^<40>Ar-^<39>Ar Dating of Terrestrial and Exterrestrial Materials : Basalts from the Japan Sea Floor, Deccan Plateau and Meteorites from Antarctica

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^{40}Ar-^{39}Ar Dating of Terrestrial and Exterrestrial Materials --- Basalts from the Japan Sea Floor, Deccan Plateau and Meteorites from Antarctica

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Through a series of ^{40}Ar-^{39}Ar dating for terrestrial and exterrestrial samples, the results for basalts from the Japan Sea floor, Deccan Plateau and for meteorites from Antarctica give significant information concerning their formation histories. ^{40}Ar-^{39}Ar ages of basalts from the Japan Sea floor give a constraint that the Japan Sea floor was formed at least 20 Ma. ^{40}Ar-^{39}Ar ages for dyke samples from the Deccan Plateau indicate a possibility for the occurrence of a little younger ages than that of the main plateau formations by a few million years. Meteorites collected from Antarctica show some variable ^{40}Ar-^{39}Ar ages reflecting their different thermal histories.

KEYWORDS: ^{40}Ar-^{39}Ar age, Japan Sea, Deccan Plateau, Meteorite, Antarctica

1. Introduction

^{40}Ar-^{39}Ar dating method is based on the decay scheme of ^{40}K into ^{40}Ar with a half live of about 12.5 billion years, which is essentially the same with the K-Ar methods. In the K-Ar method, the amounts of radiogenic ^{40}Ar and ^{40}K are measured and an age is calculated with them. In the ^{40}Ar-^{39}Ar method, instead of measuring the K content to estimate the amount of ^{40}K, ^{39}Ar is produced from ^{39}K by neutron irradiation with the reaction of $^{39}K(n,p)^{39}Ar$ and the $^{40}Ar/^{39}Ar$ ratio is measured. An age is calculated from the $^{40}Ar/^{39}Ar$ ratio for a sample by comparing that of standard sample which is irradiated by neutron under same condition with that of samples and the age of the standard should be known[1)]. Since only the measurements of Ar isotopic ratios are required to get an ^{40}Ar-^{39}Ar age, the ^{40}Ar-^{39}Ar method has a lot of merits over the conventional K-Ar method, especially accompanied with the stepwise heating processes[2)]. Hence, ^{40}Ar-^{39}Ar dating is now widely applied for terrestrial and exterrestrial samples in Earth Sciences.

By using the facility of JMTR, we have performed a lot of ^{40}Ar-^{39}Ar studies on terrestrial and exterrestrial materials so far[3)]. Some of recent results are outlined below.

2. Experimental

Basement volcanic rocks were recovered from the Japan Sea floor by drilling on Ocean Drilling Program (ODP) Legs 127/128 and rock samples were cut as cylinders (6 mm diameter x 10 mm long) and stacked in vacuum-sealed quartz ampoules (10 mm diameter x 70 mm long) together with age standard samples (JB-1 biotite; K-Ar age: 90.8 ± 1.5 Ma), CaF_2 and K_2SO_4. They were irradiated with a fast neutron flux of (1~5) x 10^{17}n/cm^2 by JMTR. CaF_2 and K_2SO_4 were irradiated in order to obtain the correction factors for interference Ar isotopes from Ca and K, respectively.

Basalts from the Deccan Plateau, India, were also irradiated in the same manner as those of the volcanic rocks from the Japan Sea floor.

In the case meteoritic samples from Antarctica, sample chips with grain sizes of 1-5 mm were wrapped in Al foil and stacked together with the hornblende age standard samples (MMhb-1: K-Ar age: 519.5 ± 2.5 Ma)[4] as well as CaF_2 and K_2SO_4. They were irradiated with total fast neutron flux of (6~100) x 10^{17} n/cm^2.

Ar gas in these samples was extracted at the Radioisotope Center, University of Tokyo. Ar isotopes were measured either at Yamagata University on a Nier-type mass spectrometer with a multiplier[5] or at the Institute for Study of the Earth's Interior, Okayama University on a VG-5400 mass spectrometer with a Daly photomultiplier[6].

Blanks and effects of interfering Ar isotopes produced from neutron-irradiated Ca and K were corrected to calculate an ^{40}Ar-^{39}Ar age, using the correction factors estimated based on the measurements of Ar isotopes for neutron-irradiated CaF_2 and K_2SO_4.

3. Results and Discussions

3.1. Ages of basement volcanic rocks from the Japan Sea floor

Through a series of ODP studies Legs 127/128, which were performed from June to October, 1989, 4 sites were drilled and basement volcanic rocks were recovered from 3 sites (site 794, 795 and 797 in Fig.1).

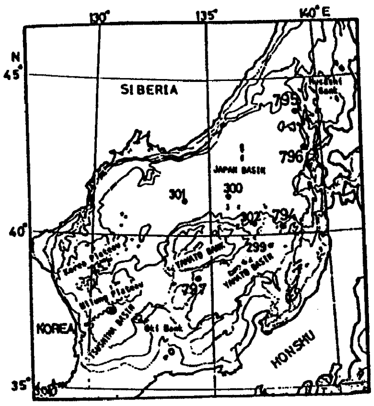

Fig. 1. Sampling sites at ODP Legs 127/128 which were performed in 1989. Site 794-797 were drilled in 1989.

Among recovered rocks, least altered rocks were selected and ^{40}Ar-^{39}Ar datings were performed in order to get information about the formation age of the Japan Sea floor. The results indicate that basement volcanic rocks from the Yamato Basin (site 794, 797) have ^{40}Ar-^{39}Ar ages of about 19-20 Ma (Fig. 2).

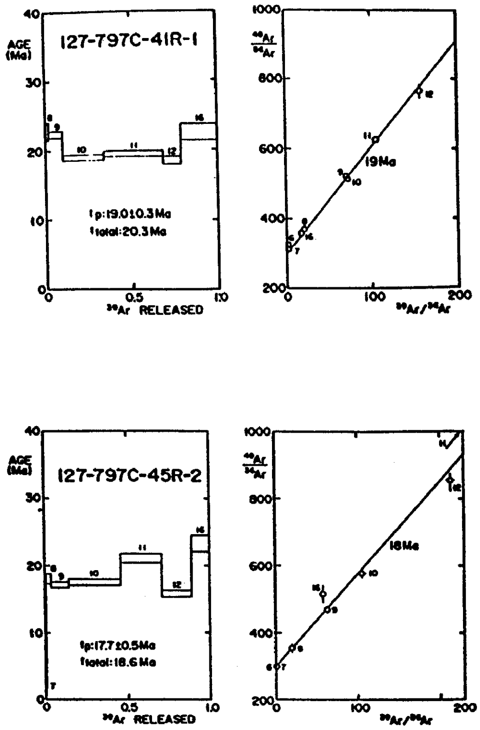

Fig. 2. ^{40}Ar-^{39}Ar ages of volcanic rocks from site 797.

On the other hand, samples from the Japan Basin (site 795) are more or less altered and they do not show any plateau ^{40}Ar-^{39}Ar ages as shown in Fig. 3. However, they indicate a possibility that they might have formed at an age older than 20 Ma. These results suggest that the Japan Sea floor should have formed at least 20 Ma and the formation of the Japan Sea might have started around 25 Ma. These results are consistent with an inference based on the radiometric ages for dredged rocks from the Japan Sea floor[7]. More details have been reported elsewhere[8].

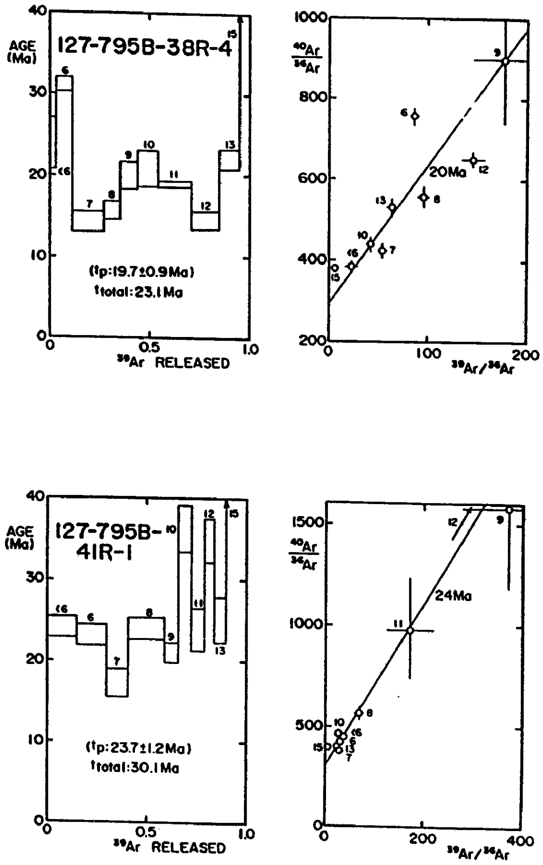

Fig. 3. ^{40}Ar-^{39}Ar ages of volcanic rocks from site 795.

3.2. Ages of dyke samples from the Deccan Plateau, India

The Deccan Plateau is located in the central part of India and covers the area of about 10^6 km^2. The total volume of lavas is estimated to be about 10^6 km^3 and it is regarded to be one of the largest volcanism on the Earth. On the other hand, the main activity of volcanism has been regarded to have occurred within a relatively short period of around 65-67 Ma[9]. However, there still remain problems about the total period of volcanic activities and their histories. In order to clarify the whole history of volcanic activities of the Deccan Plateau, we have been trying to get ^{40}Ar-^{39}Ar ages of various samples from the Deccan Plateau in space and time.

As an aspect through such studies, we have tried to get formation ages of dykes in the Deccan Plateau. Because the trends of dykes show quite typical spatial distributions: the E-W trend in the northern part of the Deccan Plateau and the S-N trend in the western part of the Deccan Plateau. Since dykes are regarded to reflect the direction of regional stress field, such spatial distribution of dykes might reflect the change of stress field. With such points in mind, we have determined several dyke samples from the western part of the Deccan Plateau as a preliminary study. The result indicates that a few samples show slightly younger ^{40}Ar-^{39}Ar ages than those of the Deccan Plateau flows by a few million years. An example is shown in Fig. 4, which shows a plateau ^{40}Ar-^{39}Ar age of about 62 Ma. Hence, there is a possibility that the volcanic activity of the Deccan volcanism might have continued at least until 62 Ma. Such points should be clarified further in a more systematic studies and we are preparing for it.

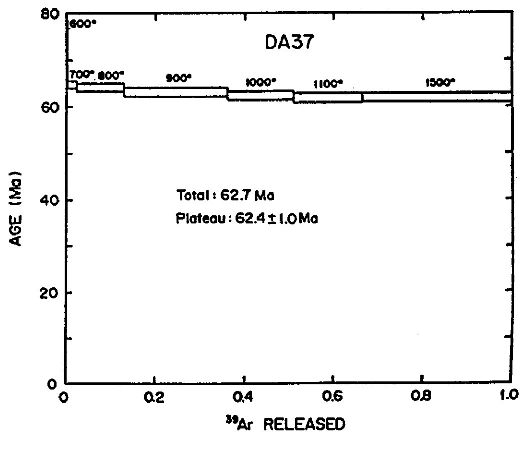

Fig. 4. ^{40}Ar-^{39}Ar age of a dyke sample from the Deccan Plateau, India.

3.3. ^{40}Ar-^{39}Ar ages of unique chondrites from Antarctica

Among a number of meteorites collected from Antarctica, some meteorites have been classified as unique chondrites, because their bulk compositions are different from those of known chondrite groups[10]. ^{40}Ar-^{39}Ar analyses for two unique chondrites indicate that they experienced different thermal histories as shown in Fig. 5.

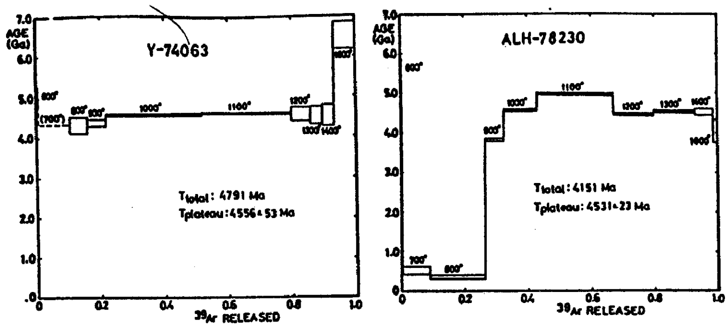

Fig. 5. ^{40}Ar-^{39}Ar ages of two unique chondrites from Antarctica.

The sample Y-74063, shows an ^{40}Ar-^{39}Ar plateau age of 4556 ± 53 Ma for almost whole temperature fractions. On the other hand, ALH-78230 also indicates an ^{40}Ar-^{39}Ar plateau age of 4531 ± 23 Ma in the higher temperature fractions, but the lower temperature fractions suggest the occurrence of a later degassing event around 400-500 Ma. Thus, although both samples are classified as unique chondrites, they have been revealed to have experienced different thermal histories. The amounts of their trapped ^{36}Ar are also different each other. More details have been discussed elsewhere[11].

3.4. ^{40}Ar-^{39}Ar analyses of a lunar meteorite and LL-chondrites from Antarctica

Y-86032 is an anorthositic breccia and has been assigned to be a lunar meteorites[12]. The result of ^{40}Ar-^{39}Ar analyses indicates a scattered ^{40}Ar-^{39}Ar age spectrum with anomalously high ages in the higher temperature fractions (Fig. 6). Such age spectrum implies a shock effect for this meteorite.

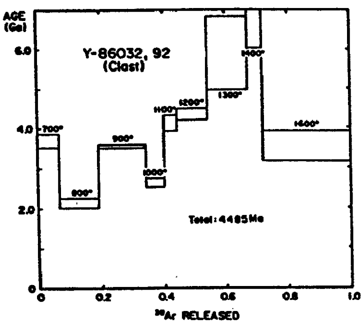

Fig. 6. ^{40}Ar-^{39}Ar age spectrum for the lunar meteorite Y-86032.

^{40}Ar-^{39}Ar analyses were performed for three LL-chondrites from Antarctica. Among them, Y-790448 indicates a plateau ^{40}Ar-^{39}Ar age of 4521 ± 28 Ma in the lower temperature fractions (600-800∞C), while it shows much younger ^{40}Ar-^{39}Ar ages in the higher temperature fractions. Such age spectrum is not uncommon and has been ascribed to the recoil effect. The other two LL-chondrites show inverse staircase spectra in the higher temperature fractions with no definite ^{40}Ar-^{39}Ar plateau ages. In the LL-chondrite group, unequilibrated chondrites seem to show older ^{40}Ar-^{39}Ar ages compared with equilibrated ones, which might reflect differences in the thermal history of each portion of their parent body. More details have been discussed elsewhere[13].

4. Summary

Application of the ^{40}Ar-^{39}Ar method is quite useful to get reliable ages for terrestrial and exterrestrial samples, since it has a lot of merits over the conventional K-Ar method. We have applied this method to various kinds of samples whose ages are significant to infer their thermal histories. Some recent results are outlined here. Although the availability to use a facility to treat irradiated materials and extract Ar gases is a severe constraint in our country, we hope more laboratories are able to use this method.

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