has shown that phase separation took place at the time ore fluids found their way into the expanded space of a shear zone. Therefore, this temperature range could represent the actual temperature of fluids. In their fluid inclusion studies, Wood et al. (1986) held that the homogenization temperature of fluid inclusions trapped at the main stage of ore deposition in the Hollinger-McIntyre gold deposit in the Abitibi greenstone belt was estimated at about 280 °C. In addition, the immiscibility of fluid led them to believe that this temperature range represents the true temperature of fluids. According to the statistical data on isotopic equilibrium temperatures for 16 shear zones hosted gold deposits (Kerrick, 1986), the temperatures fall mainly within the range of 270~340 °C, in good agreement with the data from fluid inclusions. Nevertheless, fluids in

some shear zones hosted gold deposits have much higher temperatures, for example, those from some shear in the Ruby mountains, Nevada, U. S. A. have such a high temperature range as up to 580~620 C.

The pressure of fluids from shear zones varies over a wide range. Fluid inclusion studies of 16 shear zones hosted gold deposits have shown that the fluid pressure is $(1500 \sim 4500) \times 10^5$ Pa, corresponding to a depth of 4~16 km. The estimated fluid pressure for the major shear zone hosted gold deposits is $(2000 \sim 3000) \times 10^5$ Pa, corresponding to a depth of 8~12 km (Kerrick, 1983); the fluid pressure estimated by Brown (1986) is up to 7000×10^5 Pa; the estimated fluid pressure of the Hollinger-McIntyre gold deposit is 500×10^5 Pa in terms of fluid inclusion studies (Spooner et al., 1986), corresponding to a depth of about 1.9 km. Variations in fluid pressure follow the kinetic mechanism of shear zone control over fluids. It is the pressure difference that will cause the migration of fluids. Even at the same depth there would be noticed some lateral changes in fluid pressure, as is indicated by a low fluid pressure and obvious phase separation in the expanded space of a shear zone, but an opposite trend on both sides of it (Guha et al., 1991). So strictly speaking, there would be no correlation between fluid pressure and depth as fluid pressure may be in different forms such as hydrostatic pressure, lithostatic pressure, intermediate form between hydrostatic pressure and lithostatic pressure or ultra lithostatic pressure. There would be involved great uncertainties in the calculated depth in terms of different forms of fluid pressure.

Fluid phase separation is a common feature of ore fluids in a shear zone (Table 1), as has been developed from fluid inclusion studies. Strong evidence of fluid phase separation is developed from the coexistence of two kinds (or more than two) of fluid inclusions differing in composition in the same fissure or the same crystal or in different fissures with approximate homogenization temperatures but significantly different salinities and CO_2 contents. There have been noticed three typical fluid inclusions differing in composition. They are CO_2 -rich, $\text{H}_2\text{O}-\text{CO}_2$ and H_2O -rich inclusions. The former is low in salinity while the latter is high in salinity, and $\text{H}_2\text{O}-\text{CO}_2$ inclusions are intermediate between them. Systematic fluid inclusion studies of the Sigma, Norbeau and Tadd gold deposits in the Abitibi greenstone belt and the Linglong gold deposit, Shandong province, China indicate the coexistence of the three types of fluid inclusions mentioned above. In addition, there exist some $\text{H}_2\text{O}-\text{CO}_2-\text{CH}_4$ inclusions. The types of fluid inclusions are more complicated in veins of a shear zone than in the alteration zones on both sides of it. That is to say, more end-member inclusions (CO_2 - and H_2O -rich inclusions) are present in the shear zone while more $\text{H}_2\text{O}-\text{CO}_2$ inclusions are found in the alteration zones. The coexistence of a variety of fluid inclusions is the result of fluid phase separation, i. e., from a single phase ($\text{H}_2\text{O}-\text{CO}_2-\text{NaCl}$ and minor CH_4) into two phases (CO_2 -rich and $\text{H}_2\text{O}-\text{NaCl}$ -rich phase). The two fluid phases resulting from fluid separation together with the original fluid left behind phase separation (as a result of incomplete separation) were trapped at the time ore-forming materials were precipitated or slightly later and this may reasonably account for the coexistence of various kinds of fluid inclusions.

In addition to the routine cooling and heating stage technique, solid probe mass spectrometry (Guha et al., 1990) was first adopted to analyze fluid inclusions from the

Sigma, Norbeau and Tadd gold deposits as well as from the Linglong and other gold deposits in China (Guha et al., 1991, Lu, 1991). The most outstanding advantage of this technique is that the distance between the sample-holding (only about 0.0005g of sample is required) probe head and the ionizing cell is so short that the decrepitation temperatures of fluid inclusions can be accurately determined and the compositions of gases instantaneously released at the corresponding temperatures. If this technique is used, the prerequisite should be satisfied, i. e., inclusions of different generations should be separated from one another under the microscope and then cut off by means of knife for respective analysis. For instance, three types of fluid inclusion assemblages are observed under the microscope: (1) three types of fluid inclusions ($\text{H}_2\text{O}-\text{CO}_2$, CO_2 -rich and H_2O -rich) coexist in the same fissure; (2) one single type of fluid inclusions (e. g. CO_2 -rich) occurs in the same fissure; and (3) two types of fluid inclusions (e. g. CO_2 -rich and H_2O -rich) coexist in the same fissure. Under such circumstances, fluid inclusions in different fissure should be cut off and analyzed respectively. Due to extremely small sample requirement, no painstaking efforts would be involved in sample separation. As can be seen from the mass spectrograms, the components (CO_2 , CH_4 , H_2O , C_2H_6 , H_2S , N_2 , CO , etc.) in inclusion fluids will change in proportion under different temperature conditions.

Fig. 4 is a plot of temperature vs. concentration showing the peak values of CO_2 , CH_4 and H_2O in fluid inclusions of the same generation from a quartz veins in the Sigma gold deposit. As can be seen

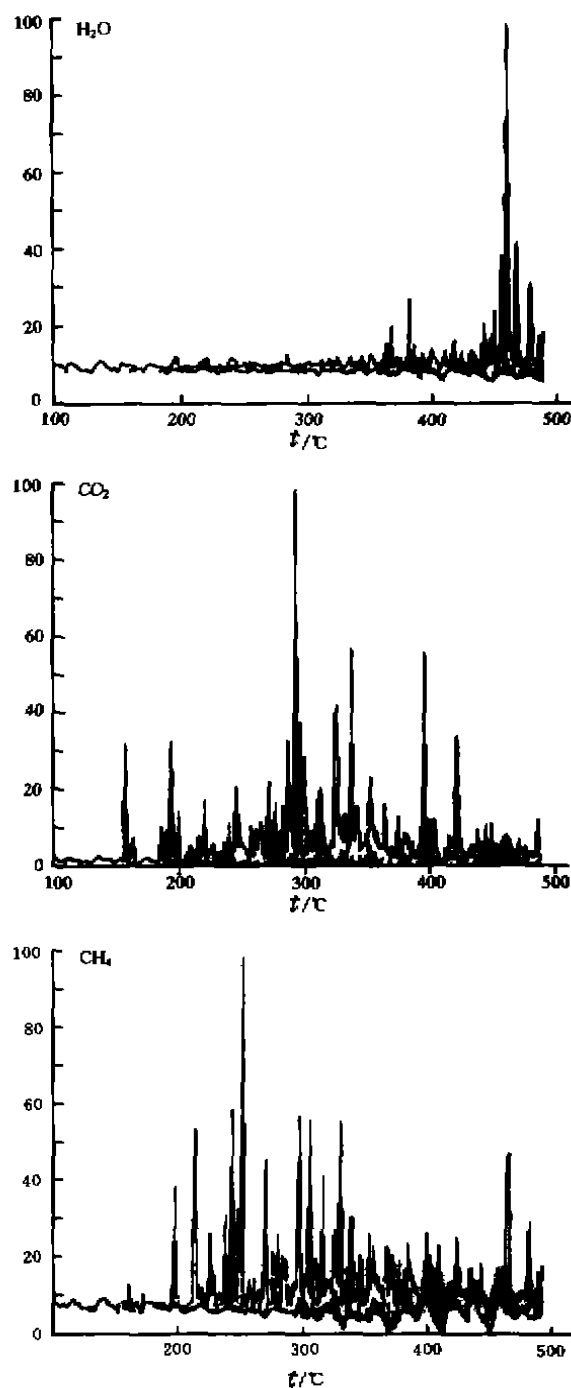


Fig. 4 Mass spectrogram of CO_2 , CH_4 and H_2O in fluid inclusions of the same generation from the Sigma gold deposits (analyzed by solid probe mass spectrometry)

图4 Sigma 金矿床同一世代流体包裹体的 CO_2 、 CH_4 和 H_2O 的质谱图

from the figure, with the rise of temperature different components will be released from inclusion fluids at different temperatures. At about 250 °C, CH₄ will be released in large amounts, together with small amount of CO₂ but no H₂O; when the temperature rises to 295 °C, CO₂ will be released in large amounts, together with a moderate amounts of CH₄ but still almost no H₂O; when the temperature rises to 460 °C, H₂O will be released in large amounts together with a small amount of CO₂ and a moderate amounts of CH₄. As can be seen, there exist at least two types of fluid inclusions in the sample analyzed: one is CO₂-and CH₄-rich inclusions but almost with no H₂O and the other is H₂O-rich but CO₂-and CH₄-poor inclusions. Microscopic examination provided evidence suggesting that the fluid inclusions are of the same generation and coexist in the same fissure, and therefore such an extreme compositional differentiation may reflect the existence of two kinds of fluids during the precipitation of ore forming materials. As described previously, this is the manifestation of fluid phase separation. It should be pointed out that fluid inclusions of the same generation have similar homogenization temperatures but different decrepitation temperatures due to differences in composition (for many other factors). Otherwise, the components could not be distinguished from one another on the mass spectrogram. Therefore, careful examination under the microscope is a prerequisite for the use of this technique. What one should pay special attention to is to select fluid inclusions of the same generation and try to avoid the possibility of "necking". These inclusions may be primary (e. g. those on a certain growth zone of the same crystal), may also be secondary or pseudosecondary, i. e., those occur in the same fissure.

As described previously, fluid phase separation is a common feature of shear zone hosted gold deposits, which reflects the control of shear zone over gold metallogensis. Fluid phase separation tends to occur in the location where fluid pressure goes down abruptly (Chi and Lu, 1991) and it is the expanded space of a shear zone that can well satisfy such requirements. Comparatively, the country rocks on both sides of a shear zone are characterized by a high degree of fragmentation and a smaller expanded space and thus the fluid pressure goes down slightly, as reflected by the low immiscibility of fluids (Guha et al., 1991). Clearly, fluid phase separation lends support to such a model that the drop of fluid pressure in the expanded space of the shear zone mentioned above is one of the fundamental driving forces for the migration of fluids in the shear zone (the seismic pumping model and the fault valve model). On the other hand, fluid phase separation is also an important mechanism governing the precipitation of ore forming materials, which is most closely related to the rise of pH of the liquid phase due to the removal of CO₂ in the process of fluid phase separation. In the Sigma gold deposit such a phenomenon has been observed that native gold is coexisting with CO₂-rich and H₂O-rich fluid inclusions within the same fissure (Robert and Kelly, 1987). It can be said that the expanded space in a shear zone has paved the way for the precipitation of ore forming materials, while serving as an extractor of ore fluids.

6 CONCLUSION

In conclusion, from the terms of the composition, stable isotopes and trace element

characteristics of ore forming hydrothermal fluids in shear zone hosted gold deposits, the possible source of ore forming fluids are: metamorphic, magmatic, mantle degassing and lower crustal granulitization derived, and deeply recycling groundwater. Isotopic homogenization of ore forming fluids in the same deposit or the same region provides evidence suggesting the such homogenization occur prior to the entrance of ore fluids into a shear zone. That is to say, there exists a homogeneous fluid zone beneath the shear zone.

The physicochemical parameters of ore fluids most closely related to the dynamic processes of the shear zone are temperature, pressure and phase state. Fluid phase separation is a common feature of ore forming fluids in shear zone, which can reflect the control of the shear zone over gold mineralization.

Shear zone fluids are recorded in two ways. One is the altered mineral assemblage resulting from the interaction between fluids and country rocks and the other is the fluid inclusions in altered minerals and gangue minerals. Both of them are the principal objects in the study of geochemical characteristics of shear zone fluids.

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GEOCHEMICAL CHARACTERISTICS OF ORE FORMING FLUIDS IN SHEAR ZONE HOSTED ARCHEAN GOLD DEPOSITS

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Abstract It terms of the composition, stable isotopes and trace element characteristics of ore-forming hydrothermal fluids in shear zone hosted gold deposits, the authors consider that it is hard to draw a decisive conclusion on the source of ore forming fluids. There are four possible sources of ore forming fluids: metamorphic, magmatic, mantle degassing and lower crustal granulitization derived, and deeply recycling groundwater. The former three sources would be supported by the geochemical evidence of their own, and thus could not be ruled out completely. The forth source has not yet accepted by most of the scientific researchers because it is in conflict to such characteristics that shear zone fluids are low in salinity and high in pressure. There is a possibility of mixing of ore forming fluids of various sources. Isotopic homogenization of ore forming fluids in the same deposit or the same region suggests precedence of such homogenization to the entrance of ore fluids into a shear zone. That is to say, there exists a homogeneous fluid zone beneath the shear zone.

The physicochemical parameters of ore fluids most closely related to the dynamic processes of the shear zone are temperature, pressure and phase state. Fluid phase

separation is a common feature of ore forming fluids in a shear zone, which can reflect the control of the shear zone over gold mineralization.

Fluids are the mediums for shear zone activity and minerogenesis. To study the geochemical characteristic of fluids is one of the important approaches to gaining a better understanding of the sources of ore forming fluids and ore forming elements present in them. It is of great importance to understand the sources of ore forming materials in the study of the connections between shear zones and mineralization. If there is no source of ore forming materials, no mineralization would take place even in the most favorable structural environments such as chemical environments of fluid activity and ore forming material precipitation, which are closely related to the dynamic processes involved in the development of shear zones.

Shear zone fluids are recorded in two ways. One is the altered mineral assemblage resulting from the interaction between fluids and country rocks and the other is the fluid inclusions in altered minerals and gangue minerals. Both of them are the principal objects in the study of geochemical characteristics of shear zone fluids.

Key words ore forming fluid, shear zone, Archean gold deposit

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