Reports

Radon Anomaly: A Possible Precursor of the 1978 Izu-Oshima-kinkai Earthquake

Abstract. *Precursory changes in the radon concentration of groundwater were observed prior to the Izu-Oshima-kinkai earthquake (magnitude 7.0) 14 January 1978. The distance from the epicenter to a continuous radon-monitoring station at Nakaizu was about 25 kilometers. A sudden drop and a subsequent increase in the radon concentration recorded on 9 January 1978 were significant. The size of the spike-like change was about 15 percent. After the earthquake, a remarkable increase in the radon concentration occurred.*

Since the first observation of changes in the radon concentration of groundwater prior to the 1966 Tashkent earthquake (*1*), these changes have been considered to be one of the most plausible precursory earthquake phenomena. Similar changes played an important role in the successful prediction of four destructive earthquakes which occurred in China between 1975 and 1976 (*2*). Intensive studies of radon concentration changes for the purpose of earthquake prediction have been carried out in Japan since 1973.

The Izu-Oshima-kinkai earthquake (magnitude, *M*, 7.0) occurred beneath the sea between the Izu Peninsula and Izu-Oshima Island at 12:24 hours (JST) on 14 January 1978. A right lateral strike-slip fault extending 17 km east of Inatori was inferred (*3*). On the east coast of the Izu Peninsula, the western edge of the fault, ground displacement occurred along a fault trending northwest-southeast with a length of 3 km. The maximum displacement of the fault was 1.3 m (*4*). A significant precursory change in the radon concentration of springwater was observed at Nakaizu, one of the radon-monitoring stations on the peninsula which have been operating since 1976 (Fig. 1).

With numerous active faults and volcanic cones, Izu Peninsula is one of the most tectonically active areas in Japan. Two major troughs, Sagami and Nankai, cut deep into both sides of the peninsula, and many earthquakes with $M \sim 8$ have occurred in these areas, for example, the 1923 Great Kanto earthquake along the Sagami Trough. The Tokai district, adjacent to the peninsula, has been designated as an intensified observational area by the Coordinating Committee for Earthquake Prediction (CCEP). Various evidence suggests the possibility of an impending Great Tokai earthquake along the Nankai Trough in the near future. During the last several years, a comprehensive observation system has been set up to predict major earthquakes in the area.

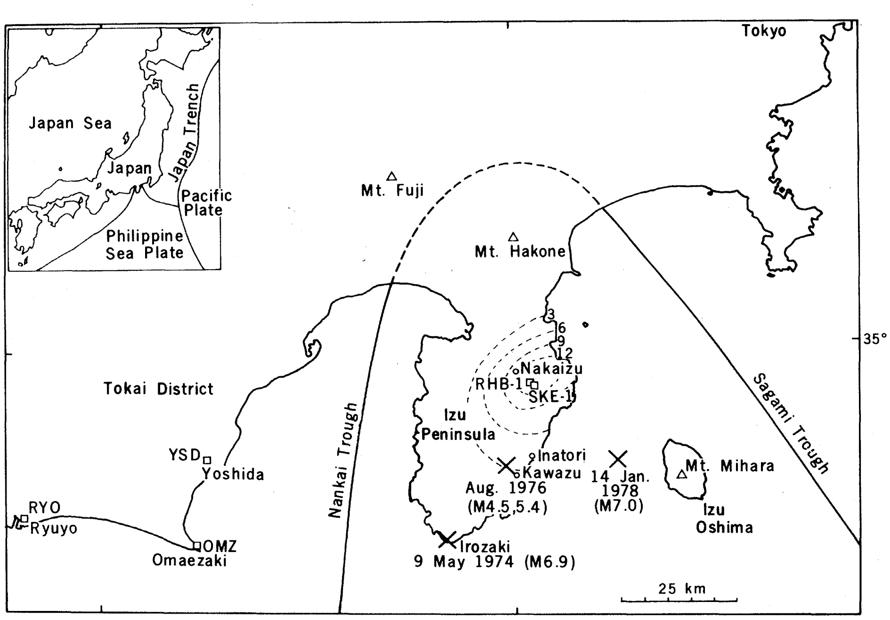

Fig. 1. Map of the Izu Peninsula and the surrounding area. The distribution of the continuous radon-monitoring stations (□) and the epicenters of the larger earthquakes (X) are shown. The contour lines (in centimeters) of uplift during the period between 1967–1969 and 1976 are shown (*12*).

Since the Izu-Hanto-oki earthquake (*M*6.9) at the southern tip of the Izu Peninsula on 9 May 1974, a variety of geophysical phenomena are being observed. Near the end of 1974, an abnormal ground uplift was found in the northeastern part of the peninsula as a result of a geodetic survey, and it reached a maximum height of 15 cm by early 1976. Microearthquake swarms also accompanied the ground uplift (*5*).

To clarify the possibility of the occurrence of a large earthquake in the area, various kinds of observations and more intensified survey activities have been pursued under the direction of the CCEP. As a part of these investigations, measurements of the radon concentration of groundwater obtained from deep wells and springs were initiated in the spring of 1976. The early discrete measurements at intervals of twice a month at five observational stations were later replaced by continuous measurements at stations SKE-1 and RHB-1 in Nakaizu, located at the center of the uplift area. The measuring system, based on the use of a ZnS(Ag) scintillation chamber, has been described (*6*). Several modifications in the original equipment have been made. In this work, two "Aqua radon meters" (Aloka model NW-101) have been used.

Three months after the installation of the equipment, two earthquakes (*M*4.5 and 5.4) occurred (in August 1976) at Kawazu, about 20 km north of the tip of the peninsula and the southernmost edge of the uplift area. No significant variation in the radon concentration was observed for these shocks. This failure to observe a radon variation was attributed either to a lack of field experience in the peninsula at that time or to the smaller size of these shocks.

The Izu-Oshima-kinkai earthquake occurred about 1½ years later, on 14 January 1978 (*M*7.0). The epicenter was about 25 km from the radon-monitoring stations at Nakaizu.

The variation in the radon concentration of the groundwater at station SKE-1

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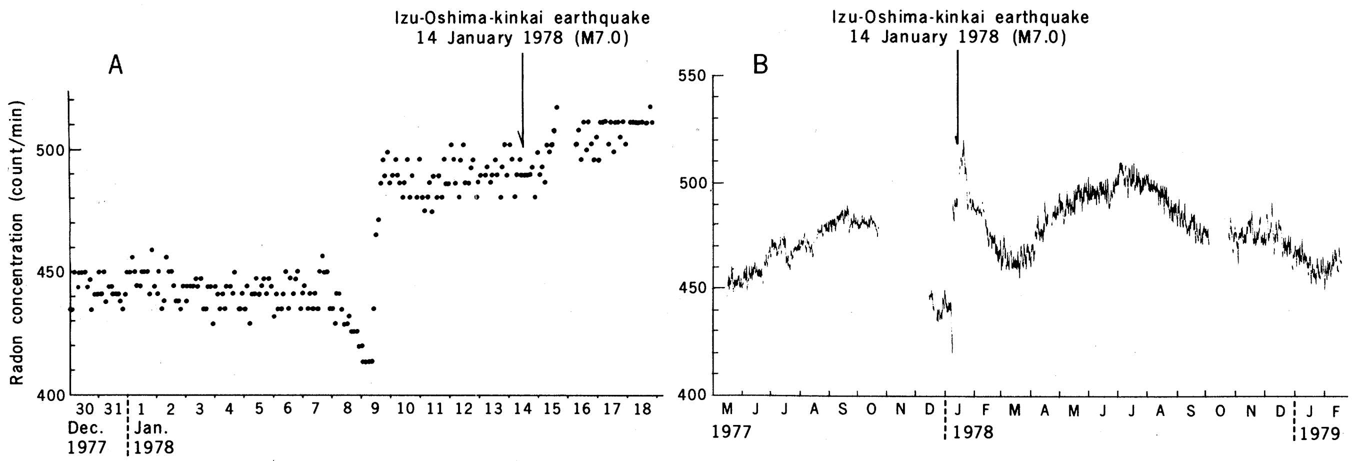

Fig. 2. Short- and long-term variations in the radon concentration of groundwater at station SKE-1 observed before and after the Izu-Oshima-kinkai earthquake. The epicentral distance is about 25 km. (A) Data for every 2-hour segment. (B) Nine-point running averages of the data from each 2-hour period.

for the period between 30 December 1977 and 18 January 1978 is shown in Fig. 2A. Even though the measurements were continuous, data for every 2-hour period on the original record were also read and plotted. The radon concentration dropped suddenly and remained at the minimum level for about 8 hours on 9 January, just 5 days before the main shock.

A longer-term variation in the radon concentration at station SKE-1 is shown in Fig. 2B; nine-point running averages of the radon concentration are shown for the period between May 1977 and February 1979. Significant variations are seen before and after the earthquake; the radon concentration began to decrease in October 1977 and fluctuated vigorously thereafter. A sudden drop and a subsequent remarkable increase were observed on 9 January 1978. Then the concentration recovered to a higher value and held that value until the earthquake. After the earthquake, the radon concentration increased rapidly. The failure to collect data in the period between 24 October and 15 December 1977 was due to a faulty connection in the signal cable. Judging from the record paper, the measuring system operated normally during the period. Therefore, dispersed short lines drawn for the period are valid (*7*).

The examination of the whole record of radon monitoring has shown no such abrupt changes except for the ones reported here since the installation of the measuring system at station SKE-1. The occurrences of the abnormal changes in the radon concentration have some correlation with those of other possible precursors of the earthquake. Significant earthquake swarm activities were observed between late October and mid-November 1977 near Oshima (*8*). A drop in the water level of an observational well (500 m deep) at Omaezaki Point (90 km from the epicenter) was noted on 28 December 1977 (*9*). A borehole strainometer at Irozaki (33 km from the epicenter) recorded a change in stress on 10 January 1978 (*10*). Activities of microearthquake swarms ($M3.7$) were significant near Oshima on 12 January 1978. Subsequently, remarkable foreshocks including two with $M4.9$ occurred in the morning of 14 January (*11*).

An annual variation in the radon concentration of up to a few percent is apparent in Fig. 2B. This is attributed to the annual variation of the water temperature in the chamber or to the atmospheric temperature. Several efforts have been made to minimize the change of the ambient temperature during radon measuring. The poor insulation of the housing in the field made it difficult to reduce the thermal disturbance sufficiently. These variations, however, are obviously different from those caused by meteorological disturbances.

The absence of clear changes in the record at station RHB-1 is attributed to the unsuitable characteristics of this well for radon monitoring; the artesian well at station SKE-1 with a depth of 350 m is located in the valley of an isolated mountainous area. The artesian layer of the well is separated from other adjacent wells. The well at station RHB-1, which belongs to a hospital, is situated on the top of a hill and is much shallower (150 m) than the well at station SKE-1. A large quantity of groundwater is intermittently pumped for use by the hospital.

Although our understanding of the whole mechanism of radon emission remains unclear, the observed precursory changes must somehow reflect the deformation or damage, or both, to the artesian layer caused by the action of stress release or stress accumulation. Even though we did not predict the occurrence of the Izu-Oshima-kinkai earthquake, our efforts were directed toward obtaining data on reliable premonitory changes through observation, a first step toward earthquake prediction. We conclude that the measurement of the radon concentration in groundwater at carefully chosen wells should offer definitive information on the likelihood of an earthquake.

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13. We thank Prof. S. Matsuo for reading the manuscript and offering criticism; we thank T. Tanimoto for providing the computer program. Supported by the Ministry of Education.

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