

ZOU Hao, ZHANG Shouting, FANG Yi and XU Zhanzhang 2013. The source of Ore-forming Material in Barite-fluorite deposits, southeast Sichuan in China: Sr isotope evidence *Acta Geologica Sinica* (English Edition), 87(supp.): 853-854.

The source of Ore-forming Material in Barite-fluorite deposits, southeast Sichuan in China: Sr isotope evidence

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Southeast Sichuan; Barite-fluorite deposit; Strontium isotope; The sources of ore-forming materials

Barite-fluorite metallogenic belt of southeast Sichuan is one of the important metallogenic belt in China, it has rich barite and fluorite resources. At present, there are more than 310 barite - fluorite veins had been found and distributed in more than 1.8 square kilometers (Li, 1977). Southeast Sichuan basin is located in the Upper Yangtze platforms fold belt of the Yangtze paraplatform. It also belong to the high and steep structure belt in east Sichuan and low-middle structure belt in south Sichuan which is the strongest in the fold deformation area of Sichuan basin. The basin basement is pre-Sinian Banxi Group, The formation thickness more than 8000m, which contain from Sinian to Quaternary strata. Due to the relatively uplift, some regions missed Devonian and Carboniferous sedimentary. The upper Sinian-Triassic were Marine sedimentary, major lithology is carbonate. Upper Triassic-Quaternary were continental sedimentary, major lithology is sand and shale rock, Quaternary have no diagenesis (Sichuan Bureau of Geology and Mineral Resources, 1987).

There are no magmatite developed in the study area and its adjacent area, so magmatic activity and barite-fluorite ore mineralization have no obvious contact. Ore-forming materials should come from the sedimentary strata, mainly fluid circulation and rock interaction, through the water/rock reaction, leaching solution formation, make the formation of the ore-forming materials into the solution. By the Yanshan movement strong influence, a series of folds and faults formed in this area, these structures play important controlling role in mineralize. Although they are not host faults, the associated NW faults control the barite-fluorite deposits output and distribution directly, they are really the ore-hosting faults. All the barite-fluorite deposits are born in NW faults without exception, group born and spatial distribution. Barite-fluorite metallogenic belt of

southeast Sichuan have some characteristics such as Mineral occurrences, large scale and wide distribution. They mainly hosted in Nanjingsuan formation (O_1n), Fenxiang formation (O_1f) and Honghuayuan Formation (O_1h) Formation, and the Honghuayuan Formation (O_1h) dark grey limestone Formation, they all have strata-bound deposit features obviously (Zou, 2013).

When rocks and minerals formed, initial ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ is the good “tracer” in study of diagenetic mineralization process and sources of ore-forming materials (Ruiz et al, 1985). In addition, the geochemical character of Sr is very similar with Ba and Ca, so Sr can be the good “tracers” with Ca and Ba (Withford et al, 1992). Therefore, the source of the Sr in minerals of containing Ca or Ba (stand for the source of the Sr in ore-forming fluid), such as fluorite, barite and calcite, etc., also indirectly reflect the source of Ca and Ba.

The $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of Sinian Doushantuo group and Dengying group strata in southeast Sichuan is 0.746668 and 0.720168 respectively. The $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of lower Cambrian is 0.708361 ~ 0.709831, the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of middle Cambrian is 0.708636 ~ 0.709641, and the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of middle Cambrian is 0.708014~0.709561. The ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ about TongZi group in lower Ordovician is 0.709211~0.710100, the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of middle Ordovician is 0.711236~0.713116, and the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of upper Ordovician is 0.718842~0.748539 (Table 1).

The $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of fluorite from barite-fluorite deposits in southeast Sichuan is 0.708800~0.7129508, and the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of barite is 0.708950~0.710136 (Table 2). Both of the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio are similar. The $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of ore in Xiaoba orefield of Youyang county is the highest than others.

Viewed from the lithology, Sinian-Ordovician strata are mainly carbonate rocks, and it can provide enough Ca for large-scale mineralization of barite and fluorite in the study area. Using the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio to trace the source, the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of most strata are around 0.710100, except

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Table 1 The $^{87}\text{Sr}/^{86}\text{Sr}$ analysis results of some strata in southeast Sichuan

Position	$^{87}\text{Sr}/^{86}\text{Sr}$	Sampling point	Reference
O _{3w}	0.718842	Xiaoba, Youyang	Pan et al. (1996)
	0.748539	Maopo, Xiushan	
O _{2b}	0.711236	Xiaoba, Youyang	
	0.713116	Maopo, Xiushan	
	0.71008	Erheshui, Pengshui	
O _{1t}	0.710100	Tongzi, Wulong	Huang et al. (2002)
	0.709211	Tongzi, Wulong	
ε ₃	0.708014~0.709561	Rongxi, Xiushan	
ε ₂	0.708636~0.709641	Rongxi, Xiushan	
ε ₁	0.708361~0.709831	Rongxi, Xiushan	Pan et al. (1996)
Z _{2dn}	0.720168	Maopo, Xiushan	
Z _{2d}	0.746668	Maopo, Xiushan	

Table 2 The $^{87}\text{Sr}/^{86}\text{Sr}$ analysis results of barite-fluorite deposits in southeast Sichuan

Host	$^{87}\text{Sr}/^{86}\text{Sr}$	Mining	Reference
Fluorite	0.709500	Erheshui, Pengshui	Cao et al. (1987)
Fluorite	0.711126	Xiaoba, Youyang	Pan et al. (1996)
Fluorite	0.708800	Tongzi, Wulong	
Purple Fluorite	0.7129508	Xiaoba, Youyang	
Barite	0.708950	Tongzi, Wulong	
Barite	0.710136	Xiaoba, Youyang	Cao et al. (1987)
Barite	0.709562	Xiaoba, Youyang	
Barite	0.709500	Erheshui, Pengshui	

Sinian Dengying group and Ordovician Wufeng group. Therefore, we concluded that the Ca source of ore-forming materials should be multisource.

The Ba source of ore-forming materials also can use for the Sr isotope to trace. Viewed from $^{87}\text{Sr}/^{86}\text{Sr}$ ratio, there are also many possibilities for the source of Ba. But from the Ba content of formation, Ba content of lower Cambrian Niutitang group stratum up to 2557~9812 ppm in southeast Sichuan, the highest sample up to 13220 ppm. The Ba content of other layers are generally below 500 ppm, except lower Cambrian Niutitang group stratum in southeast Sichuan and adjacent regions. The Ba content of ordovician limestone only 15~50 ppm in Pengshui, Youyang and Xiushan area. So these strata could not be the main Ba source of layer, which formed millions tons reserves of barite-fluorite deposits in the study area. The main Ba source of layer should be the lower Cambrian Niutitang group stratum.

Zhang (1988) argue that Yanshan movement has formed a series of NNE trend folds and faults in southeast Sichuan and adjacent regions, and the accompanying series of NW faults, After Ore-forming material gathered to the ore-forming hydrothermal fluid field by water/rock

reaction, ore-forming hydrothermal fluid upwelling to Ordovician limestone formation along the fault zone by the tectonic force and geothermal- pressure gradient, and block and stop by Dawan group mud shale and overlying thick mud shale layer. With the reduction of temperature and pressure, BaSO₄ and CaF₂ are crystallization and mineralization. The Rb-Sr and Sm-Nd isotope age of fluorite symbiosis with sphalerite shows mineralization took place in 128 ~ 130 Ma (Wang, 2013). Above all, the main mineragenetic epoch of barite-fluorite deposit in study area should be in the late yanshan movement and early Himalayan movement.

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