

Comparative Analysis on characteristics of Chemistry between Scandium Anatase Deposit in Qinglong Shazi and Laterite Gold Deposit in Western Guizhou, China

Min Zhang^{1, a}, Aiguo Nie^{1, b,*}, Fei Xie², Zhuru Zhang²

¹College of Resources and Environmental Engineering, Guizhou Institute of Technology, Guiyang, 550003, China

²Guizhou University, Guiyang, 550003, China

^a51595459@qq.com, ^bnieaiguo@163.com

*corresponding author

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Abstract. With scandium anatase deposit of Qinglong Shazi and three typical laterite gold deposit of Laowanchang, Baozidong and Shaguochang in western Guizhou as research objects, this paper makes a comparative analysis on characteristics of geochemistry between scandium anatase and gold deposit: 1) The main oxides in the scandium anatase deposits and laterite gold deposits are similar, both of which include SiO₂, Al₂O₃ and Fe₂O₃ and its features are similar with that of laterite weathering crust in the contemporary age; 2) There are large differences of TiO₂ content in the scandium anatase deposits and laterite gold deposits with the TiO₂ content is much higher in the former one of 3.42-5.03%. 3) Both the scandium anatase deposits and laterite gold deposits have gone through the intense weathering and the complete oxidization; 4) Both the scandium anatase deposits and laterite gold deposits are argillaceous ore, while Laowanchang lateritic gold mines and Baozidong lateritic gold mines are featured with silty clay-based; 5) Baozidong's equals to 10.21-14.13 with the average value is 12.17; which indicates the enrichment of the light rare earth. This obviously reflects the differences of the ore-forming environments. 6) According to the analysis result of correlation of trace elements of scandium anatase deposits of Qinglong Shazi, it can be seen that related elements can obviously be divided into two groups with the correlation coefficient above 0.6: Au-Ag-As-Sb-Hg-Tl group and Sc-TiO₂-Cu-Fe-Mn group.

Introduction

Mantle plume active region in Emei is the important concentration zone of super- large and large ore deposit[1-4]. Taking basalt region in the west of Guizhou as an example, mineral products like gold, antimony, copper, arsenic, mercury, thallium, rare earth have produced here [5-7]. In recent years, large-scale scandium anatase deposit has been founded in the Qinglong Shazi in Guiyang[8]. The genetic type of large-scale scandium anatase deposit in the Qinglong Shazi belongs to the thermal water deposit- slope deposit related with basalt eruption of Emei. The orebody occurred on the plane of unconformity of Permian Maokouan limestone karst and in red clay of the Karst negative terrain on the bottom of Emeishan basalt, of which the occurrence space is the same with red-clay gold mineral in the west of Guizhou province. However, the scandium anatase can't be found in red-clay gold deposit and vice versa. Therefore, this paper aims at make a comparative analysis on the characteristics of geochemistry of the scandium anatase deposit of Qinglong Shazi and three typical laterite gold deposit of Laowanchang, Baozidong and Shaguochang in western Guizhou.

Geological setting

Both scandium anatase deposit of Qinglong Shazi and laterite gold deposit in west of Guizhou are located in gold-concentrated area in the southwest of Guizhou province which is in the intersection portion of the southwestern margin of the Yangzi landmass and the west section of the south China

fold system from the perspective of geotectonic location. It is the core which is under the control of regional deep fracture and the main distribution in the region is the Permian Emeishan basalt (Fig. 1).

This area, living through one period of uplift and denudation after reef deposits of flats and limestone in the late middle Permian of Maokou formation, sink into the coastal zone[9]. Due to the volcanic eruption at the end of middle Permian and early of late Permian epoch, on the plane of unconformity of Permian Maokou limestone karst deposited the Emeishan basalt's first section of the clay basaltic volcanic breccia, then pyroclastic rock and tuff, which became the basalts exposed in this area in the southwest of Guizhou Province. It locates in the southeast edge of the basalt distribution range in the west of Guizhou with the thickness more than 200 meters below the earth[10]. and the eruption at the end of middle Permian and early of late Permian epoch. Conditions in the early eruption period are the littoral tidal flat[10]. Except for the general properties of the common continental tholeiite, the basalt in the region holds properties like slightly alkaline, high grade ferrotitanium, low-magnesium, SiO₂ saturation, generally containing quartz and few olivines. The degree of alkaline is the highest in the basalt distribution area in the west of Guizhou province and also the volatile component is higher than that of the other regions[11]. The mine-source stratum in initial stage of the lateritic gold deposit also serves as the ore bodies and country rocks of scandium anatase deposit of Qinglong Shazi.



Fig.1 Geology map of the study area

1 Large distribution of Emeishan basalt in Guizhou province; 2 scandium anatase deposit; 3 laterite gold deposit (point); 4 Geographical names of the cities and counties; 5 Deep fracture zone and fracture zone A Xiaojiang fault B Shuicheng-Ziyun fault C Mile-Shizong fault D Nanpan River fault E Nayong-Anshun fault (based on [1-2],[5-6],[11] revision)

Geochemical characteristics comparison between scandium anatase deposit and laterite gold deposit

Geochemical characteristics comparison of major elements.

Scandium anatase deposit of Qinglong Shazi: This paper made oxides full analysis of ten ore occurrence drilling single-ports basic analytical combination samples and according to the analysis, it can be found the main features of it are as follows: 1) The main oxides in the ore are SiO₂, Al₂O₃, Fe₂O₃ and TiO₂, with the gross accounts for 81.64-88.15%, which is similar with the features of laterite gold deposit in the west of Guizhou and laterite weathering crust of Guizhou[1,5]. However, the content of TiO₂ remains high; 2) All the iron in the ore is Fe₂O₃, which indicates the intense weathering of the ore and the rather complete of the oxidation; 3) The content of SiO₂ is less than 55% which is the argillaceous ore; 4) TiO₂ exists a positive correlation with Fe₂O₃ with coefficient of association as 0.9106, which indicates that symbiotic relationship (assorted relationship) between

anatase and the iron-bearing mineral in the protolith; 5) TiO_2 exists a positive correlation with Al_2O_3 and LOSS with coefficient of association as 0.8621 and 0.6636 respectively, which reflects the symbiotic relationship (assorted relationship) between anatase and the clay mineral in the protolith.

Laowanchang lateritic gold mines: Full analysis statistical result of 8 kinds of oxides in the ore [5] has expressed its main features as: 1) The main oxides in the ore are SiO_2 , Al_2O_3 and Fe_2O_3 , with the gross accounts for 82.51-88.47%, which is similar with the features of laterite weathering crust in the contemporary age. However, the content of TiO_2 remains low with proportion of 1.05-2.34%; 2) The main iron in the ore is Fe_2O_3 , with percentage of 6.10-17.88% and some few of FeO with 0.07-0.29%, which indicates the intense weathering of the ore; 3) The content of SiO_2 is 51.50-61.84% which are the argillaceous ore and sandy clay minerals; 4) TiO_2 exists a positive correlation with Fe_2O_3 with coefficient of association as 0.9106, which indicates that symbiotic relationship (assorted relationship) between titanium and the iron-bearing mineral in the protolith; 5) Au exists a positive correlation with SiO_2 with coefficient of association as 0.6380, which indicates that symbiotic relationship (assorted relationship) between the gold ore and the silicification in the protolith; 6) TiO_2 exists a positive correlation with SiO_2 and Au with coefficient of association as 0.7904 and 0.8699 respectively, which reflects the symbiotic relationship (assorted relationship) between titanium and Au with the silicification in the protolith.

Shaguochang lateritic gold mines: Full analysis statistical result of 8 kinds of oxides in the ore [5] has expressed its main features as: 1) The main oxides in the ore are SiO_2 , Al_2O_3 and Fe_2O_3 , with the gross accounts for 80.26-86.57%, which is similar with the features of laterite weathering crust in the contemporary age. However, the content of TiO_2 is 1.15-5.56%; 2) The main iron in the ore is Fe_2O_3 , with percentage of 13.49-20.84% and some few of FeO with 0.10-0.41%, which indicates the intense weathering of the ore; 3) The content of SiO_2 is less than 55% with the percentage of 43.96-54.66%, and all of them are the argillaceous ore; 4) Au exist a positive correlation with SiO_2 and Fe_2O_3 with coefficient of association as 0.5273 and 0.54.3 respectively, which reflects the symbiotic relationship (assorted relationship) between titanium and Au with the iron-bearing mineral in the protolith.

Baozidong lateritic gold mines: Full analysis statistical result of 8 kinds of oxides in the ore [5] has expressed its main features as: 1) The main oxides in the ore are SiO_2 , Al_2O_3 and Fe_2O_3 , with the gross accounts for 76.46-89.78%, which is similar with the features of laterite weathering crust in the contemporary age. However, the content of TiO_2 is rather low with 1.00-1.29%; 2) The main iron in the ore is Fe_2O_3 , with percentage of 7.24-22.34% and some few of FeO with 0.10-0.41%, which indicates the intense weathering of the ore; 3) The content of SiO_2 is more than 55% with percentage of 59.88-61.56%, and all of them are the argillaceous ore.

Geochemical characteristics comparison of rare earth elements.

Scandium anatase deposit of Qinglong Shazi: Randomly choose 13 ore occurrence drilling single-ports basic analytical combination samples to make rare earth elements analysis and then collect 7 basalt samples in the mine lot. The distribution pattern of the basalt and three ore-body rare earth elements is shown in Fig. 2 and the data is shown in table 1. The features are as follows:

The total amount of the rare earth elements in the basalt in the mine lot ($\sum\text{REE}$) is $(183.53-215.86)\times 10^{-6}$ and the total amount of the rare earth elements in the basalt in the west of Guizhou province is $(144.73-265.500)\times 10^{-6}$ [12], of which the abundance variation is within the scope of that of basalt in the west of Guizhou province. REE distribution pattern of Chondrite graphics of the rare earth elements in the basalt in the mine lot is right-deviation type. The LREE value of the sample is $(125.15-144.40)\times 10^{-6}$ and HREE value is HREE and thus LREE/HREE equals to 1.92-2.25, which means the enrichment of the light rare earth. Basalt in the west of Guizhou is sodium modified basalt, and two groups of elements include light and heavy rare earth shall separate from each other in the slightly alkaline medium, which then leads to the enrichment of the light rare earth.

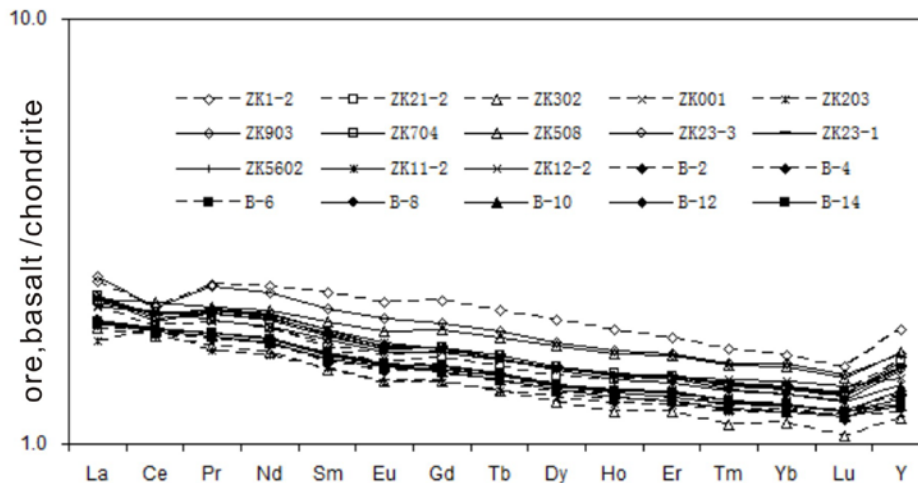


Fig. 2 Distribution pattern of scandium anatase of Qinglong Shazi and the Rare earth elements of basalt

All the total amounts ($\sum\text{REE}$) of the rare earth elements of the three ore-body in the mine lot are high with most of them are $(163.56-370.26)\times 10^{-6}$ and some amounts of the rare earth elements is $(402.26-702.67)\times 10^{-6}$; Besides, rare earth elements in the ore have different degrees of enrichment. REE distribution pattern of Chondrite graphics of the rare earth elements in the basalt in the mine lot is right-deviation type with most of the samples similar with basalt in the mine lot, which indicates the strong affinity between the two[13]. The LREE value of the sample is $(112.57-529.15)\times 10^{-6}$ and HREE value is $(35.52-244.26)\times 10^{-6}$ and thus LREE/HREE equals to 1.41-4.01, which means the formation of anatase environment has certain alkaline which lead to the further segregation of the light and heavy rare earth elements.

δEu value of basalt in the ore lot is 0.86-0.95 and all of them is smaller than 1, which presents the weak negative anomaly of Eu. δCe value of basalt in the ore lot is 0.92-0.97 and all of them is smaller than 1 which shows the proportionally syn-crystallization of main minerals plagioclase and the augite in the basalt. All the three δEu values of ore-body in the mine lot is less than 1% with the value equals to 0.79-0.93, which presents the weak negative anomaly of Eu. While the δCe value equals to 0.48-1.44, with most of the values between 0.48-0.88 and a few of them between 1.01-1.44 with a large variation. It shows that the ore-forming material source is related with basalt; however, during the mineralization process, size of the loss of the pyroxene is distinct in the complicated process like the decomposition in low temperature low pressure weak alkaline water[14] and the weathering process.

Laowanchang lateritic gold mines: The total amounts ($\sum\text{REE}$) of the rare earth elements is relatively high which is between $395.6-646.3\times 10^{-6}$. The LREE value of the sample is $331.4-514.9\times 10^{-6}$ and HREE value is $32.3-66.3\times 10^{-6}$ and thus LREE/HREE equals to 7.767-11.220 with the average value equals to 9.67, which means the clear differences between the heavy and the light rare earth elements because of the enrichment of the light rare earth elements and the loss of the heavy ones. There is a trend of weathering enrichment of the rare earth element in the gold mine forming process, especially for the light rare earth elements (Fig. 3)[5].

Shaguochang lateritic gold mines: The total amounts ($\sum\text{REE}$) of the rare earth elements is relatively high which is between $241.6-563.1\times 10^{-6}$. The LREE value of the sample is $201.0-586.2\times 10^{-6}$ and HREE value is $18.4-39.2\times 10^{-6}$ and thus LREE/HREE equals to 6.11-15.24 with the average value equals to 10.36, which means the clear differences between the heavy and the light rare earth elements because of the enrichment of the light rare earth elements and the loss of the heavy ones. There is a trend of weathering enrichment of the rare earth element in the gold mine forming process, especially for the light rare earth elements (Fig.3)[5].

Baozidong lateritic gold mines: The total amounts ($\sum\text{REE}$) of the rare earth elements is relatively high which is between $186.4-384.5\times 10^{-6}$. The LREE value of the sample is $156.1-305.9\times 10^{-6}$ and

HREE value is $15.3-21.7 \times 10^{-6}$ and thus LREE/HREE equals to 10.21-14.13 with the average value equals to 12.17 (Fig. 3) [5].

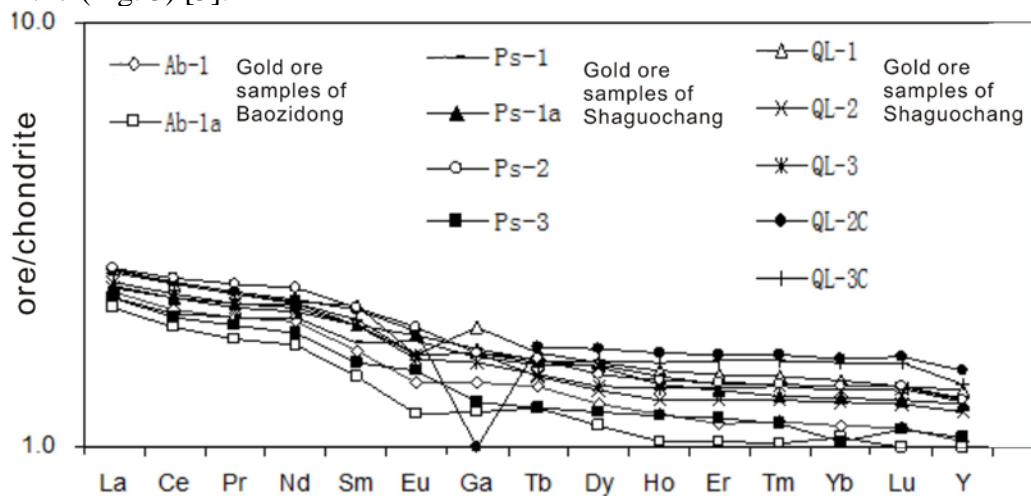


Fig. 3 Rare earth elements distribution pattern of lateritic gold mines of Laowanchang, Shaguochang and Baozidong[5]

Geochemical characteristics comparison of trace elements.

Scandium anatase deposit of Qinglong Shazi: Randomly choose 13 ore occurrence drilling single-ports basic analytical combination samples to make Quantitative analysis of trace elements. Based on the statistical result, the anatase ore has the following features: 1) Elements like Au, Ag, As, Hg, Sb, Ti, V, U, Pb, Fe, Mn, Th, Cu, Cr and Co have a degree of enrichment in the minerals, but none of them reached to the degree for comprehensive utilization. 2) According to the analysis result of correlation of trace elements in the ore (N=13), it can be seen that related elements can obviously be divided into two groups with the correlation coefficient above 0.6. The first group is the combination of Au-Ag-As-Sb-Hg-Tl, during which the correlation coefficients are: Au-Ag 0.8208, Au-As 0.8280, Au-Hg 0.9198 and Au-Tl 0.8868. The second group is the combination of Sc-Ti-Cu-Fe-Mn-V and during which the correlation coefficients are: Ti-V 0.7958, Ti-Fe 0.6180, Ti-Sc 0.6568, Ti-Cu 0.67635, Sc-Mn 0.7268 and Sc-Fe 0.9155. 3) The element of Sc is obviously concentrated in the minerals of all the three ore-body with the content variation is $24.7-53.8 \times 10^{-6}$ and the average value equals to 40.9×10^{-6} , which is 3.7 times of the earth crust on the mainland. 4) There are 750 samples in the mine lot. The content of Au is between $0.01-0.60 \times 10^{-6}$, during which 70% of them owns Au content less than 0.10×10^{-6} . The Au content in the whole mine is less than 0.20×10^{-6} . 5) The relevant discussion on the Au-TiO₂ towards the 750 samples shows that the correlation coefficient equals to -0.032 which means there is no correlation between them.

Laowanchang lateritic gold mines[5]: 1) Elements like Au, Ag, As, Hg, Sb, Ti and W have a degree of enrichment in the minerals; 2) Au-Ag-As-Sb-Hg-W in the ore shows a positive correlation with each other and the correlation coefficient are: Au-Ag 0.8229, Au-As 0.7083, Au-Hg 0.6932, Au-Sb 0.4853 and Au-W 0.9443.

Shaguochang lateritic gold mines [5]: 1) Elements like Au, As, Hg, Sb and Se have a degree of enrichment in the minerals; 2) Au-As-Sb-Se-Hg-W in the ore shows a positive correlation with each other and the correlation coefficient are: Au-As 0.9760, Au-Hg 0.7895, Au-Sb 0.9307 and Au-W 0.4857.

Baozidong lateritic gold mines [5]: 1) Elements like Au, As, Hg, Sb and Se have a degree of enrichment in the minerals; 2) Au-As-Sb-Se-Hg-Ag-Ti-W in the ore shows a positive correlation with each other.

Summary

The mains conclusions from this study are summarized as follows: 1) The main oxides in the scandium anatase deposits and laterite gold deposits are similar, both of which include SiO₂, Al₂O₃ and Fe₂O₃ and its features are similar with that of laterite weathering crust in the contemporary age; 2)

There are large differences of TiO₂ content in the scandium anatase deposits and laterite gold deposits with the TiO₂ content is much higher in the former one of 3.42-5.03%. The TiO₂ contents in the Laowanchang lateritic gold mines and Baozidong lateritic gold mines are relatively lower which are 1.05-2.34% and 1.00-1.29% respectively. The TiO₂ content in the Shaguochang lateritic gold mines is the largest which is 1.15-5.56%, and thus the variation is the largest at the same time; 3) Both the scandium anatase deposits and laterite gold deposits have gone through the intense weathering and the complete oxidization; 4) Both the scandium anatase deposits and laterite gold deposits are argillaceous ore, while Laowanchang lateritic gold mines and Baozidong lateritic gold mines are featured with silty clay-based; 5) TiO₂ exists a positive correlation with Fe₂O₃ with coefficient of association as 0.9106, which indicates that symbiotic relationship (assorted relationship) between titanium and the iron-bearing mineral in the protolith; 6) The rare earth elements total amount (\sum REE) has a degree of enrichment in the minerals in the scandium anatase deposits and laterite gold deposits and though there exists difference in the light and heavy rare earth, the difference of that is much smaller in the scandium anatase deposits of Qinglong Shazi with the LREE/HREE value equals to 1.41~4.01 and the average value is 2.71 which indicates the enrichment of the light rare earth element. The LREE/HREE values of three laterite gold deposits are: Laowanchang's equals to 1.41~4.01 with the average value is 9.67; Shaguochang's equals to 6.11~15.24 with the average value is 10.36; Baozidong's equals to 10.21~14.13 with the average value is 12.17; which indicates the enrichment of the light rare earth. This obviously reflects the differences of the ore-forming environments. 7) According to the analysis result of correlation of trace elements of scandium anatase deposits of Qinglong Shazi, it can be seen that related elements can obviously be divided into two groups with the correlation coefficient above 0.6: Au-Ag-As-Sb-Hg-Tl group and Sc-TiO₂-Cu-Fe-Mn group. The positive correlation of elements combination of the laterite gold deposits is Au-Ag-As-Sb-Hg-Tl. 8) The element of Sc is obviously concentrated in the minerals of scandium anatase deposits of Qinglong Shazi with the content variation is 24.7-53.8×10⁻⁶ and the average value equals to 40.9×10⁻⁶, which is 3.7 times of the earth crust on the mainland. There is no analyze data of element Sc in the three laterite gold deposits.

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