TRACE ELEMENT CHARACTERISTICS OF ULTRAMAFIC INCLUSIONS IN THE EASTERN PART OF LIAONING–JILIN PROVINCES BY NAA

Yang Ruiying (杨瑞瑛)
(Institute of High Energy Physics, Academia Sinica, Beijing 100080, China)
Yuan Chao (袁 朝)
(Changchun College of Geology, Changchun 130026, China)

ABSTRACT

Cenozoic basalts in the eastern part of Liaoning-Jilin contain abundant mantle-derived inclusions. The rock types of the ultramafic inclusions are composed mostly of spinel lherzolite and a few websterites. In order to study the origin of inclusions, the concnetrations of several trace elements have been measured in samples by NAA. According to geochemical characteristics of trace elements, there are two types of spinel lherzolite inclusions. The first type is refractory residues left after partial melting of the upper mantle and the second type is metasomatizing refractory residues. The websterites inclusions formed by segregation of basaltic melt derived from high degree of melting of mantle source rocks.

Keywords: Ultramafic inclusion Primitive mantle Residual mantle Partial melting Mantle metasomatism Spinel lherzolite Websterite

1 INTRODUCTION

The cenozoic basalts in the eastern part of Liaoning-Jilin form three volcanic zones, the Yitong-Yilan, Duenhua-Mishan and Yalu River-Tumen. The basalts which are particularly noteworthy for abundant large ultramafic inclusion are composed mostly of spinel lherzolite and a few websterites.

Nine rocks and six separated minerals have been analyzed for trace elements (REE, Sc, Cr, Fe, Co, Ni, Rb, Sr, Ba, Hf, Th and U). Analyzed samples are collected from Kuandion, Yitong, Wangqing, Longgang and Jiaohe. The REE concentrations of the samples were determined by preconcentrated neutron activation analysis (NAA), those of other trace elements were measured by instrumental NAA. The relative standard deviations of most analytical results of these elements are less than 5 %.

2 EXPERIMENTAL

Not only the abundances of REE in ultramafic inclusions and their separate minerals are very low, but also Fe, Co, Ni, Cr, Sc, Na, Th and U seriously interfere the peaks of REE isotopes measured. So the contents can not be obtained with good precision and accuracy by INAA. REE are determined with μg/kg level by preconcentrated NAA using a fusion dissolution process and a quantitative group separation scheme (see Fig.1), followed by radioassaying. The scheme is rapid and sensitive. The accuracy of the procedure was checked by analysing USGS DTS-1, AGV-1, G-1, G-2, the obtained results agree quite well with literature values[1]

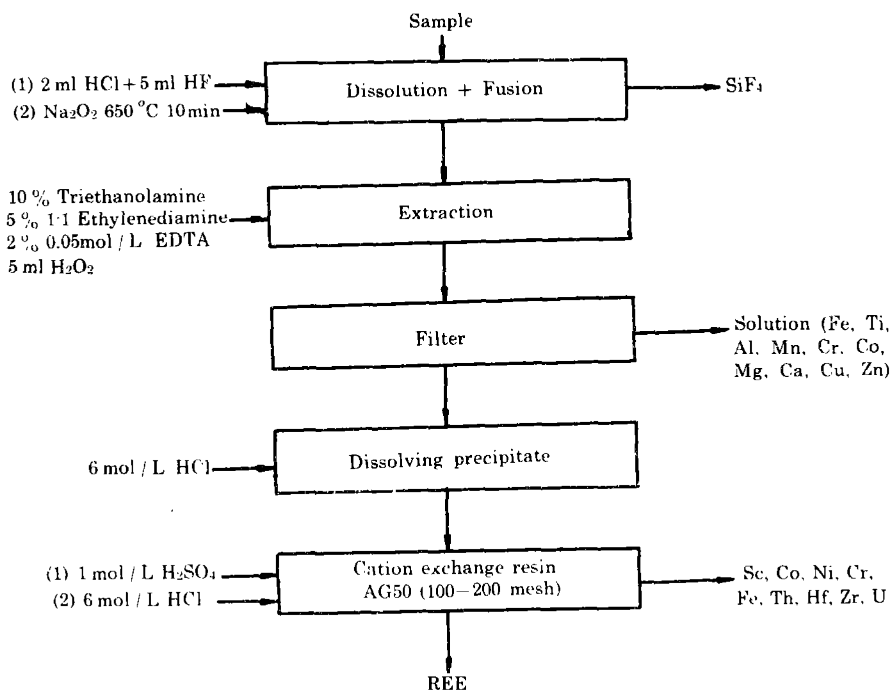

Fig.1 REE group separation scheme

3 RESULTS AND DISCUSSION

Table 1 and 2 list the data obtained for the 10 REE and other trace elements in the ultramafic inclusions and separate minerals.

3.1 Transition metal elements (TME)

In spinel lherzolite inclusions, the chondrite normalized average abundances of transition metal elements show flat patterns with small slopes. But Ti is lower and Ni and Co are slightly higher as compared with the primitive mantle[2]. It may be inferred that the inclusions are residual mantle rocks from a small amount of partial melting.

The websterites patterns have steep slopes, due to significant positive Ti anomaly and negative Co and Ni anomaly. Their Ni and Co abundances are less than halves of those of the primitive mantle, suggesting that the rocks do not belong to mantle source rocks, they represent segregation of basaltic melt derived from the mantle source rocks by high degree of melting.

3.2 Rare earth elements (REE)

According to the REE abundances and patterns of spinel lherzolite inclusions can be divided into two types. The rocks in the first type have relatively flat REE patterns

Table 1

REE abundances of ultramafic inclusions and their separated minerals μg / g

Sample No.		La	Ce	Nd	Sm	Eu	Gd	Tb	Tm	Yb	Lu	Location
Lherzolite	E_{78}	0.43	1.01	0.54	0.14	0.035	0.197	0.026	0.0143	0.096	0.014	Yitong
	W_{44}	1.43	2.08	0.82	0.16	0.055	0.102	0.0153	0.0083	0.047	0.007	Wangqing
	K_{96}	1.16	2.80	1.67	0.45	0.133	0.467	0.050	0.017	0.104	0.017	Kuandian
	H_{66}	3.58	6.47	3.81	0.78	0.176	0.889	0.09	0.029	0.136	0.017	Jiaohe
	G_{10}	0.38	0.92	0.66	0.214	0.09	0.336	0.054	0.035	0.216	0.034	
	L_{8}	0.284	0.707	0.51	0.15	0.056	0.231	0.047	0.032	0.196	0.031	Longgang
Websterite	J_{65}	0.92	2.35	1.79	0.61	0.221	0.914	0.153	0.099	0.658	0.094	Longgang
	K_{1021}	3.93	6.85	3.94	1.31	0.469	1.87	0.32	0.15	0.89	0.122	Kuandian
	H_{68}	2.56	4.88	2.65	0.65	0.271	1.105	0.191	0.114	0.669	0.101	Jiaohe
Olivine		0.07	0.17	0.10	0.027	0.008	0.037	0.0077	0.006	0.042	0.009	
Orthopyroxene	G_{10}	0.07	0.18	0.131	0.04	0.014	0.085	0.016	0.025	0.249	0.039	Longgang
Clinopyroxene		1.11	2.78	2.09	0.68	0.227	0.927	0.139	0.065	0.396	0.061	
Olivine		0.37	0.82	0.22	0.05	0.009	0.025	0.003	0.0014	0.009	0.0012	
Orthopyroxene	K_{96}	0.19	0.44	0.32	0.09	0.032	0.130	0.021	0.014	0.110	0.019	Kuandian
Clinopyroxene		3.78	10.4	7.35	2.51	0.798	2.96	0.312	0.0924	0.04	0.077	

with $(La/Yb)_{CN}$ ratios from 0.95 to 1.16 (Fig.2a). Their total 10 REE concentrations are from 2.24 to 2.94 μg/g and lower than those of the primitive mantle[3]. It implies that the inclusions of the first type are residual mantle rocks.

The rocks in the second type have very wide range of total REE concentration from 2.39 to 16 μg/g. They are commonly characterized by rather high light REE (LREE) abundances. Their REE patterns (Fig.2b) exhibit enrichment of LREE and a $(La/Yb)_{CN}$ ratios ranging from 3 to 20, but they markedly depleted in intermediate and heavy REE relative to that of primitive mantle. The high LREE is probably caused by mantle metasomatism[4]. On the basis of the REE and TME geochemistry, inclusions of the second type also have residue origin formed by partial melting of primitive mantle and were undergone mantle metasomatism. It may be seen in Fig.3 that the separated minerals in the metasomatized spinel lherzolite inclusion (K_{96}) have strongly LREE enriched patterns, their LREE contents are higher than those of the separated mineral in unmetasomatized inclusion (G_{10}). Therefore the REE abundances of the inclusions closely correlate with their modal mineralogy, the REE distributions in the bulk rocks reflect the REE abundances of separated minerals.

Table 2

Trace element contents of the ultramafic inclusions μg / g

	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Rb	Sr	Ba	Th	U	Hf
E_{78}	11.7	298	51.0	3112	1238	63658	113	2342	4.71	14.2	13.5	0.12	—	0.13
W_{44}	15.7	760	73.0	2820	1007	63588	103	1855	2.83	—	—	0.07	—	0.16
K_{96}	7.05	540	57.0	2130	1084	70829	93.0	1405	—	27.0	13.2	0.11	0.19	0.66
H_{66}	13.6	693	70.0	2920	1084	67399	114	2165	—	22.2	—	0.22	—	0.25
G_{10}	10.0	700	71.0	2848	1007	62843	86.0	1560	—	13.8	—	—	0.40	—
L_8	9.10	511	62.0	2570	1084	63415	106	2237	2.83	—	—	0.07	—	0.16
J_{65}	27.0	1713	229	2426	1084	38682	27.0	475	5.28	24.9	24.0	0.32	1.00	0.08
K_{1021}	37.8	3559	227	2440	852	65024	54.0	643	—	135	26.9	—	0.23	0.92
H_{68}	28.0	1496	144	1373	1239	47274	55.0	447	7.51	92.0	161	0.33	—	0.37

* Ti, V, Mn data by X-ray fluorescence spectrometer

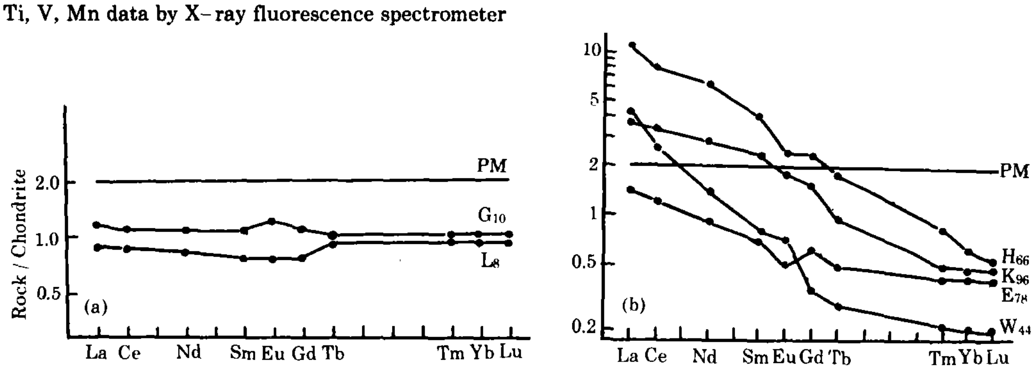

Fig.2 Chondrite normalized REE patterns

a. First type of spinel lherzolite inclusions b. Second type of spinel lherzolite inclusions

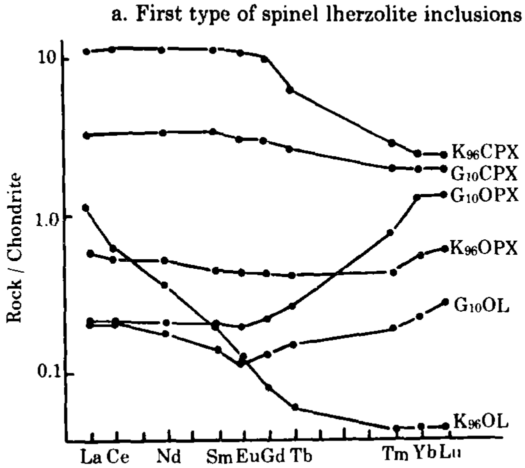

Fig.3 Chondrite normalized REE patterns of separated minerals in spinel lherzolite inclusions

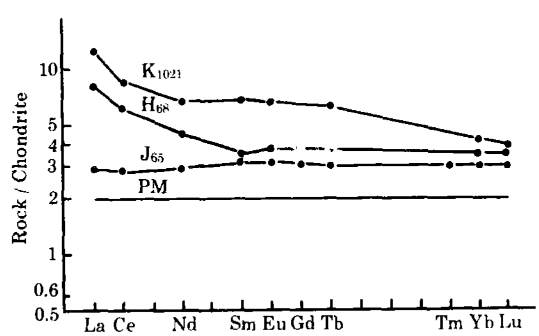

Fig.4 Chondrite normalized REE patterns of websterites

The chondrite normalized REE patterns of websterites inclusions show two significantly contrasting REE patterns (Fig.4). Sample H_{66} and K_{1021} have higher REE abundances, total 10 REE concentration range from 13.2 to 19.9 μg/g. Their REE patterns are LREE enriched type with ratio of $(La/Yb)_{CN}$ from 2.42 to 2.92, whereas another sample (J_{65}) displays slightly LREE depleted pattern with $(La/Yb)_{CN}$ ratios of 0.92. But REE abundances of the websterites are higher than that of earth's primitive mantle which are estimated to be 1.9—2.5 times of those for ordinary chondrite[2,3]. Their Sr, Ba, Rb, Th and U, contents are higher than those of spinel lherzolite inclusions. Thus, it stands to reason that the websterite melt derived from variable degrees of partial melting of mantle source rocks.

4 CONCLUSION

a. There are two types of mantle sources in Liaoning-Jilin. One is refractory residues left after partial melting of the upper mantle. The other is metasomatizing refractory residues.

b. It implies that even within a small volume beneath the area studied the upper mantle is inhomogeneous.

c. Websterites inclusions formed by segregation of primitive basaltic melt derived from high degree of melting of mantle source rocks.

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