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Geological and geophysical perspective of supercritical geothermal energy in subduction zone, Northeast Japan

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Abstract

Geological and geophysical characteristics of supercritical geothermal reservoirs in the Tohoku District, NE Japan were investigated in order to evaluate potential of future geothermal energy. Geological information in the Tohoku District (caldera, hot spring hydrothermal alteration, mine, and granitoid) and geophysical data (gravity, MT and seismicity) were accumulated into GIS database. We can evaluate present volcanism and related events, geothermal structure, depth of heat source, fracture distribution, and existence of fluid by using the GIS database. We identify the following geological features in terms of geothermal resources: “Deep fluid input”, ”Magma input”, “Geothermal gradient”, and “High temperature hot spring”, and we can classify the geothermal energy and potentials as follows: “Promising”, “Probable”, ”Possible”, and “Potential”.

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Keywords: Geothermal Reservoir, Supercritical condition, Geofluid, Subduction zone, EGS, Supercritical geothermal energy

1. Introduction

After the Great East Japan Earthquake and the accident at the Fukushima Daiichi Nuclear reactor on 3.11 (11th March) 2011, geothermal energy came to be considered one of the most promising sources of renewable energy for the future in Japan. However, there are several geological and geophysical issues. First is the National Park Issue (~80% of the potential geothermal energy in Japan lies inside National Parks), second is Onsen (hot springs) problem, and another is induced seismicity related to the development of geothermal energy. The temperatures of geothermal fields operating in Japan range from 200 to 300 °C (average ~250 °C), and the depths range from 1000 to 2000 m (average ~1500 m). In conventional geothermal reservoirs, the mechanical behavior of the rocks is presumed

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to be brittle. In order to minimize induced seismicity, a rock mass that is "beyond brittle" is one possible candidate, because the rock mechanics of "beyond brittle" material is one of plastic deformation rather than brittle failure[1, 2].

Geothermal fluid condition under "beyond brittle" is considered to be supercritical state, and one of future targets of geothermal development in Japan is supercritical geothermal reservoirs.

At Kakkonda in NE Japan, the exploration well WD-1a encountered the partly solidified Kakkonda Granite and inferred reservoir temperatures in excess of 500°C[3]. We already studied an exposed Quaternary granitoid (the Takidani Granodiorite), since it is analogous to a deep-seated geothermal reservoir which might be in supercritical geofluid condition[4,5]. The Takidani Granodiorite is located at the boundary of the Eurasian and North American Plates. In contrast, we have investigated hydrothermal activity in order to understand the evolution of supercritical geothermal fluids in certain geological settings. Temperatures are over 350°C in the "beyond brittle" condition (a temperature of ~350 °C coincides with the brittle–ductile transition)[6-9].

Tohoku District, located in northeast part of Japan, is one of representative subduction zone in the world[10, 11], where the Pacific Plate is subducting to the Eurasian Plate, and we can recognize obvious volcanic front at back-born mountain range and so-called hot fingers in Tohoku District[12].

Based on geological and geophysical survey, we could classify characteristics geothermal resources in terms of geothermal reservoir. Here, we describe some geological perspectives and feasibilities to evaluate geothermal energy under supercritical conditions.

2. Supercritical geothermal reservoir

It is possible to extract high enthalpy energy from supercritical geothermal reservoirs, and weak water-rock interactions with respect to silica solubility are estimated in high temperature conditions. However, drilling projects to reach the supercritical geofluids were limited, and our knowledge of supercritical geothermal reservoirs has been limited.

Fig. 1 shows a conceptual model of the supercritical geothermal reservoir. As mentioned above, conventional geothermal reservoirs in Japan are below ~250°C and ~1500 m in depth, where is under brittle condition in terms of mechanical behaviors of rocks and subcritical geofluid condition. Temperature profiles of the conventional geothermal reservoirs indicate hydrothermal convection is dominant mechanisms of heat and fluid transfer. The geothermal frontier lies below conventional geothermal reservoirs, where mechanical behaviors of reservoir rocks are "beyond brittle" and physicochemical state of the geofluid is considered to be under supercritical condition. Temperatures of the geothermal frontier may be higher than 350°C and heat conduction is considered to be main mechanisms of heat and fluid transport. Four big research targets which are evaluation of fluid flow, water-rock interaction (WRI)[13], creation of rock fractures and drilling technology for extremely high temperature conditions are suggested.

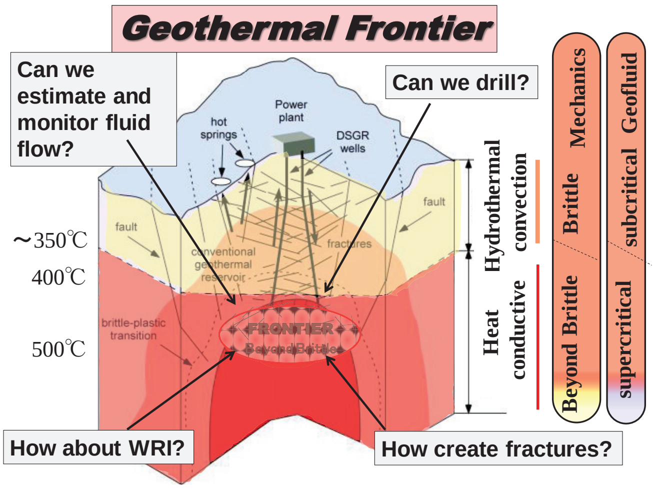

Fig. 1 Conceptual model of supercritical geothermal reservoir "Geothermal Frontier".