34. ^{3}He/^{4}He RATIOS OF PORE GASES IN DEEP-SEA SEDIMENTS, LEGS 89 AND 90[1]

Hiroshi Wakita and Yuji Sano, University of Tokyo
Naoyuki Fujii, Kobe University
and
Akira Takeuchi, Toyama University[2]

INTRODUCTION

Studies on He isotope ratios of gas and rock samples in various parts of the world have shown a close relation between the ^{3}He/^{4}He ratio and geotectonic features of the sampling area (Tolstikhin 1978; Craig and Lupton, 1982; Lupton, 1983; Sano and Wakita, in press, a). Emission of primordial He is commonly found in gases and fluid in Cenozoic volcanic areas (mid-ocean ridges, hot spots, and subduction zones), whereas that of radiogenic He is predominant in continental areas. Thus, the ^{3}He/^{4}He ratio is considered a useful tool for evaluating a variety of geotectonic environments.

Investigations on He isotope ratios in oceanic areas have been carried out mainly for fresh basalt glasses obtained from mid-ocean ridges (Lupton and Craig, 1975; Craig and Lupton, 1976; Rison, 1980; Kyser and Rison, 1982; Allegre et al., 1983; Ozima and Zashu, 1983). Because of the genetic configuration of sampling sites, the investigated area is rather limited. Alternatively, using deep-seawater samples, previous workers have reported enrichment of ^{3}He in the Atlantic Ocean (Jenkins and Clarke, 1976), Pacific Ocean (Jenkins et al., 1978), and Red Sea (Lupton et al., 1977). Lupton and Craig (1981) found an extensive plume of water enriched with ^{3}He in the Pacific Ocean. These data, however, provide indirect information on outgassing of the oceanic crust. Deep-sea sediment is considered to be an ideal material for investigating the ocean floor because of its preservation of gases emitted from the interior of the Earth. Furthermore, sampling sites can be selected all over the oceanic area. In the existing data base, however, helium studies on gases dissolved in pore water of oceanic sediment are quite sparse (Clarke et al., 1973; Barnes and Clarke, 1980; Sayles and Jenkins, 1982; Sano and Wakita, in press, b). The purpose of this study is to reveal the isotopic signature of He in an ocean floor of continental crust character in relation to its tectonic features. We report the ^{3}He/^{4}He and ^{4}He/^{20}Ne ratios of gases dissolved in pore water of sediments in the Ontong-Java Plateau (Site 586) and Chatham Rise (Site 594).

EXPERIMENTAL

Sampling Method

A sample container with a vacuum valve at one end was used for gas samples. Prior to gas collection, the lead glass container, with inside volume of about 50 cm^3, was evacuated in the laboratory by a rotary pump and a sorption pump. On the deck, both ends of 1.5-m sections of the core sample recovered in the plastic liner were capped with plastic caps. On reaching room temperature, some of the liner began to swell slightly because of gas released from the sediments. The core section was held vertically, and a plastic vessel was attached to the top of the liner and filled with deionized water. An inverted funnel was connected with the glass container by a thick rubber tube in the water (Fig. 1). Then the middle part of the plastic cap was cut to release gas into the funnel, and the gas was transferred to the container by opening the stop valve. The samples were stored about one month before analysis. Considering the low permeation velocity of He in lead glass, penetration of atmospheric He is negligible for the storage time.

Helium Isotope Measurements

After the sample container was brought back to the laboratory, about 1 cm^3 STP of gaseous sample was introduced into a metallic ultra-high vacuum line. Purification was carried out using a CuO furnace and a three-stage charcoal trap kept at 196°C. The ^{3}He/^{4}He and ^{4}He/^{20}Ne ratios were measured with a static mass spectrometer (6-60-SGA, Nuclide Co.). Ion beams of ^{3}He and ^{4}He were detected by a double collector system. Resolving power of about 600 at 1% peak height was attained for complete separation of ^{3}He beam from those of H$_3$ and HD. An in-house standard for ^{3}He/^{4}He measurements was prepared by mixing known amount of pure ^{3}He and ^{4}He gases. The mass discrimination factor of the measuring system was calculated using this standard. The atmospheric He was used as a running standard. Isotopic ratios were determined as an average of six sets of measurements of the peak heights. The mean value of the ^{3}He/^{4}He ratios in Tokyo air is $(1.42 \pm 0.04) \times 10^{-6}$ from 31 individual runs. ^{4}He/^{20}Ne ratio measurements were conducted by adjusting the magnet current. A detailed description of the measurement was given in a previous paper (Sano et al., 1982).

RESULTS AND DISCUSSIONS

Three samples were obtained at Site 586 in the Ontong-Java Plateau and six sample in Holes 594 and 594B in the Chatham Rise (Fig. 2). The observed ^{3}He/^{4}He and ^{4}He/^{20}Ne ratios are shown in Table 1, together with depths of the sampling sites. The ^{3}He/^{4}He and ^{4}He/^{20}Ne ratios vary significantly, from 4.39×10^{-7} to 1.26×10^{-6} and from 0.39 to 4.35, respectively. No correlation between the ^{3}He/^{4}He ratios and locations of sampling sites is found.

Clarke et al. (1973) measured the ^{3}He/^{4}He ratios of pore water from sections of core at three locations (Sites 148, 149, and 150) in the Caribbean Sea. Their ratios were principally radiogenic, varying from 6.6×10^{-7} to 1.4×10^{-6}. Barnes and Clarke (1980) reported that the
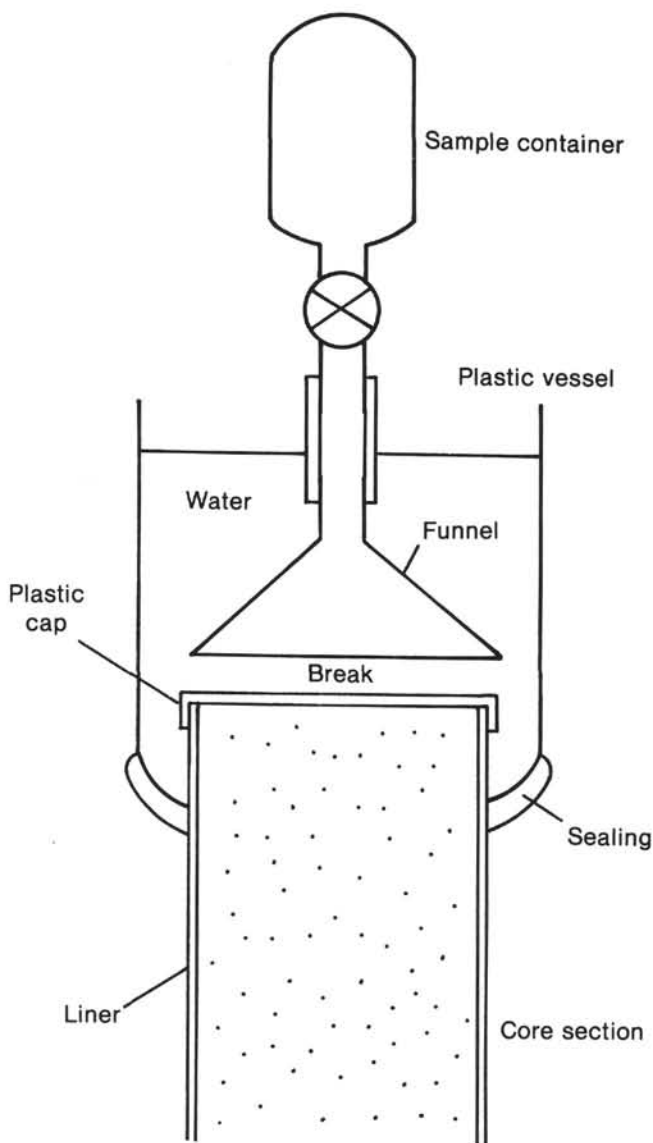
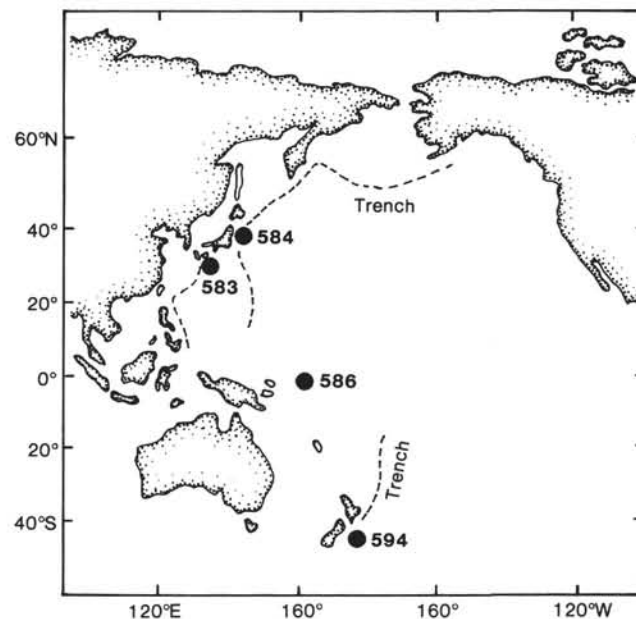Figure 1. Sampling method of pore gases in sediment.

Figure 2. Sampling sites of pore gases in sediment. Three samples were collected in the Ontong-Java Plateau (Site 586) and six samples in the Chatham Rise (Holes 594 and 594B).

Table 1. ^{3}He/^{4}He and ^{4}He/^{20}Ne ratios of pore gases in sediment from the Ontong-Java Plateau and the Chatham Rise.

No.	Depth (m)	Location	^{3}He/^{4}He ($\times 10^{-6}$)	^{4}He/^{20}Ne
Ontong-Java Plateau (Site 568)				
SG-1	191.9	0°30'S, 158°30'E	0.639 ± 0.013	4.4
SG-2	240.3		0.990 ± 0.020	0.57
SG-3	261		0.974 ± 0.009	0.52
Chatham Rise (Site 594)				
SG-4	399.5	45°31'S, 174°57'E	0.439 ± 0.007	3.2
SG-5	447.5		0.568 ± 0.021	2.6
SG-6	449.0		0.536 ± 0.009	1.4
SG-7	466.7		0.549 ± 0.030	2.2
SG-8	466.7		0.503 ± 0.011	2.9
SG-9	18.6		1.26 ± 0.03	0.39

^{3}He/^{4}He ratios of pore fluids at Sites 398, 410, 419, 424, 436, and 438 were generally higher than the atmospheric ratio, with values varying from 5.0×10^{-7} to 1.05×10^{-5}. The discrepancy in the ratio between the Caribbean Sea and the Pacific Ocean was interpreted as a possible difference in the He isotope signature of the upper mantle and the crust in the two ocean basins (Barnes and Clarke, 1980).

We already reported the ^{3}He/^{4}He ratios of gases dissolved in pore water in sediments from the Nankai Trough (Site 583) and the Japan Trench (Site 584) (Sano and Wakita, in press, b). The ^{3}He/^{4}He ratios, ranging from 2.15×10^{-7} to 1.23×10^{-6}, agree well with the present value (4.39×10^{-7} to 1.26×10^{-6}). As a whole, the He isotope signature of our study is practically radiogenic and is significantly different from that of Barnes and Clarke (1980).

Helium in pore gases of deep-sea sediments is considered to be a mixture of the following components: (1) atmospheric He dissolved in seawater and air contami-

nation during sampling and/or analysis with the ^{3}He/^{4}He ratio of 1.4×10^{-6}. This component is easily distinguished from the other components by its low ^{4}He/^{20}Ne ratio. (2) *In situ* radiogenic He in the sediments with the ratio of $(1–2) \times 10^{-8}$. The ^{3}He/^{4}He ratio of this component depends on the chemical composition of the sediment. (3) Trapped He from the degassing of the basement rock beneath the sediment. Large variation in the ^{3}He/^{4}He ratio (1.0×10^{-7}–1.0×10^{-5}) is explained by the differences in components, varying ages of the crust and initial contents of He, U, and Th in material generating He. (4) Extraterrestrial He caused by fallout of meteoritic materials with the extraordinarily high ratio of (1×10^{-4} to 1.0). The possible existence of the component was reported by Krylov et al. (1973) and Ozima et al. (1984).

The ^{3}He/^{4}He ratios of the present samples are plotted against the ^{4}He/^{20}Ne ratios in Figure 3. There is a negative correlation between ^{3}He/^{4}He and ^{4}He/^{20}Ne ra-
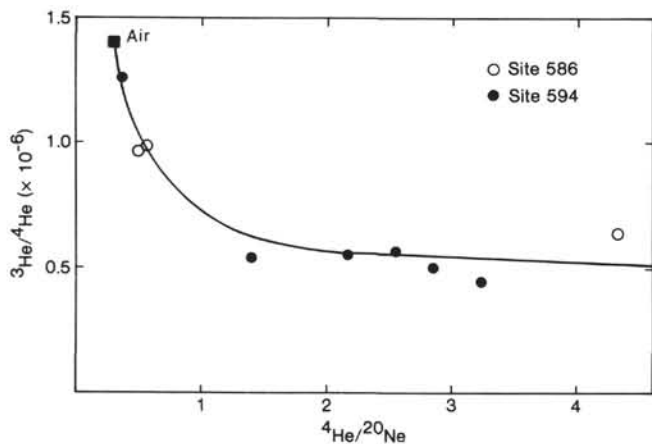
Figure 3. The ³He/⁴He ratios for samples are plotted against the ⁴He/ ²⁰Ne ratios. Solid line shows the mixing line between atmospheric He and He with ³He/⁴He ratio of 4 × 10⁻⁷.

tios. All data lie on a mixing line between the atmospheric He and gas with a ³He/⁴He ratio of about 5 × 10⁻⁷. This suggests that He in the present sediments can be explained by the mixing of two end-members: atmospheric He and radiogenic He.

For the ³He/⁴He ratios from the Nankai Trough (Site 583) and Japan Trench (Site 584), we found two-component mixing between the atmospheric He and radiogenic He with the ³He/⁴He ratio of $(2–3) \times 10^{-7}$ (Sano and Wakita, 1983). The *in situ* radiogenic ³He/⁴He ratio was calculated to be 2.0×10^{-8} based on the nuclear reactions of $^6\text{Li}(n,\alpha)^3\text{H} \rightarrow ^3\text{He}$. The value was lower by a factor of 10 than the ratio of the estimated end-member, that is, $(2–3) \times 10^{-7}$. We attributed the discrepancy to the radiogenic end-member with a much higher ³He/ ⁴He ratio. Such a component might be the trapped He in the sediment associated with degassing of the basement rocks beneath the sediment. The assigned end-member may be an admixture of He from basement rocks and sediments.

In the present samples, the ³He/⁴He ratio of the radiogenic end-member in the mixing is calculated to be 4 $\times 10^{-7}$. The value is two times higher than that of the Nankai Trough (Site 583) or the Japan Trench (Site 584). If we consider that the ³He/⁴He ratios of *in situ* radiogenic He of estimated pelagic clay of the area investigated in this study (1.5×10^{-8}) are almost the same as that of trench sediment (2.0×10^{-8}), the discrepancy may be explained by some enhancement of trapped He from the basement rocks or extraterrestrial He.

If the trapped He from the basement rocks is a major cause of the discrepancy, there should be some relation between the tectonic features of the sites where samples were taken and observed ³He/⁴He ratios. The degassing rate of He from basement rocks may reflect changes in tectonic conditions such as distance from a mid-ocean ridge, rock type, age of the crust, thickness of the sediment, alteration stage, and others. Sites 583 and 584 are located in the outer slope of the Nankai Trough and the Japan Trench, respectively, and both are on oceanic crust. Site 586 on the Ontong-Java Plateau is known to be composed of continental crust. If the observed ³He/

⁴He ratios reflect outgassing from basement plus sediment, Site 594 on the Chatham Rise may be in a tectonic feature similar to the Ontong-Java Plateau.

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