GRC Transactions, Vol. 43, 2019

Status of Japanese Supercritical Geothermal Project in FY2018

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Keywords

Supercritical geothermal development, JBBP

ABSTRACT

Japanese scientists have estimated that nationwide potential of "Supercritical Geothermal Resources", which has an origin in subduction of oceanic plates, reaches hundreds GWs in Japan. Power generation using supercritical geothermal resources (supercritical geothermal power generation) in Japan can significantly contribute to energy security and reduction of emission of CO2. Temperature range of the target supercritical rock body is around 400-500 deg-C and depth is expected to be less than several kilometers. The depth of the supercritical rock body is much shallower than the other area in the world, and it brings advantages in accessibility, economy, and safety. However, there are a lot of scientific unknowns about the nature, especially in rock-mechanical and geo-chemical behavior under supercritical conditions. We also need technological breakthroughs, because temperature and pressure conditions in the supercritical geothermal systems are far beyond the current technological limitations and experiences in the foregoing ultra-high temperature geothermal drillings suggests that presence of acidic geothermal fluid should be expected.

Japanese government identified the supercritical geothermal power generation as one of the key technologies in their strategy to drastically reduce emission of CO2 in/after 2050 (NESTI2050). Studies mainly to deepen understanding of nature of the supercritical rock body and engineering investigation have been conducted as NEDO-funded feasibility study until FY2017. In FY2018, NEDO has initiated six 2-3 years national projects related to supercritical geothermal development in addition to on-going METI funded two projects. Outline of the supercritical geothermal projects is described in this paper.

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 Nuclear Power Plant 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 Ministry of Economy, Trade and Industry (METI) and the New Energy and Industrial Technology Development Organization (NEDO), Japan (Asanuma et al., 2018).

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 the Supercritical Geothermal Projects in Japan

Conceptual model of typical supercritical geothermal system in Japan, which has been inferred from geological investigations in supercritical geothermal project in FY207, is shown in Figure-1. History of Supercritical Geothermal Projects in Japan (SCGPJ) is shown in Figure-2. The SCGPJ initiated as a scientific project in the beginning of 2010's aiming to discuss/understand nature of deep geothermal systems as a future energy system. After drastic change of Japanese energy policy following incident of Fukushima-dai-ichi Nuclear Power Plant, the SCGPJ has been mainly funded by METI and NEDO, one of the funding agencies of METI. Outline of currently on-going SCGPJ are summarized in Table-1:

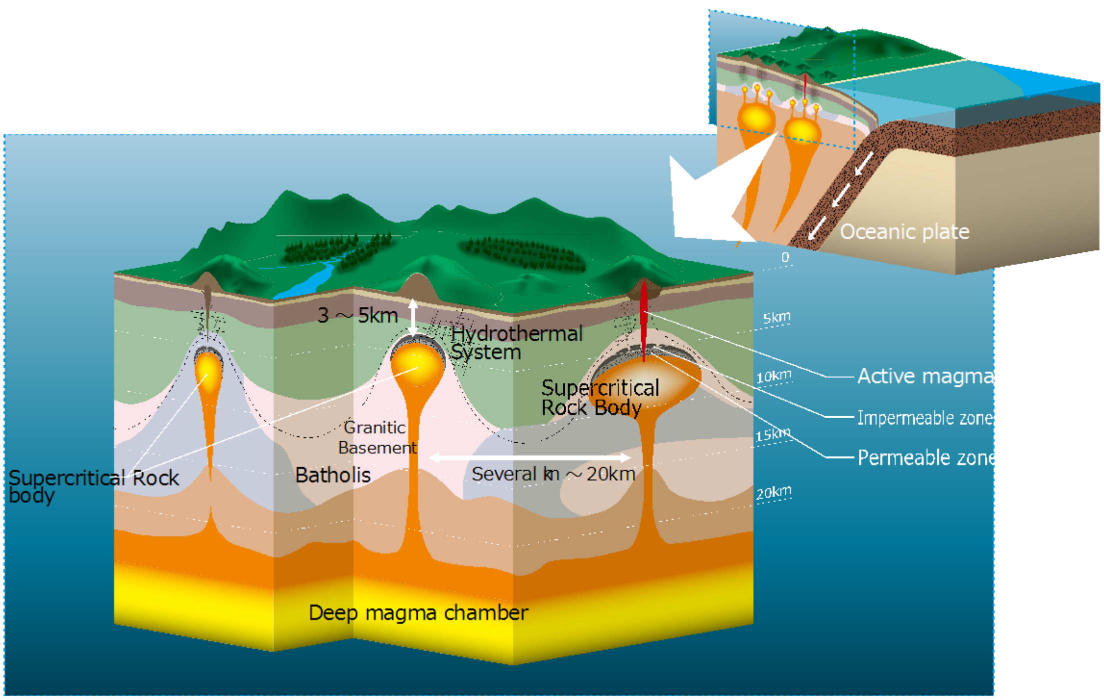

Figure 1: Typical model of supercritical geothermal system in Northeast Japan.

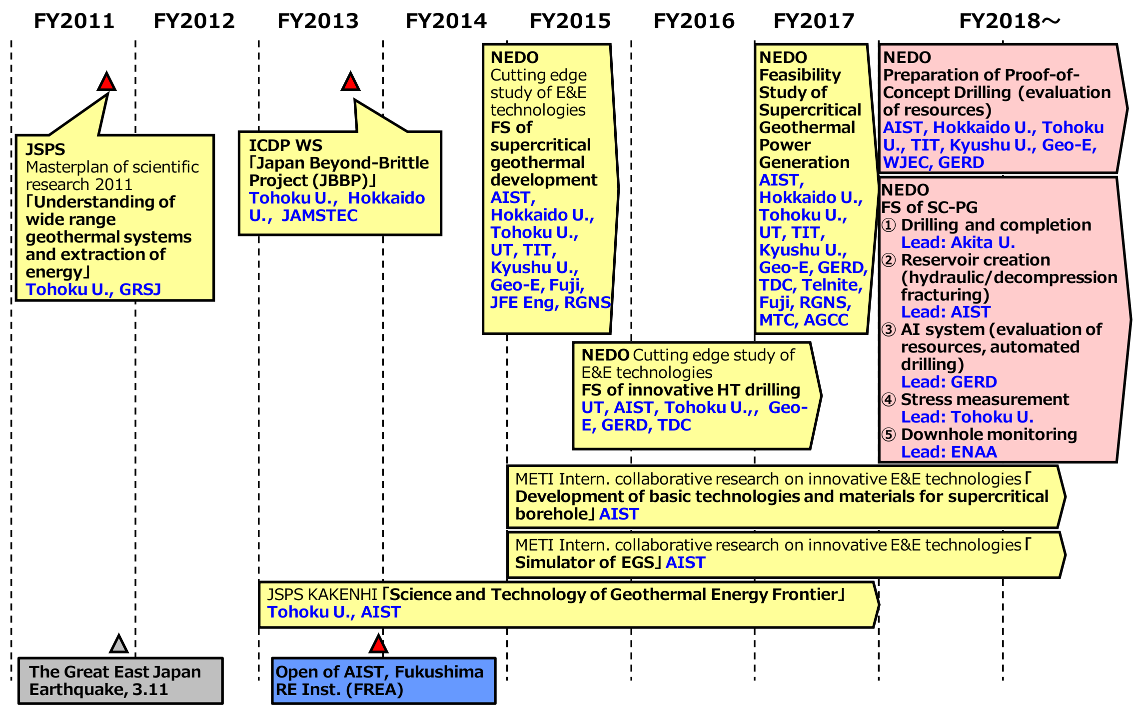

Figure 2: History of SCGPJ

Table-1: On-going SCGPJ as of April 2019

Title of PJ	Funding Agency	PI	Contractors (only direct contractors)	Outline of PJ
Evaluation of supercritical geothermal resources	NEDO	H. Asanuma (AIST)	AIST, Hokkaido U., Tohoku U., TIT, Kyoto U., Kyushu U., HRO, Geo-E, GERD, WJEC	*Collection of geological, geophysical, and hydrogeological data at three promising area in Hokkaido, Tohoku, and Kyushu. *Modeling of supercritical geotherm systems in each site and estimate extract-able energy.
Study on ell design and surface facilities specification required for supercritical geothermal power generation	NEDO	S. Naganawa (Akita U.)	Akita U., NKKTUBES, Geo-E, Fuji Electronics	*Investigation of specifications of wells and surface system. *Cost estimation. *Demonstration of feasibility of supercritical geothermal power generation from engineering and economical points of view.

Table-1: On-going SCGPJ as of April 2019 (contd.)

Title of PJ	Funding Agency	PI	Contractors (only direct contractors)	Outline of PJ
Study on creation of artificial supercritical geothermal reservoirs	NEDO	H. Asanuma (AIST)	AIST, Tohoku U., JAPEX, TDC, Renergies	*Modeling of hydraulic and decompression fracturing under high temperature/pressure conditions. *Simulation of artificial supercritical geothermal systems. *Development of 1st prototype of downhole decompression fracturing tool.
Development of AI system for supercritical geothermal development	NEDO	K. Osato (GERD)	GERD, AIST, Muroran IT, Tohoku U., Akita U., Kyoto U., Kyushu U., Geo-E, TDC, GSC	*Development of core of AI system for resource evaluation. *Development of AI system for sei-automated drilling system.
Development of stress measurement system in supercritical geothermal well	NEDO	T. Ito (Tohoku U.)	Tohoku U., OYO, GSC	*Design/manufacturing and evaluation of a prototype of in-situ stress measurement tool for supercritical boreholes.
Development of innovative monitoring system of supercritical geothermal system	NEDO	J. Kasahara (ENAA)	ENAA, Kyoto U., JFCC	*Development of acoustic monitoring system of supercritical geothermal system.
Development of basic technologies and materials for supercritical geothermal wells	METI	H. Asanuma (AIST)	FREA, AIST	*Development of a ultra HT DVS and pressure vessel with new non-metallic material for supercritical boreholes.
Development of simulator of EGS	METI	H. Asanuma (AIST)	FREA, AIST	*Laboratory studies of behavior of fracture system in geothermal conditions. *Development of simulators for EGS and supercritical geothermal system.

3. Summary

Authors in this paper consider that the drill of the 1st proof-of-concept borehole into supercritical geothermal system is the biggest opportunity to verify our scientific assumptions, and to evaluate development technologies and materials. We will propose our government and funding agencies for their financial support to the drilling within 2020's after detailed scientific/engineering investigations.

Acknowledgements

This study was supported by NEDO " Research and Development for Supercritical Geothermal Power Generation", and METI "International collaborative research on innovative E&E technologies". The authors also acknowledge all the supports from related people.

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