The research of modern He discharge in volcanic and tectonically active areas of China's continent (*)

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Summary. — The releasing features of modern helium in volcanic and tectonically active areas of China's continent are here discussed, presenting that the current escaped He in volcanic areas are mainly the mantle-derived He. The $^3He/^4He$ ratios of these He are gradually lowered during the ascent of deep-seated He towards the surface due to the strong diffusion and migmatization of the air. There is little mantle-derived He in the escaped gases from the hot springs distributed along the active tectonic belts, these gases are mostly derived from the crust The $^3He/^4He$ ratios of the crustal gases (including natural gas) in Eastern China are relatively higher than those gases in Middle-Western China. It is difficult to interpret this phenomenon by means of the differences of tectonic activity in those areas. We consider that the main reason of this occurrence may be related to the variation of the crustal thickness of China's continent from East to West.

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1. – Introduction

The He is the most common and noticeable escaped gas in modern volcanic and tectonically active areas. The $^3He/^4He$ ratio of escaped He is the most reliable indicator of its material sources as the mantle, crust and air all have their fixed $^3He/^4He$ ratios. They are $(1.1–1.4) \times 10^{-5}$, 2×10^{-8} and 1.4×10^{-6}(Ra), respectively [1]. The research samples are mainly the escaped gases from various hot springs and cold springs, as well as some natural gas. The escaped gas samples were collected by drainage sampling, and kept in the stainless-steel vacuum bottles. The $^3He/^4He$ ratios were determined on the mass spectrometer VG-5400. The He content of the samples was determined by means of chromotography, and the micro-He component was corrected by the mass spectrographic analysis.

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2. – The releasing features of He in volcanic areas

The Tengchong volcano in Yunnan Province, Tianchi volcano, Changbaishan mountains in Jilin Province and Wudalianchi volcano in Heilongjiang Province are three most well-known modern volcanoes in China's continent. They have erupted for several times since the 17th century, and now the geothermal fluid activity at the Tengchong volcanic area is the strongest among these volcanoes. There are a lot of boiling springs and fumaroles in this area, and over ten times hydrothermal explosions have been recorded since 1993. The geothermal fluid activity at the Tianchi volcanic area is relatively weak. There are only hot springs with stronger deep-seated gas releasing, and no fumarole has been found in this area. The highest temperature of thermal water here is about 81 °C. At the Wudalianchi volcanic area there are only cold springs with weaker gas releasing, and no hot spring has been found.

The measurements of the He contents and their $^3He/^4He$ ratios for escaped He show that the gas samples from the Tianchi volcanic area have the highest $^3He/^4He$ ratio among three modern volcanic areas in China (fig. 1). The $^3He/^4He$ ratios of Jinjiang hot springs and the central springs in Changbai geothermal area are remarkably the same, having an average value of 7.82×10^{-6} (5.59 Ra) and 7.89×10^{-6} (5.64 Ra), respectively. The average content of the mantle-derived He in these escaped He is about 67.29%, and the highest content may reach 71.25% [2, 3].

The $^3He/^4He$ ratio of the gas samples from the Tengchong volcanic area varies from 2.76 Ra to 5.38 Ra, averaging 3.69 Ra. The lower $^3He/^4He$ ratios demonstrate that the

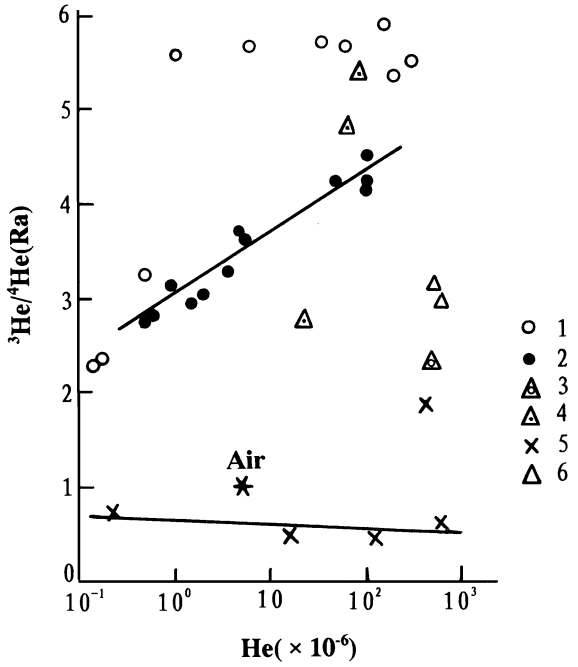

Fig. 1. – Relationship between the He content of escaped gases from the volcanic areas and their $^3He/^4He$ ratios. 1, hot springs in the Tianchi volcanic area; 2, hot springs in the Tengchong volcanic area; 3, cold CO_2 springs in the Tianchi volcanic area; 4, cold CO_2 springs in the Tengchong volcanic area; 5, other hot springs in the Tengchong area; 6, cold CO_2 springs in the Wudalianchi volcanic area.

deep-seated magma in the Tengchong volcanic area may be different from the residual mantle-derived magma of the Tianchi volcano. Our data show that the $^3He/^4He$ ratios of escaped He from the Tengchong volcanic area are positively correlated with the He contents of the escaped gas (fig. 1). The $^3He/^4He$ ratios of escaped He from those hot springs which distributed along deep faults have the highest value (averaging 4.25 Ra), the same condition was observed at the Jinjiang hot springs of the Tianchi volcanic area. The $^3He/^4He$ ratios of other hot springs, however, become lower with the decrease of the He contents (fig. 1). This fact suggests that the $^3He/^4He$ ratio of gas samples collected from the boiling springs or fumaroles could not always represent the primitive value of the deep-seated He. The cause for this occurrence may be mainly the strong diffusion of He during the ascent of deep-seated fluid towards the surface. In this process, the diffusion ability of ^3He is stronger than that of ^4He. Although we cannot rule out the influence of air contamination, the low N_2 and Ar contents of the samples discussed here demonstrate that this influence before and during sampling was minimal.

The $^3He/^4He$ ratios of gas samples from the Wudalianchi volcanic area are the lowest, on average 3.08 Ra, but the He content is the highest among three modern volcanoes of China's continent. These He discharges may be still the residual gases of the volcanic activity, but they must not be derived directly from the deep-seated magma, because there is not any thermal anomaly in that area.

3. – The releasing features of He in tectonically active areas

In recent years, in order to look for the sensitive components and springs for earthquake prediction, we have tried to study continuously the He discharges along active faults to identify those springs which are releasing a lot of deep-seated gases. The results show that those springs distributed along the active faults are releasing little deep-seated He, differently from that of the volcanic area (fig. 2). In general, the escaped gases of these springs are all crust-derived gas, mixed with a little amount of air. The $^3He/^4He$ and $^4He/^{20}He$ ratios for gas samples collected from the Tanlu fault and Jiaoliao block in Eastern China indicate the ternary origin of their mantle, crust and air (fig. 2). The results of our research show that the escaped gases with higher $^3He/^4He$ ratio are not derived directly from the current upper mantle, they are still the crust-derived gases [4].

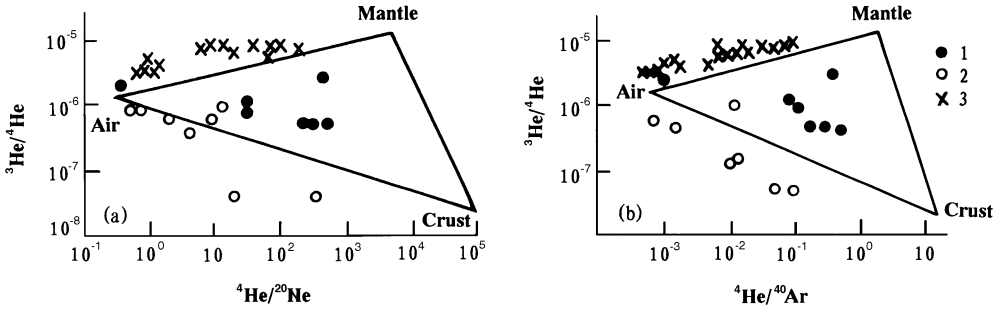

Fig. 2. – Relationship between the $^3He/^4He$ and the $^4He/^{20}Ne$, $^4He/^{40}Ar$ ratios of escaped gases from various springs. 1, hot springs in Eastern China; 2, hot springs in Middle-Western China; 3, the springs in the main volcanic areas in China.

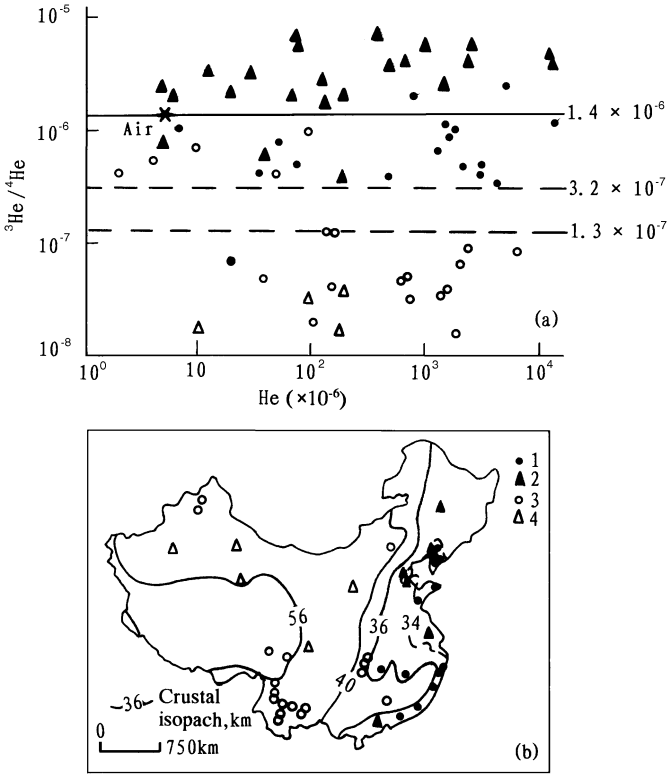

Fig. 3. – (a) Relationship between the He content of the crustal gases in China's continent and their $^3He/^4He$ ratios. (b) Scheme of the distribution of the crustal-gases samples and the crustal isopach in China's continent. 1, hot springs in Eastern China; 2, natural gas in Eastern China; 3, hot springs in Middle-Western China; 4, natural gas in Middle-Western China.

Figure 3 shows that in the China's continent, the $^3He/^4He$ ratios of the crustal gas with few exceptions are generally higher than 3.2×10^{-7} in the East, but lower than 1.3×10^{-7} in the Middle-West, regardless of the escaped gases from the hot and cold springs or natural gas. As everyone knows, the tectonic activity in Western China is obviously stronger than that in the East. Therefore the difference of the $^3He/^4He$ ratios of crustal gas between the East and the West may not be correlated with the modern tectonic activity in these areas. We discover that the boundary of the two groups of $^3He/^4He$ ratios coincides roughly with the 36 km isopach of crustal thickness. This characteristic may not be an accidental phenomenon. It is well known that the crustal thickness in China's continent varies significantly from East to West. In the coastal area in the East the crustal thickness is thinner than 34 km, but thicker than 40 km in the West, with the largest thickness of over 60 km [5]. We consider that the mantle-derived He should ascend easily in the area of thinner crust, thus the ratio of mantle-derived He in the crustal gases for this area should be slightly higher due to the integrated effect for the whole geologic history.

4. – Conclusions

This study has led to the following observations and conclusions:

1. In the Tianchi volcanic areas, the modern mantle-derived He derived from the residual mantle-derived magma can release both by way of the original eruption canal and the active deep faults, but their $^3He/^4He$ ratios are roughly the same.

2. In the Tengchong volcanic geothermal area, the modern mantle-derived He derived from the active magma in the crust release mainly by way of the active faults. There is a gradual trend of decreasing $^3He/^4He$ with decreasing He content of the escaped gases during the ascent of the mantle-derived magmatic gases towards the surface, whereas the escaped He from those geothermal fluids distributed along general active tectonic belts display the contrary trend of decreasing $^3He/^4He$ with increasing He content. This characteristic would be a useful indicator to distinguish both types of He discharges.

3. Our data show that $^3He/^4He$ ratios of the crustal gases, including natural gas and the escaped gases from hot springs, display a gradual decreasing trend from the East to the Middle-West in China's continent. We consider that this feature may not be correlated with the tectonic activity, but related to the variation of the crustal thickness. The integrated effect for the whole geologic history could increase the $^3He/^4He$ background values of the crustal gases in the area of thinner crust.

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REFERENCES

[1] WANG X., *Rare Gas Isotope Geochemistry and Cosmochemistry* (in Chinese) (Science Press, Beijing) 1989, pp. 65-236.
[2] SHANGGUAN Z. and SUN M., *Mantle-derived rare gas releasing features at the Tianchi volcanic area, Changbaishan Mountains, Chinese Sci. Bull.*, **42** (1997) 768-771.
[3] SHANGGUAN Z., ZHENG Y. and DONG J., *Material sources of escaped gases at the Tianchi volcanic geothermal area, Changbaishan Mountains, Sci. China* (Series D), **40** (1997) 390-397.
[4] SHANGGUAN Z., DU J., ZANG W. *et al.*, *Modern hot spring geochemistry at the Tanlu fault and Jiaoliao block in Eastern China, Sci. China* (Series D), **41** (1998) 87-94.
[5] MA X., *Lithopheric Dynamics Atlas of China* (in Chinese) (Geological Press, Beijing) 1987, p. 12.