THE FIRST ENHANCED GEOTHERMAL SYSTEM PROJECT IN KOREA

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ABSTRACT

The first proof of concept project for geothermal power generation by enhanced geothermal system (EGS) in Pohang, Korea has been started in Dec. 2010. The project aims to construct a MW scale geothermal power plant (GPP) within 5 km depth. A doublet system (one injection and one production wells) will be made at a first stage for the 5 years of the project period due to the limited budget and the period. The project is divided into two stages; the first stage, the first two years, for geothermal exploration for the site and drilling into 3 km deep to figure out the geology and the temperature over 100 ^{o}C, and the second stage, the next three years, will be devoted to complete a doublet system of 5 km depth including deep drilling, hydraulic stimulation, circulation test and eventually to construct a binary GPP of MW scale. The bottom hole temperature at 5 km depth is expected to be about 180 ^{o}C based on intensive geothermal exploration during the period 2002-2009 by Korea Institute of Geoscience and Mineral Resources (KIGAM). Assuming the flow rate of 40 kg/sec, the net power-generation could be 1.5 MWe for the doublet system. NEXGEO consortium with industry, research institutes and university participation is managing the project.

Keywords: Enhanced Geothermal System, Doublet system, Geothermal Power Plant, binary GPP, Pohang

1. INTRODUCTION

Korea does not have high enthalpy geothermal energy related to the volcanic or tectonic activities. Geology of Korea is characterized by the old formation and very thin sedimentary layers. Most recent volcanic activity has been reported in the year 1007 in Jeju Island, South Sea of Korea. There, however, are some anomalous regions that shows high geothermal gradient and Pohang is one of such regions that show high heat flow and geothermal gradient. Geothermal anomaly in Pohang area has been reported in 1960s from several deep drilling for oil exploration.

Based on the anomalous geothermal regime, the low temperature geothermal development project in Pohang project has been performed by Korea Institute of Geoscience and Mineral Resources (KIGAM) for 6 years from 2003-2008 (Song et al., 2006a; Lee and Song, 2008). Intensive geological and geophysical surveys such as airborne gravity and magnetic surveys, radioactive, geochemistry and magnetotelluric surveys have been performed to delineate possible fractures which can carry deep geothermal water to near surface. Four exploration wells have been drilled to figure out the geological and geothermal structure of the target area.

Well logging from the four wells commonly showed geothermal gradient higher than 30 °C/km, while national average of geothermal gradient is about 25 °C/km (Lee and Song, 2008). Assessment of geothermal resources in Korea (Lee et al., 2010) showed that the temperature at 5 km depth of Pohang area is expected to be about 180 °C, which is highest temperature that is expected in South Korea within 5 km depth so far.

Based on the scientific results, the government and industry decided to launch a proof-of-concept project for enhanced geothermal system in Korea in December 2010. In this article, we summarize our 6 years efforts in Pohang including the geological and geothermal explorations with introduction to the EGS project.

2. GEOTHERMAL AND GEOLOGICAL CHARACTERISTICS OF POHANG SITE

A geothermal ○atabase has been made and opened in July, 2010 by KIGAM (Kim et al., 2010; http://kgris.kigam.re.kr). The DB contains various geothermal properties of rock in Korea, including 2163 thermal conductivity, geothermal gradient from 715 well data, 492 heat flow data, and 180 heat production data.

It also contains corresponding properties of rocks such as density, specific heat, porosity and so forth. Using the data from the DB, a geothermal resource assessment has been carried out to figure out the heat contents and the temperature at depths in Korea (Figure 1). High-temperature can be expected at south-eastern part of Korea, where thick Tertiary Pohang Basin covers the surface.

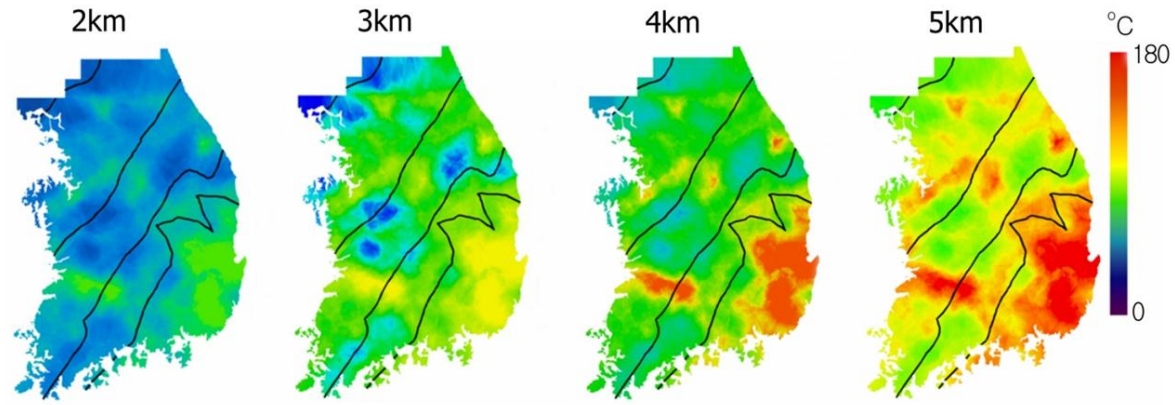

Figure 1. Estimated temperature distribution in South Korea at various depths (Lee et al., 2010). Note high temperature estimated on the south-eastern part of Korean Peninsula, where Pohang is located.

Figure 2 shows the geologic map and a 3-D geological model of Pohang area based on the geological survey and drilling results of 4 wells from Heunghae basin. The area belongs to Tertiary Pohang Basin overlying Cretaceous sedimentary rocks, biotite-granite intrusion and Eocene volcanic such as tuff. Heunghae basin, main target of the geothermal exploration, is covered with Quaternary alluvium underlain by these thick Tertiary sediments, which is quite uncommon in Korea. A thick quaternary semi-consolidate mudstone (S-MS) covers the area, thickness of which varies from more than 400 m at the south to about 200 m at the north. The layer is getting thinker to the south. Beneath the S-MS, a cretaceous sedimentary layer of sandstone and mudstone with volcanic intrusions or eruptions are underlain with about 1,000 m thick. Then andesic volcanic breccia layer is followed, and finally Paleozoic granodiolite forms the basement. Age dating of the granodiolite results in 268±4 Ma.

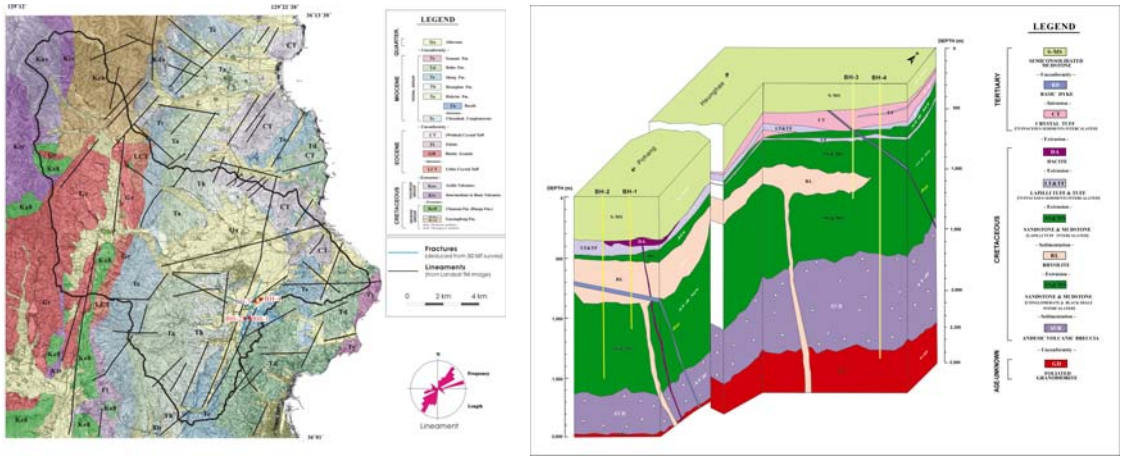

Figure 2. Geologic map with lineament distribution deduced from Landsat TM image analysis of target area(left), and a 3-D view of geological model of Heunghae basin deduced from core and well logs for 4 wells drilled from the Pohang project (Lee et al., 2007; Song et al., 2006b).

The well (BH-4) is started to be drilled on September 2005 and reached down to 2.385 km depth on November, 2006. The well is vertical starting with 16 inch diameter and ending with 6 and half inches. Drilling logs and well logging results shows that there are lots of fractured zones at various depths. From the temperature log that was obtained in 2006, right after the drilling, geothermal gradient for BH-4 is about 31 ^{o}C /km and thus bottom temperature was estimated over 90 ^{o}C (left of Figure 3). The temperature profile is surely disturbed by the drilling. Temperature profile measured in 2010 showed 91 ^{o}C in 2 km depth, and even higher temperature can be expected at the bottom (2.385 km).

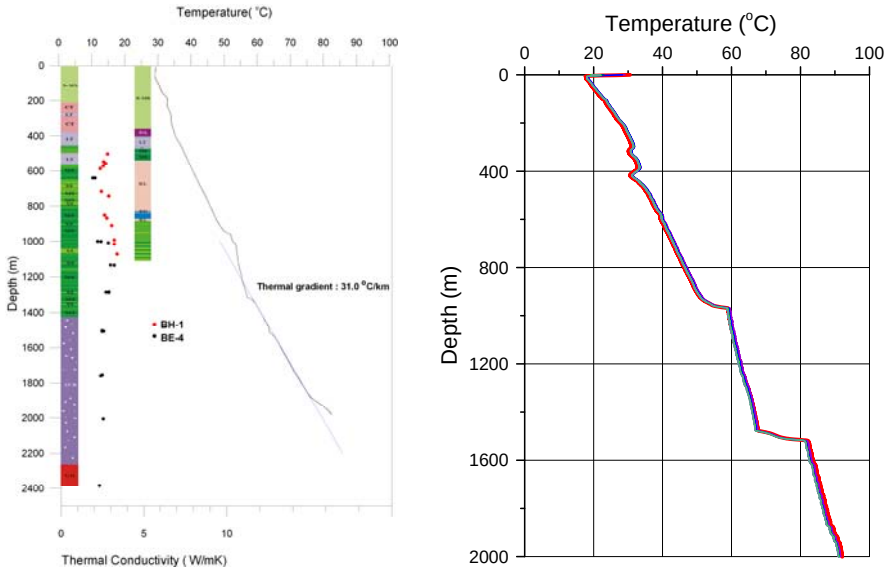

Figure 3. Geological column, thermal conductivity, and temperature logs for two wells (YR 2006) and temperature monitoring for BH-4(YR 2010). Note the temperature at 2 km depth of BH-4 of about 91 °C in 2010.

3. The Korean EGS project

The first proof of concept project for geothermal power generation by enhanced geothermal system (EGS) in Pohang, Korea has been started in Dec. 2010. The project aims to construct a MW scale geothermal power plant (GPP) in 5 years within 5 km depth of the site. Nexgeo Inc. as a project manager leads the project with institutes (KIGAM and Korea Institute of Construction Technology (KICT)), university (Seoul National University (SNU)), and industry (POSCO, Innogeo Tech. Inc.) participations. A total budget for the project is assumed to 43.8 Million US dollar, 18.5 million from the government and 25.3 million from the industry.

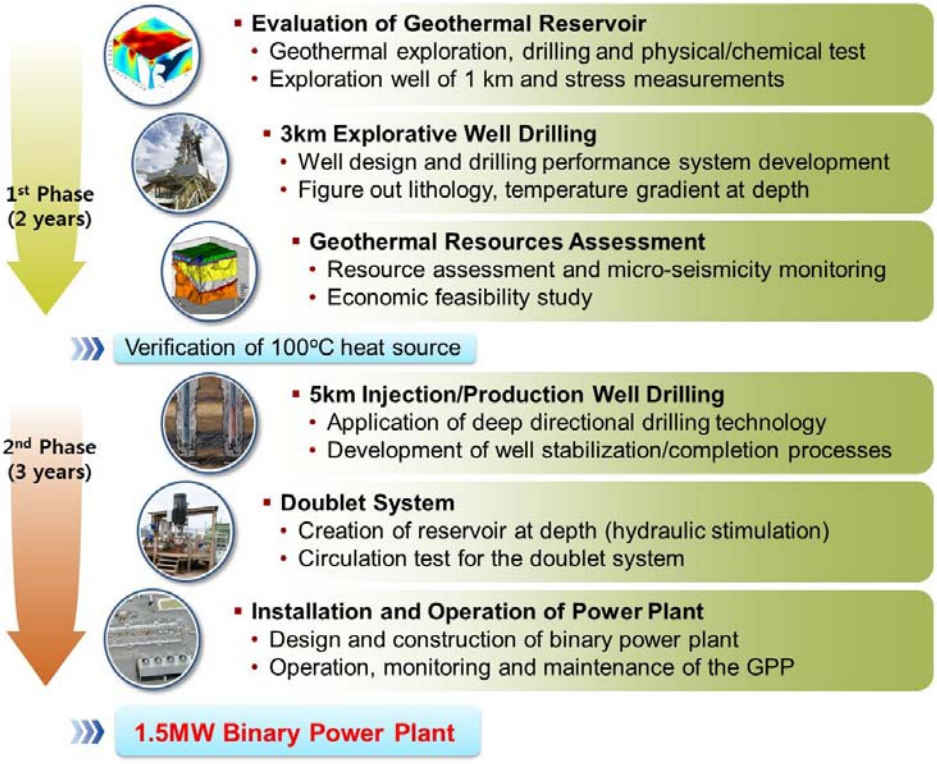

Figure 4. Master plan of the Korean EGS project.

The 5-year project is divided into two phases (Figure 4). At the first phase (2010-2012), various geothermal exploration will be conducted including geological/geophysical investigation of the target area, two exploration wells of 1 km and 3 km depths, thermal property measurements of the rock and core samples, well logging and stress field measurements, monitoring of micro-seismicity during drilling, and finally geothermal resource assessment of the site. The goal of the first phase is to confirm the temperature higher than 100 ^{o}C, and to estimate the amount of energy that can be extracted by EGS at the site selected from 5 km depth. Reaching the first goal is not necessarily very difficult because we have already observed temperature higher than 90 ^{o}C at the site. But care must be taken for 3 km drilling, because BH-4 (2.383 km) is the deepest well that has ever drilled by drilling technology in Korea. The second phase (2012-2015), will be devoted to complete a doublet system of 5 km depth including deep drilling, hydraulic stimulation, circulation test and eventually to construct a binary GPP of MW scale.

4. Discussions

In the first year of the project, most of time has been devoted to select the appropriate site for EGS within the area. Site selection is not an easy work because of various regulations and restrictions related to the agriculture, protection of green area, residential area and so forth. Despite the difficulty, thanks to the support from the local government, a pilot site is about to be fixed. An exploration well is being drilled about 1 km south of BH-4 for coring and stress measurement of the site, and it will be used as a monitoring well for micro-seismicity. Instruments for micro-seismic monitoring will be installed this year within about 5 km radius from the site. Drilling for 3 km well will start in the spring of next year. Because Korea does not have enough experience in deep drilling and stimulation of 5 km depth as well as binary power generation, comments and participations of international experts will be appreciated and mostly welcome.

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