NOBLE GASES IN A LARGE BUBBLE IN MOLDAVITE: A COMPARISON WITH PHILIPPINITE.

J. Matsuda, T. Matsumoto, A. Seta, A. Tsuchiyama[1], Y. Nakashima[2] and S. Yoneda[3]
1. Department of Earth Sciences, Graduate School of Science, Osaka University, Osaka 560-0043, Japan. (J. Matsuda's e-mail address: matsuda@ess.sci.osaka-u.ac.jp)
2. Geological Survey of Japan, 1-1-3 Higashi, Tsukuba 305-8567, Japan.
3. Department of Science and Engineering, National Science Museum, Tokyo, 3-23-1 Hyakunin-cho, Shinjuku-ku, Tokyo169-0073, Japan.

We previously crushed the philippinite with an unusually large bubble, and found that the concentrations of He and Ne were more enriched than those of heavy noble gases of Ar, Kr and Xe in the bubble, in comparison with the terrestrial atmosphere [1]. The $^{20}Ne/^{22}Ne$ and $^{21}Ne/^{22}Ne$ ratios were higher than the values expected from steady state process, and were interpreted to reflect very fast nonsteady state diffusion in the early stages of tektite formation.

In this study, we again had a chance to obtain a moldavite which has comparatively large bubble and could compare the noble gas feature in it with the data in the philippinite in our previous study. The moldavite is a typical tear-drop fluidal shape of 50x22mm and weighing 22.70g. The existence of a large internal bubble could be seen from the outside with the transparent thin color of its portion and was confirmed by an X-ray CT scanner equipped at the Geological Survey of Japan. The three-dimensional structure was reconstructed from successive imaging by the X-ray CT scanner, and the volume of the large bubble was estimated to be 0.16cm^3. There were several small bubbles of which volume are less than 0.002cm^3. The total volume of the moldavite itself including bubbles was 9.6cm^3. If bubble was formed due to the gas expansion inside the glass, the bubble should be spherical shaped. However, the largest bubble in the moldavite is not spherical and is rather prolonged shaped to the long axis of the tektite, suggesting that the deformation of tektite to the tear-drop shape was after the bubble formation.

The elemental abundances and isotopic compositions of noble gases have been measured by crushing the moldavite sample in the crushing device in Osaka University. The large crushing device is the same one as that we used for the crushing experiment of the philippinite [1]. The sample chamber of the device is cylindrical, with a diameter of 10cm and a height of 10cm, which was connected to a purification line and a VG 5400 noble gas mass spectrometer. A piston goes slowly down to crush the sample by turning a handle. The experimental procedures of measuring noble gases are given in our previous works [1, 2]. The procedural blanks of noble gases were measured using the same experimental setup without crushing the sample before the measurement.

The moldavite sample was crushed with a violent sound in the crushing device. Our results of noble gas analyses are listed in Table 1. As the isotopic ratios of all noble gases are atmospheric, we do not list them for Ar, Kr and Xe. The elemental abundances are enriched in He and Ne compared to those in the terrestrial atmosphere, which is compatible with the previous works for tektites [1, 3-5] and for impact glasses [2]. The He/Ar and Ne/Ar ratios are higher than those in air by three orders of magnitude although Kr/Ar and Xe/Ar ratios are almost identical to the air values (Fig. 1). The isotopic ratio of He is identical to the air value, which is identical to our previous work for a large bubble in philippinite [1]. The isotopic ratio of Ne is also identical to the air value, which is compatible with the data of previous observations for many tektites [3-5], but is different from that for a large bubble in the philippinite [1]. The Ne isotopic ratios in philippinite were fractionated from the air value and were higher than the latter values.

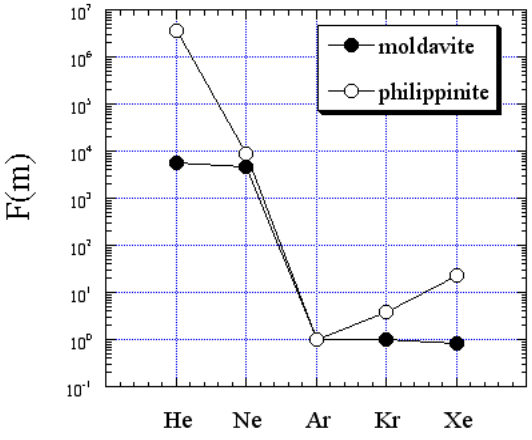

Fig. 1. The elemental abundance patterns of noble gases in the moldavite and the philippinite [1] displayed by the fractionation factor F(m).

$$F(m) = (^{m}X/^{36}Ar)_{sample}/(^{m}X/^{36}Ar)_{air}$$

Table 1. Noble gas contents (in cm^3STP) and their isotopic ratios of the bubble gases in the moldavite in this study and the philippinite [1].

	moldavite	philippinite	air
^{4}He	8.3x10 $^{-7}$	3.0x10 $^{-5}$	
^{3}He/^{4}He	1.33(12) x10 $^{-6}$	1.30(17) x10 $^{-6}$	1.40 x10 $^{-6}$
^{22}Ne	2.2x10 $^{-7}$	2.4x10 $^{-8}$	
^{20}Ne/^{22}Ne	9.89(12)	10.52(52)	9.80
^{21}Ne/^{22}Ne	0.0290(3)	0.0299(3)	0.0290
^{36}Ar	8.7x10 $^{-10}$	5.0x10 $^{-11}$	
^{84}Kr	1.8x10 $^{-11}$	4.0x10 $^{-12}$	
^{130} Xe	8.3x10 $^{-14}$	1.3x10 $^{-13}$	

Numbers in parentheses are uncertainties (1 s.d.) in isotopic ratios and corresponding to the last digits.

We looked for the cause of the difference of Ne isotopic ratios between the philippinite and the moldavite. We calculated the ^{22}Ne partial volume ratio in the bubble of the moldavite by assuming that the whole amount of ^{22}Ne was derived from the large bubble. The calculated ratio is $1.4x10^{-6}$ which is almost identical to the value ($1.6x10^{-6}$) in the terrestrial atmosphere. Thus, the Ne partial pressure in the bubble in the moldavite was almost reached to the air value. This is not the case for the big bubble in the philippinite where the partial volume ratio was $4.5x10^{-9}$, much lower than the atmospheric value and that in the moldavite. This is probably due to the difference of the ages for the philippinite and the moldavite. The age of philippinite is estimated to be 0.7my, but that of moldavite is 15my and much older. As the moldavite has been exposed to the atmosphere for a longer time, Ne could be fully diffused into the tektite and reached to the partial pressure in the bubble as same as that in the terrestrial atmosphere. Thus, it is compatible with the model that a very high ^{20}Ne/^{22}Ne ratio was obtained in a very short time by nonsteady state diffusion during melting stage of the tektite formation and was lowered later by slow diffusion from the atmosphere [1]. On the contrary, the partial pressures in heavy noble gases in the bubble of the moldavite still show the values at the formation. They are much lower than the atmospheric values under one atmospheric pressure, suggesting that the tektite was formed at high altitude of the atmosphere as indicated by our previous works [1,5].

References:

[1] Matsuda J., Maruoka T., Pinti D.L., and Koeberl C. (1996) Meteoritics &Planet. Sci., 31, 273-277.

[2] Matsuda J., Matsubara K., Yajima H., and Yamamoto K. (1989) Geochim. Cosmochim. Acta 53, 3025-3033.

[3] Hennecke E.W., Manuel O.K., and Sabu O.K. (1975) J. Geophys. Res.,80, 2931-2934.

[4] Matsubara K. and Matsuda J. (1991) Meteoritics, 26 217-220.

[5] Matsuda J. and Matsubara K. and Koeberl C. (1993) Meteoritics, 28, 586-599.