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Note

A Survey of a High Natural Radiation Spot in Tono Area, Japan

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We observed absorbed dose rate in air at a uranium ore outcrop which is known as one of the high natural radiation spot of the Tono area in central Japan. This outcrop was mainly Toki granite and weathered soil. The absorbed dose rate in air measured on the rock and surface soil using a pocket survey meter ranged from 572 to 9684 nGy h^{-1}, and significantly high values were observed at a small rock body and the bottom of a trench. The uranium concentration of the soil in the trench was 1220 ppm which is a significantly high value. The measured absorbed dose rates in air were reasonably high compared with the general environment.

Key words: Tono area, high background natural radiation, uranium deposit

1. Introduction

There are various types of radiation in the natural environment. Everyone on the earth is exposed to ionizing radiation from radioactive materials of natural sources as internal and external exposures. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has reported that the world average radiation dose received from natural radiation is approximately 2.4 mSv per year[1)]. The sources of terrestrial gamma radiation are natural radionuclides, mainly the ^{238}U series, ^{232}Th series and ^{40}K which have existed in the earth's crust since its birth. The terrestrial gamma radiation dose rate is caused by natural radionuclides in soil and rock, and it depends on their radionuclide contents.

In Japan, many researchers have studied the terrestrial gamma ray dose rate and its relation to geological conditions[2-8)]. In general, the concentrations of natural radionuclides in granitic rock and its weathered soil, and the granitic rock zone enhance the gamma ray dose rate[9, 10)]. On the main Japanese Island, western Japan has relatively high gamma ray dose rate areas in comparison to eastern Japan, depending on the geological conditions. On the other hand, there are high background radiation areas in various locations worldwide, including Japan[11)]. The average absorbed dose rate in air has been reported for such high background radiation areas as Kerala and Madras in India, Yangjiang in China and Guarapari in Brazil[1)]. As well, the external dose has been estimated at those locations[12, 13)].

In Japan, some potential areas for uranium exploration have been identified[14)]. Gifu Prefecture is a well-known

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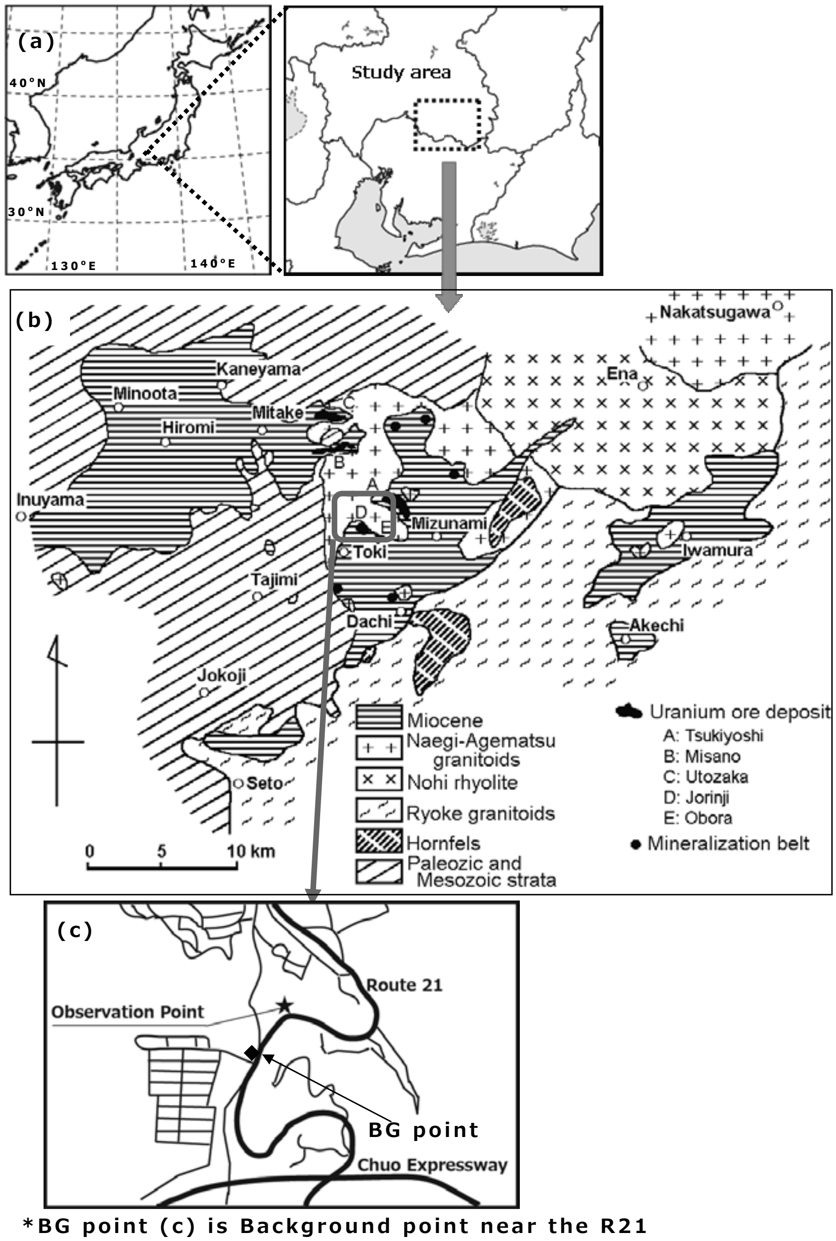

Fig. 1. Overview of study area (Tono area). (a) Outline (b) Geological conditions (c) Location of the R21 outcrop (Geological map was created with reference to Kobayashi[21])

relatively high background radiation area in Japan[15, 16]. Shimo *et al.*[15] reported that the terrestrial gamma ray dose rate in air of Gifu Prefecture was high in the Tono and Hida areas (areas with high distributions of acidic igneous rock), and low in the Seino area (an area of mainly sedimentary rock). Almost 50 years ago, results from a car-borne survey reported on a high radiation spots (outcrops) in the Tono area[17]. Recently, Hosoda *et al.*[18] also reported the absorbed dose rate in air of 552 nGy h^{-1} and ^{238}U series activity concentration of 914 Bq kg^{-1} at a shrine-yard in Toki City of the Tono area. In this paper, we report about the recent data of one high radiation spot in the Tono area. In addition, we also report the compositions of natural radionuclides.

2. Experimental

Figure 1 presents an overview of the study area and its geological conditions. The geological outline of the area has been described in some reports[19-21]. Briefly, the geology of this area can be classified into five units: Miocene (Mizunami Group), Naegi-Agematsu granitoids, Nohi rhyolite, Hornfels, and Paleozoic and Mesozoic strata (Fig 1b). The Mizunami Group is distinguished

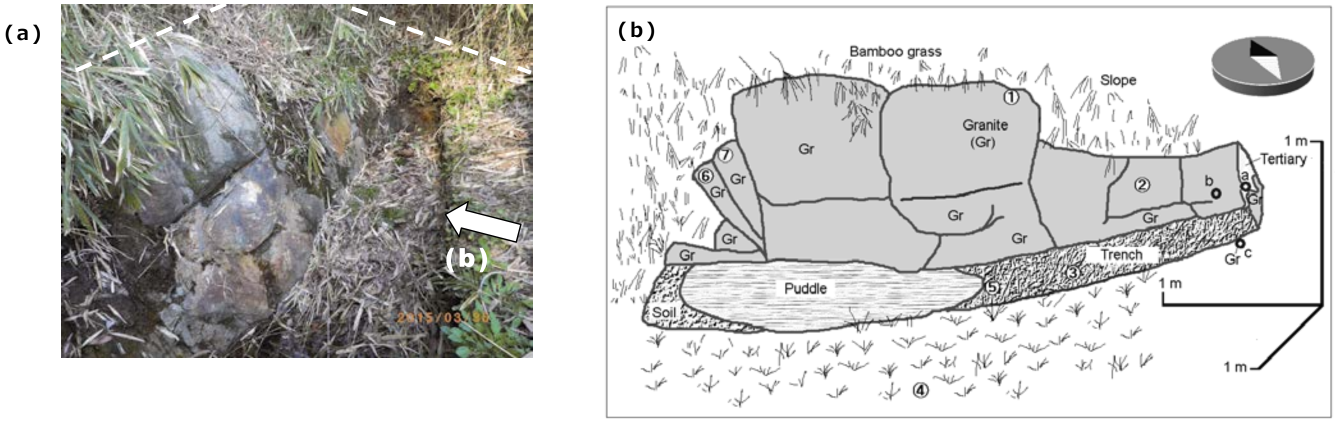

Fig. 2. The R21 outcrop in the Tono area. (a) Photo (b) Sketch.

Table 1. Absorbed dose rate in air at R21 outcrop

Point No.	Latitude	Longitude	Absorbed dose rate in air (nGy h^{-1})	Outline
1	35°22.798	137°11.503	572	Medium-grained biotite granite
2	35°22.799	137°11.507	3387	Medium-grained biotite granite
3	35°22.795	137°11.505	8376	Weathering soil in the trench
4	35°22.793	137°11.507	1973	Outside soil of trench
5	35°22.797	137°11.497	9662	Weathering soil in the trench near the puddle
6	35°22.799	137°11.505	4362	Medium-grained biotite granite
7	35°22.800	137°11.505	9684	Medium-grained biotite granite
Control (BG)	35°22.714	137°11.447	70	Paved road
a	–	–	3289	Toki lignite-bearing formation (East end of trench, brown color)
b	–	–	1973	Medium-grained biotite granite
c	–	–	2442	Medium-grained biotite granite

between the Toki-lignite-bearing formation, and the Homgo, Akeyo and Oidawara formations[20]. The Paleozoic and Mesozoic strata that are the basement of the pre-Tertiary period consist mostly of Cretaceous Toki granite with a part that is a Mesozoic sedimentary formation[20]. And there are some uranium ore deposits (Tsukiyoshi, Misano, Utozaka, Jorinji and Obora) in this area[22].

The survey point (35°22.798'N, 137°11.505'E) was an outcrop, identified as the R21 outcrop and east-facing, on the western side of the north-south road, Route 21; the outcrop is near the Jorinji ore deposit[22]. This point was previously reported as a high radiation spot (>10 mr h^{-1} (87.3 μGy h^{-1})), and it has uraninite and coffinite[23]. We measured 1 cm dose equivalent rates at this outcrop by placing a pocket survey meter (PDR111, Hitachi-Aloka Co., Japan) just above the rock and soil. The measured 1cm dose equivalent rates in units of μSv h^{-1} were converted to absorbed dose rate in air in units of nGy h^{-1} using a conversion factor (CF = 756 (mGy Sv^{-1}))[24] re-evaluated using the method adopted by Hosoda *et al.*[25]. This conversion factor was estimated by the data of contact measurement using a pocket survey meter and NaI(Tl) scintillation spectrometer (EMF-211, EMF-Japan). Furthermore, a difference of close contact measurement and 1m height measurement is around 2%[26]. We also measured gamma ray pulse height distributions using a 3-inch diameter x 3-inch long NaI(Tl) scintillation spectrometer (EMF-211, EMF-Japan). These data were unfolded by the response matrix method for the calculation of ^{238}U, ^{232}Th and ^{40}K activity concentrations and its contributions to air kerma rate[27, 28]. According to Beck[26], a space having a radius of around 20 cm under a flat surface is measured in case of contact measurement. The measurement points were selected so that such a condition may be satisfied. The uncertainties of ^{238}U-series, ^{232}Th -series, ^{40}K and absorbed dose rate were evaluated as < 6%, 7-13%, 2-5% and < 2%, respectively. We also measured the 1 cm dose equivalent rate and gamma ray pulse height distributions on the road near the R21 outcrop as a control point where is sidewalk along the R21.

Table 2. Contents of K, U and Th at R21 outcrop evaluated by the NaI(Tl) scintillation spectrometer

Point No.	Time (sec)	Live time (sec)	^{40}K (%)	^{238}U (ppm)	^{232}Th (ppm)
1	300	300	2.53	180.0	14.1
3	300	223	7.24	1220.0	17.3
4	300	297	2.14	357.0	6.2
Control (BG)	900	900	1.98	2.5	8.3

3. Results and Discussion

A photo and a sketch of the R21 outcrop are shown in Fig. 2. There was a trench, dug by the Geological Survey of Japan at this outcrop, to allow observation of the rock body of Toki granite. The rock body had the following dimensions: width, 3.5m; height, 1.2 m; depth, 1.5 m. The top of this outcrop had become a slope, and there was small rain puddle at the bottom of the trench. The granite rock mass had some cracks, and the top was covered with bamboo. The cracks and the bamboo growth confirmed that the Mizunami Group of the Miocene period were overlapped with some unconformity at the eastern end of this trench[22].

Table 1 lists the absorbed dose rates in air that we measured at the R21 outcrop with an uncertainty of 13 %. Absorbed dose rate in air ranged from 572 to 9684 nGy h^{-1}, and significantly high values were observed at Point Nos. 5 and 7 compared to the control point (Background). Absorbed dose rates in air of small granite rock (Point Nos. 6 and 7) and surface soil (Point Nos. 3 and 5) were higher than of the large rock (Point No. 1). In particular, absorbed dose rate in air of surface soil was especially high considering the geographical condition effects. Although there are some high radiation spots in the trench, absorbed dose rate in air at points several meters outside the trench were back to the background level. Table 2 shows the radionuclides concentrations at Point Nos. 1, 3, 4 and the control point as evaluated by the NaI(Tl) scintillation spectrometer. The bottom of the trench (Point No. 3) had a high uranium concentration (1220 ppm). These results were quite high compared with the general environment. Shimada *et al*. reported that U_3O_8 concentration in rock samples collected near the R21 outcrop ranged from 0.01 to 0.05%[23], which is similar to present result. They also reported high U_3O_8 concentration in sandstone samples collected at this outcrop (6.25%) which was higher than present result.

There are various element enrichment processes in nature. We thought that the high dose rate points of the rock were formed from enrichment by dissolved uranium through the ground water. The high dose rate points of surface soil were formed by a similar groundwater dissolution phenomenon and the effect of fine soil particles made by weathering of the rock body. However, we could not confirm the generation process of these high natural radiation points. It is necessary to survey more spots with high natural radiation.

4. Conclusion

We investigated the uranium ore outcrop located near Route 21 in the Tono area of central Japan from the viewpoint of natural radiation. We measured absorbed dose rates in air using a pocket survey meter and the values ranged from 572 to 9684 nGy h^{-1}. We found significantly high values at a small rock body and the bottom of a trench. The uranium concentration on the top of the main rock body was 1220 ppm. These results were quite high compared with the general environment. We could not confirm the generation process of the high natural radiation points. It is necessary to survey more spots with high natural radiation in order to identify the actual generation process.

Conflict of Interest Disclosure

The authors declare that they have no conflict of interest.

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