Analysis on the geochemical characteristics of Chachalongwa copper, lead and zinc polymetallic ores

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Abstract. The tectonic position of the Chachalongwa Cu, Pb, Zn polymetallic ores is located at the junction of the Qinqi-Kun orogenic system and the eastern Kunlun arc basin system. Through analysis of mineral assemblage, trace elements, rare earth elements, tectonic background and geochronology, the lithology, rock assemblages, geochemical characteristics of each ore-bearing strata in Xianqilongwa have been found out. It is found that the ore-bearing strata are volcanic rocks of the late Triassic Elashan Formation. As can be seen from the TAS diagram of principal elements, the magma evolution is in the direction of rich silicon, alkali, and poor magnesium, iron. the more that the magma differentiation, the higher that acid degree. From the diagram of rare earth partition mode, it can be found that the curve is inclined to the right, and is a negative Eu type of LREE enrichment. As the acidity of the rock increasing, the contents of elements such as Cu, Zn, Ni, Co, V, Ti, Mn and Sr are decreased, and compared with Taylor's crustal abundance, the content of elements such as Pb, Zn, Cr, Ga and Sn increased gradually. According to the geological tectonic environment, it can be roughly determined that the tectonic environment is the volcanic rock area of the orogenic belt, it shows that the volcanic rocks is in the tectonic orogenic belt environment. The age obtained by Rb - Sr and K - Ar methods was 210 ± 14Ma - 235 ± 12Ma, it shows that the geological ages of volcanic activity is the late Triassic, and the period of volcanic activity is not so long.

1. Introduction

The tectonic position of the Chachalongwa Cu, Pb, Zn polymetallic ore deposit is located at the junction of the Qinqi-Kun orogenic system and the eastern Kunlun arc basin system[1], the magmatic intrusions in this area include Indosinian period and Yanshanian period, and the multiple activities of magma with hydrothermal solution are favorable ore-controlling factors[2-3]. The rock masses of each stage are superimposed and interwoven with each other, and it plays an important role in the Formation of hydrothermal and hydrothermal metasomatic deposits during the evolution of magma intrusion[4-5]. The ore-bearing Formation is a central type of volcanic rock series, and belong to basic - neutral volcanic rock with clastic rocks in continental facies. The lower part is clastic andesite, the middle part is dolomite, and the upper part is rhyolite, there is an integrated contact between the strata[6-7]. The lithofacies and different types of volcanic rocks are circular, semi-circular and lamellated around the volcanic mechanism[8-9]. In the early stage, the assemblage type of intermediate basic volcanic rocks or interbeds was dominated by normal sedimentary clastic rocks, and developed from the bottom to the top by a coarse and thin rhythm, which belonged to the prologue of volcanic eruption, and in the middle and late period, the volcanic activities of the intermediate acid - neutral
volcanic eruptions were relatively strong, eruption facies, spillage facies lava can be seen, lithologic lithofacies changes greatly with typical characteristics of continental volcanic rocks[10].

2. Geochemical analysis

2.1. Principal element (Table 1, 2)

Table 1. Analysis of principal elements in volcanic rocks of Elashan Formation (1).

| Sample number | Rock name             | SiO₂ | TiO₂ | Al₂O₃ | Fe₂O₃ | FeO  | MnO | MgO | CaO |
|---------------|-----------------------|------|------|-------|-------|------|-----|-----|-----|
| ELS-1         | Rhyolite              | 76.45| 0.14 | 11.23 | 1.35  | 1.33 | 0.02| 0.45| 0.35|
| ELS-2         | Agglomerate           | 72.97| 0.10 | 12.83 | 1.41  | 1.28 | 0.02| 0.35| 0.77|
| ELS-3         | Tuff lava             | 76.30| 0.12 | 10.61 | 0.47  | 1.90 | 0.04| 0.10| 1.26|
| ELS-4         | Rhyolite              | 74.93| 0.19 | 12.99 | 0.36  | 1.13 | 0.04| 0.16| 1.51|
| ELS-5         | Agglomerate           | 75.86| 0.26 | 13.32 | 1.48  | 1.36 | 0.03| 0.51| 0.82|
| ELS-6         | Fluid-grained         | 69.61| 0.05 | 13.66 | 1.66  | 2.54 | 0.03| 0.73| 1.57|
| ELS-7         | Anemite ash lava      | 68.70| 0.70 | 13.27 | 3.21  | 0.42 | 0.17| 0.40| 3.40|
| ELS-8         | Dellenite             | 69.95| 0.20 | 14.58 | 1.06  | 1.98 | 0.07| 0.76| 2.31|
| ELS-9         | Andesite              | 59.82| 0.04 | 16.26 | 0.80  | 5.65 | 0.05| 1.21| 4.58|
| ELS-10        | Andesite              | 59.65| 0.80 | 16.70 | 0.24  | 3.54 | 0.07| 2.60| 5.54|
| ELS-11        | Basaltic andesite     | 51.71| 1.40 | 18.76 | 3.68  | 5.19 | 0.16| 2.82| 8.41|

The SiO₂ content of the volcanic rocks of the Elashan Formation in the Late Triassic period is 51.71% - 76.45%, the range of change is larger, the content of Al₂O₃ is 10.61% - 18.76%, and as the content of SiO₂ increases, the content of K₂O and Na₂O increases slightly, it is a positive correlation. the content of MgO, CaO, Fe₂O₃ and FeO are decreasing, it is a negative correlation, the magma evolution is in the direction of rich silicon, alkali, and poor magnesium, iron. As can be seen from the TAS diagram of the all silicon-alkali (Figure. 1), the volcanic rock series of Elashan Formation is potassium calcalkaline series. The eigenvalues σ are between 0.58 - 2.86, and belong to the alkaline rock series, the value of alkalinity rate is between 1.33 - 6.66, the average value of andesite is 1.63, the value of Angorite is 2.64, the value of rhyolite is 3.84, the index is lower, and the range of variation is narrower, the orogenic belt shows the characteristics of the island and active continental volcanic rocks, the main body belongs to calc-alkaline rock series. The differentiation index is 39.56 - 94.35, the average of andesite is 54.26, the average of dolomite is 78.89, the average of rhyolite is 89.57, and the range of variation is large, the results show that the trend of magma differentiation and evolution is increasing from neutral - intermediate acid - acid, the more the differentiation and evolution of magma, the higher the acidity. The component of magnesium - iron is first separated from the melt, and the composition of the residual melts in the middle and late stages is more and more enriched with the low melting
pulp and the felsic, while the Mg and Fe are less and less. With the increasing of the crystallization of magma, the MFI index and the alkali-calcium index increase.

![Figure 1. All silicon-alkali diagram (TAS)](image)

(Pc- picrite basalt; B- basalt; O1- basaltic andesite; O2- andesite; O3- dacite; R- rhyolite; S1- trachybasalt; S2- black tortoise coarse surface andesite; S3- trachyte andesite; T- trachyte, coarse-surface dacite; F- accessory feldspar rock; U1- tephrite, basanite; U2- reverberant alkali rock; U3- alkali syenite; Ph- phonolite; Ir- irvine boundary, alkaline at the top and subalkaline at the bottom)

2.2. Rare earth element (Table 3, 4)

The ∑REE of late Triassic volcanic rocks ranges from 125.78 (10^{-6}) to 250.78 (10^{-6}), andesite ∑REE 163.93 (10^{-6}), dolomite ∑REE 193.58 (10^{-6}), rhyolite ∑REE 203.77 (10^{-6}) and ∑REE tend to be enriched in late stage (rhyolite). The ∑REE values of andesite, dolomite and rhyolite gradually increased from 3.90 to 12.82, (La/Yb) N is 3.28 - 13.52, the value all over 1, it indicates that the volcanic rocks are light rare earth enriched type. Sm/Nd is 0.14 - 0.31, which indicates that the volcanic rocks of the Elashan Formation originated from the granite and sedimentary rocks in the crust.

![Figure 2. Standardized distribution pattern of chondrites of rare earth element](image)
The values ranges of Eu/Sm from 0.06 to 0.30, which are less than 0.35, δEu is 0.20 - 0.85. The REE partition pattern mode (Figure. 2) shows that the curve is inclined to the right, and Eu has a strong negative anomaly, Ce is medium negative anomaly, it indicates that there is strong differentiation and crystallization in the rock Formation process, and the origin of rare earth elements is consistent with the magmatic evolution process.

### Table 3. Analysis of rare earth elements in volcanic rocks of Elashan Formation (1).

| Sample number | Rock name       | La  | Ce  | Pr  | Nd  | Sm  | Eu  | Gd  | Tb  |
|---------------|----------------|-----|-----|-----|-----|-----|-----|-----|-----|
| ELS-1         | Rhyolite       | 31.00 | 54.00 | 4.80 | 24.00 | 7.40 | 0.44 | 6.00 | 0.32 |
| ELS-2         | Agglomerate    | 41.89 | 75.83 | 9.67 | 31.90 | 5.25 | 0.63 | 4.10 | 0.70 |
| ELS-3         | Tuff lava      | 33.45 | 62.05 | 9.64 | 30.90 | 4.93 | 0.88 | 4.20 | 0.70 |
| ELS-4         | Rhyolite       | 42.00 | 82.00 | 11.00 | 40.00 | 6.70 | 0.92 | 7.3 | 1.35 |
| ELS-5         | Agglomerate    | 40.00 | 73.00 | 7.30 | 26.00 | 5.40 | 0.75 | 6.5 | 0.52 |
| ELS-6         | Fluid-grained  | 48.00 | 28.00 | 5.60 | 28.00 | 8.00 | 1.00 | 5.00 | 1.52 |
| ELS-7         | Anemite ash lava | 42.00 | 75.00 | 5.20 | 26.00 | 4.60 | 0.88 | 10.91 | 7.5 | 0.16 |
| ELS-8         | Dellenite      | 53.13 | 93.29 | 13.88 | 43.42 | 5.87 | 1.05 | 4.48 | 0.70 |
| ELS-9         | Andesite       | 46.00 | 82.00 | 7.40 | 36.00 | 9.80 | 1.65 | 6.7 | 1.60 |
| ELS-10        | Anemite ash lava | 42.00 | 75.00 | 5.20 | 26.00 | 4.60 | 0.88 | 10.91 | 7.5 | 0.16 |
| ELS-11        | Basaltic andesite | 13.89 | 31.15 | 5.47 | 21.50 | 5.21 | 1.56 | 5.96 | 0.90 |

### Table 4. Analysis of rare earth elements in volcanic rocks of Elashan Formation (2).

| Dy  | Ho  | Er  | Tm  | Yb  | Lu  | Y  | ΣREE | LR/H | δEu | δCe (La/Y | (Ce/Y | Sm/N |
|-----|-----|-----|-----|-----|-----|----|------|------|-----|-----|-----|-----|-----|
| 4.70 | 1.60 | 2.80 | 0.66 | 4.10 | 0.64 | 36.00 | 178.46 | 5.84 | 0.20 | 0.96 | 5.10 | 3.41 | 0.31 |
| 3.97 | 0.90 | 2.44 | 0.40 | 2.59 | 0.40 | 21.94 | 202.61 | 10.66 | 0.40 | 0.88 | 10.91 | 7.57 | 0.16 |
| 4.03 | 0.86 | 2.40 | 0.37 | 2.40 | 0.36 | 21.50 | 178.67 | 9.26 | 0.58 | 0.82 | 9.40 | 6.69 | 0.16 |
| 6.6 | 1.82 | 3.5 | 0.6 | 4.6 | 0.4 | 36 | 244.79 | 6.98 | 0.40 | 0.90 | 6.16 | 4.61 | 0.17 |
| 5.1 | 1.5 | 2.6 | 1.05 | 2.8 | 0.64 | 28 | 201.26 | 7.33 | 0.38 | 0.96 | 9.63 | 6.74 | 0.21 |
| 3.80 | 1.10 | 2.30 | 0.59 | 3.10 | 1.00 | 27.00 | 164.01 | 6.44 | 0.45 | 0.35 | 10.44 | 2.34 | 0.29 |
| 3.40 | 0.69 | 2.05 | 0.50 | 2.90 | 1.30 | 26.50 | 197.19 | 9.02 | 0.57 | 1.04 | 9.76 | 6.69 | 0.18 |
| 4.31 | 0.92 | 2.57 | 0.40 | 2.65 | 0.40 | 23.71 | 250.78 | 12.82 | 0.60 | 0.81 | 13.52 | 9.11 | 0.14 |
| 6.10 | 1.45 | 3.30 | 0.65 | 4.40 | 1.65 | 39.50 | 248.20 | 7.07 | 0.59 | 0.97 | 7.05 | 4.82 | 0.27 |
| 3.05 | 0.60 | 1.78 | 0.30 | 1.60 | 0.25 | 15.25 | 139.65 | 9.03 | 0.67 | 0.87 | 10.34 | 7.90 | 0.19 |
| 5.29 | 1.10 | 3.16 | 0.30 | 2.86 | 0.41 | 26.82 | 125.78 | 3.90 | 0.85 | 0.86 | 3.28 | 2.82 | 0.24 |

2.3. Trace element

Compared with Taylor's crustal abundance, the volcanic rocks of the Elashan Formation are characterized by the high content of elements such as Pb, Zn, Cr, Ga and S, with the increasing of the acidity of the rocks and decreasing of content of elements such as Ni, Co, V, Ta, Mn and Sr. Among the iron elements, the content of Cr, Ni, Co, V, Ti, Mn in andesite, andesite and rhyolite is generally lower than the average content of intermediate acid rocks, and the content of Cu, Zn, S in the metallogenic elements is lower than the middle acid rock content, and the Pb content is higher than the middle acid content. The average content of Zr is similar to the average content of the neutral rocks in the andesite class, the andesite and rhyolite class. For the purposes of Ba and Be, the content of Ba is obviously higher than the average of rhyolite worldwide, and the anganite is slightly the same, while the andesite is lower, the Be in the andesite is slightly higher, the rhyolite and the anganite are slightly lower. The large ionic stone elements (K, Rb, Ba, Sr) in the Elashan Formation is relatively concentrated, and the Ti group elements (Ti, Zr, Nb, Ta) are the elements of the large volcanic rocks (K, Rb, Ba, Sr) in the Elashan Formation. The content of compatible elements is slightly lower, which
characterized by enriching of K, Rb, Ti, Th and poor of Nb, Y, Sm, Ta, and increased about content of K, Rb, Ti, K from neutral to acidic.

3. Tectonic environment and metallogenic ages

3.1. Tectonic environment

The chemical composition of oceanic volcanic rocks and continental volcanic rocks shows that belong to continental volcanic arc basalt, it indicates that the rocks form in the late orogenic environment. According to the geological tectonic environment, the tectonic environment is the volcanic rock area of the orogenic belt, obviously forms in the strong tectonic environment, and the tectonic changes are more intense in the late stage (rhyolite). It shows that the late Triassic volcanic rocks were formed in the orogenic environment. The lithophile elements of the rocks such as La are closed to the andesite of the orogenic belt and are symbiotic with the granite intrusive rocks. The late Triassic basalts in this area are strongly enriched inconsistent elements such as K, Rb, Ba, Th and losing of Sr, Ta, Nb, which is very similar to the island arc basalt in general.

According to the petrochemistry and trace elements mentioned above, the tectonic environment formed in the collisional orogenic environment is the continental volcanic rocks, which formed by the late Triassic volcanic rocks, and developed from the mature silica-aluminum crust in the southern margin of the North China plate, it is similar to Arc igneous rocks of active continental margin in Andes. The sea water of the Zongwulong - Zekou area mostly withdrew in the late Indosinian period. The arc - land collision from the north to the south, combined with the extrusion of oceanic crust material from the belt, resulted in the eruption of volcanic rocks in the Elashan Formation and the activity of the remelted K - rich granite magma.

3.2. Metallogenic ages

The late Triassic volcanic rocks occurred in the late Triassic Elashan Formation, which was unconformable to the early and middle Triassic Longwuhe Formation and Gulangdi Formation. The obtained Rb-Sr ages of andesite in the lower part of the Formation is 231 ± 8Ma, K - Ar ages is 235 ± 12Ma - 215 ± 14Ma - 213 ± 11Ma, combined with the contact relationship of underlying strata and intrusive contact relationship of rock mass in the Elashan Formation. The isotopic ages of the Elashan Formation is determined to be 231 ± 8Ma - 210 ± 14Ma, and the maximum is 235 ± 12Ma. The ages of volcanic activity is the late Triassic, which began in the early Carney period of the late Triassic and finally in the late Triassic Nori period, the period of volcanic activity is not so long.

4. Conclusion

(1) The tectonic position of the Chachalongwa Cu, Pb, Zn polymetallic ore deposit is located at the junction of the Qinqi - Kun orogenic system and the eastern Kunlun arc basin system, the magmatic intrusions in this area include Indosinian period and Yanshanian period, the multiple activities of magma and hydrothermal solution are favorable ore-controlling factors. The Elashan formation ore-bearing strata is a series of central eruptive volcanic rocks of continental meso basic-neutral volcanic rock intercalated with clastic rocks, it can be seen from the TAS diagram of all silicon - alkali rocks that it is calcium - potassium series.

(2) The SiO₂ content of the volcanic rocks of the Elashan Formation is 51.71% - 76.45%, the range of change is larger, the content of Al₂O₃ is 10.61% - 18.76%, and as the content of SiO₂ increases, the content of K₂O and Na₂O increases slightly, it is a positive correlation. the content of MgO, CaO, Fe₂O₃ and FeO are decreasing, it is a negative correlation, the magma evolution is in the direction of rich silicon, alkali, and poor magnesium, iron. The more the differentiation and evolution of magma, the higher the acidity.

(3) The ∑REE values of andesite, dolomite and rhyolite gradually increased from 3.90 - 12.82, (La/Yb) N is 3.28 - 13.52, numerical value all over 1, it indicates that the volcanic rocks are light rare earth enriched type. The REE partition pattern mode shows that the curve is inclined to the right, and
Eu has a strong negative anomaly, Ce is medium negative anomaly, it indicates that there is strong differentiation and crystallization in the rock Formation process, and the origin of rare earth elements is consistent with the magmatic evolution process.

(4) Compared with Taylor's crustal abundance, the volcanic rocks of the Elashan Formation are characterized by the high content of elements such as Pb, Zn, Cr, Ga and S, with the increasing of the acidity of the rocks and decreasing of content of elements such as Ni, Co, V, Ta, Mn and Sr, the large ionic stone elements (K, Rb, Ba, Sr) in the Elashan Formation is relatively concentrated. The ages obtained by Rb - Sr and K - Ar methods was 210 ± 14Ma - 235 ± 12Ma, it shows that the geological ages of volcanic activity is the late Triassic, and the period of volcanic activity is not so long.

Acknowledgments

This work was supported by Project of National Natural Science Foundation of China (No.51468055), the Ministry of Education "Chunhui Project" (No.Z2016073), Fundamental Research Project of Natural Science Foundation of Qinghai Province (No.2016-ZJ-720) and the Construction Project of Postgraduate Courses of Qinghai University (No.qdyk-180405).

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