Status report on the Japanese Supercritical Geothermal Project for FY2017

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ABSTRACT

Japanese scientists have estimated that nationwide potential of “Supercritical Geothermal Resources in Japan”, originating by the subduction of oceanic plates, reaches hundreds GWs. Power generation from the supercritical geothermal resources in Japan can contribute significantly to both energy security and reduction of emissions of CO_2. The temperature range of the target supercritical rock body is about 400-500^oC and its depth is expected to be less than several kilometers. The depths of the supercritical rock bodies in Japan are much shallower those in other areas in the world, which brings advantages in terms of accessibility, economy, and safety. However, there are a lot of scientific unknowns about their nature, especially regarding rock-mechanical and geochemical behavior under supercritical conditions. Technological breakthroughs will be necessary, because the temperature and pressure conditions in the supercritical geothermal systems are far beyond the current technological limitations and also

because experiences in previous ultra-high temperature geothermal drilling suggest that the presence of acidic geothermal fluid is likely. The Japanese government has recognized that supercritical geothermal power generation is one of the key technologies in its strategy to drastically reduce CO_2 emissions in and after 2050 (NESTI2050). In FY2017, funded by NEDO (New Energy and Industrial Technology Development Organization), a team of Japanese researchers from 14 organizations have started a national project to improve understanding of the nature of supercritical rock bodies and the engineering necessary to extract geothermal energy. This project is a feasibility study combining science, engineering, economics, and environmental issues.

1. Background

It has been estimated that Japan has the world third largest potential of hydrothermal resources (conventional naturally existing geothermal resources) (Stefansson, 2005). However, the installed capacity of geothermal power generation in Japan has remained around 0.5 gigawatts, even after Japanese government drastically changed its energy policy from being highly nuclear oriented after the incident of Fukushima-dai-ichi in 2011. This is because there are many factors obstructing the development of hydrothermal systems in Japan. These include uncertainties about geothermal reservoirs, the relatively small sizes of reservoirs, difficulties in the establishment of a social consensus, and costs.

As geothermal researchers in Japan we have been investigating the most suitable and industry-acceptable ways of developing geothermal resources that can solve negative factors and increase geothermal power generation significantly. We have concluded that this can be achieved by development in and beyond the zone of brittle-ductile transition (BDT) in volcanic basement. We expect that high temperature and geologically/rock-mechanically homogeneous rock bodies are widely distributed and are hydraulically isolated from shallow systems (Saishu et al., 2015) beyond the BDT. The nature of the rock bodies in the BDT can be used to solve many of the factors hindering the development of hydrothermal systems. We initiated a project named "Japan Beyond-Brittle Project (JBBP)" in 2010 and started feasibility studies (Muraoka et al., 2014).

Using MT surveys and analyses of earthquakes (Ogawa et al., 2014), we discovered a rock body beneath a volcano, with high temperatures (possibly >400℃) and several percent of brine having an origin in ancient sea water. We understood that such rock bodies originate as magma created by subduction of an oceanic plate. We also inferred that this rock body in the BDT should contain supercritical liquid. Such supercritical geothermal resources should contain a huge amount of energy, capable of generating more than several tens of gigawatts of electricity for 30 years for each rock body. Geological investigations from various aspects have also revealed that the emplacement depth of a subduction-related supercritical rock body in Northeast Japan (Tohoku) is less than several kilometers. This is much shallower than supercritical rock bodies occurring in other subduction zones. These supercritical rock bodies are therefore accessible by current drilling technologies. The Japanese government has recognized that the geothermal power generation using supercritical rock bodies as energy sources (“supercritical geothermal power generation”) is one of the eight key technologies in their strategy to drastically reduce CO_2 emissions in or after 2050 (NESTI2050, CAO, Japan, 2107). These studies to deepen understanding of nature of supercritical rock bodies and engineering investigations to extract thermal energy are underway as a national project (Supercritical Geothermal Project) funded by

METI and the New Energy and Industrial Technology Development Organization (NEDO), Japan.

Based on experience from previous drilling of the well WD-1a in Kakkonda, Japan (Muraoka et al., 1998) and two wells of the Icelandic Deep Drilling Project (IDDP) in Krafla and Reykjanes, Iceland (Mortensen et al., 2014; Friðleifsson, et al., 2017), we expect that conditions in supercritical geothermal systems are extremely harsh. Moreover, insufficient scientific understanding of the supercritical geothermal systems brings uncertainties in the R&D plan. We concluded therefore that scientific and technological studies should be mutually linked, and that in drilling the first exploration borehole into a supercritical rock body is extremely important to obtain both scientific information and to investigate future engineering aspects.

2. Outline of NEDO 2017 Supercritical Geothermal Project

In spring of 2017, the New Energy and Industrial Technology Development Organization (NEDO), Japan, made a public request for proposals for “Feasibility studies of R/D for supercritical geothermal resources” which includes (a) Understanding of the state of supercritical geothermal reservoir, and evaluation of expected electric power, (b) Evaluation of the materials and equipment necessary for supercritical geothermal power generation, (c) Development and economic evaluations of supercritical geothermal power generation systems, and (d) Evaluation of methods for minimizing environmental impacts and ensuring safety. Our two proposals (from geothermal researchers and engineers) have been accepted and we have started an 8 month-long project.

Results from one of the teams, which consists of AIST (PI: Hiroshi Asanuma), Hokkaido University, Tohoku University, University of Tokyo, Tokyo Institute of Technology, Kyushu University, Geothermal Engineering Co., Ltd., Geothermal Research and Development Co., Ltd., Teiseki Drilling Co., Ltd., Telnite Co., Ltd., Fuji Electric Co., Ltd., Renergies Co., Ltd., AGC Ceramics Co., Ltd., Metal Technology Co., Ltd., are summarized below.

- A conceptual model of supercritical geothermal systems in Tohoku (Northeast Japan) was developed (Figure-1) from the integrated interpretation of geological and geophysical data.

- Permeability inside the naturally existing supercritical geothermal system was estimated to be 10^{-14}-10^{-15} (m), with a thickness reaching several hundred meters inside the granitic supercritical rock body.

- Hydraulic and decompression (thermal shock) fracturing mechanisms can be effectively used to develop the impermeable rock body, although mechanisms of fracturing are much different from those in subcritical (brittle) zones. A borehole producing from a supercritical geothermal regime will have productivity around 30-40 MWe for 15-20 years. A borehole heat exchanger (co-axial borehole) cannot produce thermal energy at a commercially acceptable cost.

- A typical supercritical rock body in Northeast Japan with several production boreholes could produce >100MWe.

- In some of the cases, costs for supercritical geothermal power generation is comparable with current hydrothermal power generation, although there are remaining uncertainties especially regarding the cost of new materials.

- Methodologies for neutralization and washing of SiO_2 should be investigated to protect turbines from corrosion and mechanical damages.
- SiC/SiC composite (Kohyama, 2012) demonstrated a good potential as a new anti-corrosive material for casing and pipes. Cost reduction of this new ceramic material is the crucial issue to be investigated.
- Applicability of existing Portland cements to HT boreholes and applicability of non-Portland cement for industrial use to supercritical borehole should be evaluated.
- Risks for induced large earthquakes have been estimated to be low under our assumptions on stress state inside/around the supercritical rock body.

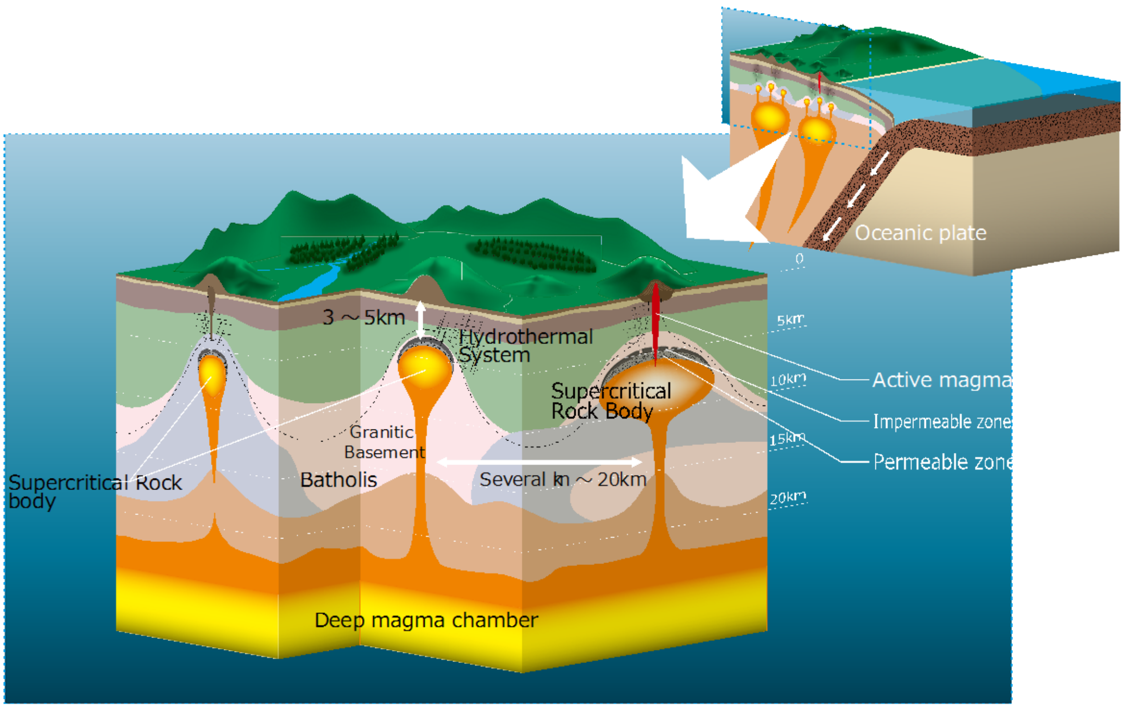

Figure 1: A model of supercritical geothermal systems in Tohoku (Northeast Japan).

3. Summary

After review of results from studies in 2017, NEDO decided to move forward to the next phase, “preparation of an exploration well”. We believe that supercritical geothermal resources have a potential to increase geothermal power generation drastically and to reduce the CO_2 emission in Japan, although we need scientific/technological breakthroughs to achieve them. We will continue the studies to drill the first exploration borehole and operation of a commercial-scale pilot plant by "all-Japan" scheme with support from governmental funding agencies.

Development of ultra-high temperature or supercritical geothermal resources has been activated in many of industrialized geothermal countries (Reinsch et al., 2017), and international collaboration would be practical to reduce cost and time of research and development.

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