〈特別寄稿〉

Scientific Field Methods in Groundwater Hydrology

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1. Hydrology as a scientific discipline

The following statements made by famous hydrologists express present status of hydrology in the academic world.

'Hydrology, the science of water, has natural place alongside oceanography, meterology, geology, and others as one of the geosciences; yet in the modern science establishment, this niche is vacant. Why is this?'(Bras and Eagleson, 1987).

'In practice, hydrology is regarded mostly as a technological discipline rather than a science; this attitude is responsible for much bad science in hydrology which, in turn, has led to much bad technology in applied disciplines. It is argued that the present offers a unique opportunity to fill the vacant niche of science of hydrology.'(Klemes, 1988).

'Hydrology is at a crossroads, a time when the field is struggling to gain recognition as an earth science, not only as a goal-oriented subdiscipline responding to engineering needs '(Bras, 1988).

'The study of "Opportunities in the hydrologic sciences" results from an increased awareness by the hydrologic community of the need for fundamental advances in hydrologic science to generate solution to emerging complex problems of water technology, and from the realization that the time has come for hydrology to become better established as a science alongside other recognized geosciences'(Eagleson, 1989).

Groundwater, and important part of hydrologic cycle, has mostly been regarded as water resources rather than as an object of scientific research. But awareness of the importance of groundwater as an element of natural environments stimulated scientific researches aiming at understanding groundwater as one of hydrologic processes. Above statements suggest that fundamental scientific understanding of groundwater is a key to solution to emerging complex problems of groundwater.

2. Groundwater and natural environments

In the early stage of water resources development, groundwater was the most important and easily accessible water resources in almost everywhere in the world because groundwater is distributed areally, whereas the river is distributed as a line and the lake as a point. Therefore, needs for technological advances in groundwater prospecting was strong, and many textbooks were written on the groundwater hydraulics or well hydraulics, which mostly concerns about the groundwater near well or in a relatively small area.

With increasing use of groundwater, environmental problems such as land subsidence, sea water intrusion, groundwater pollution, drying up of shallow wells and springs became serious social concerns. These problems simultaneously arose during the period of high economic growth in 1970's in Janpan.

Cries for clear air, clear water and better en-

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vironments became strong in 1980's in Japan. Movement by citizens to recover springs in the city started in Tokyo and other cities. To solve these problems, recognition of the role of groundwater in the hydrologic cycle became inevitable. Selection of 'MEISUI HYAKUSEN' (one hundred conserved waters) in 1985 by the Environmental Protection Agency, Japan stimulated a movement for conserving hydrologic environment. Concept of environmental creation in regional planning becomes a useful concept to take positive human attitude to natural environments.

Global environmental problems highlighted the important role of global as well as local hydrologic cycle on global environments. Hydrology can be a scientific discipline and the time has come for hydrology to take a step toward a better established scientific discipline. Groundwater hydrology as a part of contemporary hydrology should be based on scientific background.

3. Scientific techniques to groundwater investigation

The groundwater flow system is a natural system controlled by hydrogeological as well as geomorphological conditions (Toth, 1963:Freeze and Whitherspoon, 1967). It is also controlled by artificial conditions such as irrigation, drainage, pumping etc. Technological advances in field methods in groundwater investigation made it possible to reveal the groundwater flow system under various natural and artificial conditions. The following methods are the techniques presently used:

a) Piezometer network

A piezometer is used to measure a point hydraulic head, a governing potential of groundwater flow. Therefore, many piezometers are necessary to observe regional flow of groundwater. In order to avoid installing many piezometers at a point, Shimada et al.(1980) applied the packer method to measure many hydraulic potentials at different depths in a single borehole. A successful result is shown in Fig.1, which reveals potential distribution in a small granite island. The flow pattern thus obtained was confirmed by the distribution of tritium concentration in groundwater. This study was conducted as a feasibility study to store oil in the rock.

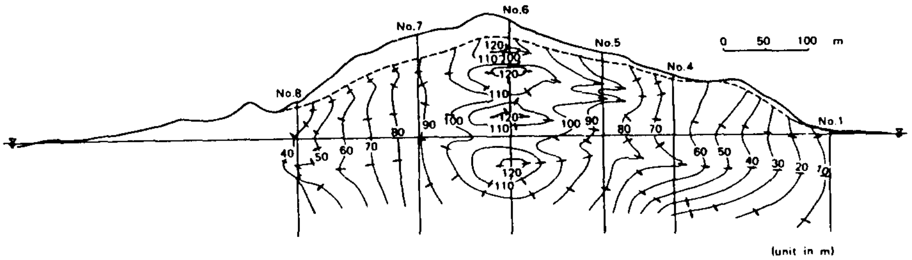

Fig. 1 Distribution of hydraulic head in a granite island (Shimada et al., 1980)

b) Water temperature as a tracer

The water temperature in the subsurface environment is a conservative physical quantity. Heating and cooling at the earth's surface, heat flow from the deep interior, and horizontal advective effect are three main processes to affect the subsurface temperature. The advective effect distorts a temperature field established by heat conduction. So if we know the

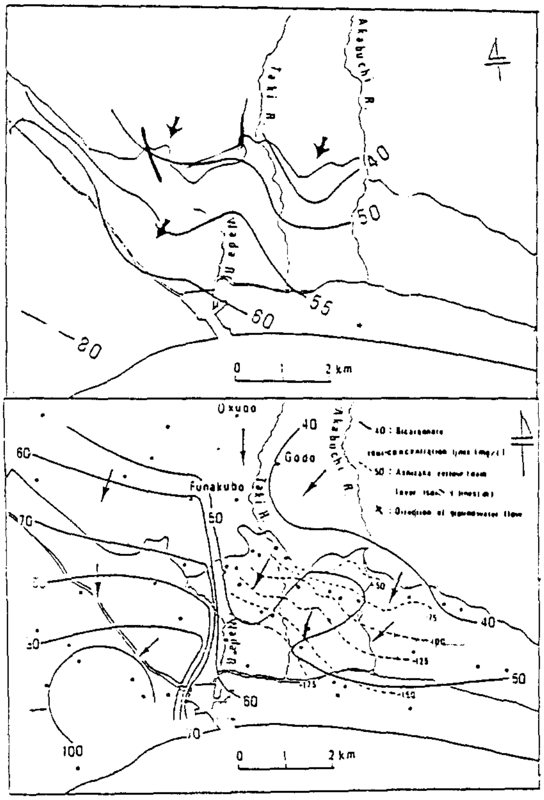

Fig. 2 Seasonal changes of groundwater temperature on vertical cros-sections in Nagaoka plain (Kayane et al., 1985). s (a):October to March. (b):April to August

temperature field without distortion, the groundwater flow pattern can be estimated by observing the distorted field. One example is shown in Fig.2, where the regional flow of groundwater and the interaction of river and groundwater are clearly shown (Kayane et al., 1985). Taniguchi(1987) analysed this temperature field quantitatively to obtain the flux dis- Ikeda(1987) distinguished the groundwater flow pattern in two different aquifers in the same tribution of groundwater.

c) Water quality as a trace

The water quality can be used as a tracer of oundwater flow in two ways. One way is to use a substance contained in a water when the water was recharged. Environmental isotopes stated below are typical examples of such substance. Another tracer is a substance which is disolved during the course of groundwater flow. area. Fig.3 revealed by the distribution of bicarbonate concentration shows the different flow patterns in two aquifers at the southern foot of Mt. Fuji. The estimated flow patterns are assured by the distriubtion of hydraulic heads.

d) Environmental isotopes as tracers

Environmental isotopes are divided into two groups, one being the radioactive isotopes and the other the stable isotopes. Among others, the tritium, a radioactive isotope of hydrogen with mass number of 3 having a half-life of 12.4 years, has frequently been used to estimate the residence time of groundwater. Flow pattern of groundwater can also be determined by observing the distribution of tritium concentration in groundwater (Bae and Kayane, 1987). Concentration of the deuterium and the oxygen-18, the stable isotopes composing water molecule itself, in groundwater is determined by physical processes in the hydrologic cycle in the atmosphere before recharged to subsurface environment (Dansgaard, 1964). Each precipitation has its own stable isotope composition. Each river water, a mixture of precipitated water in a drainage basin, has its own composition. These stable isotopes are ideal tracers of the hydrologic cycle as the tritium is. Mizutani(1986) showed one example that the groundwater in a small alluvial fan is recharged by two rivers and the influence boundaries by two rivers are clearly delimited

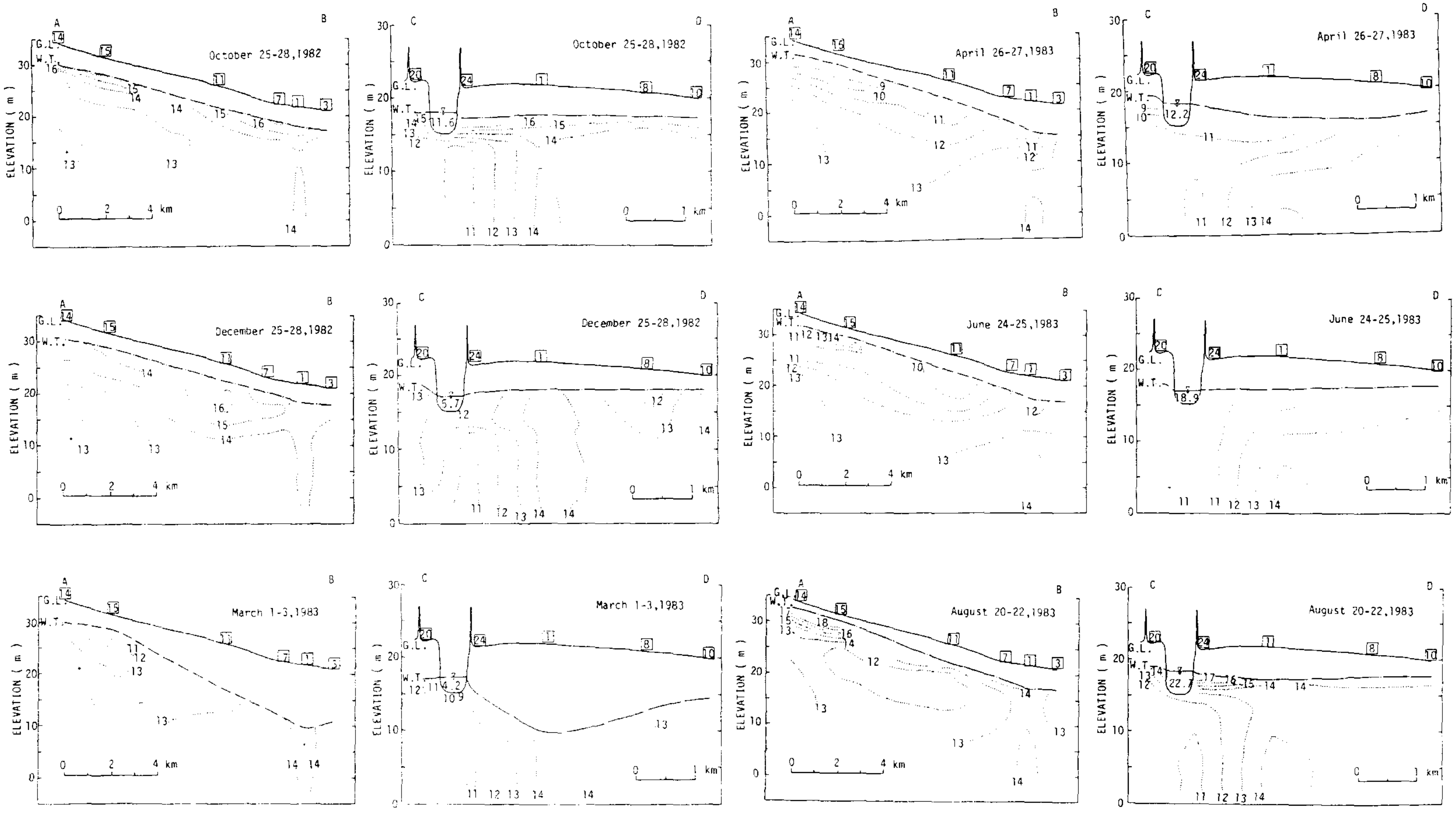

Fig. 3 Direction of groundwater flow estimated by the distribution of bicarbonate conentration (Ikeda, 1987). Upper: New Fuji lava and Ashitaka upper part of volcanic sand and gravel aquifers. Lower:Old-Fuji and Ashitaka lower part of volcanic sand and gravel aquifers(Ikeda, 1987).

1987). Quantitative evaluation of groundwater flow within a very complicated geology was made by using this model (Bae, et al., 1989). The three-dimensional digital simulation is a useful tool to detect groundwater flow under complex hydrogeologic conditions. Qualitative interpretation to groundwater flow in the real world will be quantitatively evaluated by using this model as made by Freeze and Whitherspoon(1967) for two-dimensional vertical cross-sections.

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