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La-Ba dating of bastnaesite

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Abstract

La-Ba geochronometer has been applied for the first time to bastnaesite. The formation age of 586.8 Ma for bastnaesites from Gakara, Burundi, has been determined with the high precision of ±3.7 Ma. It has been found that the retention of radiogenic ^{138}Ba produced from ^{138}La can be perfect in bastnaesite.

Introduction

The Gakara bastnaesite-monazite deposits (Fig. 1), 20 km southeast of Bujumbura in the Republic of Burundi were described in detail by Aderca and Van Tassel (1971). The deposits are of the irregular vein-and-stockwork type and are located in a Precambrian gneiss-pegmatite complex. The genetic affiliation of the bastnaesite-monazite ore assemblage has been discussed in terms either of a speculative, hidden carbonatite intrusion (van Wambeke, 1977) or of the widespread granite and/or pegmatite magmatism (Aderca and Van Tassel, 1971).

The age of the surrounding granitic pegmatite has been determined by a whole-rock Rb-Sr isochron at 969 ± 8 Ma (Brinckmann et al., 1987). However, no conventional method can determine the age of the REE deposits themselves, because the mineralization under consideration consists essentially of bastnaesite that has been partly altered to monazite, and no conventional geochronometer has been directly applicable to bastnaesite so far. To overcome this difficulty, the La-Ba dating method recently developed by us (Masuda and Nakai, 1983; Nakai et al., 1986a) has been applied. A unique aspect of this dating method is that it is possible in principle to obtain the age from a single sample, because one can take the initial ^{138}Ba/^{137}Ba ratio to be substantially invariant (Masuda and Nakai, 1983). It goes without saying, however, that when using the La/Ba system, one can obtain a more dependable age if more than one sample is studied. In a case where an alteration took place, such alteration may give rise to a disturbed age.

Analytical technique

Four grains of about 0.05 g each were used for analysis. Samples were dissolved in HCl-$HClO_4$. Each of the solutions was divided into two fractions, one fraction for La and Ba abundance determinations, another for Ba-isotope measurements. The abundances of La and Ba were determined by stable-isotope dilution with a JEOL-05RB mass spectrometer. For isotope-abundance measurement, Ba was separated through a cation-exchange column with elution by 2*N* nitric acid and loaded as nitrate on a side filament of a Re triple-filament system. Ba-isotope ratios were measured with a VG354 mass spectrometer equipped with five Faraday collectors. All Ba-isotope ratios were normalized against ^{136}Ba/^{137}Ba = 0.6996. During this work, the average measured value of ^{138}Ba/^{137}Ba for a Merck $BaCl_2$ reagent (Art 1716) was 6.39028 ± 0.00008 ($2\sigma_m$). The total Ba blank from the separation procedure was less than 2 ng, which is negligible for the present measurement.

Results and discussion

The resultant La-Ba analytical data of the four bastnaesite samples are given in Table 1 and plotted in Figure 2. Sample K2 is composed of bastnaesite and microcrystalline monazite, which is regarded as a product of secondary alteration. The point for K2 deviates from a line formed by the three "pure" bastnaesite samples, K1, N1, and N2. When least-squares fitting (York, 1969) is applied to the three primary bastnaesites, an isochron for them yields an age of 548.5 ± 3.4 Ma (MSWD = 0.0663) with the electron-capture (EC) partial-decay constant (4.44×10^{-12} yr^{-1}) and the β^--decay partial-decay constant (2.30×10^{-12} yr^{-1}) of ^{138}La, which were obtained by Sato and Hirose (1981) by γ counting. However, Nakai et al. (1986a) suggested that λ_{EC} a little smaller than the value reported by Sato and Hirose (1981) would be adequate. Nakai et al. (1986b) presented 4.15×10^{-12} yr^{-1} as the value of λ_{EC}. Furthermore, λ_{β^-} is considered to be modified. Masuda et al. (unpub. ms.) recommended 2.77×10^{-12} yr^{-1} by comparing La-Ce and Sm-Nd isochron results for three mineral systems. When we employ these values (4.15×10^{-12} yr^{-1} as λ_{EC}, 2.77×10^{-12} yr^{-1} as λ_{β^-}), the slope of the foregoing isochron turns out to correspond to 586.8 ± 3.7 Ma. Here it should be emphatically noted that, aside from the accuracy, the formation age of 586.8 Ma could be determined with the precision as high as ±3.7 Ma.

As mentioned above, it is possible to obtain the formation age based on the measurement of a single grain, employing the invariable initial value for the ^{138}Ba/^{137}Ba ratio. In this calculation, the ^{138}Ba/^{137}Ba ratio (6.39028 ±

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Fig. 1. Location of the Gakara REE deposits and the Western Rift in Central Africa, with faults (thick lines). Shaded parts and solid circles indicate Cenozoic volcanic provinces and Late Proterozoic alkaline massifs, respectively.

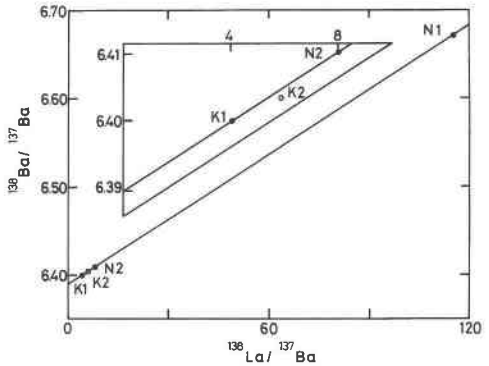

Fig. 2. La-Ba mineral-isochron plot for the Gakara bastnaesite-monazite deposits, Burundi. The isochron line except for K2 yields an age of 586.8 ± 3.7 Ma ($2\sigma_m$) ($\lambda_{EC} = 4.15 \times 10^{-12}$ yr^{-1}) with an initial $^{138}Ba/^{137}Ba$ ratio of 6.39005 ± 0.00030 ($2\sigma_m$).

0.00008) for $BaCl_2$ reagent, which is in agreement with the initial value determined from the isochron, 6.39005 ± 0.00030, can be used as the initial value. The results of "single point" calculations without consideration of an isochron are given in Table 2. It can be seen that the "single-point" values for K1, N1, and N2 are in complete agreement with each other within the experimental uncertainties. Naturally, the samples with low $^{138}La/^{137}Ba$ ratios have higher uncertainties. But, disregarding the uncertainties, the remarkable agreement among the ages determined (583.3, 586.4, and 579.3 Ma) for three samples should be emphatically noted. This agreement means that, for the bastnaesite deposits of Gakara, one could obtain a reliable age even from a single mineral grain.

Whichever value of decay constant may be employed for the age calculation, the resulting age of the bastnaesite deposits is much younger than the surrounding pegmatite, 969 ± 8 Ma, indicating that the deposits cannot be derived from the pegmatite. The younger age implies that the bastnaesite deposits may be connected with a carbonatitic magmatism. Many alkaline complexes are situated in the Western Rift area of Central Africa. In Burundi, alkaline plutonic rocks (with a carbonatite subintrusion) are known from an area about 60 km northeast of Gakara. Feldspathoidal syenites gave a U-Pb age on zircons of 739 ± 7 Ma and a slightly disturbed Rb-Sr–isochron age of 699 ± 13 Ma (Tack et al., 1984). The larger Western Rift region (Lake Kivu–Lake Malawi) forms a Late Proterozoic alkaline province with carbonatite magmatism in the time bracket of about 700–500 Ma (Tack et al., 1984).

Sample K2, a mixture of bastnaesite and monazite, does not fall on the isochron formed by the other three samples (Fig. 2). This sample can be considered to have suffered a secondary alteration of bastnaesite into monazite. The slope of a line between the point of K2 and the initial point (6.39028 ± 0.00008 for $^{138}Ba/^{137}Ba$ of the $BaCl_2$ reagent) corresponds to 524.9 Ma ($\lambda_{EC} = 4.15 \times 10^{-12}$ yr^{-1}), which is younger by 61.9 Ma than the isochron age. However, this age for K2 is unlikely to have a significance. The observed age depends on the proportions of bastnaesite and monazite and on the isotopic composition of monazite.

TABLE 1. La and Ba concentrations and isotopic data for the Gakara bastnaesite-monazite deposits

	La (%)	Ba (ppm)	$^{138}La/^{137}Ba$*	$^{138}Ba/^{137}Ba$**
		Bastnaesite		
K1	17.94	351.1	4.007	6.40000(70)
N1	18.41	12.95	114.9	6.67044(37)
N2	17.65	172.1	8.051	6.40967(24)
		Bastnaesite-monazite (about 1:1)		
K2	17.30	230.9	5.878	6.40311(30)

* Uncertainties are <0.5%.
** Error is $2\sigma_m$. Normalized against $^{138}Ba/^{137}Ba = 0.6996$.

TABLE 2. Calculated "single-point" ages

Bastnaesite	
K1	583.3 ± 49.9 Ma
N1	586.4 ± 4.0 Ma
N2	579.3 ± 12.6 Ma
Bastnaesite-monazite (about 1:1)	
K2	524.9 ± 18.3 Ma

Note: Each respective error was evaluated by taking into account the precision of La/Ba abundance ratio and that of Ba isotopic ratio.

CONCLUDING REMARKS

The La-Ba geochronometer utilizing the electron-capture decay of ^{138}La has been used successfully for the direct age determination of bastnaesite. The high precision in age determination or the high chronological resolution strongly suggests that this new dating method can be a powerful tool in research on the genetic characterization of rare-earth minerals in ore deposits. The results of this

study indicate that the radiogenic ^{138}Ba produced from ^{138}La is retained very well in bastnaesite.

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