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STRUCTURAL CONTROLLED RESERVOIRS WITHIN THE HORST AND GRABEN STRUCTURE AT THE HOHI GEOTHERMAL AREA, JAPAN

Shiro Tamanyu

Geological Survey of Japan, 1-1-3 Higashi, Tsukuba, 305 Japan

ABSTRACT

Structural control on the formation of reservoirs was investigated at the Hohi geothermal area in Japan. Stratigraphic correlations among the drill holes indicate that the subsurface geological structure is characterized by horst and graben structures. Temperature logging data show that the subsurface isothermal structure is characterized by relatively higher temperatures near the horst than the graben. Feed point pressure tests were used to clarify the hydrothermal systems into two groups in terms of pressure. One of pressure systems is strongly controlled by an impermeable horizon, and the other is controlled by topography.

Potential reservoirs for electric generation are expected at shallow parts of the horst and deep portions of the transitional zone between horst and graben.

INTRODUCTION

Many deep bore holes have been drilled in the Hohi geothermal area for the deep geothermal energy exploration program of the Ministry of International Trade and Industry in Japan (Fig. 1). The modelling of the geothermal area has been conducted using integrated data from various kinds of surface surveys and well loggings. Correlations of logging data among the bore holes are useful tools for reconstruction of subsurface structures using geology, temperature and hydraustatic pressure. As the result of these analyses, the most likely locations for geothermal reservoirs were determined to be in fault systems above the horst, and also transitional zones among horst and graben.

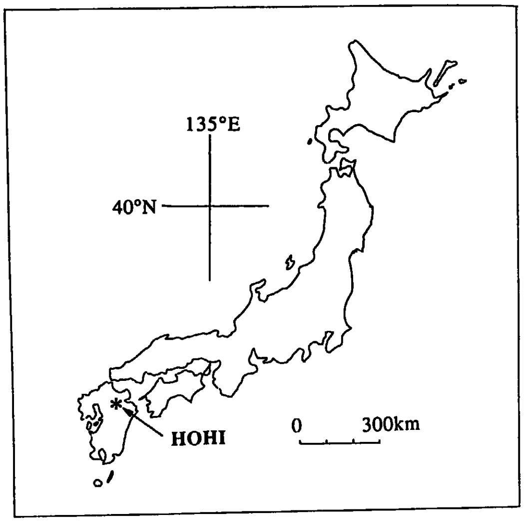

Fig. 1. Index map of studied area

GEOLOGICAL FRAMEWORK

The geologic framework and evolutionary history of the Hohi area were investigated using stratigraphic correlations among drill holes (Tamanyu, 1993). This work indicated that four stages of volcanism and tectonism occurred in Pliocene and Pleistocene epochs. The results of the study indicate that five volcanic depressions, about 10 kilometers in diameter, were the centers of volcanism in the Pliocene, and that the Beppu-Kuju graben was formed with extensive volcanism in early Pleistocene age (Fig. 2). Within these depressions, thick volcanic piles accumulated with corresponding subsidence rates of about 1 km/Ma in average.

SUBSURFACE ISOTHERMAL STRUCTURE

Contours of shallow subsurface temperatures are usually concordant with surface geothermal manifestation such as fumaroles, alteration zones, hot springs etc.

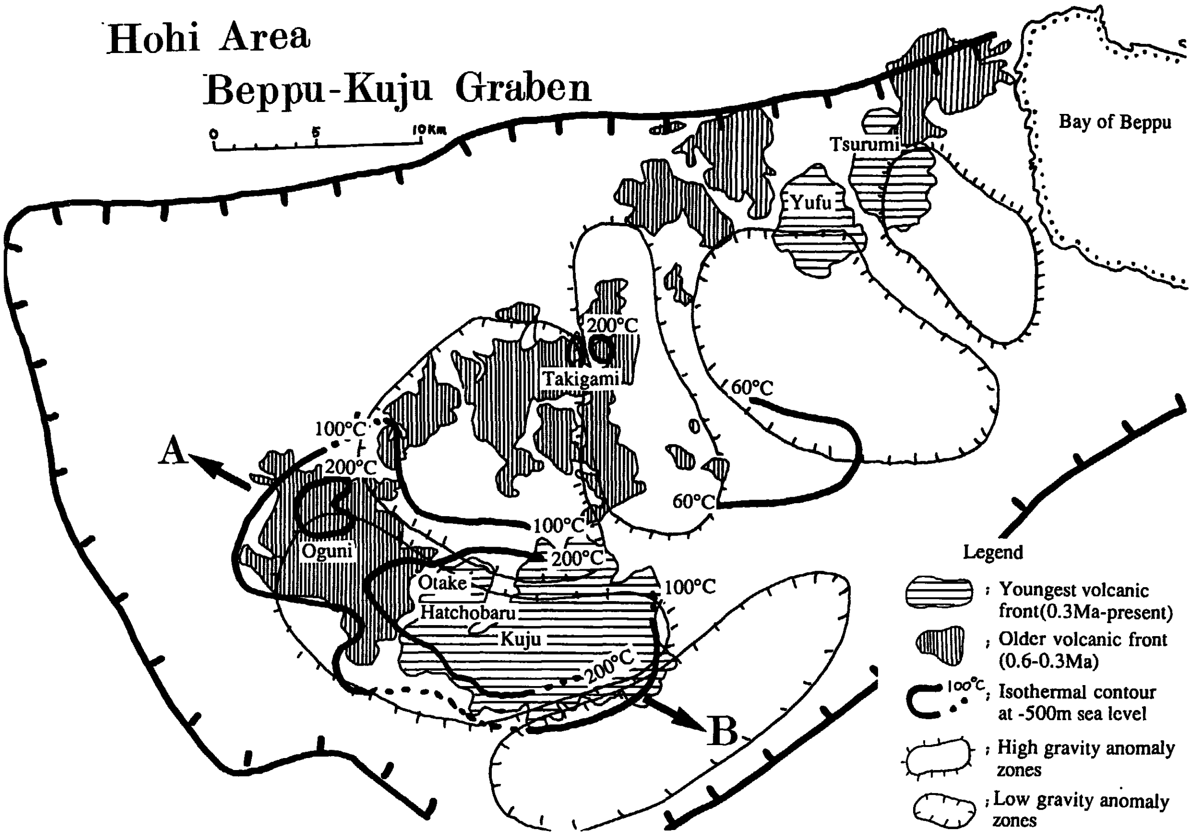

Fig. 2. Distribution map of young volcanics, gravity anomaly zones and subsurface isothermal contours in the Hohi area (Compiled from MITI, 1987, NEDO, 1989, 1990)

(Fig. 3) On the other hand, contours of deep subsurface temperatures are concordant with subsurface relief of the pre-Tertiary basement (Fig. 4). This thermal pattern indicates that hydrothermal convection is dominant in the Neogene formations, and conductive heat transfer is dominant in pre-Tertiary basement. The Neogene formations play a role of a permeable porous media for fluid flow, while pre-Tertiary basement plays a role of impermeable media with only exception of fracture permeability (Tamanyu, 1994). The top surface of pre-Tertiary formation can be estimated by analysis of Bouguer gravity anomaly data with reference to bore hole control points.

WELL CIRCULATION LOSS AND PRESSURE

Feed point pressures of each well were analyzed from water level and the fluid temperature which have reached in equilibrium to surrounding formations. The relationship between feedpoint elevation and feed pressure for the drill holes are shown on Fig. 5(Pritchett et al., 1985, MITI, 1987).

The values from wells in the Takenoyu area constitute the lower boundary for all data. The following correlations between feed point pressure P(bar), elevation Z_D (m) of main zone of circulation loss, and Z_S (m) of well head elevation were obtaincd. The Hatchobaru wells show a correlation roughly equivalent to "Other areas"(MITI, 1987).

Takenoyu area:

$$P=53.8-0.08715Z_D+0.00255(Z_S-1,000)$$

"Other areas":

$$P=76.7-0.08806Z_D+0.06585(Z_S-1,000)$$

Wells in the Takenoyu area have large circulation losses, and the coefficients of well head elevation (Z_S) are small. This indicates that groundwater level is roughly constant regardless of well head elevation (Z_S), and that areas of high permeability are connected horizontally. It is concluded that fracture systems are developed in the reservoir of this area.

Under "Other areas", circulation losses occurred at shallow depths in wells DW-1, -3,

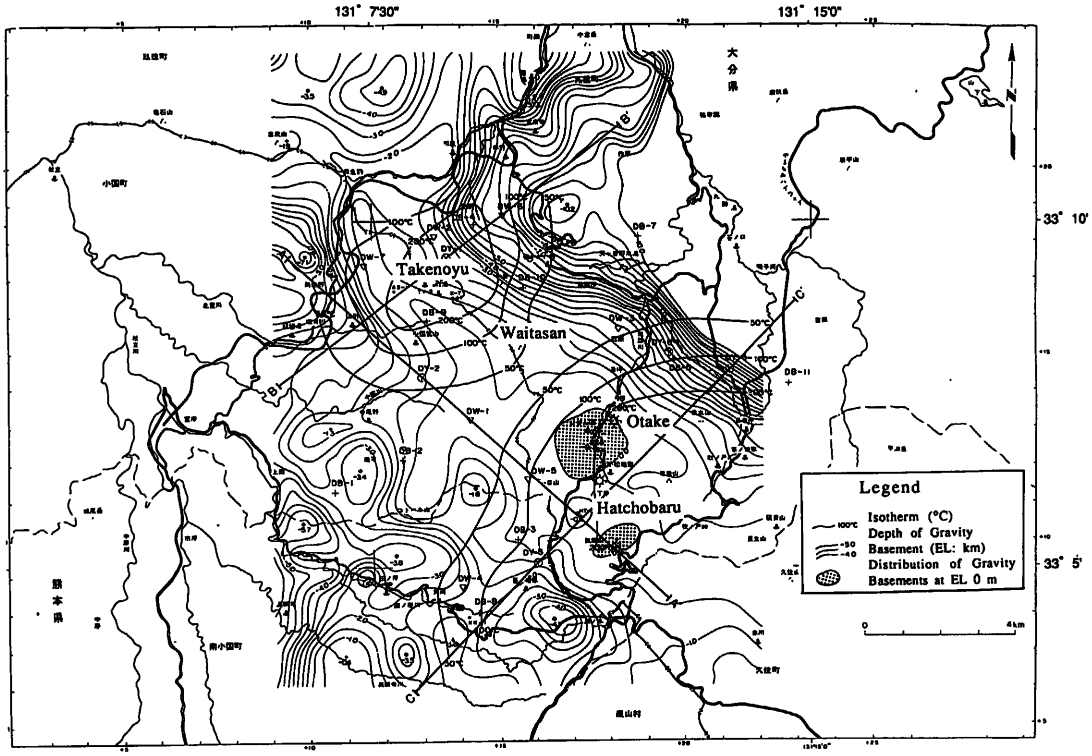

Fig. 3. Isothermal contour map at 0 km in the Hohi area (MITI, 1987)

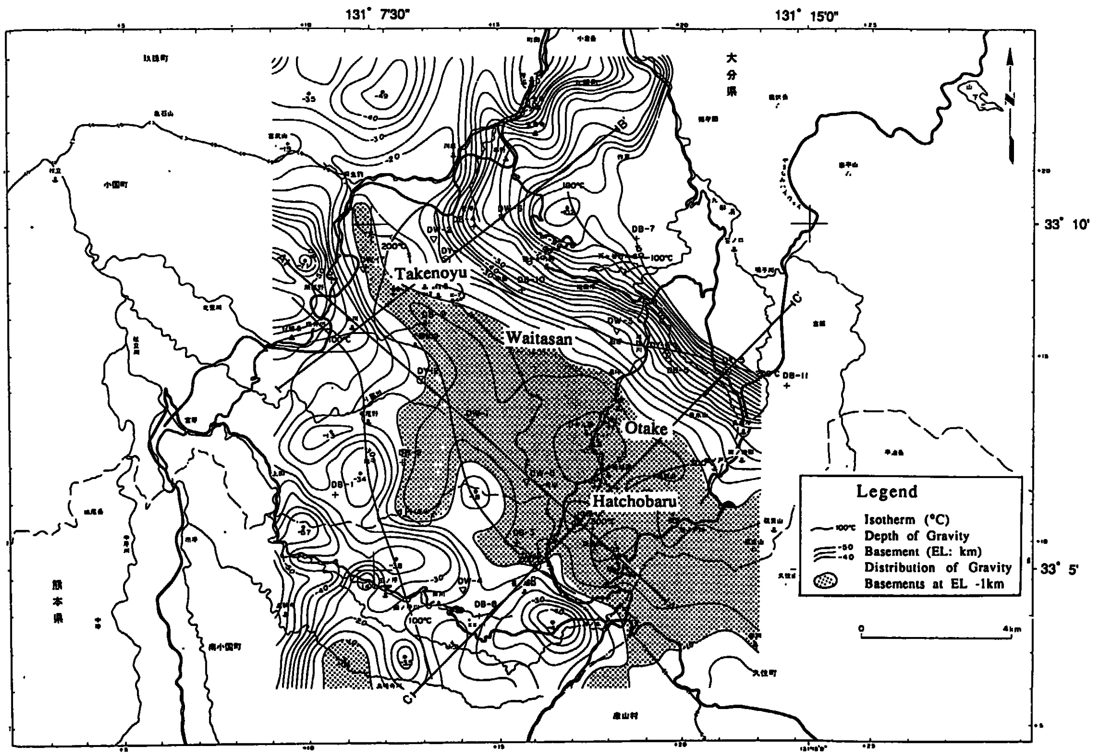

Fig. 4. Isothermal contour map at -1 km in the Hohi area (MITI, 1987)

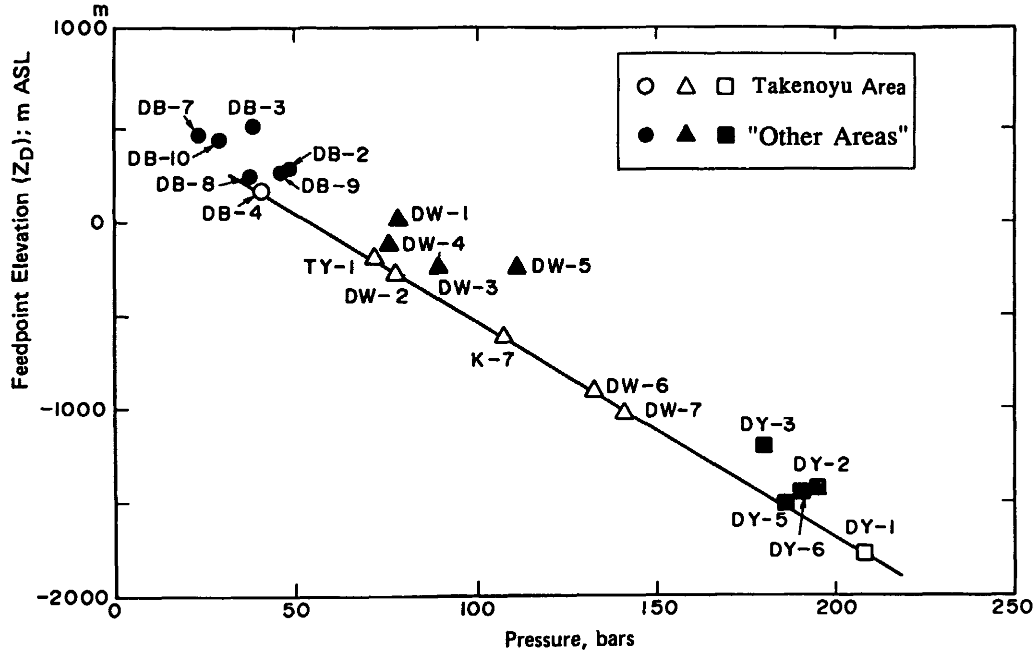

Fig. 5. Elevation-pressure relationship of the major lost circulation (Pritchett et al., 1985, MITI, 1987)

-4 and DY-2. The increase in pressure is proportional to well head elevation (Z_S), and overall horizontal permeability is small. Circulation loss at these wells is thought to be mainly due to fractures.

The pressure of the main circulation loss observed at the deep part of well DY-5 does not fit the pressure elevation curve obtained for "Other areas" and has about 20 bars lower value, similar to that in Takenoyu area. Therefore, the reservoir observed at the deep part of well DY-5 has different characteristics from those of "other areas".

According to above mentioned description by MITI(1987), the hydrothermal systems are characterized as follows. The hydrothermal system in Takenoyu area is characterized as a reservoir in a porous formation covered with impermeable layer. The shallow water system in "Other areas" is characterized by downflow driven by topographic elevation in fracture system. The deep water of DY-5 is characterized by reservoir in fracture system covered by an impermeable formation.

CONCLUSION

The geothermal fluid flow in the Hohi area is strongly controlled by horst and graben structure of pre-Tertiary basement which is covered with thick Neogene formations. In general, the Neogene formations are relatively the permeable, while pre-Tertiary formations are impermeable. The top surface of pre-Tertiary formation can be estimated by analysis of Bougour gravity anomaly data with reference to bore hole control points.

Potential thermal water for electric generation is expected at shallow parts of horst, and deep parts of transitional zone between horst and graben (Fig. 7). In general, the temperature of the former is higher than of the latter, and the pressure of the former is higher than of the latter because the latter is situated in a thick permeable zone within graben which is covered with impermeable horizon.

ACKNOWLEDGEMENT

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