Significance and Methodology of Geothermal Resource Potential Survey in Japan

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Keywords: *Geothermal, JOGMEC, Resource Potential Survey, Airborne Geophysical Survey, AGG, HTEM, Heat-flow Drilling, Corling,*

ABSTRACT

While Japan is blessed with high geothermal energy potential, many areas remain unsurveyed due to the mountainous landscape of Japan and the environmental regulation regarding national parks. In these areas, Japan Oil, Gas and Metals National Corporation (JOGMEC) conducts airborne geophysical surveys (gravity, electromagnetic, magnetic) and heat-flow drilling surveys in order to understand the geological structure. The data obtained through these surveys is provided to geothermal resource developers as well as local governments in order to reduce exploration risks and promote their further survey for geothermal resource development.

In addition to these surveys, from this year, JOGMEC starts implementing surface geophysical surveys (gravity, magnetotelluric) and deeper drilling survey for identifying geothermal fluids in order to acquire more detailed subsurface information. By conducting these surveys, JOGMEC hope to reduce the exploration risk and contribute to the further geothermal resource development.

1. INTRODUCTION

The Japanese Government has positioned geothermal power generation as a baseload resource for its stability of the generation at low cost. The target of the installation is to triple its installed capacity, reaching 1,500 MW by 2030. However, the progress has been very slow due to the long lead time and exploration risk of geothermal energy. JOGMEC is taking various measures in order to promote the introduction of geothermal development.

Geothermal energy potential in Japan are mostly associated with Quaternary volcanoes thus are usually found in mountainous areas, which makes it difficult to access and investigate. In addition, approximately 80% of the geothermal energy potential in Japan are located in the national parks where surveys are restricted for the purpose of nature conservation. The airborne geophysical survey is an effective method to acquire data over a broad area without modification of the land surface (Tosha et al., 2016).

In such circumstances, JOGMEC conducts geothermal resource potential survey as an early stage survey of areas with high geothermal potential in order to reduce exploration risks and understand the geological structure. We adopt airborne geophysical surveys and heat-flow drilling surveys in our research. The purpose of this paper is to explain the methodology and significance of these surveys especially focusing on the heat-flow survey.

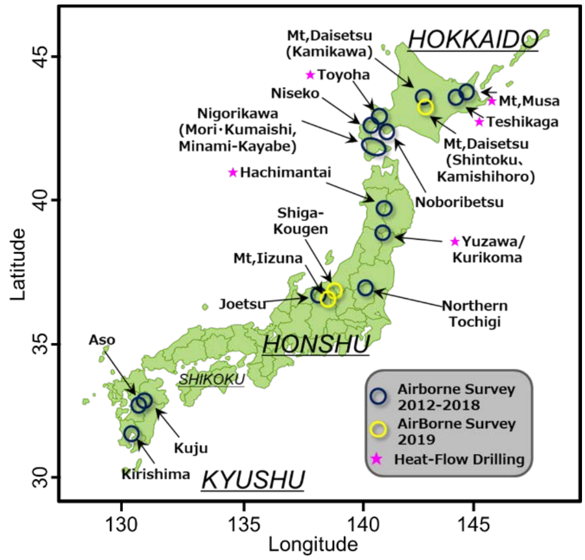

Figure 1: JOGMEC Geothermal Resource Potential Survey Project areas in Japan.

2. AIRBORNE GEOPHYSICAL SURBEYS

During the airborne geophysical surveys, regional geological information is gathered in order to identify the geothermal energy potential signs such as calderas, faults and low resistivity zones through using AGG (Airborne Gravity Gradiometer) and HTEM (Helicopter Time-domain Electro-Magnetics) systems. Starting from 2012, these surveys took place in 17 areas in Japan, especially Kyushu, Tohoku and Hokkaido regions, and the survey results have been provided to more than 100 companies and local governments (as of February 2020). By using helicopters, JOGMEC established survey techniques which enabled gathering more detailed and more steady geological data compared to the conventional techniques without compromising and altering the land surface.

2.1 Method

These surveys measure gravitational gradients and resistivity. The airborne surveys using helicopters are advantageous for its lower flight attitude and slower flight speed than that of aircraft-based survey, enabling acquiring stronger signal as well as higher density of survey points. (Fig. 2). In the airborne surveys, a survey area of 300 to 500 km^2 where geothermal resources are expected should be selected initially. Then spatial filters should be applied to aerial gravity gradient data, resulting some filters revealing geological structures that match faults and fractures (Tosha et al. 2016).

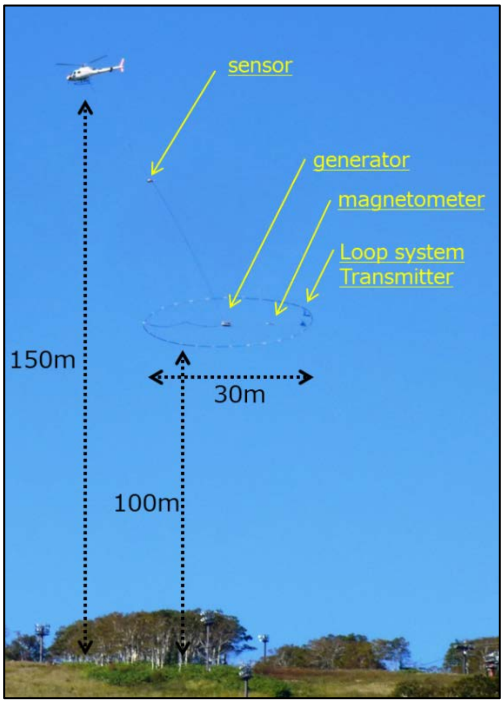

Figure 2: Airborne Geophysical surveys (HTEM).

2.2 Results

In 2016, the airborne geophysical survey was conducted in the Teshikaga region, located in the eastern part of Hokkaido. This survey covered an area of approximately 1,278 km^2 in the towns of Teshikaga, Shibecha, Nakashibetsu, Kiyosato and Koshimizu. A part of this area was designated as Special Protection Area of Akan-Mashu National Park. Several geothermal surveys had been carried out before and further geothermal resource potential is expected.

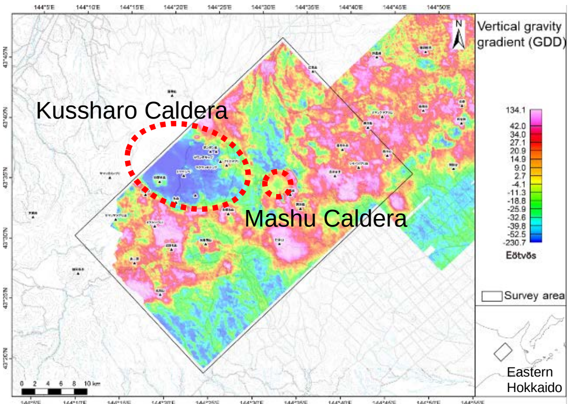

Figure 3: Maps of vertical gravity gradient (GDD) resulted from AGG.

The airborne gravity gradiometer survey provided detailed vertical gravity gradient anomaly distributions (Fig. 3). Vertical gravity anomalies illustrate a shallower density structure compared to normal gravity, and potential fault structures may have developed in the subsurface at this abrupt area. In order to pinpoint these areas, shape index and other factors were taken into account as well as the usual vertical gravity deviation, and linear structures and ring structures were extracted.

Many of the linear structures extracted were circular, reflecting calderas such as Kussharo and Mashu, or in the E-W to NW-SE direction, which was consistent and continuous with the regional stress field and the alignment direction of Quaternary volcanic rocks.

From the HTEM survey, we were able to obtain detailed shallow resistivity profiles (Fig. 4.). In this area, the low resistivity range (< 20-50 Ω-m) extend around Mt. Nita and Mt. Atusanupuri, etc. These low resistivity zones overlap with alteration zones reported in previous studies, however, most of them are distributed in places where alteration zones have not been identified so far.

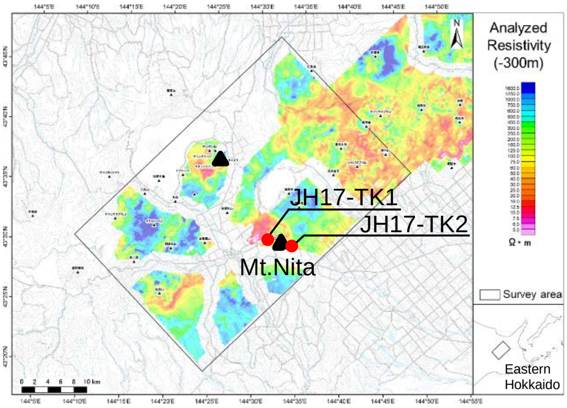

Figure 4: Maps of analyzed resistivity at the depth of 300m resulted from HTEM and boreholes of Heat-flow Drilling surveys.

These shallow low resistivity zones tend to extend along with the steepest part of the vertical gravity anomaly. Many of these low resistivity zones are believed to represent the potential hydrothermal alteration zones in the subsurface and are likely to be hydrothermal cap rocks.

Based on the characteristics of vertical gravity anomaly distribution and shallow low resistivity distribution, we selected the areas around Mt. Atusanupuri and Mt. Nita to be promising. Through this survey, we have decided to carry out the heat-flow drilling survey around Mt. Nita, one of the selected prospective site, after evaluating their prospects from various perspectives, based on the previous knowledge on the thermal structure and geothermal fluids as well as the field confirmation through the surface exploration.

3. HEAT-FLOW DRILLING SURVEYS

Airborne geophysical surveys show the subsurface structure, but it will not provide information on subsurface temperature. In order to complement this, heat-flow drilling surveys have been carried out to elucidate the subsurface thermal structure in areas where high geothermal resource potential was estimated through the airborne geophysical surveys previously, and geological information such as coring has been obtained together with temperature information.

12 boreholes have been drilled from 2017 to the present, and the temperature gradient data in the range of 7°C to 16°C/100 m was gathered. The results of the heat-flow drilling survey is to be released when the survey is complete. So far, the report of the survey in one area in Japan has been released, and the surveys of other areas will be released in due course.

3.1 Method

The heat-flow drilling survey is labeled as a part of the wide-area survey, thus its primary purpose is to contribute to the understanding of the thermal and geological structure of the target area. Nevertheless, when we determine the drilling point, we aim to get as close as possible to the geothermal potential of the target area based on the interpretation of airborne geophysical survey data and existing geological information. Since this survey does not involve the collection of geothermal fluids, no license is required under the Hot Springs Act.

The drilled holes are vertical boreholes with a drilling depth of about 500 to 1000 m, and all-core drilling is being performed by the wireline method. The Derrick height of this survey is 22 – 29 m and painted in colors that does not spoil the landscape. (Fig. 5.). The casing program is about three stages, and the core is generally taken for HQ and buried after the survey is finished.

Figure 5: Derrick for Heat-flow Drilling Surveys in Hokkaido region.

A geological columnar map of the sampled core is created by observing and recording the rock type, lithology, fracture development, hydrothermal alteration, presence or absence of hydrothermal and aerial mineral veins, presence or absence of clastic veins, relative strength of magnetism, etc., through visual observation and microscopic observation.

The fluid inclusions in the hydrothermal vein minerals will be observed by fluid inclusion tests to determine the temperature and salinity of the inclusions in the survey area, and the inclusion status (primary, secondary, pseudo-secondary, etc.) and type (liquid single phase, gas-liquid two-phase, gas phase, multiphase, etc.) of the inclusions will be described in the columnar map, and the fluid temperature and salinity (NaCl equivalent) of the most recent inclusions will be estimated by measuring the homogenization temperature and depression of the freezing point.

Binding with these analyses, the samples will be age-determined and the rock mass classification will be compared with existing information to establish the geological stratigraphy of the boreholes. In addition, density, resistivity and uniaxial compressive strength will be measured as rock properties tests and the outcomes will be used to evaluate the results of airborne geophysical surveys.

In each stage of the casing program, electric and fracture logging will be conducted be sides the temperature logging layer. Once drilling reaches to the target depth, the temperature of the bottom hole is estimated using data from three temperature recovery tests at 24, 72 and 120 hours after the mud circulation is stopped.

3.2 Results

Based on the results of the aforementioned Airborne Geophysical Surveys in Teshikaga region, two boreholes (JH17-TK1 and JH17-TK2) were drilled in 2017 around Mt. Nita as Heat-flow Drilling surveys. Considering the surrounding geological conditions, the boreholes in JH17-TK1 and JH17-TK2 were set to 800 and 900 m, respectively.

The altered minerals in each well are described below. In the JH17-TK1 hole, smectite and illite/smectite mixed layer minerals are mainly due to secondary metamorphism and partly accompanied by pyrite, which is locally affected by hydrothermal alteration. On the other hand, in JH17-TK2, mainly smectite, chlorite and chlorite/smectite mixed layer minerals were found, and these altered minerals were accompanied by secondary quartz, magnetite, illite and zeolite minerals. Particularly below 460m, the magnetite is characterized by the formation of magnetite spots and veinlets.

The temperature profiles of both holes showed typical thermal conductivity, with maximum in-hole temperatures of 72.4°C (JH17-TK1: 800.8 m depth, Fig. 6.) and 75.4°C (JH17-TK2: 891.1 m depth Fig. 7.) and geothermal gradients of 7-8°C/100 m. The fluid inclusions test showed that the homogenization temperatures in the JH17-TK1 were 118-183°C and JH17-TK2 were 243-284°C, and the higher temperatures in JH17-TK2 than in JH17-TK1 are consistent with the occurrence of altered minerals.

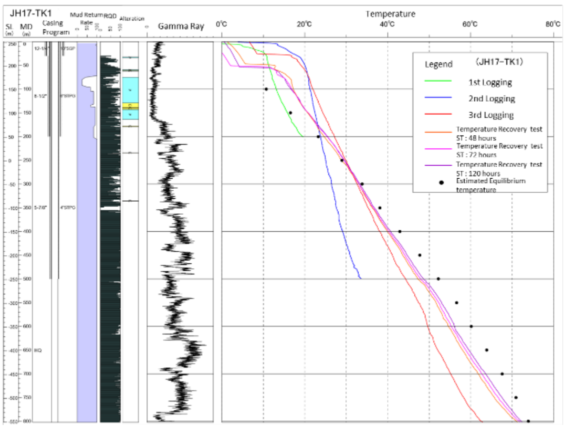

Figure 6: Temperature profile of JH17-TK1.

Proceedings 42nd New Zealand Geothermal Workshop
24-26 November 2020
Waitangi, New Zealand
ISSN 2703-4275

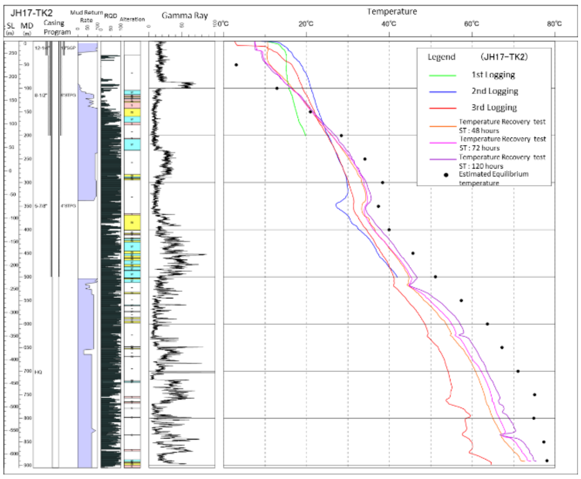

Figure 7: Temperature profile of JH17-TK2.

Low resistivity anomalies extracted by the Airborne Geophysical Surveys are considered to correspond to alteration of smectite and chlorite, which are widely observed in the shallow part of both holes. However, volcanic rocks and pyroclastic flow sediments identified in the upper part of the survey area also generally show low resistivity, so it cannot be attributed to alteration.

If you need more detail data, please contact us.

4. CONCLUSION

As stated above, JOGMEC will continue to carry out geothermal resource potential surveys in areas with high potential in order to reduce the initial survey risk of geothermal resources.

In addition to these surveys mentioned above, from 2020, JOGMEC starts implementing surface geophysical surveys (gravity, magnetotelluric) and deeper drilling survey for identifying geothermal fluids in order to acquire more detailed subsurface information. We hope that our initiatives will contribute to the promotion of geothermal resource development in Japan and the stable supply of energy.

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