Rare-Earth Element Geochemistry of Eclogites from the Ultra-High Pressure Metamorphic Belt in Central China*

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Abstract: Based on their REE contents and REE patterns, eclogites from the ultra-high pressure metamorphic belt in central China may be roughly divided into six types including LREE-rich, LREE-rich + positive Eu anomaly, LREE-rich + negative Eu anomaly, REE pattern-smooth, MREE-rich and HREE-rich. The LREE-rich, LREE-rich + positive Eu anomaly and LREE-rich + negative Eu anomaly types of eclogites are dominant. REE types of eclogites in different areas can be compared and the REE features of the same REE type of eclogites in different areas are similar. The results of reconstruction of the primary rocks show that the primary rocks of eclogites possibly are dominated by continental tholeiites which are the product of partial melting of relatively fertile mantle and the rocks of tholeiite crystallization-differentiation. There is perfect evolution relationship among the primary rocks of the LREE-rich, LREE-rich + positive Eu anomaly and LREE-rich + negative Eu anomaly types of eclogites and among those of the REE pattern smooth and MREE-rich types of eclogites, the former three types were derived from continental settings and the latter two from nearly oceanic settings. Meanwhile, it is concluded that the mantle sources of primary rocks of the eclogites are inhomogeneous and the primary rocks of eclogites in this area appear to have undergone varying degree of crustal contamination.

Key words: ultra-high metamorphic belt; eclogite; REE geochemistry; central China

Introduction

In recent years, coesite- and diamond-bearing ultra-high pressure metamorphic belts (UHPM-b) have been found in succession in orogenic belts of different areas and ages, indicating that ultra-high pressure metamorphism (UHPM) may be a basic regional metamorphism in the processes of continent-continent collision. Eclogites are the most important and specific component in UHPM-b. Studies of these rocks are of great importance in reconstructing the history of UHPM, discussing the evolution history of paleo-structures of paleo-landmasses, and tracing the nature and state of deep crustal materials. The UHPM-b in central China is located on the border between the North China Craton and the Yangtze Craton. Since coesite and diamond were found in eclogites in this metamorphic belt (Okay et al., 1989; Wang Zhonggang et al., 1989; Xu et al., 1992), many researchers have carried out studies on the isotopic chronology, petrology and mineralogy of eclogites and explored the processes of formation and evolution of the metamorphic belt.

As is known, the primary rocks of ultra-high pressure metamorphic rocks (UHPM-r) are

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the basis for exploring the formation and evolution of the metamorphic belt. Because the primary rocks vary in chemical composition in the processes of formation of UHPM-r at high pressures, little has been reported on the geochemistry of UHPM-r in previous literature, especially on the features of primary rocks in terms of the geochemical data of UHPM-r. The rare earth elements (REE) are relatively stable in the processes of UHPM (Wang et al., 1989). So, it is a valid way to study the features of primary rocks in terms of the REE geochemistry of UHPM-r. This paper presents the available REE data of eclogites from the UHPM-b in central China, summarizes the REE geochemical features of the eclogites, and discusses the features of primary rocks of the eclogites.

Geology and REE Data

Geology of eclogites

The UHPM-b in central China extends from the border of Shanxi, Henan and Hubei provinces through northern Hubei, southern Henan, western Anhui, central Anhui and northern Jiangsu to Shandong Peninsula with a length of about 2000 km and a width of 50 ~ 100 km. The metamorphic belt is cut into two parts by the Tancheng-Lujiang fault. In the western part of the fault the metamophic belt extends east-westwards and in the eastern part, south-northwards. Eclogites are the most important and specific component in this UHPM-b. At present, eclogites are found in western UHPM-b including Yinshan, Dawu, Hongan, Luoshan, Yingshan of Hubei Province and Xinyang, Xinxian of Henan Province, in central UHPM-b including Yuexi, Taihu, Qianshan, Huoshan of Anhui Province, and in eastern UHPM-b including Donghai of Jiangsu Province, and Rizhao, Lunan, Zhucheng, Qingdao, Weihai of Shandong Province. Eclogites in the UHPM-b are mainly nodular, lenticular, banded and stratoid in form, and range in size from several square centimeters to hundreds of square meters. The wall-rocks of eclogites are mainly schist, gneiss, amplibolite, marble, granulite ultra-basic rock, etc. Table 1 lists several classification schemes of ecoligtes from the UHPM-b, which were proposed by different researchers. In Table 1 we can see that there are a variety of rock types and mineral assemblages of eclogites in the UHPM-b, and obvious differences are recognized in forming temperature and pressure for the different types of eclogites.

REE data of eclogites

This paper presents the REE data of 94 eclogites from the UHPM-b in central China. Samples, including all the types of eclogites classified by different authors (Table 1), were collected from most of the eclogite localities in the UHPM-b. In the paper the eclogite localities in western Tancheng-Lujiang fault are called the Dabieshan area, and in the eastern part the Su-Lu area. It is worthy of note that nearly 200 REE data on eclogites from the UHPM-b are available, some of the REE data are ruled out because of big analytical errors, a too small number of elements analysed and obscured characteristics. Listed in Table 2 are the statistical REE data of eclogites from the Dabieshan and Su-Lu areas. Shown in Fig. 1 are the REE distribution patterns in eclogites from both areas.

REE Contents and REE Distribution Patterns

Table 1. The classification schemes of eclogites from the UHPM-b in central China

Data source	Classification criterion	Rock type	Characteristic mineral	Chemical feature	Formation condition
Wang et al., (1989)	Field occurrence; mineral assemblage	1) Eclogite in serpentinite as being lenticular, banded, stratoid and brecciated in form	Orthopyroxene, rutile		
		2) Eclogite in serpentinite as being nodular	Rutile, quartz, amphibole		
		3) Eclogite in gneiss and in association with marble	Phengite, rutile, coesite		
		4) Eclogite in amphibolite	Kyanite, epidote, quartz		
Zhang Zeming (1993)	Minor mineral	1) Glaucophane eclogite	Glaucophane, phengite, rutile		$T=500\pm50$℃ $P=1.6\pm0.2$GPa
		2) Kyanite eclogite	Kyanite, phengite, rutile		$T=700$℃ ± $P\geqslant1.8$GPa
		3) Eclogite orthopyroxenite	Orthopyroxene		$T=670$℃ ± $P=3.1$GPa ±
		4) Coesite eclogite	Coesite, carbonate, rutile		$T=550\sim750$℃ $P=2.6\sim2.8$GPa
		5) Eclogite	Rutile, phengite, quartz		$T=600\sim750$℃ $P=1.0\sim1.7$GPa
Liu Xiaochun (1995)①	Formation condition	1) Amphibole eclogite			$T=624\sim698$℃ $P>2.0$GPa
		2) Coesite-bearing eclogite			$T=647\sim755$℃ $P=2.8\sim3.5$GPa
		3) Quartz eclogite			$T=755\sim783$℃ $P>1.6$GPa
		4) Garnet pyroxenite			$T=676\sim829$℃ $P>1.2$GPa
Wei Chunjing et al., (1996)	Metamorphic evolution stage	1) Eclogite at the pre-summit stage	Garnet with progressively metamorphic zoning		$T=380\sim600$℃ $P=0.5\sim1.2$GPa
		2) Eclogite at the summit stage	Coesite + kyanite + diamond, etc.		$T=590\sim800$℃ $P>1.9$GPa
		3) Eclogite at early retrograde metamorphic stage	Glaucophane + phengite + talc, etc.		$T=540\sim610$℃ $P=1.0\sim1.5$GPa
		4) Eclogite at late retrograde metamorphic stage	Amphibole + plagioclase, etc.		$T=470\sim490$℃ $P=0.6\sim0.8$GPa
		5) Eclogite at late superimposed metamorphic stage	Amphibole + plagioclase + muscovite, etc.		$T=450\sim580$℃ $P=0.4\sim0.9$GPa
Wang Shiguang (1997)	Chemical composition	1) Mg-eclogite	Mainly pyrope	MgO>10%	
		2) Fe-eclogite	Mainly almandine	MgO<10%	
		3) Ca-eclogite	Mainly grossular	CaO>19%	

① Liu Xiaochun, 1995, Study on metamorphic relationship between coesite-bearing eclogites and their country rocks and related gold mineralization in the Dabie-Sulu District. Post Ph. D. Dissertation of Institute of Geochemistry, Chinese Academy of Sciences (unpubl.).

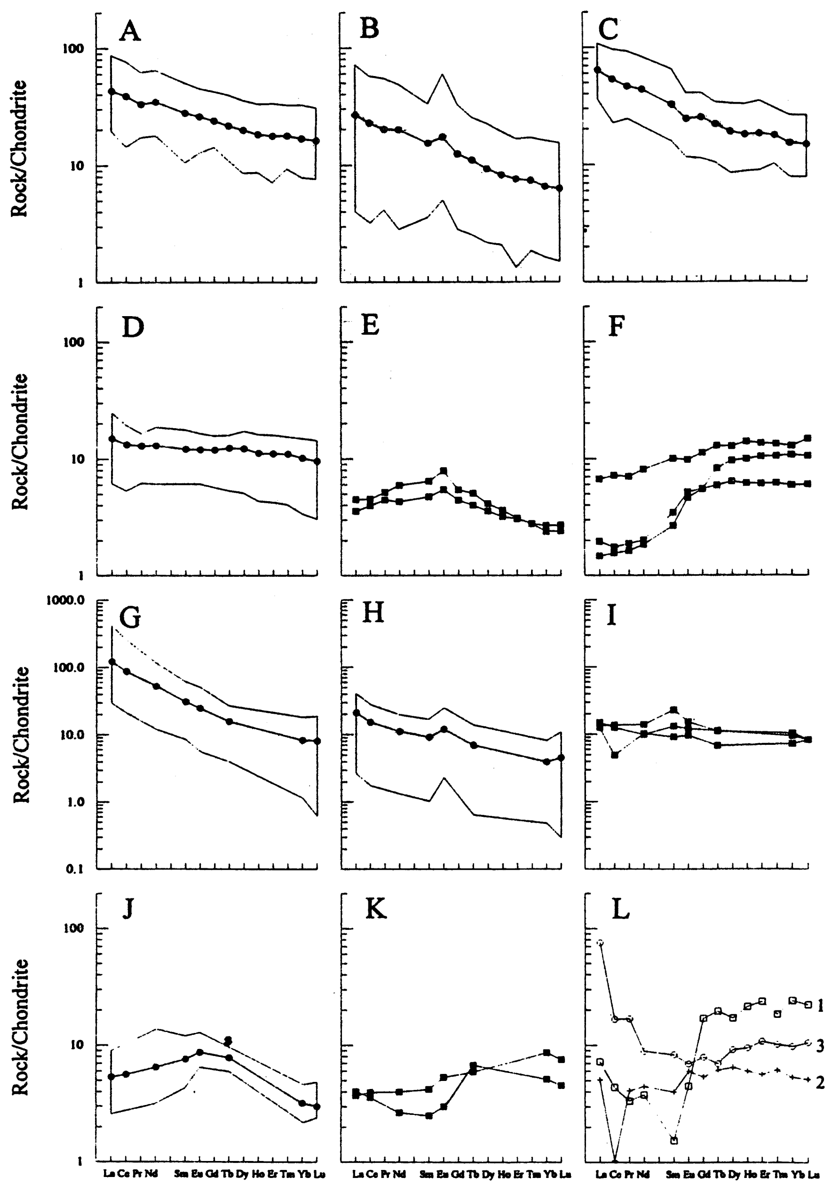

Fig. 1. The chondrite-normalized REE distribution patterns in eclogites from the UHPM-b in central China (after Boynton, 1984). A-F: LREE-rich type, LREE-rich + positive Eu anomaly type, LREE-rich + negative Eu anomaly type, REE pattern-smooth type, MREE-rich type and HREE-rich type in the Dabieshan area; G-K: LREE-rich type, LREE-rich + positive Eu anomaly type, REE pattern-smooth type, MREE-rich type and HREE-rich type in the Su-Lu area; L: specific REE type of eclogites. 1. After Zhang Yong et al. (1991); 2. after Zhang Zeming (1993); 3. after Liu Xiaochun (1995)①. In the figure, the shadow field is the range of REE variations; solid dot curve represents the average of REE pattern; solid square, the REE pattern of an individual sample.

① Liu Xiaochun, 1995, Study on metamorphic relationship between coesite-bearing eclogites and their country rocks and related gold mineralization in the Dabie-Sulu District. Post Ph. D. Dissertation of Institute of Geochemistry, Chinese Academy of Sciences (unpubl.).

Eclogites in the Dabieshan area

Based on their REE contents (Table 2) and REE distribution patterns (Fig. 1), eclogites in the Dabieshan area can be divided into 6 types.

(1) *LREE-rich (LREE-R)-type eclogites* This is one of the major types of eclogites in the Dabieshan area (statistically accounting for about 27% of the samples), which occurs in most statistical eclogite localities. The REE contents of this type of eclogites vary over a wide range; $\sum$REE (excluding Y): $(45.57-190.58)\times10^{-6}$, LREE: $(33.81-148.63)\times10^{-6}$, HREE: $(11.76-41.95)\times10^{-6}$, and LREE/HREE: 2.53 − 6.22. The REE patterns are of the LREE-enrichment type (Fig. 1A); $(La/Yb)_N$: 1.85 − 5.74, $(La/Sm)_N$: 1.20 − 2.68, $(Gd/Yb)_N$: 1.24 − 2.71, δEu: 0.95 − 1.04, and δCe: 0.92 − 1.08 (except for 2 samples whose δCe values are 0.74 and 1.44).

(2) *LREE-rich + positive Eu anomaly (LREE-R-P-Eu-A)-type eclogites* This type is the dominant one in the Dabieshan area (accounting for about 41% of the statistical samples) and occurs in most of the statistical eclogite localities. The REE contents of this type of eclogites also vary over a wide range but are slightly lower than those of the LREE-R-type eclogites. Their $\sum$REE, LREE, HREE and LREE/HREE data are $(10.83-135.51)\times10^{-6}$, $(7.41-109.50)\times10^{-6}$, $(2.55-25.01)\times10^{-6}$ and 2.17 − 7.22, respectively. The REE patterns also are of the LREE-rich type (Fig. 1B); $(La/Yb)_N$: 2.30 − 13.68, $(La/Sm)_N$: 1.02 − 2.61 and $(Gd/Yb)_N$: 1.13 − 9.22. The most obvious feature of this type of eclogites is the positive Eu anomaly (δEu: 1.07 − 1.81). Most of the samples show weak negative Ce anomalies (δCe close to 0.92, except for one sample with δCe of 1.50).

(3) *LREE-rich + negative Eu anomaly (LREE-R-N-Eu-A)-type eclogites* 8 of the 63 statistical samples are assigned to this type of eclogites in the Dabieshan area. The rocks occur in Luotian, Yingshan of Hubei Province, Taihu, Qianshan, Yuexi of Anhui Province, etc. The REE contents of this type of eclogites are less variable, and slightly higher than those of the LREE-R-type eclogites. Their $\sum$ REE, LREE, HREE and LREE/HREE values are $(66.73-220.34)\times10^{-6}$, $(55.83-189.00)\times10^{-6}$, $(10.90-38.12)\times10^{-6}$ and (3.24 − 6.03), respectively. The REE patterns also are of the LREE-rich type (Fig. 1C); $(La/Yb)_N$: 2.50 − 6.82, $(La/Sm)_N$: 1.56 − 3.64, and $(Gd/Yb)_N$: 1.31 − 2.62. The most obvious feature of this type of eclogites is the negative Eu anomaly (δEu: 0.77 − 0.94). δCe varies over a wide range(0.53 − 1.21).

(4) *REE pattern smooth (REE-P-S)-type eclogites* 7 of the 63 statistical samples belong to this type of eclogites in the Dabieshan area. The samples were collected from Luwang, Huahe and Zhangjiawan of Hubei Province and Shima of Anhui Province. Their $\sum$ REE is $(17.79-56.80)\times10^{-6}$, LREE is relatively low $[(12.30-38.78)\times10^{-6}]$, HREE is relatively high $[(5.49-18.45)\times10^{-6}]$, and LREE/HREE is 1.84 − 2.46. The REE patterns are of the REE pattern-smooth type (Fig. 1D); $(La/Yb)_N$: 0.95 − 2.69, $(La/Sm)_N$: 0.83 − 0.88, $(Gd/Yb)_N$: 1.00 − 1.81, δEu: 0.97 − 1.10, and δCe: 0.81 − 1.09.

(5) *MREE-rich (MREE-R)-type eclogites* Only 2 of the 63 statistical samples belong to this type of eclogites in the Dabieshan area. Samples were collected from Yangjiafan and Fanjiawan of Hubei Province, respectively. Their REE contents are low ($\sum$REE of the two samples are 12.85×10^{-6} and 15.61×10^{-6}, respectively). The REE patterns are of the MREE-rich type (Fig. 1E) with $(La/Yb)_N$, $(La/Sm)_N$ and $(Gd/Yb)_N$ being 1.96, 2.78, 0.70, and 1.32, 1.32, 1.87, respectively.

(6) *HREE-rich (HREE-R)-type eclogites* Only 3 of the 63 statistical samples belong

Table 2. The statistical results of REE data of eclogites from the UHPM-b in central China($\times 10^{-6}$)

	REE type	LREE-R		LREE-R-Eu-P-A		LREE-R-Eu-N-A		REE-P-S		MREE-R		HREE-R	
	Number of samples	17		26		8		7		2		3	
		Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Dabieshan area	La	6.05~26.90	13.37	1.26~22.40	8.28	11.15~33.40	19.98	1.91-7.72	4.64	1.10-1.39	1.25	0.46-2.07	1.05
	Ce	11.58~62.15	31.60	2.61~46.66	18.34	18.20~78.20	43.49	4.33-15.69	10.80	3.21-3.65	3.43	1.26-5.8	2.83
	Pr	2.13~7.59	4.06	0.51~6.68	2.45	3.00~11.40	5.68	0.76-2.02	1.59	0.54-0.63	0.59	0.20-0.86	0.43
	Nd	10.68~38.92	20.84	1.69~29.27	12.00	12.70~50.20	26.32	3.66-11.30	7.86	2.58-3.56	3.07	1.11-4.85	2.39
	Sm	2.05~9.83	5.46	0.70~6.51	2.98	3.08~12.80	6.34	1.19-3.42	2.38	0.92-1.25	1.09	0.52-1.95	1.05
	Eu	0.95~3.32	1.91	0.37~4.39	1.27	0.85~3.00	1.80	0.45-1.20	0.89	0.40-0.58	0.49	0.34-0.72	0.48
	Gd	3.72~10.98	6.19	0.73~8.42	3.20	2.94~10.60	6.55	1.47-4.13	3.12	1.15-1.40	1.28	1.42-2.90	1.92
	Tb	0.52~1.87	1.03	0.12~1.19	0.52	0.49~1.62	1.04	0.25-0.76	0.59	0.19-0.24	0.22	0.28-0.61	0.43
	Dy	2.77~11.44	6.41	0.70~7.19	2.98	2.72~10.57	6.11	1.64-5.48	3.97	1.15-1.33	1.24	2.05-4.09	3.08
	Ho	0.63~2.39	1.32	0.15~1.37	0.59	0.62~2.32	1.28	0.31-1.15	0.81	0.23-0.26	0.25	0.44-1.00	0.72
	Er	1.48~6.94	3.74	0.28~3.49	1.59	1.90~7.34	3.83	0.88-3.31	2.34	0.64-0.65	0.65	1.28-2.84	2.10
	Tm	0.30~1.06	0.58	0.06~0.55	0.24	0.33~0.97	0.57	0.13-0.50	0.36	0.09-0.09	0.09	0.20-0.43	0.32
	Yb	1.65~6.70	3.53	0.34~3.34	1.38	1.63~5.50	3.17	0.71-3.07	2.14	0.50-0.56	0.53	1.24-2.69	2.06
	Lu	0.25~1.02	0.54	0.05~0.51	0.21	0.26~0.87	0.49	0.10-0.48	0.32	0.08-0.09	0.09	0.20-0.49	0.35
	ΣREE	45.57~190.58	100.55	10.83~134.51	56.02	66.73~220.34	126.67	17.79-56.80	41.83	12.85-15.61	14.23	11.64-31.3	19.19
	LREE	33.81~148.63	77.23	7.41~109.50	45.31	55.83~189.00	103.61	12.3-38.78	28.17	8.75-11.06	9.91	3.89-16.25	8.22
	HREE	11.76~41.95	23.32	2.55~25.01	10.71	10.90~38.12	23.05	5.49-18.45	13.66	4.10-4.55	4.33	7.12-15.05	10.97
	LREE/HREE	2.53~6.22	3.41	2.17~7.22	4.14	3.24~6.03	4.51	1.84-2.46	2.07	2.13-2.43	2.28	0.36-1.08	0.69
	δEu	0.95~1.04	1.00	1.07~1.81	1.28	0.77~0.94	0.86	0.97-1.10	1.01	1.19-1.34	1.27	0.92-1.15	1.07
	δCe	0.74~1.44	1.03	0.67~1.50	0.98	0.53~1.21	0.96	0.81-1.09	0.95	0.94-1.00	0.97	0.91-1.05	0.99
	Eu/Sm	0.30~0.45	0.35	0.34~0.67	0.44	0.23~0.33	0.29	0.35-0.41	0.38	0.43-0.46	0.45	0.37-0.65	0.53
	$(La/Sm)_N$	1.20~2.68	1.55	1.02~2.61	1.70	1.56~3.64	2.16	0.83-1.88	1.21	0.70-0.75	0.73	0.56-0.67	0.60
	$(Gd/Yb)_N$	1.24~2.71	2.01	1.13~9.22	3.26	1.31~2.62	1.69	1.00-1.81	1.44	1.32-1.87	1.60	0.14-0.87	0.45
	$(La/Yb)_N$	1.85~5.74	3.36	2.30~13.68	5.26	2.50~6.82	4.58	0.95-2.69	2.03	1.96-2.78	2.37	0.20-0.52	0.40
Su-Lu area	REE type	LREE-R		LREE-R-P-Eu-A				REE-P-S		MREE-R		HREE-R	
	Number of samples	13		6				3		7		2	
		Range	Average	Range	Average			Range	Average	Range	Average	Range	Average
	La	64.50~9.20	26.26	12.54~0.83	6.48			4.60~3.86	4.21	2.73~0.80	1.65	1.25~1.15	1.20
	Ce	111.00~16.80	52.01	22.00~1.40	12.32			11.01~9.96	10.35	8.24~1.20	4.50	3.20~2.90	3.05
	Nd	55.50~7.20	27.54	11.60~0.78	6.65			8.29~5.88	6.76	8.25~1.00	3.47	2.40~1.60	2.00
	Sm	11.90~1.70	5.99	3.30~0.20	1.80			4.42~1.75	2.90	2.33~0.39	1.40	0.82~0.49	0.66
	Eu	3.72~0.64	1.87	1.83~0.17	0.88			1.11~0.70	0.90	1.60~0.47	0.82	0.39~0.22	0.31
	Tb	1.27~0.33	0.80	0.66~0.03	0.33			0.53~0.32	0.46	0.73~0.25	0.40	0.32~0.28	0.30
	Yb	3.83~0.98	1.91	1.70~0.10	0.82			2.16~1.50	1.87	1.50~0.40	0.75	1.80~1.07	1.44
	Lu	0.61~0.16	0.30	0.36~0.01	0.15			0.27~0.27	0.27	0.27~0.08	0.12	0.25~0.15	0.20
	Eu/Sm	0.38~0.21	0.32	0.85~0.41	0.57			0.40~0.25	0.33	0.62~0.39	0.45	0.48~0.45	0.46
	$(La/Sm)_N$	4.64~1.61	2.79	5.37~1.37	2.51			1.39~0.59	1.04	2.33~0.39	0.77	1.60~0.88	1.24
	$(La/Yb)_N$	25.88~5.52	9.51	20.62~2.61	6.85			1.73~1.30	1.54	3.23~0.93	1.55	0.79~0.43	0.61

Note: Because the REE data of eclogites in the Su-Lu area are not available, only part of the statistical REE contents and REE parameters are presented in the table.

to this type of eclogites in the Dabieshan area. The samples were collected from Yangjiaban and Wansuiping of Hubei Province and Pailou of Anhui Province. Their ΣREE is relatively low $[(11.64 - 30.30) \times 10^{-6}]$, but HREE is relatively high $[(7.12 - 15.05) \times 10^{-6}]$, and LREE/HREE is 0.36 – 1.08. The REE paterns are of the HREE-rich type (Fig. 1F); $(La/Yb)_N$: 0.20 – 0.52, $(La/Sm)_N$: 0.56 – 0.67, and $(Gd/Yb)_N$: 0.14 – 0.87.

Eclogites in the Su-Lu area

The REE analytical results for eclogites in the Su-Lu UHPM-b are not complete. But as is shown in Fig. 1, the eclogites can be divided into 5 types.

(1) *LREE-R-type clogites* This is the most dominant REE type of eclogites in the Su-Lu area (accounting for about 44% of the statistical samples) and occurs in most statistical eclogite localities. Their REE patterns are of the LREE-rich type (Fig. 1G); $(La/Yb)_N$: 5.52 – 25.88 and $(La/Sm)_N$: 1.61 – 4.64. The rocks show no obvious Eu and Ce anomalies.

(2) *LREE-R-P-Eu-A-type eclogites* This type of eclogites accounts for about 20% of the statistical samples in the Su-Lu area and occurs in most statistical eclogite localities. Their REE patterns are of the LREE-rich type (Fig. 1H) with $(La/Yb)_N$ and $(La/Sm)_N$ being 2.61 – 20.62 and 1.37 – 5.37, respectively. The most obvious feature of this type of eclogites is the positive Eu anomaly.

(3) *REE-P-S-type eclogites* Only 3 of the 31 statistical samples belong to this type of eclogites in the Su-Lu area. The samples were collected from Qinglongshan, Jianchang of Jiangsu Province and Datuan of Shandong Province. Their REE patterns are of the REE pattern-smooth type (Fig. 1I); $(La/Yb)_N$: 1.37 – 1.73 and $(La/Sm)_N$: 0.59 – 1.39. One of the three samples displays an obvious negative Ce anomaly.

(4) *MREE-R-type eclogites* This type of eclogites accounts for about 22% of the statistical samples in the Su-Lu area and occurs in most statistical eclogite localities. Their REE patterns are of the MREE-rich type (Fig. 1J) and their $(La/Yb)_N$ and $(La/Sm)_N$ are 0.93 – 3.23 and 0.40 – 1.02, respectively.

(5) *HREE-R-type eclogites* Only 2 of the 31 statistical samples belong to this type of eclogites in the Su-Lu area. The two samples were collected from Chaihu of Jiangsu Province. Their REE patterns are of the HREE-rich type (Fig. 1K) with $(La/Yb)_N$ being 0.43 – 0.79.

REE characteristics of eclogites from the UHPM-b in central China

From the above analysis, the REE geochemical characterictics of eclogites from the UHPM-b in central China can be summarized as follows:

(1) *Various REE-types of eclogites* As can be seen in Table 2, there are 6 REE types of eclogites in the Dabieshan area and 5 REE types of eclogites in the Su-Lu area. In addition, in both areas there occur a small number of specific REE-type eclogites. For example, Zhang Yong et al. (1991) collected one sample representing the MREE-depletion-type eclogites in the Dabieshan area, whose REE patterns show strong Sm-depletion (Fig. 1L). As Zhang Zeming (1993) reported, there is a sample characterictic of the strong Ce-depletion-type eclogites in the Dabieshan area (Fig. 1L). Liu Xiaochun (1995)① collected a sample characterictic of the strong La-enrichment-type eclogites in the Dabieshan area (Fig. 1L).

(2) *Relative concentrations of the main REE types of eclogites* Though eclogites in

① Liu Xiaochun, 1995, Study on metamorphic relationship between coesite-bearing eclogites and their country rocks and related gold mineralization in the Dabie-Sulu District. Post Ph. D. Dissertation of Institute of Geochemistry, Chinese Academy of Sciences (unpubl.).

the UHPM-b in central China are diverse in REE types, the main REE types of eclogites are relatively concentrated. For example, in the Dabieshan area, eclogites are dominated by the LREE-R and LREE-R-P-Eu-A types (accounting for 68% of the statistical samples), coming next are the LREE-R-N-Eu-A and REE-P-S types (24% of statistical samples), the other types are of less importance (only 8% of the statistical samples); in the Su-Lu area, the main REE types of eclogites are LREE-R, LREE-R-P-Eu-A and MREE-R (84% of the statistical samples), the others are of less importance (only 16% of the statistical samples).

(3) *Comparison of the REE types of eclogites in different areas* In Table 2, the 6 REE types of eclogites in the Dabieshang area are comparable with the 5 REE types of eclogites in the Su-Lu area except for the LREE-R-N-Eu-A type. It is worthy of note that the REE data on eclogites in the Su-Lu area are not complete and δEu values can not be calculated. So, the REE data on the LREE-R-N-Eu-A-type eclogites can not be worked out, but it doesn't mean that there is no possibity of the existence of this REE type of eclogites in the Su-Lu area. That is to say, the REE types of eclogites in the Dabieshan area are corresponding to those in the Su-Lu area except for some spectific REE type.

(4) *The same REE type of eclogites with common REE characteristics* From Table 2 and Fig. 1, we can see the REE contents of the same REE type of eclogites in the Dabieshan and Su-Lu areas vary within the same range, and their REE distribution patterns are also similar with each other.

Discussion and Conclusions

The regularity of REE activity in the processes of ultra-high pressure metamorphism (UHPM) is the key to understanding the nature of primary rocks and the structural settings of eclogites. At present, there are various views with respect to whether the REE migrated or not during the formation of eclogites. Hatsky et al. (1990) considered that the REE were not mobilized in the processes of formation of eclogites in the light of the REE behaviour during UHPM. Cotkin (1997) also suggested that the REE were relatively stable in the processes of formation of eclogites in his study of eclogites in Norway. Wang et al. (1989) presented a lot of facts to illustrate that the REE did not obviously migrate during metamorphism of low amphibolite faciese. So, in the case of no late hydrothermal alteration, the REE can be used to reconstruct and discriminate the features of the primary rocks of eclogites. In Fig. 2, most of the eclogites from the UHPM-b in central China fall within the field of continental tholeiites and their primary rocks possibly are dominated by continental tholeiites which are the product of partial melting of a relatively fertile mantle and the rocks of its crystallization-differentiation. Combining their geologic occurrence, REE contents (Table 2) and REE patterns (Fig. 1), the following features of eclogites from the UHPM-b in central China can be summarized.

1. The REE distribution patterns in eclogites of the LREE-R, LREE-R-P-Eu-A and LREE-R-N-Eu-A types are of the LREE-enrichment type. The major difference for the three types of eclogites is that the REE contents of the LREE-R type are higher than those of the LREE-R-P-Eu-A type and lower than those of the LREE-R-N-Eu-A type in addition to whether there exist positive or negative Eu anomalies. This feature shows that there is a good evolution relationship between the primary rocks of the three types of eclogites, that is to say, the primary rocks of the LREE-R-P-Eu-A and LREE-R-N-Eu-A types of eclogites may be the accumulative rocks (similar to gabbro in composition) and residual magmas of the original magmas of primary rocks of the LREE-R-type eclogites, respectively. According to the same prin-

ciple, the primary rocks of the MREE-R-type eclogites may be the accumulative rocks (similar to gabbro in composition) from the original magmas of primary rocks of the REE-P-S-type eclogites. The primary rocks of the HREE-R type eclogites may be the accumulative rocks (similar to pyroxenite in composition) from the original magmas of primary rocks of the LREE-R and REE-P-S-type eclogites.

2. The REE contents of the same REE type of eclogites in different areas vary over a wide range, reflecting that the mantle sources of the primary rocks of eclogites are inhomogeneous. Differences exist in REE contents and REE patterns between the LREE-R type (including LREE-R-P-Eu-A and LREE-R-N-Eu-A types) and the REE-P-S type (including MREE-R type), indicating that the primary rocks of both types of eclogites were formed in different structural settings, the former from continent settings and the latter from nearly ocean settings.

3. The REE contents of a few LREE-R type eclogites are very high. As Wang Shiguang et al. (1995) reported, two eclogites collected from Zhimafang in northern Jiangsu are strongly LREE-enriched, with ΣREE (8 elements) being 415.72×10^{-6}, $(La/Yb)_N$ and $(La/Sm)_N$ being more than 200 and 20, respectively. Their REE patterns are similar to those of kimberlites. In Fig. 2, the two samples fall near the field of kimberlites. It needs to be further studied whether their primary rocks are kimberlites or not. As viewed from the structural settings, it is possible that kimberlites occur in central China. Liu Guohui (1997) suggested that the primary rocks of eclogites in central China be kimberlites and the products of their crystallization- differentiation.

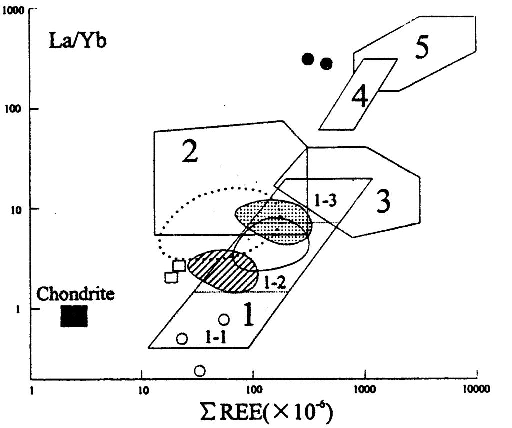

Fig. 2. La/Yb-ΣREE diagram of eclogites from UHPM-b in central China (after Allegre et al., 1978). Because the REE data on eclogites in the Su-Lu area are not complete, the diagram is established mainly on the basis of the REE data of eclogites in the Dabieshan area. The LREE-R type eclogites fall within the field defined by the solid curve; the LREE-R-P-Eu-A type eclogites in the field defined by the dotted curve; the LREE-R-N-Eu-A type eclogites in the dotted field; the REE-P-S type eclogites in the hatched field; the MREE-R type eclogites in the open square field; the HREE-R type eclogites in the open circle field; and the strongly REE-R type eclogites in the solid circle field (Wang et al., 1995). 1. The field of basalts: 1-1. ocean tholeiite, 1-2. continent tholeiite, and 1-3. alkaline basalt; 2. the field of calcareous-argillaceous sedimentary rocks; 3. the field of granite; 4. the field of kimberlites; 5. the field of carbonatites.

4. The primary rocks of eclogites from the UHPM-b in central China may have undergone varying degree of crustal contamination. Some researchers considered the primary rocks of the LREE-R-type eclogites as the products of basalt magmas due to crustal contamination. This conclusion is surported by Sr, Nd, H and O isotopic evidence (Li, et al., 1994; Gao et al., 1995; Zheng et al., 1998). Zhang Zeming (1993) suggested that one eclogite sample with a strong negative Ce anomaly (Fig. 1L) had resulted from marine contamination of its primary rock. In Fig. 2, some samples fall near the border area between calcareous-argillaceous-sedimentary rocks and basalts and they seem to be the result of marine contamination. Of course, we can not exclude the possiblity that the primary rocks of eclogites within the field of calcare-

ous-argillaceous-sedimentary rocks are sedimentary rocks. Liu Xiaochun(1995) considered the primary rock of the eclogite sample with strong La-enrichment (Fig. 1L) as a calcareous argillite.

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