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The Geochemical Effect of Lanthanides: Its Types and Application for Magmatic Rocks—A New Method to Semi-Quantitatively Determine Strength of Magmatic Fluid Complexation and Fractional Crystallization

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ABSTRACT: In this paper, the relationship between rare earth elements (REEs) geochemical behavior and their ionic radii was studied. According to the basic law called the effect on geochemistry of lanthanides, five types and some of subtypes of REEs occurrence, both in magmatic rocks and their minerals, were found, which may correspond to the evolutionary way of magmatic rocks. Analysis of REEs data for an amazonite-topaz granite pluton in East Xinjiang, one of the administrative regions of West China, and Cenozoic alkaline volcanic-intrusive rocks in the Xialiaohe depression of Bohai Bay Basin, China show that types II1, III and IV of effect on geochemistry of lanthanides not only reflect fluid complexation and fractional crystallization existed in magmatic evolution directly, but also can determine semi-quantitatively the strength of fluid complexation and fractional crystallization. Therefore, the effect on geochemistry of lanthanides, a new way to study semi-quantitatively evolution of magmatic rocks, is probably practicable. Moreover, the mafic lavas of different sources from the margin of Gonghe Basin, Qinghai Province, China, can be effectively distinguished in the diagram which can be drawn with some parameters of linear equation of LREEs and its ion radius.
KEY WORDS: effect of geochemistry of lanthanides, magmatic evolution, strength of fluid complexation and fractional crystallization.

1 INTRODUCTION

The "effect on geochemistry of lanthanides" (EGL) is an interesting natural phenomenon discovered by the author during the study of REEs in coal (Yang, 2010, 2009, 2008). All lanthanides have geochemical behavior closely related to their internal structure. For example, a geochemical parameter, after processed statistically appropriately, usually showed a good linear relationship with some of its structural parameters like REE's +3 valence etc.. Exceptions are rare. However, there is greater difference between LREE's linear relationship (La–Eu) and HREE's (Gd–Lu). Actually, this special phenomenon not only exists in coal, but also in all natural substances, including organism and inorganic objects. Lanthanides in the coal are mainly derived from silicate debris outside the coal basin. Different magmatic rocks may have different forms of effect on lanthanide geochemistry and thus reasonable explanation of their geological origin is necessary. Though researchers may be more or less aware of this phenomenon (Han, 2008), they didn't give it a full attention, not to mention quantitative investigation on the geochemical process related to REEs.

There are many patterns of the EGL. Among those forms, the relationship between REEs contents normalized by chondrite and their +3 valence ionic radii, (RREEC/CH-+3VIR) which showed in any geological body, is a very important one (Yang, 2011).

2 SEVERAL TYPES OF THE EGL IN MAGMATIC ROCKS AND THEIR MINERALS

After examination of 1 308 groups of REEs data on magmatic rocks from 76 literatures published in China from 2003 to 2012, there are five major types of the EGL in magmatic rocks and their minerals discovered by the author.

Type I. This is a discrete type, There is no relationship between normalized REEs contents by chondrite and their +3 valence of ion radii (RREEC/CH-+3VIR), i.e., either RLREEC/CH-+3VIR or RHREEC/CH-+3VIR has no correlation, because their correlative coefficients is too low (Pan et al., 2012; Sun and Ni, 2008; Chen et al., 2005; Deng et al., 2003). This can be seen in the case of the basaltic andesite sample ZQ47-99 cited in literature (Pan et al., 2012) (Fig. 1).

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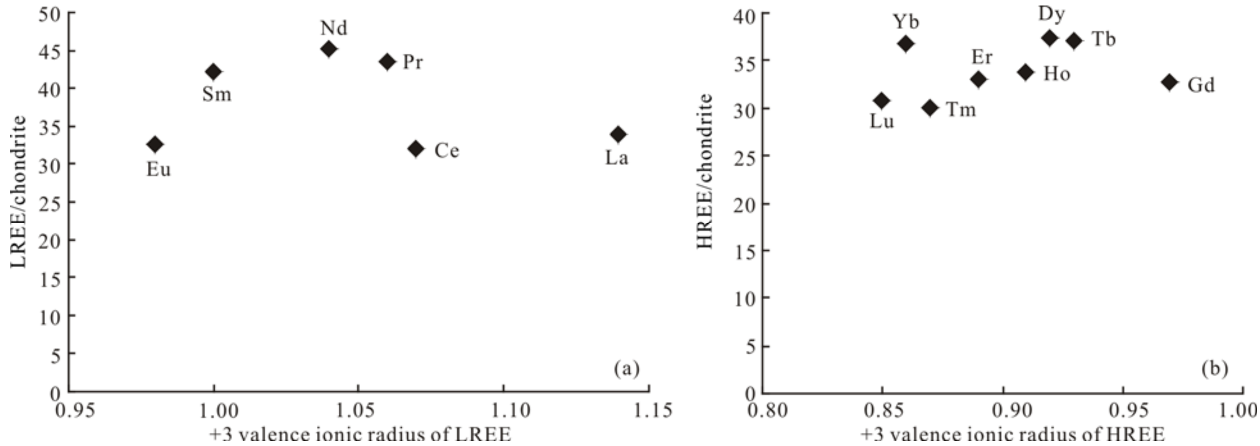

Figure 1. Correlation analysis of chondrite-normalized LREE (a) and HREE (b) and the ionic radii in basaltic andesite of Batu formation from Inner Mongolia, China (chondrite values from Herrman, 1970).

Theoretically, type I can be divided into four subtypes according to different combinations between the positive or negative correlation coefficients of RLREEC/CH-+3VIR and RHREEC/CH-+3VIR. Subtype IA , its correlation coefficients of LREE-+3 ion radius (CCLREEC/CH-+3VIR) or HREE' one (CCHREEC/CH-+3VIR) are showed to plus; such as subtype IB, both CCLREEC/CH-+3VIR and CCHREEC/CH-+3VIR are negative; IC, CCLREEC/CH-+3VIR is positive but CCHREE/CH-+3VIR is negative, on the contrary, ID, CCLREEC/CH-+3VIR is negative but CCHREEC/CH-+3VIR is positive.

Type II. This is a single discrete or single correlation type, namely either RLREEC/CH-+3VIR or RHREEC/RH-+3VIR is correlated (Ren et al., 2012; Xie et al., 2012; Li X R et al., 2011; Qi et al., 2011; Yu et al., 2011; Song et al., 2010; Tian et al., 2010; Cao et al., 2009; Gu L X et al., 2007; Tang et al., 2007; Zhang et al., 2006; Jia et al., 2004; Yuan H L et al., 2003). This type can be divided into two subtypes: subtype II1, such as the amazonite-topaz granite Sample T11 from the East Xinjiang Autonomous Region, China (Gu L X et al., 2007) (Fig. 2). RLREEC/CH-+3VIR is not correlated but RHREEC/CH-+3VIR is. Subtype II2 is just opposite to subtype II1, in which RHREEC/CH-+3VIR is correlated but not RLREEC/CH-+3 VIR. Depending on the different positive-negative combinations between CCLREEC/CH-+3VIR and CCHREEC/CH-+3VIR, theoretically, subtype II1 can be divided into 6 sub-subtypes. For example, II1A is a subtype which has a positive CCHREEC/CH-+3VIR correlation, while CCLREEC/CH-+3VIR is positive and too low; II1B, which has negative CCHREEC/CH-+3VIR while CCLREEC/CH-+3VIR is positive and too low; II1C, which has CCHREEC/CH-+3VIR positive while CCLREEC/CH-+3VIR is negative and too low; Ⅱ1D, which has negative CCHREEC/CH-+3VIR while CCLREEC/CH- +3VIR is negative and too low; II1E, which has positive CCLREEC/CH-+3VIR while CCHREEC/ CH-+3VIR is positive and too low and II1F, which has positive CCLREEC/ CH-+3VIR while CCHREEC/CH-+3VIR is negative and too low. Subtype II2 can also in turn be divided into 6 sub-subtypes theoretically which are: II2A, II2B, II2C, II2D, II2E and II2F.

Type III. This is a type that both CCLREEC/CH-+3VIR and CCHREEC/CH-+3VIR are positive, which is so-called double-positive-related type (Chen S L et al., 2012; Duan et al., 2012; Liu J P et al., 2012; Zhao et al., 2012; Fan et al., 2011; Cui et al., 2010; Li Y S et al., 2008; Long et al., 2008; Zhang L S et al., 2012; Zhang Y, et al., 2012; Zhang W Y et al.,2012; Zhang and Yang, 2008; Zhang et al., 2008; Gu S Y et al., 2007;

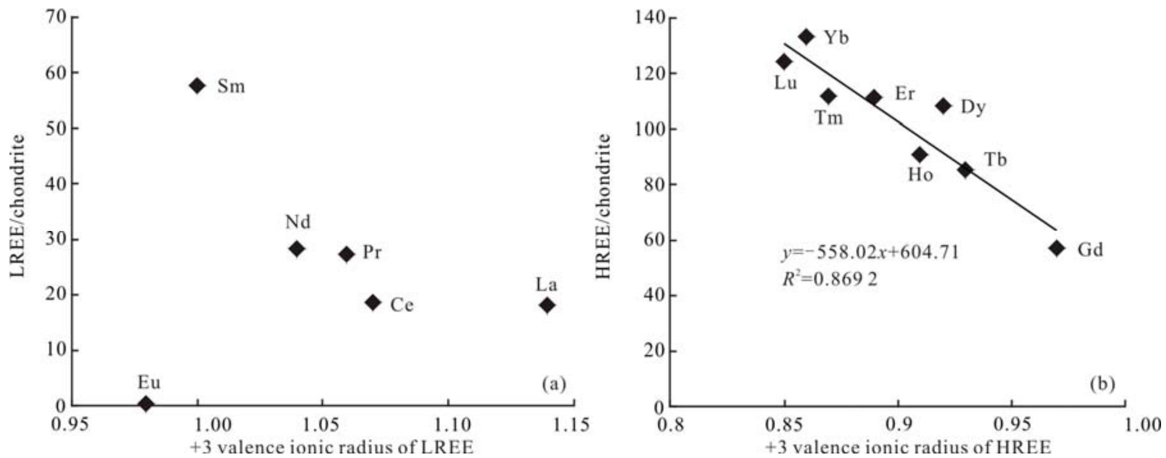

Figure 2. Correlation analysis of chondrite-normalized LREE (a) and HREE (b) and the ionic radii in granite of Baishitouquan, eastern Xinjiang, China (chondrite values from Herrman, 1970).

Lai et al., 2007; Liu P H et al., 2007; Lu, 2007; Tan et al., 2007; Wang et al., 2007; Niu, 2006; Tian et al., 2006; Xu X C et al., 2006; Qiu et al., 2005; Nie et al., 2005; Xu X J et al., 2005; Zhang and Zhang, 2005; Huang et al., 2004; Wu et al., 2004; Li Y J et al., 2003; Peng et al., 2003; Yuan F et al., 2003; Zhang C L et al., 2003). Generally, the correlation of RLREEC/CH-+ 3VIR is better than that of RHREEC/CH-+3VIR. This can be seen in the case of alkali basalt sample LH04 in literature (Wu et al., 2004) (Fig. 3).

Type IV. This is also known as type of double-negative correlation, i.e., both CCLREEC/CH-+3VIR and CCHREEC/CH-+3VIR are negative, it is just the opposite to Type III (Tang et al., 2008), such as zircon Sample Q43 cited in document (Zhao Z H et al., 2010) (Fig. 4).

Type V. This is called anti-related type. i.e., no matter it is positive or negative, CCLREEC/CH-+3VIR is always opposite to CCHREEC/CH-+3VIR (Li X R et al., 2011; Luo et al., 2010; Yang et al., 2008; Xiong et al., 2006; Peng et al., 2005; Wang et al., 2003). This type can be divided into two subtypes: subtype V1, such as a second of granite Sample 3-2' cited in literature (Xie et al., 2009) (Fig. 5), when CCLREEC/CH-+3VIR is positive but CCHREEC/CH-+3VIR negative. Subtype V2 is just opposite to subtype V1, when CCLREEC/CH-+3VIR is negative but CCHREEC/CH-+3VIR positive.

Actually, it is relatively rare that there is only one type of the EGL in same geological body or study area described as literature (Gu L X et al., 2007), in which only existed type II1. Typically, there are two or more types coexisting, which can be seen from literature (Chen S L et al., 2012; Fan et al., 2012; Li et al., 2012; Sun H S et al., 2012; Sun Z M et al., 2012; Wang et al., 2012; Yang et al., 2012; Long et al., 2011; Zhang, Y, et al.,2012; Zhang and Lin, 2010; Xie et al., 2009; Xu et al., 2009; Zheng et al., 2009; Guo et al., 2007; Yan et al., 2005; Yuan et al., 2005; Zhang Z S et al., 2005; Zhao et al.,2010). The latter may be caused by different magmatic sources or different phases of magmatic evolution in same magma source. If so, the several

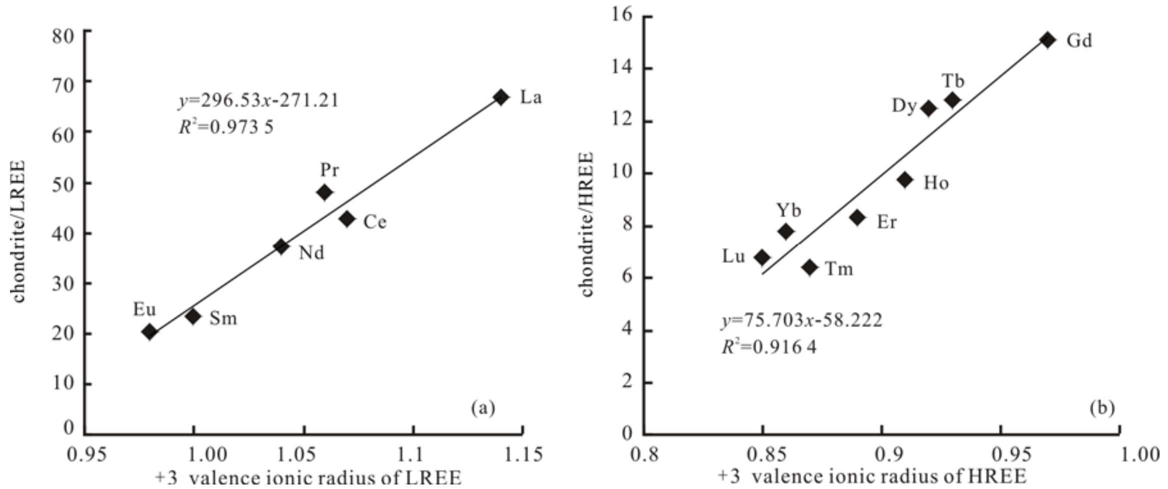

Figure 3. Correlation analysis of chondrite-normalized LREE (a) and HREE (b) and the ionic radii in alkaline granite from Liaohe Basin, China (chondrite values from Herrman, 1970).

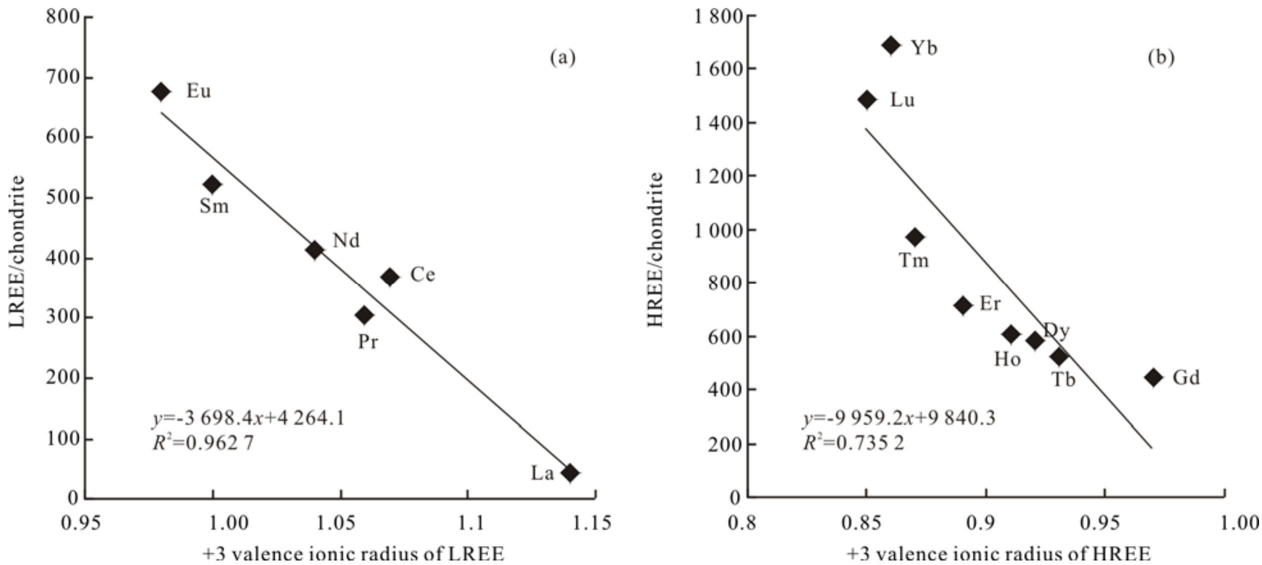

Figure 4. Correlation analysis of chondrite-normalized LREE (a) and HREE (b) and the ionic radii in alkaline syenite from Shuiquangou, Hebei Province, China (chondrite values from Herrman, 1970).

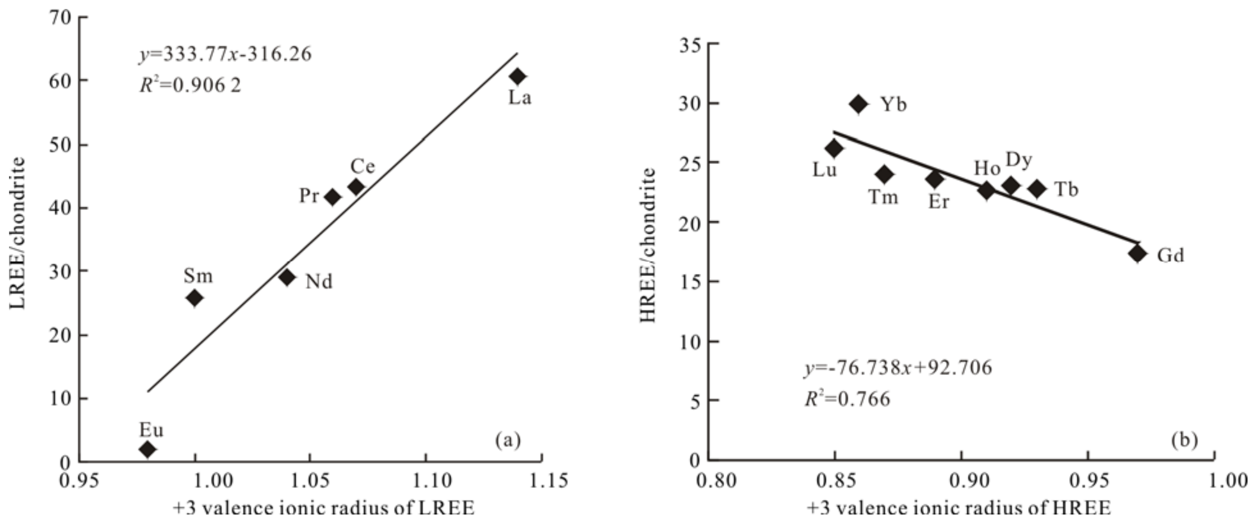

Figure 5. Correlation analysis of chondrite-standardized LREEs (a) and HREEs (b) and the ionic radius in alkaline syenite from Granite, eastern Guizhou, China (chondrite values from Herrman, 1970).

types of the EGL have no clear boundaries among the types. For example, the RLREEC/CH-+3VIR of Sample T11 in Fig. 2 should be a good correlation as an EGL type IV rather than a type II if there is no obvious Eu anomaly. In addition, even if the same EGL type, there are also obvious difference in their graphics appearance. For example, though CCLREEC/CH-+3VIR is all positive in some samples, some of the graphics show linear and others show anti-"Z" shape. The difference in magmatic evolution and/or origin will be further studied and identified.

The probability of the above five types of EGL is different in magmatic rocks. From 1 380 groups of REEs data collected by the author, these EGL types have a certain relationship with the magmatic evolution. Based on previous research, firstly, as an example of amazonite-topaz-granite's evolution in Xinjiang Baishitouquan rocks, and then the fractional crystallization of Sha-third of alkaline volcano-intrusive rocks in Liaohe Basin, to explain how the EGL types II1, III, IV are used to trace in evolutionary process of magmatic rocks would be attempted in this paper. Secondly, from the EGL point of view, different magmatic sources would be identified by the EGL parameters analysis to the mafic lavas from margin of Gonghe Basin, Qinghai Province, China. The geological significance of other EGL types for magma geochemistry will be further discussed in other papers.

3 GEOLOGICAL BACKGROUND OF STUDY AREA AND SAMPLES

The topaz granite from Baishitouquan, East Xinjiang Autonomous Region, China, was formed from residual magma on the upper crust through partial melting and then highly fractional crystallization. Generally this kind of granite is low in total REEs, which is gradually decreasing in the rocks from the bottom to the top, and is enriched in HREEs but depleted in Eu (Gu L X et al., 2007). The Baishitouquan granite intrusion is divided into five sections along the hillside to the top: the light color granite section (Section a), the section of granite with amazonite (Section b), amazonite granite section (Section c), the section of granite with topaz-amazonite (Section d) and the topaz-albite granite section (Section e) (Gu L X et al., 2007). Figure 6 is geological map of the Baishitouquan rock, which located in eastern Xinjiang, China. They are characterized by high Al contents, alkaline enrichment and high contents of volatile element F. This F-bearing residual magma can affect the enrichment of REEs, especially HREEs during the beginning of magmatic evolution. However, with a lot of accessory minerals containing REEs crystallized out of the parent rock, the complexation of fluid containing F for REEs would become weaker, and the total REEs was decreased, which was consistent with the field observations, the sample analysed and results of experimental petrology (Li et al., 2002).

The Sha-third (E_2s^3) of volcanic-intrusive rocks in Liaohe Basin are a set of slightly alkaline bimodal rock series, in which mafic end member is alkaline basalts and middle-slightly-alkaline end member is trachyte lavas. It has been reported that basaltic rocks of the asthenosphere is a result of the low-degree of partial melting in the mantle, then through the fractional crystallization process of olivine, pyroxene, and finally, when basaltic magma was raised up into the upper curst, olivine, pyroxene, plagioclase and magnetite etc. continued to be crystallized out of the parent magma to form trachyte. In the whole process, the contamination effect of crustal material for the magma was not considered to be significant (Wu et al., 2004).

Late Paleozoic mafic lavas, located at the margin of Gonghe Basin, Qinghai Province, China, are distributed in the south side of Animaqing ophiolite belt, north side of Zongwulong tectonics belt, as well as Kuhai-Saishitang belt located between these two. Previous study shows that the mafic lavas in Animaqing belt constituted the ancient ridge hotspot structure, which, as the center of OIB in Majixueshan, is transited gradually into MORB to the east and west sides (Guo L X et al., 2007). Mafic lavas in Kuhai-Saishitang belt are made up of E-MORB and continental rift basalts, while the rocks in Zongwulong construction belt are a type of N-MORB which is slightly enriched in large ion lithophile elements. Mafic lavas of the Denier Section, the Buqingshan Section, the Majixueshan Section, where they separately located at Animaqing belt, Zongwulong belt and Kuhai-Saishitang belt, are all basaltic lavas, but with different $Mg^{\#}$ values.

REEs data cited from the above literature had been normalized by REEs average value of 22 chondrite. Here REEs data of different lithofacies in Baishitouquan granite rock, East Xinjiang Autonomous Region, were listed in Table 1.

As can be seen in Table 2, RLREEC/CH-+3 VIR of all lithofacies in Baishitouquan granite is a negative trend while their RHREEC/CH-+3VIR is negatively correlated. Therefore, their EGL all belong to Type II1D.

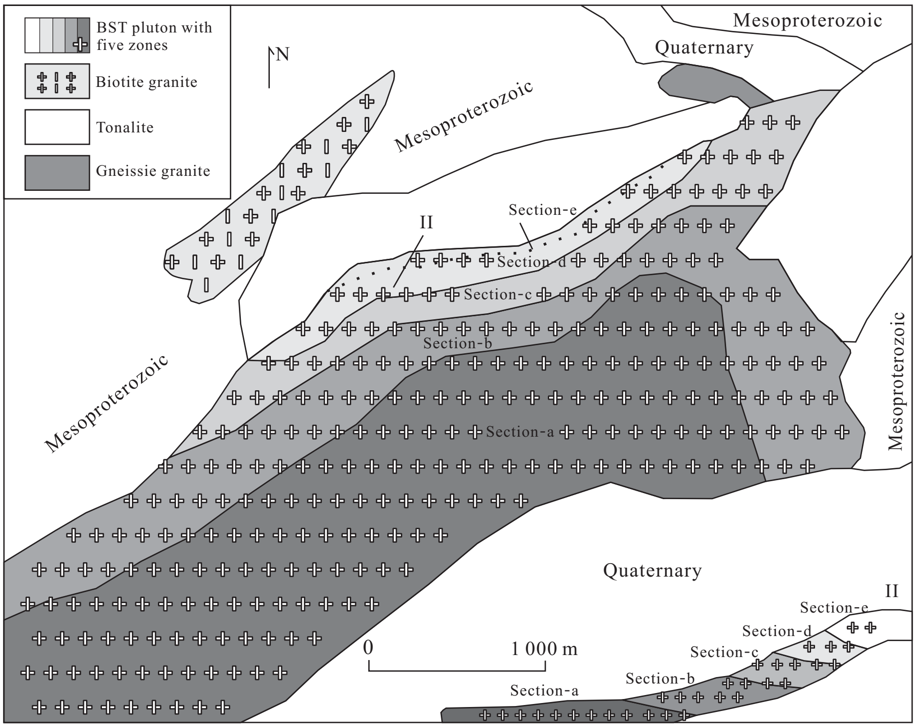

Figure 6. Geological map of the Baishitouquan rock in eastern Xinjiang (from Wu et al., 2011).

Table 1 Chemical analyses of REE for the Baishitouquan pluton in the East Xinjiang ($w/10^{-6}$)

	Section a			Section b			Section c			Section d			Section e		
	T1	T2	T3	T4	T7	T9	T11	T15	T17	T18	T19	T20	T21	T22	T30
La	3.1	3.59	4.09	6.67	5.52	1.04	5.71	8.792	6.53	7.02	4.98	7.12	3.02	4.92	1.93
Ce	10.95	10.76	12.85	22.36	18.62	5.17	17.46	29.01	21.15	23.82	16.35	25.94	8.55	17.09	5.79
Pr	1.77	2.04	2.28	3.89	3.11	0.765	3.26	5.54	41.66	4.63	3.1	4.78	1.37	2.69	0.85
Nd	9.41	11.24	12.23	20.7	15.73	4.6	16.88	28.49	19.33	21.65	14.32	22.04	5.77	12.07	3.56
Sm	6.79	8.35	8.82	14.37	9.93	3.58	11.51	19.02	12.93	13.76	9.25	14.09	3.75	8.08	2.32
Eu	0.026	0.024	0.032	0.018	0.011	0.01	0.02	0.011	0.024	0.038	0.026	0.017	0.046	0.093	0.013
Gd	11.23	14.4	15.32	23.01	14.01	5.87	17.68	25.38	14.23	14.16	8.39	14.66	4.26	9.57	2.6
Tb	2.69	3.34	3.63	5.45	3.16	1.45	4.25	6.07	3.96	3.69	2.51	3.87	1.244	2.7	0.716
Dy	21.68	26.273	28.65	42.35	24.63	11.312	33.45	43.99	27.28	26.33	16.84	27.64	9.59	19.79	5.02
Ho	4.42	5.43	5.85	8.46	5.01	2.2	6.61	7.73	5.17	4.1	3.05	4.36	1.61	3.02	0.8
Er	15.45	18.76	20.4	29.87	18.82	7.3	23.36	25.02	14.68	12.71	8.1	13.41	5.11	8.63	2.14
Tm	2.31	2.82	2.98	4.56	3.19	1.08	3.68	3.83	2.58	1.99	1.48	2.12	0.88	1.27	0.353
Yb	15.44	18.87	19.75	30.89	23.51	6.89	25.25	25.43	17.52	13.27	10.08	14.03	6.07	7.88	2.2
Lu	2.4	2.903	3.05	4.71	3.72	0.99	3.84	3.56	2.22	1.71	1.23	1.82	0.79	0.98	0.29

From Gu L X et al. (2007).

According to this manner, the Sha-third (E_2s^3) alkaline volcanic-intrusive rocks in Liaohe Basin are easily known as type III of the EGL, because both CCLREEC/CH-+3VIR and CCHREEC/CH-+3VIR are positive (Fig. 3). However, there are two types of the EGL in the mafic lavas from the margin of Gonghe Basin, Qinghai Province, China. The first type of the EGL, such as mafic lava samples from the AM series of Denier Section, Majixueshan Section in Animaqing belt and Kuhai-Saishitang belt, belongs to type III; the second of EGL type, such as mafic lava samples from the WSA series of

Denier Section, Buqingshan Section in the Animaqing belt and the Zongwulong belt, belongs to atypical type IV and its transitional types.

4 DISCUSSION

4.1 Semi-Quantitative Analysis of Fluid-Complexation for Rees in Baishitouquan Amazonite-Topaz Granite from Xinjiang Autonomous Region, China

The differentiation of fluid plays a very important role during rock formation and its zoning process. If there is a high alkalinity fluid with plenty of ions as F^{-}, $CO^{3,}$ HCO^{3-}, or a geological body intensely transformed by the hot liquid, the REEs of the fluid or body can not only migrate in the form of the complex, but their ability to be migrated also successively increases as their +3 valence ionic radii decrease (Liu, 1987). Expressed in the way of the EGL, i.e., chondrite-normalized REEs value would decrease as their ionic radii increases and should have been showed in the type IV of the EGL in these rock sections. In addition to the fluid complexation, there as some degree of fractional crystallization in the Baishitouquan rock which caused Eu loss and low CCLREEC/CH-+3VIR. Because of this reason, the EGL showed type II1 instead of type IV. Therefore, this indicates that the EGL is completely applicable in confirming whether the volatile-fluids existed or not in geological body easily and rapidly.

Moreover, the relative size of the complexation of the fluid rich in volatile for REEs can also be given by means of the EGL. First, we examine "degree of simply" about complexation. The more simple this action is, the better the negative correlation showed in Fig. 2b, even it might show a type IV of the EGL, if its better negative correlation as showed in Fig. 2a too. Therefore, if a sample has an absolute value of negative correlation coefficient of RREEC/CH-+3VIR, or RHREEC/CH-+3VIR is known, the size of the simple degree of fluid complexation to REEs will be indirectly obtained. In Fig. 7a, there were five rock sections in Baishitouquan rock, East Xinjiang Autonomous Region, China, which changed from Section a to Section e, that is, from the bottom to the top and from early to late, on the whole, the magmatic fluid complexation would be gradually changed from strong to weak in the way of the parabola.

The simple degree of the fluid complexation is only showed how much its proportion compared to other geological actions, which, however, cannot show how much its complex strength is, and the latter are related to negative slope of RREEC/CH-+3VIR, especially of RHREEC/CH-+3VIR. The higher the negative slope values of the RHREEC/CH-+3VIR are, the higher its HREEs contents are. In Fig. 7b, CCHREEC/CH-+3VIR for the abscissa, the negative slope of HREE/CH-+3VIR for the vertical axis, as a result, the fluid complex strength for REEs in Baishitouquan granite zones, from Section a to Section e, early to late, strong to weak, can be expressed synthetically. However, because of fractional crystallization existed in that magma, which may leads to reducing concentrations of HREE, the changes order of fluid complex for REEs in Fig. 7b is less than its simple degree in Fig. 7a.

Previous studies indicate that the vertical zonation role for the rocks from "a" section to "e" section is the result of the fractional crystallization and fluid transportation. However, our study shows that both fractional crystallization and fluid transportation exist. Fluid transportation is a dominant factor, and fractional crystallization is less dominant, according to the analysis of effect on lanthanide geochemistry from "a" section to "e" section of the Baishitouquan rock.

4.2 Semi-Quantitative Analysis on Fractional Crystallization for E_2s^3 of Volcanic-Intrusive Rock in Liaohe Basin

During magmatic crystallization, the compatible elements are always enriched in crystalline phase while the incompatible ones enriched in residual magma. As the degree of crystallization for residual magma increased, its compatible elements are dramatically reduced while its contents of incompatible elements are elevated in the lava. (Han, 2008) Expressed by way of the EGL, if REEs, especially LREEs, in residual lava formed by fractional crystallized were normalized by the chondrite, it's CCREEC/CH-+3VIR should be a positive, and, so its EGL belongs to type III, as shown in Fig. 3. From the correlation between REEs and their +3 valence ionic radii in volcanic-intrusive rocks located at Liaohe Basin, we can see

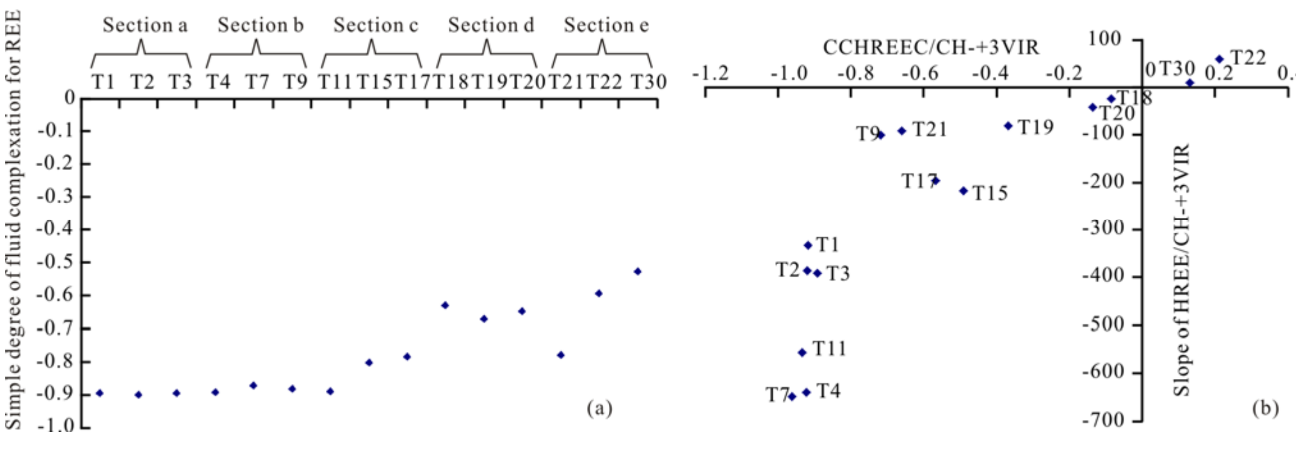

Figure 7. The semi-quantitative analyses of fluid simple degree (a) and fluid complexation intensity (b) for the Baishitouquan pluton in the eastern Xinjiang.

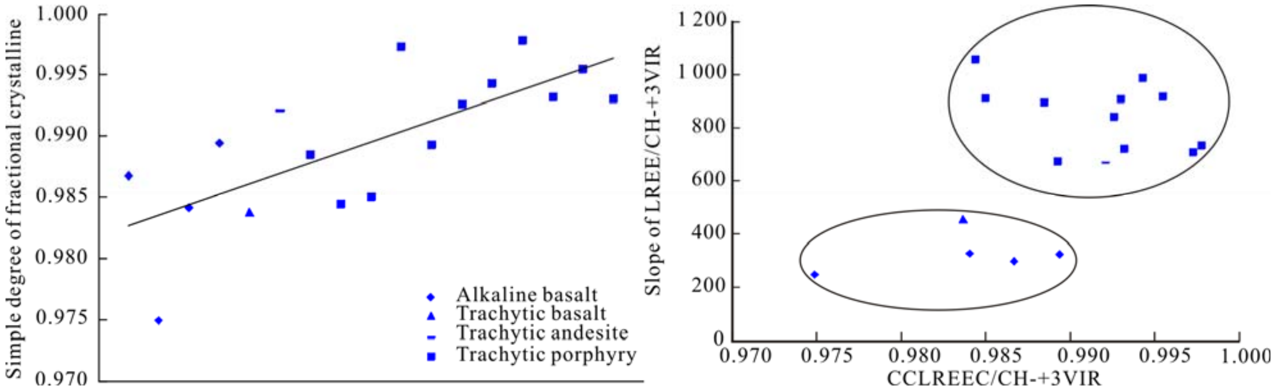

Figure 8. Semi-quantitative analyses both simple degree (a) and intensity (b) on fractional crystalline for Sha-third of volcanic-intrusive rocks in Liaohe Basin.

that the larger a REE ionic radius is, the richer will a REE be. Therefore, to some extent, if a sample of basalt or trachyte formed by fractional crystallized, its CCREEC/CH-+3VIR, specifically CCLREEC/CH-+3VIR, may describe its simple degree of fractional crystallization semi-quantitatively. The larger CCLREEC/CH-+3VIR is, the higher its degree of fractional crystallization is. As shown in Fig. 8a, the general change of the fractional crystallization in the Sha-third of volcanic-intrusive rock located at Liaohe Basin increases from basalt to trachytic porphyry. If the fractional crystalline strength was represented by positive slope of the LREE/CH-+3VIR linear equation, imitating Fig. 7b to plot figure, the above conclusions can also be obtained and the two different areas in this figure were divided which respectively belong to basaltic rocks and trachytic rocks (Fig. 8b). However, plotted figure like Fig. 7a by means of CCREEC/CH-+3VIR, the degree of fractional crystallization of trachytic porphyry is slightly lower than that of basalt. Figure 9 is this because of the alteration diversity between basalt and trachyte which further affect distribution of HREEs? We will study it further in the future. In short, LREE is more practicable for studying magmatic fractional crystallization.

4.3 Different Sources of Late Palaeozoic Mafic Lava in the Margin of Gonghe Basin

Though the mafic lavas in Animaqing, Zongwulong sections and Kuhai-Saishitang belt were located at different tectonic units, or at the same units but different sections, the

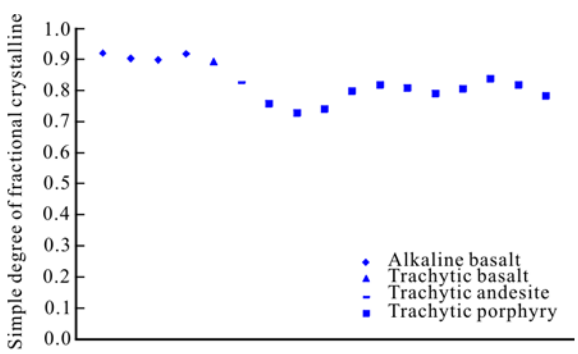

Figure 9. Relative size of simple degree on fractional crystalline represented by CCREEC/CH-+3VIR.

samples from the WSA (WSA is a sample number of letters) series in the Denier Section and Buqingshan Section in Animaqing belt, from the EGL point of view, can be grouped into the same class, which basically belongs to Type IV of the EGL or it's transitional types. While AM (AM is also a sample number of letters) series of mafic lavas in Denier Section, mafic lavas in Jixueshan Section and Kuhai-Saishitang belt can be grouped into other classes, which is Type III of the EGL. Previous study (Guo A L et al., 2007) indicated that the former represents affinities N-MORB sources of materials while the latter has a tendency to affinity E-MORB and continental materials. Difference in the two mafic lava sources is showed in Fig. 10, which CCLREEC/CH-+3VIR for the abscissa and slope of RREEC/CH-+3VIR for the vertical axis. According to the preceding discussion about the types III and IV of the EGL, E-MORB lava may be formed in the fractional crystallization process while N-MORB lava may be formed in the fluids process during their magmatic evolution process. Further study on these rocks will be necessary.

5 CONCLUSIONS

1. Five types of REEs distribution patterns in magmatic rocks and their minerals were confirmed by means of the EGL. Type I, no correlation between RLREEC/CH-+3VIR or RHREEC/CH-+3VIR; type II, either RLREEC/CH-+3VIR or RHREEC/CH-+3VIR shows correlation; type III, both RLREEC/CH-+3VIR and RHREEC/CH-+3VIR show positive correlation; type IV, both RLREEC/CH-+3VIR and RHREEC/CH-+3VIR show negative correlation; type V, both RLREEC/CH-+3VIR and RHREEC/CH-+3VIR show correlation but they also show the opposite correlations. Based on the combination of positive-negative correlation between their CCLREEC/CH-+3VIR and CCHREEC/CH-+3VIR, or combination of correlation-discrete between RLREEC/CH-+3VIR and RHREEC/CH-+3VIR, types I, II and V can be divided into some subtypes of EGL theoretically. Either only one type of the EGL or many types exist in the same geological body. In the latter case, there may be transitional relations in different EGL types. Each of the EGL type may have a corresponding relationship with the ways of magmatic rocks evolution and fractional crystallization.

2. The REEs analysis of both topaz-amazonite granite in East Xingjiang Autonomous Region and Sha-third of alkaline

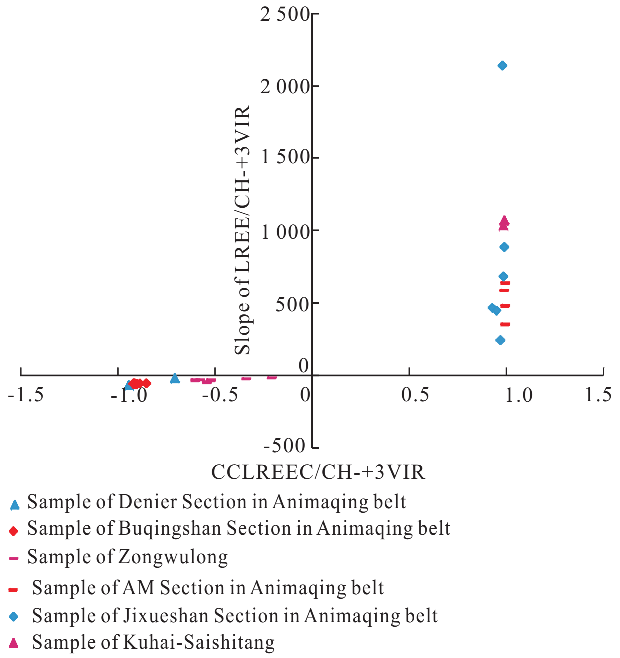

Figure 10. Distribution on the two different source of mafic lava in the margin of Gonghe Basin showed in the slop of LREE/CH-+3VIR chart.

volcanic-intrusive rocks in Liaohe Basin in this study shows that hydrothermal alteration and fluid may play a leading role in the magmatic evolution when their EGL type is IV or II1. Therefore, during the vertical zoning from “a” section to “e” section for amazonite-topaz granite in East Xinjiang, both fluid transportation and fractional crystallization may have been existed, with the former playing a more important role. While the fractional crystallization may play a leading role in the magmatic evolution when their EGL type is III. Therefore, the magmatic fluid complexation and magmatic fractional crystallization may be semi-quantitatively identified by ways of the EGL.

3. Using EGL principle, N-MORB lava and E-MORB lava or mainland material located at the margin of Gonghe Basin, Qinghai province, can be distinguished well in the figure by plotting of CCLREEC/CH-+3VIR and by the slop of its linear equation.

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