Emission of radon and thoron due to the fracture of rock (*)

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Summary. — In order to investigate the fundamental processes of radon anomaly related to earthquakes, the measurement of the emission of radon and/or thoron from a rock under pressure has been carried out. The thoron emission increases after the crush of a rock. Before the crush, however, its increase is scarcely observed during compression. The emission of thoron varies under the gradual compression of the lumps of fractured rocks and diminishes to zero when they are compressed entirely. It is suggested from these facts that the precursory anomaly of radon related to earthquakes occurs in the fractured rock region such as faults.

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1. – Introduction

One of the present authors, Okabe, had shown the relation between atmospheric radon content and earthquakes more than four decades ago [1]. Since the First International Conference on Rare Gas Geochemistry, the increase of radon content in the groundwater and in the soil gas related to earthquakes has been attracting many researchers because it is expected that earthquakes could be predicted by measuring the radon anomaly [2]. Recently, an anomalous increase of radon content in the groundwater and in the atmosphere has been reported to appear before the Kobe earthquake, 1995 in Japan [3, 4].

The mechanism of the occurrence of radon anomaly prior to the earthquakes is stated as follows [5]. During the build-up of the stress preceding an earthquake, the strain field change spreads over a large area. Radon may be affected by opening or closing of the cracks of rocks under the observatory.

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In order to investigate the fundamental processes of radon anomaly preceding earthquakes, radon and thoron emissions from test pieces of rock are measured under uniaxial pressure. The measurements are also done after compression of the fractured rocks.

2. – Experiment

Figure 1 shows the schematic diagram of the experimental system used in this work. A columnar test piece of rock is set in an air-tight Tedlar Bag. Pressure is added to it with the bag directly by using the hand-operated oil press and the strain is measured by the strain gauge. The air in the bag containing radon and thoron emitted from the sample rock is circulated through a filter and a radon monitor, and then sent back to the bag by a pump. The filter removes radon and thoron's daughter nuclides. In the radon monitor which was developed by Iida [6], the daughters generated by the decay of radon and thoron in the chamber are collected electrostatically and the alpha-particles emitted by them are counted by a ZnS(Ag) scintillation

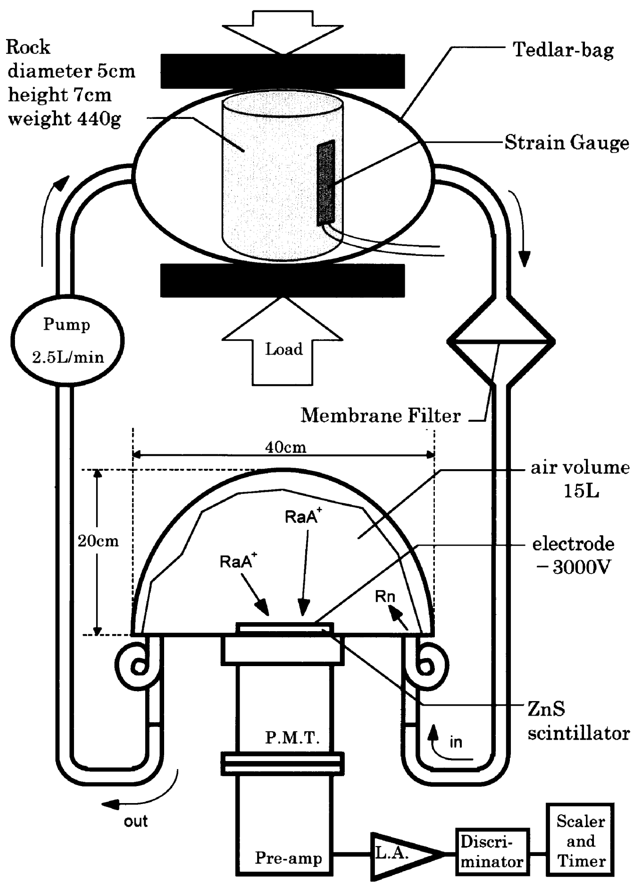

Fig. 1. – Schematic diagram of the experimental system.

detector. The cylinders filled with the lumps of fractured rocks are also examined in the same way.

The rocks tested in this study are granite specimens collected in Misasa, that is the famous area of radioactive hot springs in Japan. These samples emit mainly thoron. In small-scale experiments made in the laboratory, such as this study, the short-lived thoron is considered to be a better indicator for the radon anomaly because the variation of its content in the air corresponding to the change of conditions shows the saturation in a shorter time.

3. – Results and discussion

Figure 2 shows the results obtained for the test piece of rock under pressure. Time variation of the total alpha count, together with that of load and strain is shown. At the 24th hour, the bag including the rock is connected with the experimental system. Then the count increases to about twice the background level, due to the addition of radon and thoron emitted from the rock. After the 48th hour, the pressure is increased by

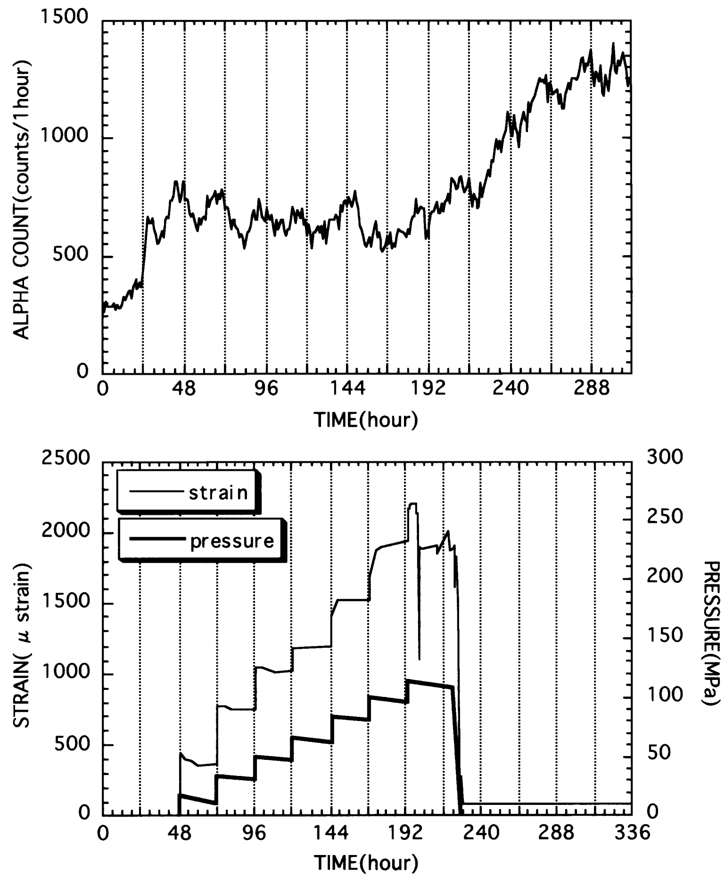

Fig. 2. – Time variation of the total alpha count, the load and the strain obtained from the experiment of the test piece of rock under pressure.

steps of about 16.6 MPa every day. At the 198th hour, a noise considered to be caused by the occurrence of small cracks in the rock is heard and the anomaly of strain appears. The alpha count, however, scarcely increases. At the 226th hour of addition of pressure, the rock is completely crushed in an instant and the alpha count increases to about four times that of the background level. It maintains a high level from then on. The emission of thoron is considered to be increased by the increment of the surface area of the rock due to crush. This phenomenon is considered to be the small-scale model of the coseismic event.

Figure 3 shows the results for the fractured-rock sample. Time variation of the total alpha count and that of load are shown with the sample volume which is the space in the cylinder filled with the fractured rocks. The bag with the sample is connected with the experimental system at time = 0 and the alpha count increases to about twice the background level. The sample is pressed every day. At the 24th and the 48th hour, the load is immediately released due to the rearrangement and crush of the rocks, and the sample volume decreases remarkably. After the 72th hour, the load remains for about half a day and, after the 96th hour, it remains till the next day, while the sample rocks

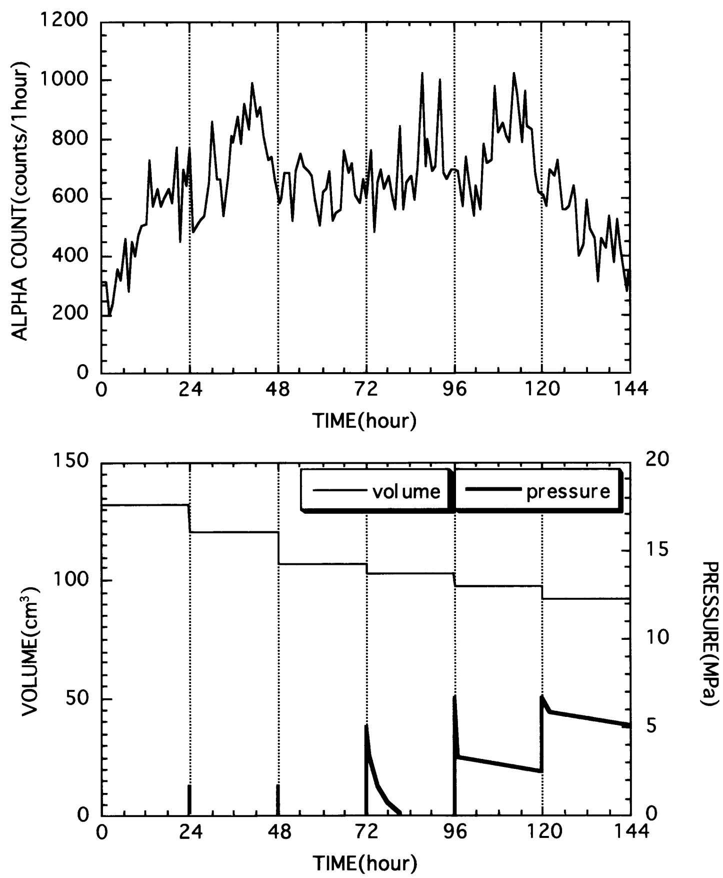

Fig. 3. – Time variation of the total alpha count, the load and the volume of the sample obtained from the experiment of the lumps of fractured rocks under compression.

are gradually crushed and compressed. At the 120th hour, the sample rocks are completely crushed and compressed, and there is no gap among the crushed rock sample. The alpha count increases to about three times that of the background level after the 24th, the 72th and the 96th hour of compression. These facts mean that the thoron emission from the sample increases. After the 120th hour, it decreases to the background level because the thoron emission disappears due to the vanishing of the gaps among the sample rocks. At the fault near the epicenter, it is considered that the radon content in the groundwater and in the soil gas increases with increasing stress, and, when the fractured rocks are completely compressed, the earthquake is imminent because the stress is no longer released and the radon content decreases. Therefore, the behavior of thoron emission mentioned above, especially after the 96th hour up to the 144th hour, is considered to be the small-scale model in time and space which illustrates the preseismic event occurring in the area of fractured rocks such as the faults.

4. – Conclusion

The measurements of the thoron emission from the test piece of rock and the fractured-rock sample under pressure are carried out for the investigation of the fundamental processes of radon anomaly related to earthquakes. It is suggested from the result of this study that the precursory anomaly of radon which increases and then decreases before the earthquakes occurs in fractured-rock regions such as faults.

REFERENCES

[1] OKABE S., *Mem. Coll. Sci., Kyoto Univ., Ser. A*, **28** (1956) 99.
[2] For example, BALDERER W. and MARTINELLI G., *Environ. Geochem. Health, Suppl.*, **16** (1995) 147.
[3] IGARASHI G. *et al.*, *Science*, **269** (1995) 60.
[4] YASUOKA Y. and SHINOGI M., *Health Phys.*, **72** (1997) 759.
[5] FLEISCHER R. L., *Geophys. Res. Lett.*, 8 (1981) 477.
[6] IIDA T., *Atmospheric Radon Families and Environmental Radioactivity* (Atom. Energy Soc. Jpn.) 1985, p. 65 (in Japanese).