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^{40}Ar-^{39}Ar dating of lamprophyre dykes in the Baimazhai nickel deposit, Yunnan Province, China, and its geological significance

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Abstract The Baimazhai nickel deposit, Yunnan Province, China, is located in the southern part of the Sanjiang (Tri-river) alkali-rich intrusive rock belt (Sanjiang ARIR). In this paper was conducted ^{40}Ar-^{39}Ar dating of two phlogopites in lamprophyres which are, as dikes, widely distributed in the orefield, and two plateau ages were acquired, i.e., 32.46±0.62 Ma and 32.01±0.60 Ma, respectively (averaging 32.23±0.60 Ma). The ages are obviously younger than those of the ore-hosted complex and mineralization of the Baimazhai nickel deposit. In combination with the characteristics, it is indicated that lamprophyres in the orefield and those in the Sanjiang ARIR are similar in tectonic setting, mineral assemblage and geochemistry. It is considered that lamprophyres in the orefield are the important component of the Sanjiang ARIR, and the lamprophyres and ore-hosted complex in the orefield represent the products of two times of different magmatic activity from different mantle sources. On the other hand, the age of lamprophyres in the orefield is older than that of the strike-slip shearing of the Ailaoshan-Honghe fault belt, suggesting that the strike-slip shearing of the Ailaoshan-Honghe fault belt is not the factor leading to magmatic activity of lamprophyres in the orefield, while it is more possible that magmatic activity of the Sanjiang ARIR promoted strike-slip shearing of the fault belt.

Key words lamprophyre; ^{40}Ar-^{39}Ar dating; geological significance; Baimazhai nickel deposit;Yunnan Province

1 Introduction

Lamprophyres are the important component of the Sanjiang alkali-rich intrusive rock belt (Sanjiang ARIR) in China. They are spatially and temporally associated with alkali-rich syenite, monzonite, granite-porphyry and gold mineralization (Hu Yunzhong et al., 1995; Huang Zhilong et al., 1999). These rocks are important for understanding tectonic setting, mantle metasomatism, crust-mantle interaction, magmatic evolution and mineralization of the Sanjiang ARIR. The Baimazhai nickel deposit, Yunnan Province, China, is located in the southern part of the Sanjiang ARIR. Lamprophyre dykes are widely distributed in the orefield. Guan Tao et al. (2003, 2004, 2005) conducted a detailed study on petrology, mineralogy and major and trace element geochemistry of lamprophyres in the orefield, and modeled the provenance of the lamprophyres in terms of the rare-earth element (REE) data. Huang Zhilong et al. (2003) modeled the processes of crystallization differentiation of the lamprophyres in the orefield. In this paper are presented two ^{40}Ar-^{39}Ar ages for the lamprophyres in the orefield, and is also discussed the geological significance.

2 Samples and analytical methods

Geological, petrological, mineralogical and geochemical characteristics of lamprophyres in the Baimazhai nickel deposit are described by Guan Tao et al. (2003), Wang and Zhou (2006) and Zhang et al. (2006). Phlogopite as one of the essential minerals of lamprophyres in the orefield occurs as phenocrysts and matrix. Phlogopites of the two generations in the rocks have no interpenetration relationship, indicating that they are the products of synchronous magmatism. Phlogopites from two samples were selected for ^{40}Ar-^{39}Ar dating.

The ^{40}Ar-^{39}Ar ages were determined at the Isotope Laboratory of Guilin Institute of Geology and Mineral Resources, China. Whole-rock samples were ground as fine as 0.2–1 mm in grain size. Phlogopite was then separated by means of electromagnetic separation, heavy-media separation and binocular microscope. The selected phlogopite samples were washed by supersonic waves, and then were sealed in the quartz bottle to receive neutron irradiation in the reactor at the Institute of Atomic Energy in China. The standard sample for monitoring neutron flux is ZBH-25 biotite whose age is 132.7±1.2 Ma. The irradiated phlogopite sample was heated in an electron bombardment furnace, followed by the determination of Ar isotopic composition on an MM-1200 mass spectrometer. The static vacuum of the Ar purification system is 2.7×10^{-8} Pa. All of the analysis data have been corrected by mass discrimination adjustment, atmospheric argon correction, blank correction and interfering element isotope adjustment.

3 Results and discussion

The results of ^{40}Ar-^{39}Ar dating of lamprophyres in the Baimazhai nickel deposit are listed in Table 1, and their plateau ages and isochron ages are shown in Fig. 1.

Table 1. The results of ^{40}Ar-^{39}Ar dating of lamprophyres in the Baimazhai nickel deposit

Stage	Temperature (℃)	$^{40}Ar/^{36}Ar$	$^{39}Ar/^{36}Ar$	$^{37}Ar/^{39}Ar$	$^{40}Ar/^{39}Ar$	$^{39}Ar(\times10^{-13}$ mol)	^{39}Ar (%)	$^{40}Ar/^{40}Ar$	Appearance age (Ma±σ)
BMZ-18, Phlogopite, W=0.0611g, J_0=0.0040863									
1	300	1383.4270	277.50888	0.80738	3.9203	0.26	1.26	78.50	28.6±12.44
2	500	1281.9957	236.616512	0.29559	4.1692	1.01	4.87	76.83	30.4±2.82
3	620	1333.4838	232.422328	0.27761	4.4659	1.25	6.10	77.72	32.62±2.55
4	720	1451.3752	253.804846	0.24093	4.5542	2.90	13.98	79.52	33.26±1.37
5	850	1920.0780	379.765253	0.21743	4.2778	3.88	18.72	84.46	31.26±1.02
6	920	2147.5291	419.117248	0.25848	4.4189	3.70	17.84	86.09	32.28±1.28
7	1000	2158.5099	427.494922	0.22759	4.3580	4.29	20.68	86.16	31.84±1.11
8	1100	1661.0455	305.872268	0.25147	4.4644	2.04	9.84	82.08	32.61±1.92
9	1200	1438.6563	222.481084	0.27201	5.1382	1.01	4.89	79.35	37.49±4.48
10	1300	1383.4270	249.872590	0.16341	4.6906	0.39	1.90	78.53	34.25±8.80
BMZ-87, Phlogopite, W=0.0611, J_0=0.0040841									
1	300	1488.6650	293.694957	0.66324	4.0626	0.30	1.34	80.01	29.6±10.89
2	500	1609.4771	317.096346	0.29090	4.1438	1.22	5.48	81.50	30.27±2.33
3	620	1645.3229	302.377015	0.24720	4.4640	1.66	7.58	81.91	32.59±1.91
4	720	1753.7092	321.197855	0.21444	4.5399	2.80	12.59	83.02	33.14±1.42
5	850	1732.1219	334.042285	0.18725	4.3007	4.02	18.06	82.80	31.41±0.98
6	920	1717.0250	324.271203	0.21903	4.3838	3.88	17.43	82.65	32.01±1.22
7	1000	1763.1265	337.883746	0.19692	4.3436	4.69	21.09	83.10	31.72±1.01
8	1100	1804.0293	352.468542	0.16468	4.2799	2.19	9.85	83.48	31.26±1.79
9	1200	1657.3191	299.868277	0.23462	4.5414	1.08	4.86	82.04	33.15±4.20
10	1300	1647.1572	402.646808	0.18734	3.8536	0.40	1.82	81.91	28.17±8.57

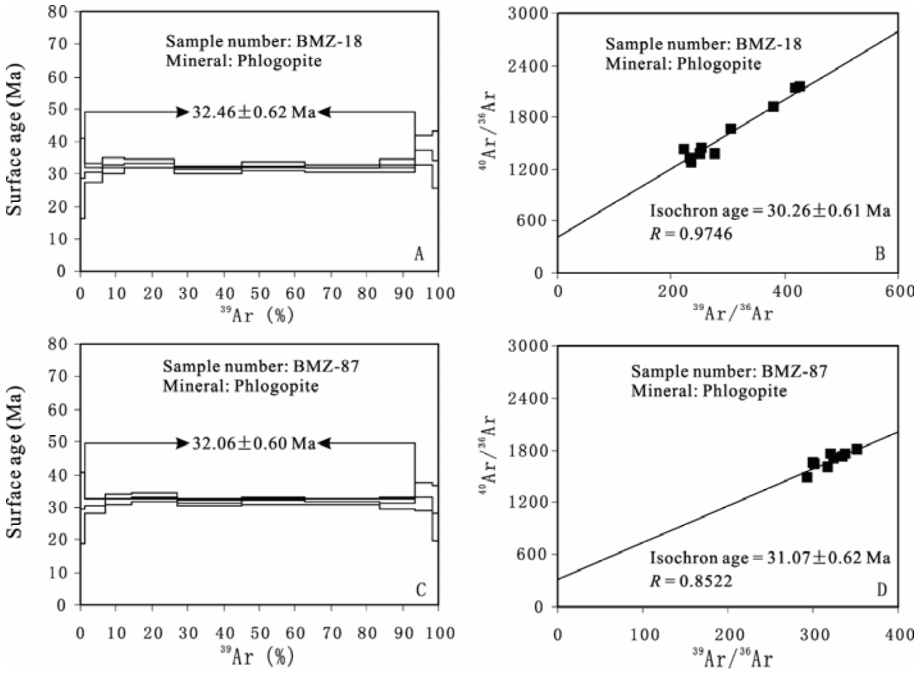

Fig. 1. The ^{40}Ar-^{39}Ar plateau ages (A, C) and isochron ages (B, D) of lamprophyres in the Baimazhai nickel deposit.

3.1 The ages of lamprophyres

The ^{40}Ar-^{39}Ar age spectrum of lamprophyres in the orefield is stable (Fig. 1), belonging to a typical close system age spectrum which has not suffered thermal disturbance, indicating that the analytical data are precise. The plateau ages of the two samples (BMZ-18 and BMZ-87) are very similar (32.46±0.62 Ma and 32.01±0.60 Ma, respectively, averaging 32.23±0.60 Ma), and are close to their isochron ages (30.26±0.61 Ma and 31.07±0.62 Ma, respectively). This feature excludes the possibility of the existence of excess argon in the high temperature stage. Therefore, the plateau age can truly represent the emplacement age of lamprophyres.

It is commonly accepted that the plateau age of biotite represents its cooling age. Because the closure temperature of the K-Ar system for biotite is lower (about 300℃; Wijbrans and McDougall, 1986), when the petrogenic temperature of a geologic body is higher, the ^{40}Ar-^{39}Ar age of biotite is lower than the actual age of the geologic body, while the cooling velocity of the geologic body is high, the ^{40}Ar-^{39}Ar age of biotite is equal to that of the geologic body (Heizler et al., 1988). The phlogopite in this paper is hosted in the lamprophyres which are hypabyssal to eruptive phase and the cooling velocity is high, its ^{40}Ar-^{39}Ar age can approximately represent the crystallization age of lamprophyres. Therefore, the plateau age of phlogopite (32.23±0.60 Ma) can represent the emplacement age of lamprophyres in the orefield.

3.2 Geological significance

The ore-hosted rock body in the Baimazhai nickel deposit is a basic-ultrabasic complex which is composed of peridotite, pyroxenite, and gabbro (Guan Tao et al., 2003; Wang and Zhou, 2006; Wang et al., 2006; Zhang et al., 2006). The ore-hosted complex body in the orefield intruded into the Ordovician rammell and is considered as the product of Variscan magmatic activity (Zhang Qi et al., 1992; Deng Jiafan, 1999). Wang Denghong et al. (2003) and Shi Guiyong et al. (2006) reported that the Re-Os isochron ages of copper-nickel sulfide ores in the orefield were 249±32 Ma and 259±18 Ma, respectively. According to Wang et al. (2006), the zircon SHRIMP age of the ore-hosted complex body was 262±2 Ma. It is obvious that the age of the ore-hosted complex and the mineralization age of the Baimazhai nickel deposit are consistent with the age of the Emeishan basalt (about 260 Ma; Boven et al., 2002; Zhou et al., 2002). So, the mineralization of the Baimazhai nickel deposit is related to the activity of Emeishan mantle plume (Shi Guiyong et al., 2006; Wang and Zhou, 2006; Wang et al., 2006). On the other hand, although there is a coupling relation in space between the lamprophyres and the ore-hosted complex in the orefield, the age of the former (about 32 Ma) is far younger than that of the latter (about 260 Ma). This feature shows that the lamprophyres and ore-hosted complex in the orefield represent the products of two times of magmatic activity from different mantle sources.

The Sanjiang ARIR has a close genetic relation with Cu-Au mineralization (Hu Yunzhong et al., 1995; Bi Xianwu, 1999; Huang Zhilong et al., 1999; Bi Xianwu et al., 2004). At present, the Cu-Au mineralization associated with lamprophyres has not been found in the Baimazhai nickel deposit. Zhang Yuquan and Xie Yingwen (1998) reported that the ages of the Shilicun tremolite granite and Tongchang orthophyre in Jinping County, Yunnan Province, were 35.8±0.5 Ma and 37.7±0.7 Ma, respectively. These two rock bodies are away from the Baimazhai nickel deposit, and the Cu-Au mineralization associated with lamprophyres has not yet been found. In combination with the characteristics that lamprophyres both in the orefield and in the Sanjiang ARIR are similar in tectonic setting, mineral assemblage and geochemistry (Guan Tao et al., 2003, 2005), it is considered that lamprophyres in the Baimazhai nickel deposit are a type of rocks which are associated with Cu-Au mineralization.

A good many high precision chronology data from the Sanjiang ARIR have been published by many scholars (Chung et al., 1997; 1998; Zhang Yuquan and Xie Yingwen, 1998; Lee et al., 1998; Zhang and Schärer, 1999; Wang et al., 2001; Wang Jianghai et al., 2001; 2003; Zhang Huihua et al., 2005). The statistics results provided by Wang et al. (2001) showed that the ages of the Sanjiang ARIR could be divided into two time phases, namely, from 0 Ma to 16 Ma and from 28 Ma to 40 Ma (Fig. 2). The age of lamprophyres in the Baimazhai nickel deposit is close to the ^{40}Ar-^{39}Ar age of potassium-high lavas in the Mangkang Basin, Tibet, which are located in the northern part of the Sanjiang ARIR (33.5±0.2 Ma; Zhang Huihua et al, 2005), also close to the ^{40}Ar-^{39}Ar age of alkali basalt within Vietnam, not far from Jinping County (30.0±1.1 Ma; Chung et al., 1997), and the ^{40}Ar-^{39}Ar age of phlogopites in lamprophyres from the Laowangzhai gold deposit which is located in the middle part of the Sanjiang ARIR (30.8±0.4 Ma to 34.3±0.2 Ma; Wang Jianghai et al., 2001), and the ages of the Shilicun tremolite granite and Tongchang orthophyre in Jinping County (35.8±0.5 Ma and 37.7±0.7 Ma, respectively (Zhang Yuquan and Xie Yingwen, 1998). Therefore, lamprophyres in the orefield are believed to the product of magmatic intrusion of alkali-rich intrusive rocks which were formed in the early stage after collision between the Indian plate and the Asian plate.

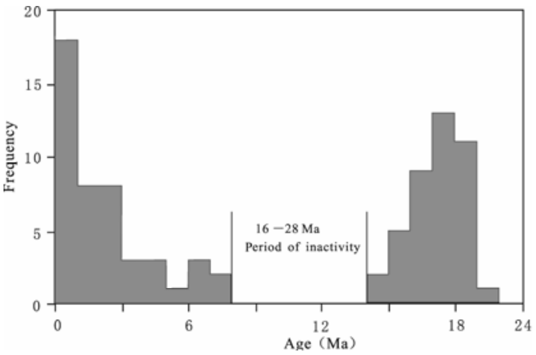

Fig. 2. Temporal distribution of the Cenozoic Sanjiang alkali-rich intrusive rock belt (the primary data taken from Wang et al., 2001).

The Sanjiang ARIR is apparently controlled by the Ailaoshan-Honghe fault belt (Zhang and Schärer, 1999; Wang et al., 2001). During the Cenozoic, collision and subduction between the Indian plate and the Asian plate, which was taken as a way of regulating stress, led to strike-slip shearing of the Ailaoshan-Honghe fault belt (Zhang Liansheng and Zhong Dalai, 1996; Zhang and Schärer, 1999). Kincard and Silver (1996) considered that the viscosity diffusion of heat through upper mantle lithosphere and lower crust could cause small-scale melting of lithospheric mantle in the process of shearing. Kameyama et al. (1999) suggested that the effect of heat produced by viscosity diffusion lasted for a short time (about 5 Ma), which is apparently shorter than the time span of magmatic activity of the Sanjiang ARIR. On the other hand, the age of strike-slip shearing of the Ailaoshan-Honghe fault belt ranges from 22 Ma to 27 Ma (Leloup et al., 1995; Zhang and Schärer, 1999), which is obviously younger than the age of lamprophyres in the Baimazhai nickel deposit. So, strike-slip shearing of the Ailaoshan- Honghe fault belt is not the factor leading to magmatic activity of lamprophyres in the orefield, while it is more possible that magmatic activity of the Sanjiang ARIR promoted strike-slip shearing of the Ailaoshan-Honghe fault belt.

4 Conclusions

(1) Reported in this paper are two plateau ages [32.46±0.62 Ma and 32.01±0.60 Ma, respectively (averaging 32.23±0.60 Ma)], which represent the emplacement age of lamprophyres in the Baimazhai nickel deposit, Yunnan Province, China.

(2) The age of lamprophyres in the orefield is obviously younger than that of the ore-hosted complex and mineralization of the Baimazhai nickel deposit. We considered that lamprophyres in the orefield are the important component of the Sanjiang ARIR, and lamprophyres and ore-hosted complex in the orefield represent the products of two times of different magmatic activity from different mantle sources.

(3) The age of lamprophyres in the orefield is older than that of strike-slip shearing of the Ailaoshan-Honghe fault belt, suggesting that strike-slip shearing of the Ailaoshan-Honghe fault belt is not the factor leading to magmatic activity of lamprophyres in the orefield, while it is more possible that magmatic activity of the Sanjiang ARIR promoted strike-slip shearing of the Ailaoshan-Honghe fault belt.

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