New Method of Prospecting Groundwater Resources for Irrigation

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Exploitation of water resources in hills and mountain areas has been intensified recently in Japan for the purpose of, for example, irrigating orchards, vegetables and pastures as well as supplying water to be used for plant protection, with the improvement and expansion of farm management. In most of these areas, mainly located on piedmonts and plateaus, not only surface water but also groundwater are not readily available, and therefore new groundwater resources have to be exploited ultimately.

However, the groundwater in such piedmonts and plateaus exists in fissures of rock beds, showing very irregular distributions. No scientific method to detect fissure groundwater accurately has been developed yet.

The author carried out a research to develop a method of prospecting groundwater by means of natural radioactivity since 1950, with an aim of exploiting groundwater in such areas lacking in water. At first, a prospecting apparatus was constructed for trials, and with modifications and improvements the γ-ray spectrum groundwater prospecting instrument which can detect groundwater during the driving of motor car was finally developed in 1956. Thus, the method of detecting groundwater in wide areas was established.

This instrument was already used in about 40 districts in Japan, Republic of Korea, etc. with successful results. Based on data obtained by this instrument, exploitation of groundwater in deep earth layer was made, and in all cases water sources were acquired successfully in these areas lacking in water.

In the present paper, groundwater exploration by means of natural radioactivity and subsequent exploitation of underground water sources will be described with an example of a wide area groundwater survey[1] at Taradake National Developmental Pilot Project, that was reported at the meeting of International Commission on Irrigation and Drainage held in 1975 in Moscow.

Purpose of groundwater exploration

The survey area is northeast slope of Taradake volcano, located at southwest border of Saga Prefecture of Kyushu and is National Developmental Pilot Project District. Though agriculture predominated in the area, its productivity was low with small holdings of 65 are in an average. However, as an area amounting to 1,200 ha, suitable for growing mandarin orange, remained un-used, the Pilot Project was started in 1964 to develop a model orchard of mandarin orange on about 2,000 ha of land, including upland crop area converted to the orchard, as a step for farm management improvement program. The area is on the fan-shaped deposit of volcanic products, stretching towards the Ariake Bay, on the foot of the volcano, and lacking in water. Therefore the problem there was water supply for irrigation and plant protection of the orchard.

Exploitation of surface water as well as groundwater was taken up. For the former, it was planned to supply water to three reservoirs to be constructed in the district with a total capacity of 463,000 m^3, by constructing head works in the upper stream of Hama River. For the latter, seven deep wells with a total supply of 5,650 m^3/day of water, irrigation facilities for 640 ha of the orchard and 42 tanks to be used for plant protection were designed. The author worked on groundwater survey in this project.

Prospecting groundwater by natural radioactivity

As mentioned above, there was no appropriate method to prospect fissure water in rocky areas so far. The author developed new instrument[2] based on the phenomenon that natural radioactive isotopes in deep layers of earth ascend through fissure groundwater veins and accumulate at surface of the earth.

Using this instrument, mounted on a car as shown in Plate 1, the survey was conducted by driving all roads of the district. Two scintillation counters, one for cosmic rays and the other for natural radioactivity were equipped. Cosmic rays which disturb the detection of groundwater were automatically eliminated, and γ-rays detected at the earth surface were divided into three groups by their energy and recorded.

The survey covering the whole district was finished within only 4 days. Fig. 1 shows four zones, W, X, Y, and Z, where high

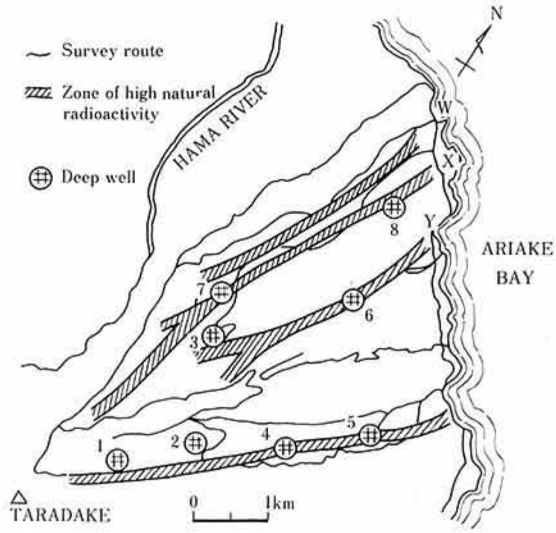

Fig. 1. Areas showing strong radioactivity (W, X, Y and Z zones) identified by the survey using a car-mounted groundwater-prospecting instrument

intensity of natural radioactivity was observed. Width of the zones ranged from 100–200 m. Radioactive intensity of low energy γ-rays was 1.55–1.88 times that of normal areas outside of the zones, suggesting that the natural radioactive isotopes in deep earth layers ascended to the earth surface through fissure groundwater veins and detected as high radioactive zones.

Distribution of fissure groundwater veins becomes wider when it is closer to the coastal line. The similar pattern of distribution was observed in piedmont areas of Mount Fuji. Occurrence of fissure groundwater veins is

Table 1. Results of the pumping test

Well No.	1	2	3	4*	5*	6*	7*	8*	Total
Maximum discharge m^3/day	—	452	441	1,250	1,700	1,276	720	1,400	7,259
Specific capacity m^3/day/m	—	9.8	16.1	61.8	89.7	33.1	22.4	39.4	
Transmissibility coefficient(T) m^2/day	—	5.1	7.9	49.10	50.24	61.42	29.09	30.09	
Storage coefficient(S)	—	1.17×10^{-5}	1.92×10^{-5}	2.99×10^{-1}	3.0×10^{-1}	1.96×10^{-1}	8.06×10^{-4}	2.61×10^{-4}	

* Indicates deep wells installed on the zones showing strong natural radioactivity

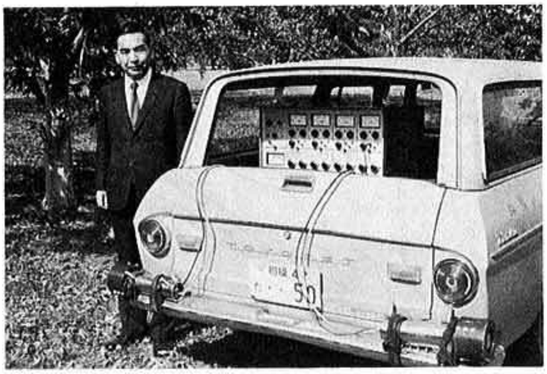

Plate 1. Car-mounted groundwater-prospecting instrument

considered as follows: Structural fissure systems were developed in rock beds, in a direction to crater, by tectonic pressures associated with the eruption of volcano, and groundwater was stored in fissures of rocks or in fractured zones.

Exploitation of confined groundwater

Location of deep wells to be bored was selected above the fissure groundwater veins, shown in Fig. 1. To avoid the mutual interference of pumping effect, one deep well for each of middle and lower streams of X, Y, and Z zones was installed. Deep well No. 1, 2 and 3 were those installed before this survey was made and have no relation to fissure groundwater veins.

Well-boring was made by rotary boring, and the depth of boring was about 300 m, although slightly different with different wells. Trial boring conducted at wells No. 1, 2, and 3 before the survey showed the depth of 300–374 m, and pumping water was impossible with well No. 1 due to a very low water level, 207 m.

The wells No. 3 to 8 bored into fissure groundwater veins based on the natural radioactivity measurement gave large hydraulic constants and uplift quantity, as shown in Table 1.

Quantitative estimation of groundwater

To maintain these deep wells, quantitative estimation of groundwater is needed. For that purpose, cycling of groundwater was examined by measuring ^{14}C in the groundwater as follows: A sample (200 liters) of groundwater was taken, acidified with sulphuric acid, and CO_2 was released by circulating N_2 gas. CO_2 was absorbed by ammonia water, which was then added to $CaCl_2$ solution and heated to precipitate $CaCO_3$. CO_2 gas generated from $CaCO_3$ was introduced to a proportional counter, and ^{14}C activity was measured by a low background counter.

The result revealed that the groundwater of the deep well No. 6 was $4,250 \pm 115$ years of age. The well No. 6 is a flowing artesian well which belongs to the Y zone of fissure groundwater vein, and is of confined acquifer layer. Thus, it was made clear that old groundwater has been stored without active exchange with surface water. Groundwater of deep well No. 5 on the Z zone showed 180 ± 80 years of age, relatively new as compared to that of well No. 6.

As indicated in Table 1, wells located on the Z zone show transmissibility coefficient T, and storage coefficient S higher than those of other zones, suggesting that water exchange with surface water is being done to some extent at the headwater conservation area of mountain-side. Therefore it was concluded that in the future utilization of groundwater it would be desirable to depend mostly on Z zone, with supplemental use of X and Y zone as countermeasures for drought with prolonged intervals enough to restore water level.

Conclusing remarks

It was proved that prospecting of groundwater in wide area by means of natural radioactivity was very effective in detecting fissure groundwater efficiently.

By applying this method to a district lacking in water at the piedmont of a volcanic mountain, 7,259 m^3/day of groundwater, exceeding the planned rate of uplifting, 5,650 m^3/day, could be obtained. Together with the water source from reservoirs, it was made possible to supply enough water for irrigation and plant protection of 640 ha of mandarin orange orchard. Thus, the new method using natural radioactivity measurement, developed by the author, was verified to be extremely useful in practical application.

References

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