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REE Geochemistry of Sulfides from the Huize Zn-Pb Ore Field, Yunnan Province: Implication for the Sources of Ore-forming Metals

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Abstract: REE abundances in sulfides from the Huize Zn-Pb ore field were determined with the ICP-MS after preconcentration. The REE abundances in 26 sulfide samples (including pyrite, galena and sphalerite) are very low, with the ΣREE ranging from 1.6×10^{-9} to 166.8×10^{-9}. Their LREE/HREE ratios range from 7.6 to 98, showing LREE enrichment relatively. The *δ*Eu values are below 1, indicating that they were deposited from an Eu-depleted and reducing fluid-system. Similar to the ore-hosting carbonate strata, calcite separates from carbonate veinlets filling in the fractures or faults crosscutting the carbonate strata also show clear Eu-depletion. This indicates that the carbonate veinlets and their parent fluid was possibly sourced from the strata and inherited the REE geochemical features of the strata. Therefore, REE-geochemical characteristics of both the sulfides and calcites, which were deposited from an ore-forming hydrothermal system, are similar to those of carbonate strata, and strongly suggest that the ore metals were mainly sourced from carbonate strata.

Key words: Huize Zn-Pb ore field, REE geochemistry, sulfide, fluid, ore-forming metal

1 Introduction

The Huize Zn-Pb ore field, Yunnan Province is located in the Sichuan-Yunnan-Guizhou Zn-Pb-polymetallic region (Fig. 1). It includes the Kuangshanchang (>1 Mt of Zn+Pb metals), Qilinchang (>3 Mt of Zn+Pb metals) and several other Zn-Pb deposits (Fig. 2). Both the Qilinchang and Kuangshanchang deposits are ranked as large Pb-Zn deposits because each has metallic reserves more than 1 Mt. In addition, the reserves of Ag and Ge, as byproducts, are also ranked as large-scale. The ore grades are generally between 25% and 35% of Pb+Zn, and up to 60% or more.

Why and how have so many metals accumulated in the Huize area? Are there any deposits of similar reserves and/or of the same type in the adjacent area? They are questions of wide interest and still open. A key to answering these questions is to identify the source of ore-forming metals and fluids. Previous studies, mainly based on studies in geology, isotope and element geochemistry, advanced four interpretations as follows: (1) Host rocks and the Emeishan basalt (Liao, 1984; Chen, 1993; Liu and Lin, 1999; Han et al., 2001; Huang et al., 2001a, 2001b, 2003; Li et al., 2002, 2004; Li, 2004; Han et al., 2004); (2) strata of the Upper Sinian, Lower Cambrian, Devonian and Carboniferous (Li et al., 1999); (3) the Precambrian basement (Hu, 2000) and (4) Lower Sinian volcanic rocks (Zhou et al., 2001). Obviously, the sources of the metals and fluids are still controversial and needs more efficient methods to constrain.

The REE is an efficient indicator to trace the source of fluids and metals (Henderson, 1984; Taylor and McLenna, 1985; Wang et al., 1989; Chen, 1996; Chen and Zhao, 1997; Liu and Tang, 1999; Zhang, 2004). The REE geochemical study of sulfides may be useful for tracing the source of the ore-forming fluids and metals of the Huize Pb-Zn ore field.

REE contents in sulfides are very low, occasionally below the detection limits of the ICP-MS. Fe, Pb and Zn are rich in sulfides and can easily contaminate the ICP-MS channels. Therefore, it is difficult to study REE geochemistry of sulfides without either a highly sensitive ICP-MS instrument or REE-preconcentration of sulfides before the ICP-MS analysis. In this study, 0.5 gram of sulfide powder was used for each sample to preconcentrate the REE contents in solution measured with the ICP-MS. Before the ICP-MS analysis, Pb and Zn were removed from the solution by adjusting pH in terms of the amphoteric behavior of Pb and Zn ions. In this paper we

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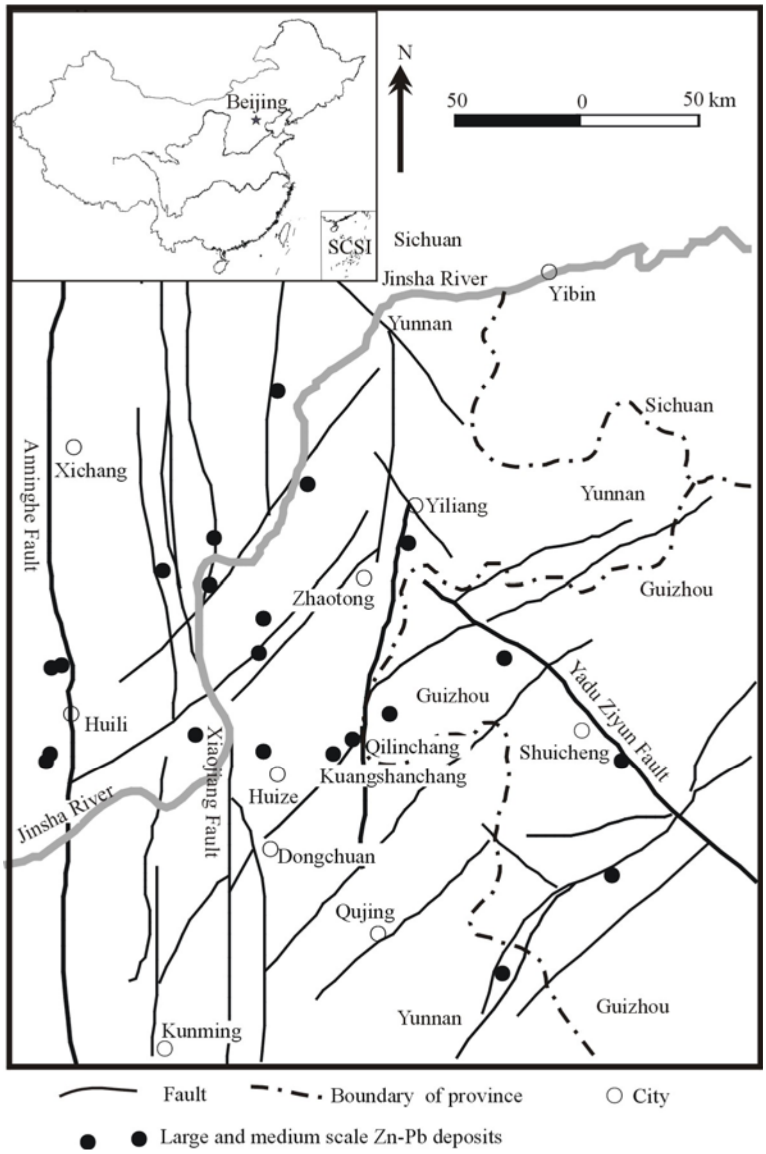

Fig. 1. Geologic map of the Sichuan-Yunnan-Guizhou region.

report the results of sphalerite, galena and pyrite from the Huize ore field, and address that the ore-forming fluids and metals were mainly sourced from the hosting carbonate strata instead of the Emeishan basalt, which was considered the metal and fluid sources in previous studies (Huang et al., 2001a, 2001b, 2003; Li et al., 2002, 2004; Li, 2004).

2 Samples and Analysis

All the samples were collected from underground of the Nos. 6, 8 and 10 orebodies in the Qilinchang deposit, and the No. 1 orebody in the Kuangshanchang deposit. The specimens contain pyrite, sphalerite, galena and calcite. After crushing, sorting, washing, drying and handpicking under a binocular microscope, five grams of sulfide separates with a purity of >99% were obtained for each sample. Pure sulfide separates were powdered to <200 meshes.

An REE measurement was carried out at the ICP-MS Laboratory of the Institute of Geochemistry, Chinese Academy of Sciences. 0.5 gram of sulfide powder was analyzed by using the method described by Qi et al. (2005). However, several novations, aimed to remove S, Pb and Zn, should be briefly addressed as below: Firstly, sulfur was removed by adding 3 mL of HNO_3 and heating to dry for three times. Secondly, through putting in 2 mL of 50% triethanolamine solution and 6 mL of 30% NaOH, and keeping the pH >12, Zn and Fe were dissolved and removed as solution by centrifuging. After this process, Pb was precipitated as $PbSO_4$ together with REE hydroxides and $Mg(OH)_2$. Thirdly, using HNO_3 as the solvent and the NH_4Cl/NH_4OH solution as a buffer, Pb was solved, and then discarded by centrifuging. The analytical results of REE were calculated according to the internal standard.

3 Results

Table 1 lists the REE contents for pyrite, sphalerite and galena, and Table 2 provides the REE parameters for ores, wall rocks and calcites from ores and carbonate veinlets occurring in the NE-trending fault zones. Figure 3 shows the chondrite-normalized REE patterns for sulfides. From Table 1, Table 2 and Fig. 3, the following understandings can be drawn out:

(1) The contents of REE in sulfides from the Huize Zn-Pb ore field are very low. The values of ΣREE for 13 pyrite samples range $6.7–166.8\times10^{-9}$, 11 sphalerite ones range $1.6–92.0\times10^{-9}$, and the ΣREE values for two galena samples are 9.2×10^{-9} and 2.9×10^{-9}, respectively. Relatively, pyrite has higher average REE contents than sphalerite, which has higher REE contents than galena. This sequence in contents may be related to the gradual decrease in strength of Fe^{2+}, Zn^{2+} and Pb^{2+}.

(2) All the sulfide samples have high LREE/HREE ratios, which range from 7.6 to 98 (Table 1), implying a strong REE fractionation. On the whole, the LREE/HREE ratios for pyrite, sphalerite and galena gradually decrease. The $(Gd/Yb)_n$ values of pyrite range from 0.96 to 5.2 (Table 1), suggesting that HREE fractionation is weak;

Table 1 REE abundances in sulfides of the Huize Zn-Pb ore field ($\times10^{-9}$)

Sample	HQ490	HQ490	10-14	10-14	HZQ78	HZQ78	HZQ84	HZQ92	HZQ81	HZQ102	HZQ53	HZQ46	HZQ85	HQ495	HQ488
Mineral	Py	Py	Py	Py	Py	Py	Py	Py	Py	Py	Py	Py	Py	Py	Py
La	3.035	4.041	5.916	4.941	4.272	5.811	2.043	18.260	1.695	7.716	60.343	22.547	5.344	3.405	2.274
Ce	6.402	8.552	8.235	7.285	6.140	8.054	3.170	23.747	2.886	10.538	78.273	30.144	7.824	5.932	4.837
Pr	0.633	0.781	0.744	0.617	0.512	0.701	0.319	2.017	0.279	0.804	6.403	2.455	0.712	0.628	0.495
Nd	2.323	2.675	2.311	1.724	1.620	2.453	1.137	5.891	1.083	2.694	18.250	7.997	2.268	2.348	2.080
Sm	0.317	0.435	0.244	0.207	0.158	0.241	0.204	0.442	0.150	0.232	1.614	0.645	0.274	0.503	0.430
Eu	0.107	0.086	0.033	0.049	0.033	0.035	0.026	0.088	0.030	0.028	0.195	0.116	0.055	0.097	0.079
Gd	0.408	0.366	0.227	0.226	0.147	0.243	0.122	0.299	0.124	0.237	0.996	0.556	0.220	0.376	0.344
Tb	0.046	0.063	0.024	0.021	0.018	0.023	0.013	0.032	0.020	0.019	0.077	0.052	0.021	0.050	0.043
Dy	0.304	0.413	0.160	0.141	0.068	0.098	0.073	0.112	0.166	0.125	0.172	0.188	0.087	0.288	0.259
Ho	0.092	0.097	0.043	0.063	0.029	0.050	0.034	0.036	0.065	0.053	0.061	0.047	0.046	0.070	0.068
Er	0.238	0.175	0.166	0.127	0.032	0.058	0.063	0.075	0.076	0.070	0.165	0.121	0.072	0.172	0.147
Tm	0.033	0.029	0.016	0.014	0.008	0.008	0.013	0.012	0.016	0.010	0.022	0.016	0.010	0.044	0.017
Yb	0.330	0.195	0.137	0.190	0.037	0.041	0.063	0.076	0.059	0.076	0.155	0.140	0.057	0.201	0.153
Lu	0.039	0.027	0.021	0.033	0.007	0.008	0.016	0.008	0.013	0.011	0.032	0.024	0.008	0.024	0.020
$(La/Pr)_n$	1.89	2.04	3.13	3.15	3.28	3.26	2.52	3.56	2.39	3.77	3.71	3.61	2.95	2.13	1.81
$(La/Nd)_n$	2.53	2.92	4.96	5.55	5.10	4.59	3.48	6.00	3.03	5.54	6.40	5.46	4.56	2.81	2.12
$(Gd/Yb)_n$	1.00	1.51	1.34	0.96	3.23	4.82	1.57	3.17	1.70	2.53	5.19	3.20	3.14	1.51	1.81
$(La/Yb)_n$	6.20	13.96	29.18	17.55	78.30	96.14	21.90	161.92	19.41	68.81	262.53	108.42	63.68	11.43	10.02
∑REE	14.31	17.93	18.28	15.64	13.08	17.82	7.30	51.10	6.66	22.61	166.76	65.05	17.00	14.14	11.24
LREE	12.82	16.57	17.48	14.82	12.74	17.30	6.90	50.45	6.12	22.01	165.08	63.90	16.48	12.91	10.19
HREE	1.49	1.36	0.79	0.81	0.35	0.53	0.40	0.65	0.54	0.60	1.68	1.14	0.52	1.22	1.05
LRE/HRE	8.61	12.14	22.01	18.22	36.86	32.78	17.39	77.63	11.35	36.56	98.23	55.86	31.66	10.55	9.70
δ Eu	0.91	0.66	0.43	0.69	0.67	0.44	0.51	0.74	0.66	0.37	0.47	0.59	0.68	0.68	0.63
δ Ce	1.11	1.16	0.94	1.00	1.00	0.96	0.95	0.94	1.01	1.02	0.96	0.98	0.97	0.98	1.10

Sample	HQ487	8-1	HZ911-9	HZQ85	HZQ26	HQ487	1-20	HZQ38	HZQ57	HQ493	1-15	10-22	HZQ57	1-11
Mineral	Py	Sp	Sp	Sp	Sp	Sp	Sp	Sp	Sp	Sp	Sp	Sp	Ga	Ga
La	4.664	0.428	2.870	1.665	12.064	14.947	3.811	0.430	6.246	4.609	1.115	7.016	2.534	0.752
Ce	9.337	0.796	4.252	2.375	14.902	37.841	5.272	0.609	8.279	6.044	1.761	10.292	2.916	0.927
Pr	0.936	0.150	0.543	0.284	1.354	5.357	0.579	0.080	0.917	0.649	0.194	1.206	0.430	0.135
Nd	3.357	0.875	2.315	0.874	4.547	23.211	2.199	0.315	3.620	2.680	0.823	4.960	1.974	0.504
Sm	0.618	0.126	0.511	0.124	0.397	3.874	0.290	0.042	0.586	0.436	0.178	0.779	0.843	0.378
Eu	0.113	0.045	0.042	0.027	0.059	0.875	0.039	0.006	0.079	0.086	0.008	0.159	0.051	0.014
Gd	0.468	0.140	0.364	0.105	0.254	2.269	0.224	0.039	0.424	0.395	0.124	0.659	0.243	0.055
Tb	0.049	0.018	0.049	0.009	0.022	0.287	0.017	0.004	0.039	0.038	0.015	0.087	0.025	0.006
Dy	0.358	0.074	0.284	0.044	0.073	1.585	0.100	0.016	0.187	0.209	0.106	0.498	0.083	0.047
Ho	0.071	0.015	0.045	0.009	0.019	0.290	0.018	0.002	0.032	0.046	0.017	0.107	0.017	0.005
Er	0.178	0.025	0.119	0.023	0.047	0.712	0.038	0.003	0.062	0.104	0.050	0.209	0.019	0.006
Tm	0.030	0.005	0.013	0.004	0.004	0.103	0.005	0.001	0.007	0.016	0.009	0.038	0.003	0.000
Yb	0.211	0.033	0.112	0.022	0.018	0.618	0.035	0.003	0.022	0.084	0.028	0.155	0.012	0.014
Lu	0.031	0.006	0.022	0.005	0.006	0.075	0.006	0.000	0.003	0.013	0.006	0.025	0.006	0.006
$(La/Pr)_n$	1.96	1.12	2.08	2.31	3.51	1.10	2.59	2.13	2.68	2.79	2.26	2.29	2.32	2.19
$(La/Nd)_n$	2.69	0.95	2.40	3.69	5.13	1.25	3.35	2.64	3.34	3.33	2.62	2.74	2.48	2.89
$(Gd/Yb)_n$	1.79	3.40	2.62	3.82	11.19	2.96	5.16	10.97	15.65	3.78	3.51	3.43	15.94	3.18
$(La/Yb)_n$	14.90	8.68	17.26	50.48	444.32	16.30	73.41	101.38	192.73	36.84	26.38	30.53	138.65	36.58
∑REE	20.42	2.74	11.54	5.57	33.77	92.04	12.63	1.55	20.50	15.41	4.43	26.19	9.16	2.85
LREE	19.03	2.42	10.53	5.35	33.32	86.10	12.19	1.48	19.73	14.50	4.08	24.41	8.75	2.71
HREE	1.40	0.32	1.01	0.22	0.44	5.94	0.44	0.07	0.78	0.91	0.35	1.78	0.41	0.14
LRE/HRE	13.63	7.64	10.45	24.15	75.26	14.50	27.53	21.97	25.43	16.01	11.51	13.73	21.39	19.55
δEu	0.64	1.04	0.30	0.72	0.57	0.90	0.46	0.46	0.48	0.63	0.17	0.68	0.34	0.30
δCe	1.08	0.76	0.82	0.83	0.89	1.02	0.85	0.79	0.83	0.84	0.91	0.85	0.67	0.70

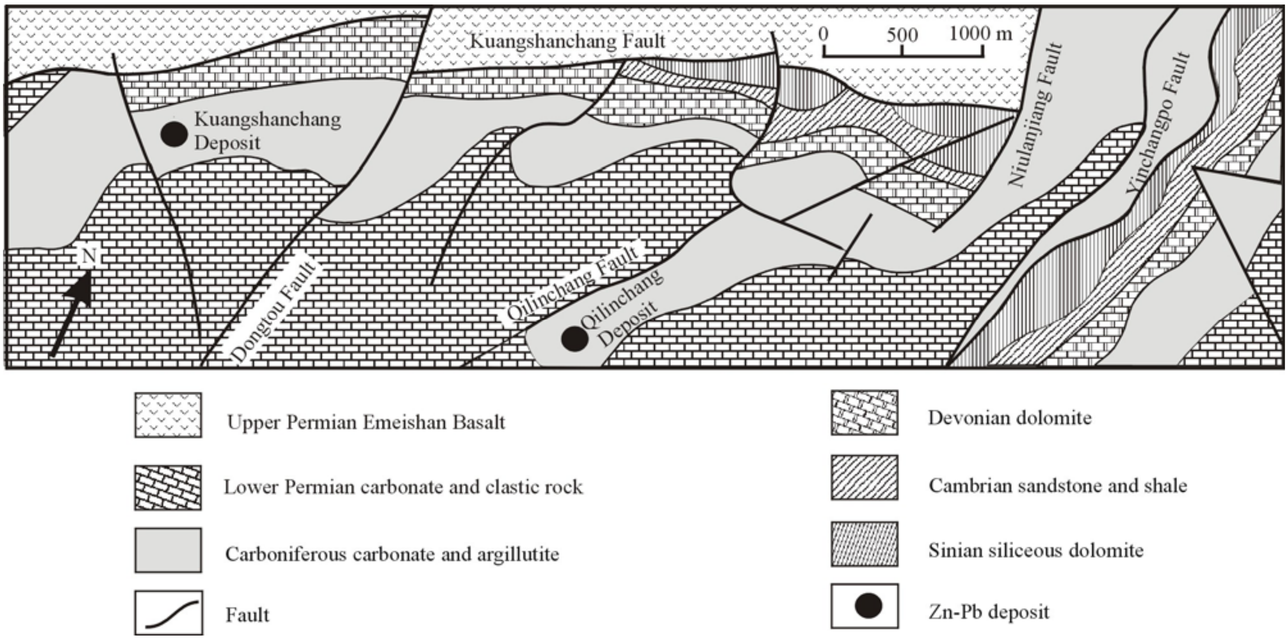

Fig. 2. Geologic map of the Huize Zn-Pb ore field.

while the $(Gd/Yb)_n$ values of sphalerite and galena range from 2.6 to 15.7 and 3.2 to 15.9, respectively (Table 1), indicating that HREE fractionation is much stronger.

(3) With δEu<1, the sulfide samples show Eu-depletion. To some extent, the δEu values of pyrite, sphalerite and galena decrease in turn (Tables 1 and 2). Similar variations in δCe values can be also observed for pyrite, sphalerite and galena. Pyrite does not show clear Ce anomaly, whereas sphalerite and galena show significant Ce anomalies (Fig. 3).

4 REE Geochemistry of Sulfides and the Source of Fluids and Metals

The sulfides of the Huize ore field are the products of hydrothermal fluids. Their REE geochemical features are controlled by five factors: (1) Chemical properties of the REE, (2) mineralogical features of sulfides, (3) the phases and contents of minerals co-existing with sulfides, (4) physicochemical conditions of the fluid-system, and (5) the fluid sources. The first two issues were well studied by chemists and mineralogists. The third and fourth were discussed in details in previous studies (Zhou, 1996; Huang et al., 2001b; Li et al., 2004; Li, 2004) and are beyond the scope of this paper. Only the last problem is still open and of our interest.

The rare earth elements (REE) have similar chemical properties and behave coherently in most geochemical processes. However, according to coordination chemistry (Dai, 1987), REE^{3+} and Ce^{4+} are hard acid, whereas Eu^{2+} is a soft acid (Chen and Fu, 1991; Chen and Zhao, 1997; Ma and Liu, 1999). Hence it is easy for Eu^{2+} to separate from the other REE^{3+} ions during the geochemical process, resulting in negative or positive Eu anomalies on chondrite-normalized REE patterns for geologic samples. Compared with the LREE, the HREE ions have smaller radius and are harder, causing fractionation between LREE and HREE. In the process of water-rock reaction, the solid products in a reducing environment have high δEu (usually, >1), low ΣREE values and high LREE/HREE ratios, whereas those in oxidizing conditions show low δEu (usually, <1), high ΣREE and low LREE/HREE ratios (Chen and Fu, 1991; Chen, 1996; Ma and Liu, 1999; Chetty and Frimmel, 2000). The above was called the redox model for REE geochemical evolution (Chen and Fu, 1991).

Pyrite, galena and sphalerite of the Huize ore field have very low ΣREE values ($<1\times10^{-6}$) and high LREE/HREE ratios (7.6–98), indicating a reducing environment or fluid-system. This conclusion is supported by the mineral association rich in sulfides that can be formed by a fluid-system with high activity of S^{2-}; and the high S^{2-} activity is an indubitable indicator of a reducing environment. According to the redox model for REE geochemical evolution, the sulfides from the Huize ore field, which were formed in reducing conditions, should have high δEu values instead of Eu-depletion (Tables 1 and 2). This can be interpreted by considering the following two possibilities: (1) The fluid-system and its source might be depleted in Eu and/or (2) calcite, the gangue mineral co-existing with sulfides, is enriched in Eu to result in Eu-depleted sulfides to keep the Eu mass balance.

Calcite is almost the only gangue mineral in the Huize ore field and other minerals are rare. It has three

Table 2 REE geochemistry of the sulfide, calcite and wall rocks of the Huize ore field

Sample		∑REE（$\times10^{-6}$）	LREE/HREE	δEu	δCe
Pyrite	Range (13)	0.007 –0.167	9.70–98.23	0.37–0.74	0.94–1.16
	Average	0.03	32.42	0.54	0.92
Sphalerite	Range (11)	0.002–0.092	7.64–75.26	0.30–1.04	0. 76–1.02
	Average	0.02	22.56	0.58	0.86
Galena	Range (2)	0.003 -0.009	19.55–21.39	0.30–0.34	067–0.70
	Average	0.006	20.47	0.32	0.69
Lumpy calcite	Range (16)	31.898–357.141	3.725–17.906	0.33–0.96	1.08–1.25
	Average	106.94	8.71	0.62	1.18
Disseminated calcite	Range (9)	22.601–106.670	8.219–24.947	1.14–2.04	1.11–1.28
	Average	65.16	14.98	1.56	1.16
Veined calcite	Range (3)	23.700–36.241	30.711–40.702	1.73–2.53	1.00–1.03
	Average	31.35	36.24	2.17	1.01
Calcite veinlet in the NE-trending fault zone	Range (6)	5.471–23.093	4.533–8.688	0.44–0.74	090–1.09
	Average	10.90	5.69	0.61	1.00
Vuggy calcite	Range (4)	1.901–9.736	2.217–5.669	0.74–3.71	0.61–1.18
	Average	4.143	3.64	1.93	0.85
Sinian dolomite	Range (3)	1.914–7.724	2.850–5.785	0.53–0.70	0.91–1.07
	Average	4.54	5.03	0.62	1.00
Cambrian shale	(1)	227.47	7.80	0.60	1.01
Middle Devonian sandstone	(1)	102.74	9.26	0.48	1.02
Upper Devonian limestone	Range (4)	10.377–34.462	5.200–6.670	0.51–0.70	0.78–1.321
	Average	20.12	5.86	0.61	1.07
Limestone of the Datang Formation, Carboniferous	Range (2)	11.994–15.919	8.707–9.373	0.68–0.68	1.09 –1.17
	Average	13.96	9.04	0.68	1.13
Dolostone of the Baizuo Formation, Carboniferous	Range (6)	3.052–8.968	3.722–8.454	0.39–0.71	0.67 –1.82
	Average	4.74	5.30	0.56	1.06
Limestone of the Weining Formation, Carboniferous	Range (3)	9.310–40.508	6.735–7.507	0.43–0.76	1.02–1.15
	Average	19.87	7.06	0.60	1.07
Limestone of the Maping Formation, Carboniferous	Range (2)	23.108–39.481	5.145–6.256	0.60–0.67	0.39–0.66
	Average	31.30	5.70	0.64	0.52
Permian limestone	Range (3)	0.937–1.902	2.618–4.991	0.84–1.32	0.35–1.26
	Average	1.55	4.15	1.12	0.76
Permian sandstone	(1)	65.75	8.68	0.41	1.07
Emeishan basalt	Range (9)	149.01–325.88	4.39–7.21	0.86–0.95	0.99–1.04
	Average	247.38	6.10	0.90	1.03

Note: Except for pyrite, sphalerite and galena, all the samples are from Huang et al. (2001a), Li (2004) and Li et al. (2004). In brackets are the numbers of samples.

occurrences: lumpy, disseminated and veined. The lumpy one makes up about 85% of the total calcite amount while the disseminated and veined comprise about 10% and less than 5%, respectively. According to Huang et al. (2001b) and Li et al. (2004), the lumpy calcites show negative Eu-anomalies (Table 2). This rules out the second possibility/ hypothesis that the co-existing calcite was enriched in Eu while sulfides were depleted in Eu to keep the Eu mass balance. Although the disseminated and veined calcites show positive Eu-anomalies (Table 2), they cannot result in Eu-depletion in so many sulfides because the amounts of veined and disseminated calcites are too little to keep mass balance.

In the stratigraphic sequence of Sinian to Permian, only the Permian limestone shows clear positive Eu-anomaly (Table 2). Very interesting is that the vuggy calcite occurring in the Permian limestone also shows strong positive Eu-anomaly (Table 2). This indicates that the vuggy calcite and its parent fluid might be sourced from or interacted with the Permian limestone and inherited the REE signature of the latter. Additionally, the ΣREE value, LREE/HREE ratio and δCe of the vuggy calcite are similar to those of the Permian limestone (Table 2). The similarities in REE geochemical signatures between the Permian limestone and its hosting vuggy calcite suggest that the hydrothermal product and its parent fluid should

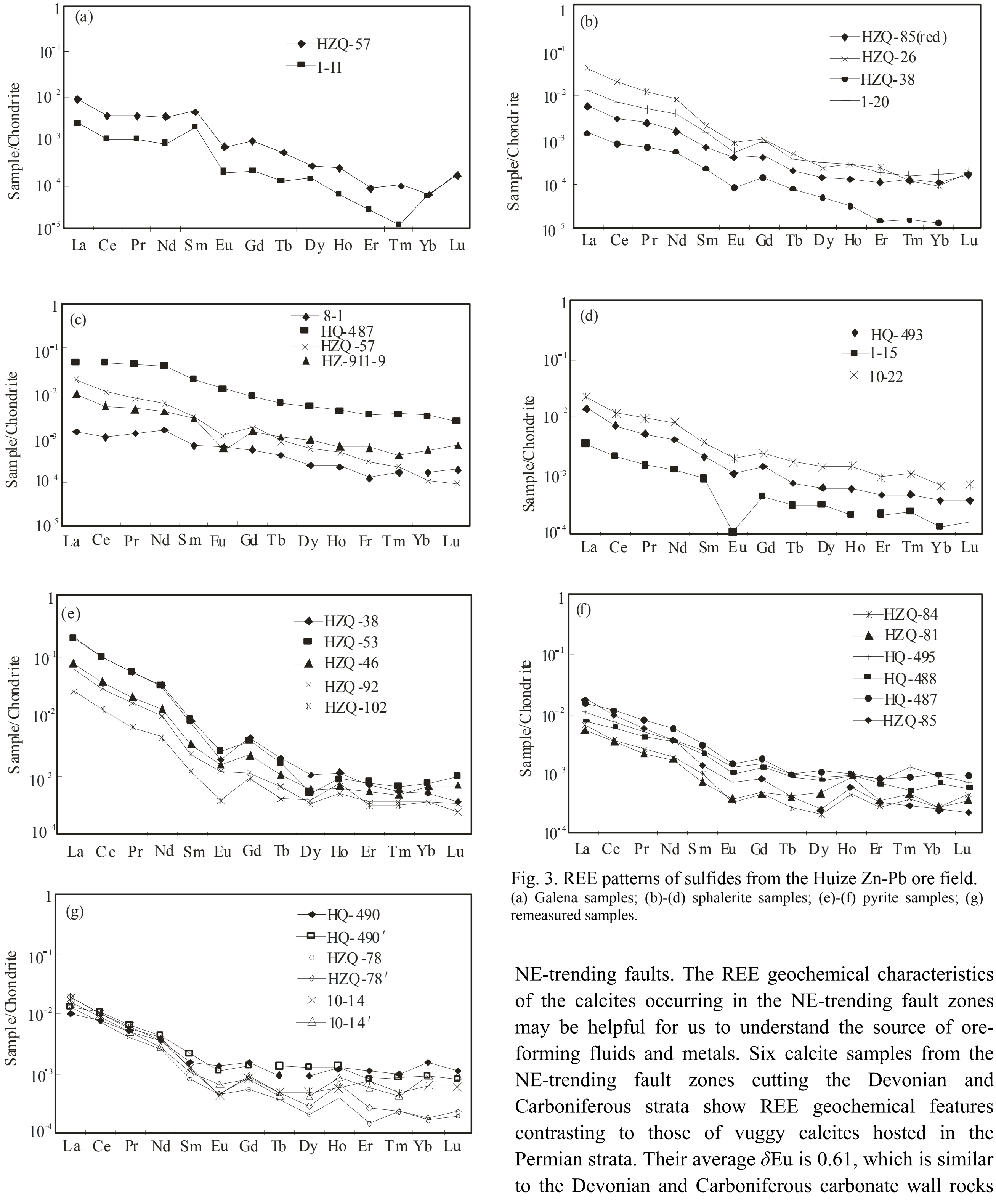

Fig. 3. REE patterns of sulfides from the Huize Zn-Pb ore field.
(a) Galena samples; (b)-(d) sphalerite samples; (e)-(f) pyrite samples; (g) remeasured samples.

have inherited the REE geochemical features of their source rocks. That is to say, the sulfides and their parent fluids of the Huize Pb-Zn ore field must come from a source with clear Eu-depletion, instead of a source, such as the Permian limestone, with positive Eu-anomaly or without Eu-depletion.

The orebodies in the Huize ore field are controlled by NE-trending faults. The REE geochemical characteristics of the calcites occurring in the NE-trending fault zones may be helpful for us to understand the source of ore-forming fluids and metals. Six calcite samples from the NE-trending fault zones cutting the Devonian and Carboniferous strata show REE geochemical features contrasting to those of vuggy calcites hosted in the Permian strata. Their average δEu is 0.61, which is similar to the Devonian and Carboniferous carbonate wall rocks (average δEu ranging 0.56–0.68; Table 2). Their ΣREE values (average 10.9), LREE/HREE (average 5.7) and δCe (average 1.0) are also similar to those of the Devonian and Carboniferous wall rocks (Table 2). The similarities in REE geochemistry between the calcites occurring in fault zones and their wall rocks again suggest that the wall rocks provided fluids and metals to the ore-forming system.

Previous studies (Li et al., 2002) reveal that the carbonate rocks in the Huize ore field are strongly recrystallized, and that their Pb, Zn, Ge, Ga, Cd and In contents are lower than both the averages in the carbonate rocks of East China and the Clarke value. This may be a signature of that the metals have been leached out and transported to ore-hosting structures during the metallogenesis.

In previous studies (Liao, 1984; Chen, 1993; Liu and Lin, 1999; Han et al., 2001; Huang et al., 2001a, 2001b, 2003; Li et al., 2002, 2004; Li, 2004), the Emeishan basalts were argued to be a fluid-metal source of the Huize ore field. However, this idea cannot be supported by the REE geochemical characteristics of sulfides presented in this paper, which differ from those of the Emeishan basalts (Table 2). Moreover, the Emeishan basalts remain fresh and unaltered, disagreeing with the interpretation that the ore-forming fluids and metals were provided by the Emeishan basalts.

5 Conclusion

Sulfide minerals of the Huize Zn-Pb ore field have very low REE contents, high LREE/HREE ratios and negative Eu-anomalies. These sulfides were deposited in a reducing environment from a Eu-depleted fluid-system. REE geochemical characteristics of the sulfides are similar to those of carbonate wall rocks, but differ from those of the Emeishan basalts. This indicates that the ore-forming fluids and metals were mainly sourced from the hosting carbonate wall rocks instead of the Emeishan basalts.

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