

Magmatic noble gases in the crater lakes Nyos and Monoun

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Introduction: After the gas disasters at Lake Nyos in 1986 and Lake Monoun in 1984, geochemical studies have been carried out to find the cause of the gas burst and to clarify depth profiles of CO₂ concentration, pH, temperature etc. [1]. The CO₂ is being accumulated at the bottom layers of the lakes from an underlying magmatic source, as revealed from the carbon isotopic ratios of the dissolved CO₂ gas ($\delta^{13}\text{C} = -3.5\text{‰}$) [1]. Helium isotopic ratios $^3\text{He}/^4\text{He} = 8 \times 10^{-6}$ and 4×10^{-6} for Lake Nyos and Lake Monoun, respectively [2], also support the magmatic origin. We collected gas and water samples from various depths at both lakes in October 1999, January 2001 and December 2001. Isotopic compositions of He, Ne and Ar as well as concentrations of all noble gases were measured to figure out depth profiles of noble gases and to compare them with other geochemical data obtained for both lakes.

Experimental: Two collection methods were employed for gases dissolved in lake water: 1) gas exsolved from water in a Niskin water sampler was collected in a plastic bag and then transferred into a glass bottle with high vacuum stop cocks (in 1999), and 2) gases exsolved from various depths were directly collected in glass bottles through plastic hoses that had various intake depths (in January and December of 2001). The gas was sealed in a glass ampoule with breakable seal on a vacuum line in laboratory, and the ampoules were attached to a noble gas purification line connected to a modified-VG5400 (MS-III) noble gas mass spectrometer. After purification of noble gases, Ar, Kr and Xe were retained on a charcoal trap cooled at the temperature of liquid nitrogen, then Ne was trapped on a sintered stainless steel trap cooled at 15K and He was measured. After the He analysis, Ne released from the trap at 45K was measured. Finally, Ar, Kr and Xe were released from the charcoal trap at 200°C and measured for Ar isotopic ratios and abundances of ^{40}Ar , ^{84}Kr and ^{132}Xe .

Results and discussion: Depth profiles of $^3\text{He}/^4\text{He}$ ratio for Lakes Nyos and Monoun are presented in Fig. 1. The ratios higher than the atmospheric value of 1.4×10^{-6} confirm the magmatic gas input to the lake water as already reported in [1, 2]. Though the ratios are almost constant in the depth ranges of 80-210m and 30-100m for Nyos and Monoun, respectively, the highest ratios of 8.2×10^{-6} and 5.2×10^{-6} were observed at 20-40m above the bottoms of Nyos and Monoun, respectively. No systematic differences among the profiles for 1999 and 2001 were observed, suggesting magmatic He input of constant $^3\text{He}/^4\text{He}$ ratios for both lakes.

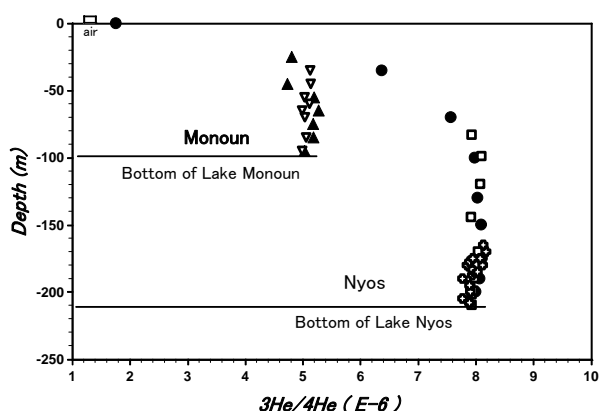


Fig. 1. $^3\text{He}/^4\text{He}$ depth profiles for the Lakes Nyos and Monoun.

Fig. 2 compares $^{40}\text{Ar}/^{36}\text{Ar}$ ratios for Nyos samples collected in 1999, January of 2001 and December of 2001. The ratios for samples of 1999 collected using plastic bags are systematically lower than those collected using pendent hoses. The low ratios are attributed to contamination from a small amount of air that remained in the plastic bag attached to the Niskin bottle, whereas $^{40}\text{Ar}/^{36}\text{Ar}$ ratios in gases from the hoses were much higher with a maximum value of 600. Noble gas concentrations in CO_2 gas exsolved from waters are very low, e.g., $\leq 40\text{ppm } ^{40}\text{Ar}$ in CO_2 gas.

The highest $^{40}\text{Ar}/^{36}\text{Ar}$ ratio of 600, observed in the bottom water in January 2001 just prior to the degassing operation at the Lake, seems to have disappeared in December 2001, 10 months after the degassing operation. Almost uniform $^{40}\text{Ar}/^{36}\text{Ar}$ ratios (530-540) and $^4\text{He}/^{20}\text{Ne}$ ratios (~ 1100) between the depths of 195m and 208m in December 2001 are quite a contrast to those in January 2001. This may have resulted from the gas removal from bottom layer of the lake (203m). This interpretation is confirmed in Fig. 3, where the Ar data points for January 2001 lie roughly on a single straight line, suggesting a simple mixing of atmospheric and magmatic Ar. While the data points for the depths 190-208m in December 2001 are plotted in a narrow area away from the line, showing low Ar concentration with almost constant $^{40}\text{Ar}/^{36}\text{Ar}$ of 530 in the bottom layer. The depletion of Ar in the bottom water might have been caused by the degassing with CO_2 .

The gases from Lake Nyos with high $^{40}\text{Ar}/^{36}\text{Ar}$ ratios are accompanied by a small contribution of MORB-type Ne. These results indicate that magmatic gas is now being supplied to the bottom layer of these crater lakes with the incoming CO_2 gas.

References: [1] M. Kusakabe, G. Z. Tanyileke, S. A. McCord and S. G. Schladow (2000) Recent pH and CO_2 profiles at Lakes Nyos and Monoun, Cameroon: implications for the degassing strategy and its numerical simulation. *Journal of Volcanology and Geothermal Research* **97**, 241-260. [2] Y. Sano, M. Kusakabe, J. Hirabayashi, Y. Nojiri, H. Shinohara, T. Njine and G. Tanyileke (1990) Helium and carbon fluxes in Lake Nyos, Cameroon: constraint on next gas burst. *Earth and Planetary Science Letters* **99**, 303-314.

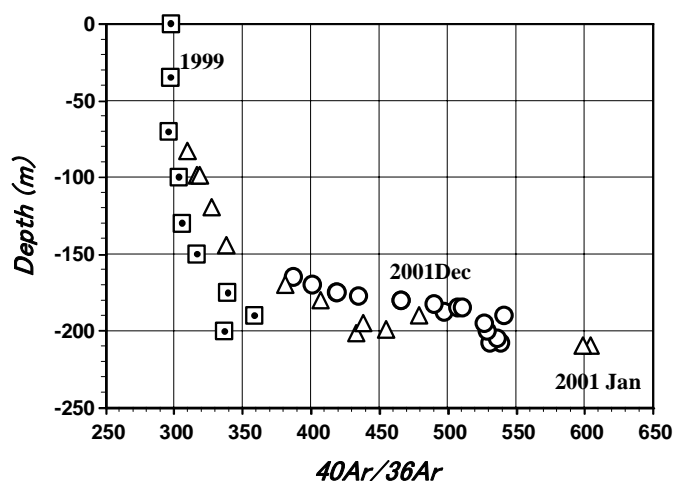


Fig. 2. Depth profiles of $^{40}\text{Ar}/^{36}\text{Ar}$ ratios in Lake Nyos. The ratios for samples collected by different methods are compared.

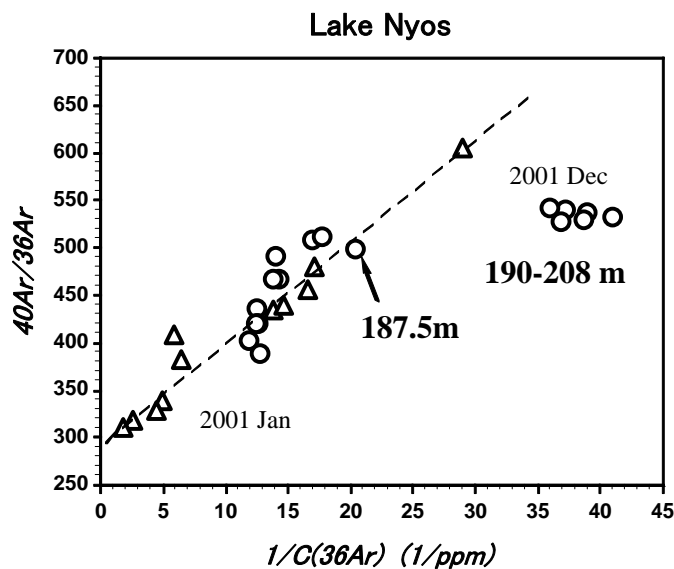


Fig.3. Ar isotopic compositions for samples of January and December in 2001 are compared.