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Airborne Survey by a Helicopter for Evaluation of Geothermal Resources

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ABSTRACT

Airborne gravity gradiometer surveys were conducted in the Kuju and Kirishima areas, in the western part of Japan, for acquisition of basic data for the evaluation of geothermal potential in 2013. Total line length is 2340 km in the Kuju area and 518 km in the Kirishima area. Detailed geological structure was identified with these data. This report presents a summary of these airborne surveys.

1. INTRODUCTION

The Japan Oil, Gas and Metals National Corporation (JOGMEC) was established in February 2004, which integrates the functions of the former Japan National Oil Corporation and the former Metal Mining Agency of Japan.

Our main function is to secure a stable supply of oil and natural gas, ensure a stable supply of nonferrous metal and mineral resources, and to implement mine pollution control measures. However, new functions were added to the JOGMEC in September 2012, which seek to encourage the development of geothermal resources and to contribute to the stable supply of coal to Japan.

JOGMEC supports the smooth development of geothermal resources in Japan by providing assistance to geological, geophysical, and well-drilling surveys, equity capital or liability guarantees, and information and data on geothermal resources. In addition to these supports, JOGMEC started R&D programs of geothermal reservoir exploration techniques and evaluation & management strategies in 2013. This presentation introduces the airborne survey as provision of data on geothermal resources.

We conducted airborne geophysical surveys which aim to acquire basic data for the evaluation of geothermal resources in order to promote geothermal development. Most geothermal resources are distributed in mountainous areas or within national parks, where it is difficult to gain access. In fact, about 80% of the geothermal resources in Japan are presently located in the natural parks. The airborne geophysical survey is an effective method to acquire data over a broad area without modification of the land surface. In this paper, we introduce the result of the airborne gravity gradiometer survey in the Kuju and Kirishima areas that was performed in 2013.

2. AIRBORNE GRAVITY GRADIOMETER SURVEY

The gravity gradiometer survey method measures the spatial variation of the gravitational acceleration. It is possible to measure the gravity with high resolution compared with conventional gravity surveys, which measure only in the vertical direction (Figure 1, from the website of Fugro Airborne Surveys). As shown in Figure 2, spatial variation of the xyz-axes component of a gravity vector G is represented by the nine tensor components. The tensor is symmetric (Tij = Tji) which indicates that there are six independent components. Using the Laplace equation (Txx + Tyy + Tzz = 0), it is possible to determine an additional component. Therefore, there are only five independent components (Txx, Txy, Txz, Tyy, and Tyz). If these five are measured, it is possible to uniquely determine the remaining components. The gravity gradiometer survey method is capable of measuring these five separate components.

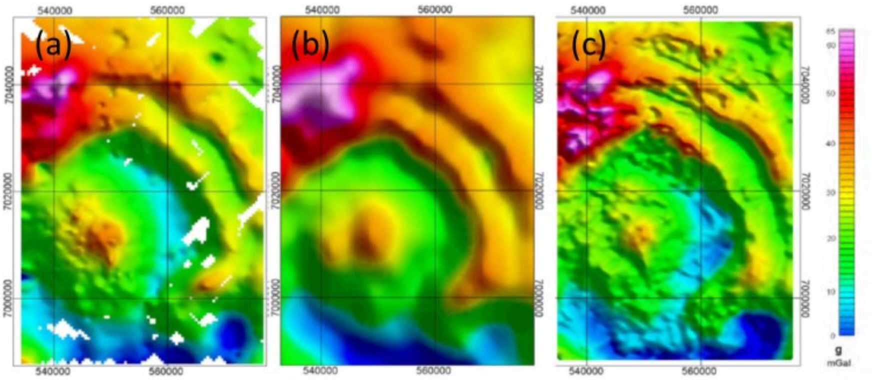

Figure 1: Comparison of three gravity survey data. (a) Grand gravity survey. (b) Conventional airborne gravity survey. (c) Airborne gravity gradiometer.(http://www.fugroairborne.com/).

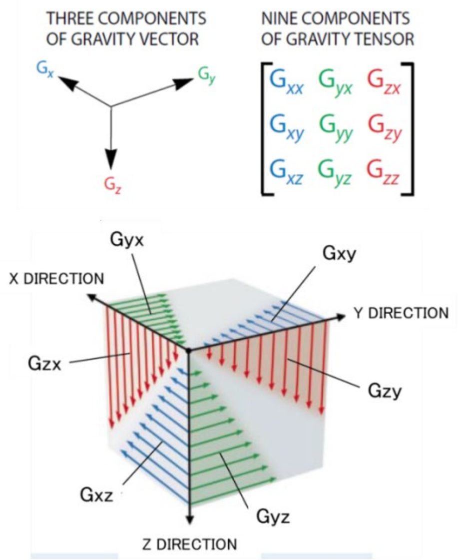

Figure 2: Gravity tensor (http://www.bellgeospace.com/).

The airborne gravity survey that was conducted was carried out by a helicopter equipped with a gravity gradiometer Falcon (Figures 3 and 4). Work efficiency is lowered as compared to fixed-wing aircraft survey, but can be expected to provide detailed distribution by gravity navigation measurements at low speed and low altitude.

We carried out the airborne gravity gradiometry survey in two areas, Kuju and Kirishima, in 2013 (Figure 3). The acquired line length was 2,340 km in the Kuju Area and 518 km in the Kirishima Area. These data are processed and interpreted with other geological and geophysical data to evaluate the geothermal potential.

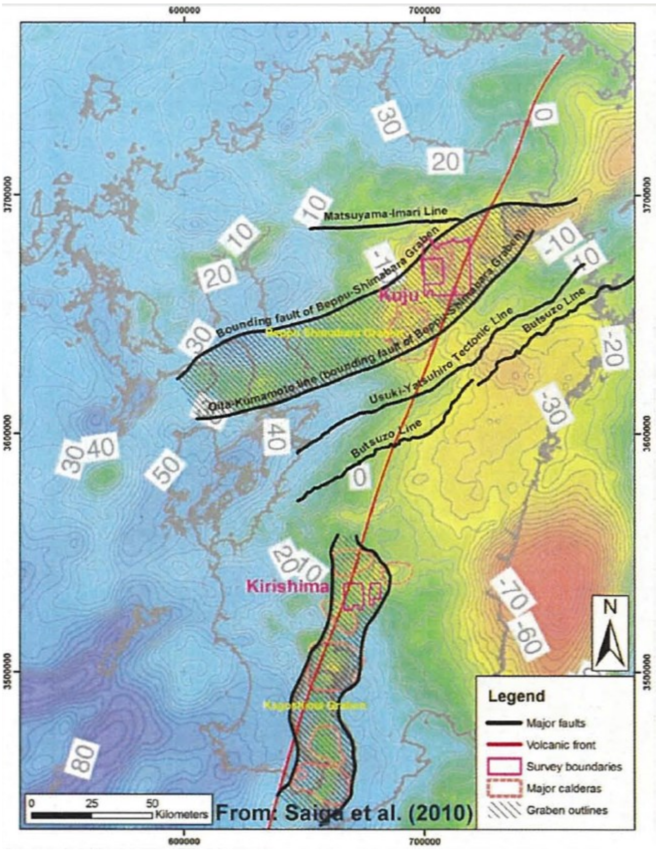

Figure 3. Survey areas with major tectonic elements (after Saiga et al., 2010).

3.DATA INTERPRETATION

In this section an interpretation is presented, however, detailed work with other data is still underway.

3.1 Kuju Area

The Kuju Area is located in the northern part of Kyushu (Figure 3), and part of the Beppu-Shimabara Graben which is major NE-SW tectonic structure. The tectonic structure of the Kuju Area is highly fragmented, which can be attributed to the poly phase tectonic activity.

The most prominent and continuous fault structures mapped from the gravity gradiometer data in the area are NW-SE trending (Figure 4). Another important set of faults, mostly located in the south of the survey area, is roughly ENE-WSW trending. This set seems to be slightly sigmoidal in map view, changing from more EW orientation in the west to ENE-WSW in the east.

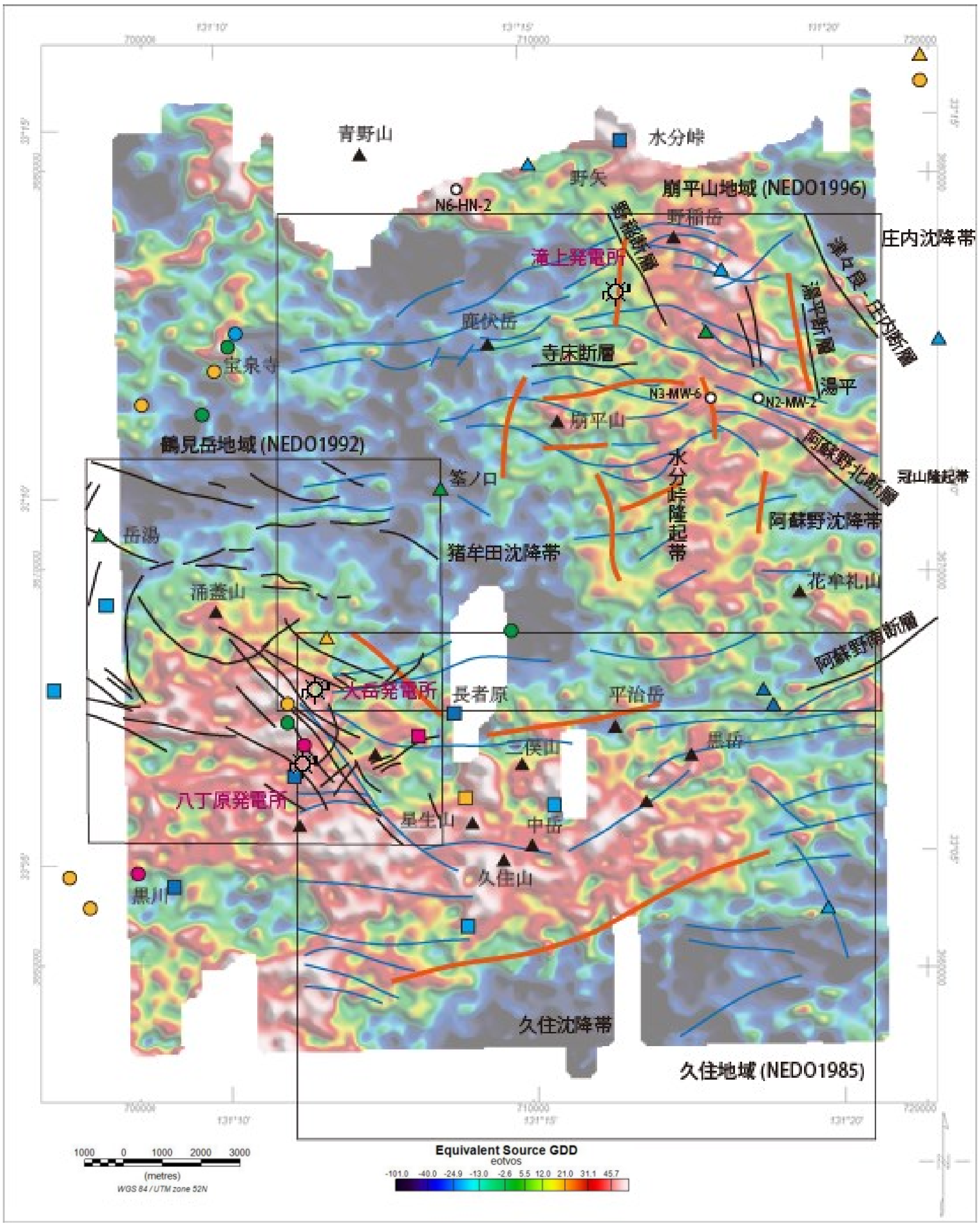

Figure 4. GDD and structural interpretation map in the Kuju Area. GDD shows airborne gravity gradient with equivalent source.

In the northeastern part of the area, anastomosing E-W trending faults are abundant. In the area of the Shishimuta Caldera some subtle curved structures were mapped. These are interpreted as caldera ring fissures. Some structures in a radial configuration with respect to these ring fractures could also be formed during the formation of the caldera. These have been attributed as caldera ring fissures. Some of those fissures have orientations sub-parallel to the curvilinear E-W trending faults, which suggests they may have been reactivated. Kamata (1989) mentions that fewer normal faults and shallow micro-earthquakes occur inside the caldera and attributes this to the structurally incoherent character of the rocks beneath the caldera.

To interpret and gain understanding of the fault kinematics within the survey area, the regional fault structure was interpreted from the available datasets. Figure 5 shows this tentative interpretation of the regional structure of the Hohi Volcanic Zone. The Hohi

Volcanic Zone appears to be a pull-apart structure along sigmoidal dextral transtensional faults that link the Matsuyama-Imari Line with the Oita-Kumamoto Line, the southern boundary fault of the Beppu-Shimabara Graben. The northern part of the Kuju survey area is situated in an E-W corridor of strike-slip faulting. The southwest part of the survey area is dominated by the NW trending dextral transtensional faults, which are sigmoidal and merge into the Oita-Kumamoto Line. The light grey faults in the south of the Kuju survey area, also visible in Figure 5, have been interpreted as normal faults that accommodate some of the differences in lateral displacement between the NW trending transtensional faults, essentially forming a pull-apart graben which contains the Waita and Kuju volcanic complexes. These normal faults might originally have been formed as dextral transtensional faults, similar to the E trending faults north of the Aso Caldera. Within the Kuju area it is clearly visible that they are now offset by the NW trending dextral transtensional faults. The location of the volcanic activity is controlled by the location of the volcanic front, but on a smaller scale also controlled by the location of the active faults and dilatational strain. In the Kuju survey area the shift of volcanic activity from the Waita volcanic complex to the Kuju volcanic complex seems structurally controlled, whereby the intersection of the pull-apart structure (with dilational strain) with the volcanic front is a determining factor.

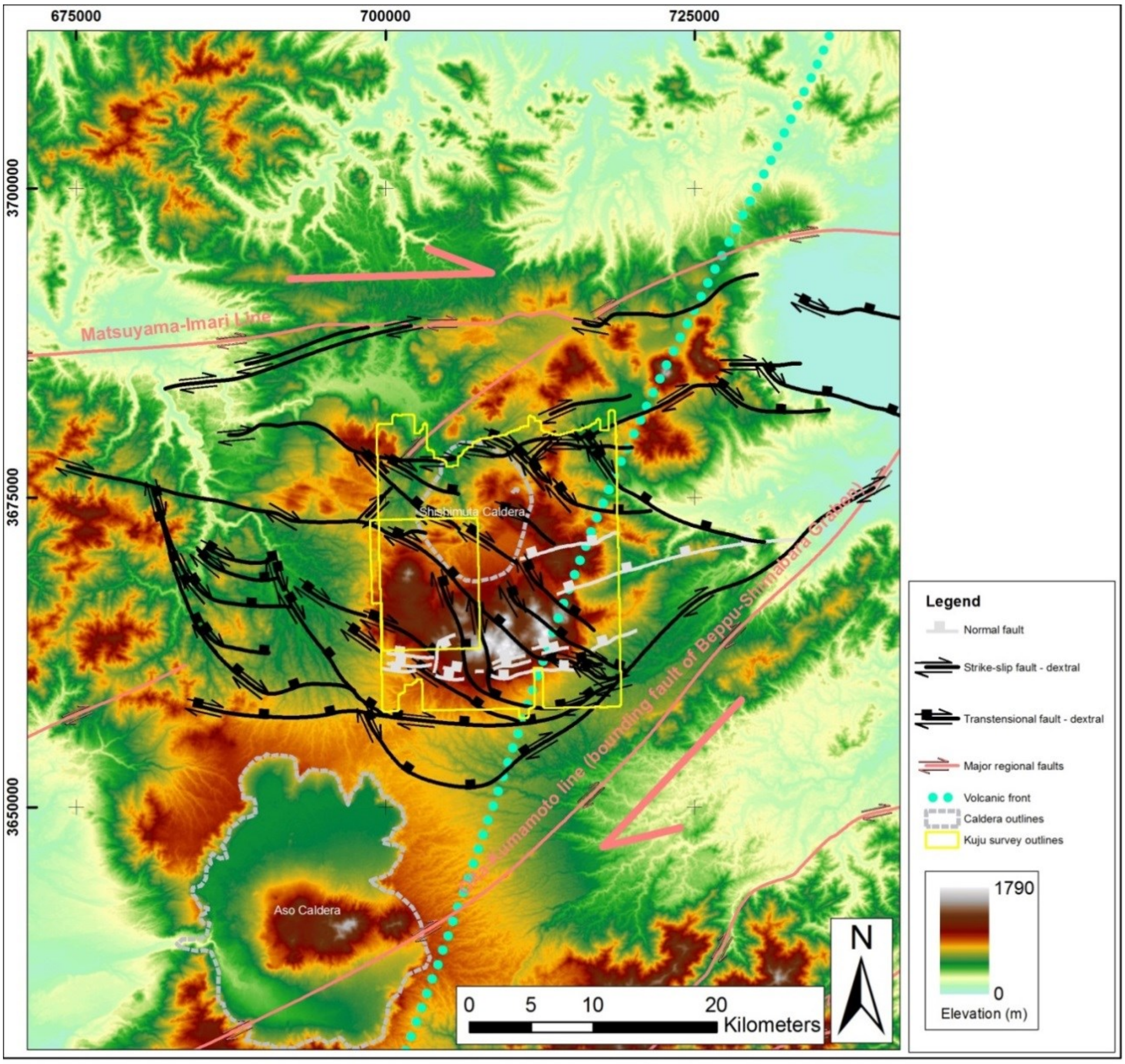

Figure 5. Regional fault interpretation of the northern part of Kyushu.

3.2 Kirishima Area

Figure 6 shows the GDD in the Kirishima Area. Structures are grouped according to their orientation and kinematics.

Several NNW-SSE striking corridors with a low gravity response were identified in the gravity gradiometer data (Figure 7). Boundaries are undulated and these irregularities are interpreted as primary as well as fault-related features. The offsets along faults cross-cutting multiple corridors diminish eastward. A couple of ENE-WSW striking corridors with a low gravity response were identified.

Faults with ENE-WSW orientations were interpreted as normal-sinistral faults (transtentional). Faults with ESE-WNW orientations were also interpreted as normal-sinistral faults (transtentional). These predominant normal components are interpreted from literature (Goko, 2000).

As a result of the interpreted orientations of ENE-WSW and ESE-WNW structures the central part of the survey area is interpreted as a horst-like feature with an ENE-WSW strike.

Faults with NE-SW orientations were interpreted as normal-dextral faults (transtentional). The predominant normal component is interpreted from literature (Goko, 2000). The minor dextral component was observed as offsets of volcanic corridors and interpreted lava flows.

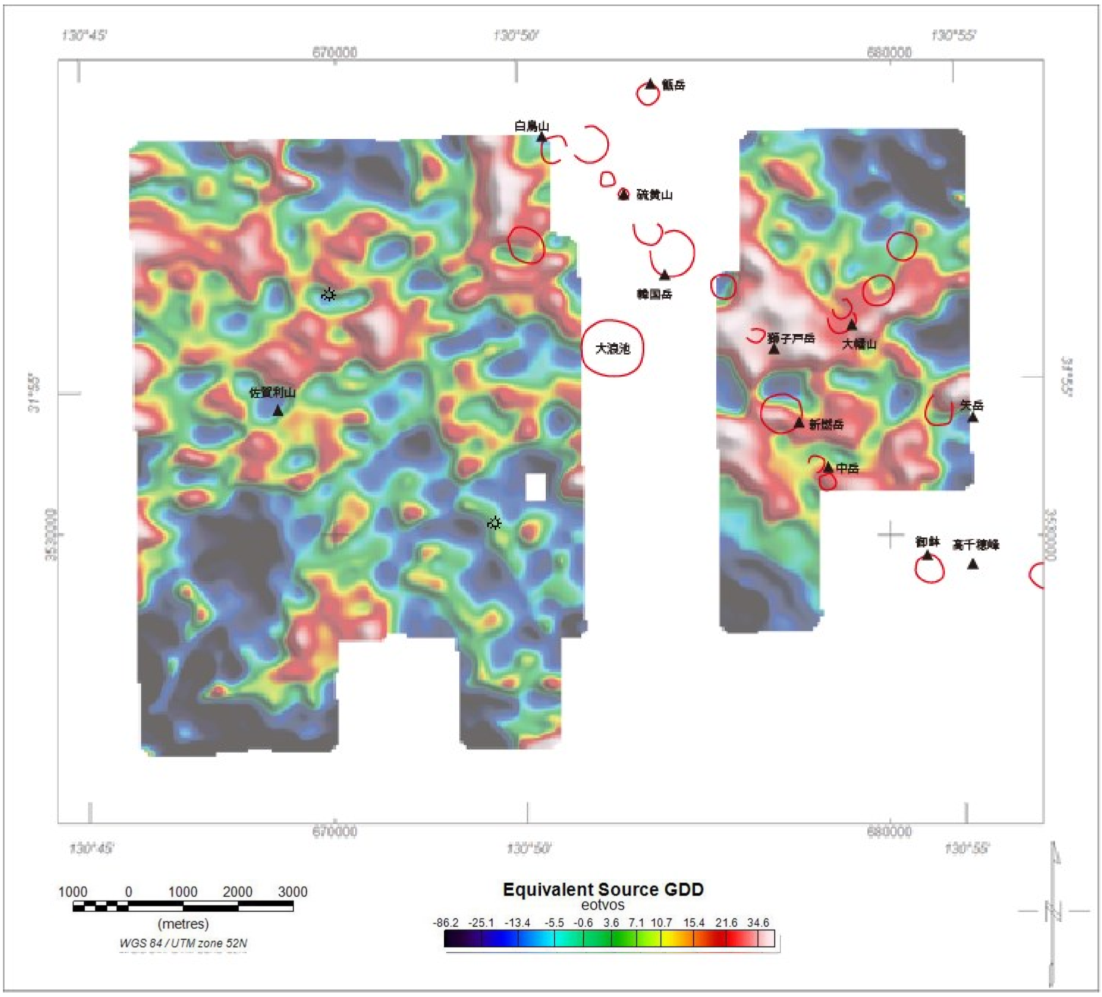

Figure 6. GDD Map of the Kirishima Area. GDD shows airborne gravity gradient with equivalent source.

4. FUTURE SURVEYS

It is necessary to modify the application to relevant authorities in accordance with the equipment mounted to the aircraft and to fly with low altitude, and to negotiate with the local government and/or community of the survey area.

From the viewpoint of environmental protection, consideration should be given to the ecosystem of rare and endangered species. We have to conduct the airborne survey in the season when the impact on the ecosystem of the study area is the smallest.

We carried out only the airborne gravity gradiometer survey, however, we also intend to conduct the airborne time-domain electromagnetic survey in the Kuju and Kirishima areas. By conducting airborne gravity gradiometer survey and airborne electromagnetic survey to provide basic data for evaluation of the geothermal potential in other areas will lead to the promotion of geothermal development.

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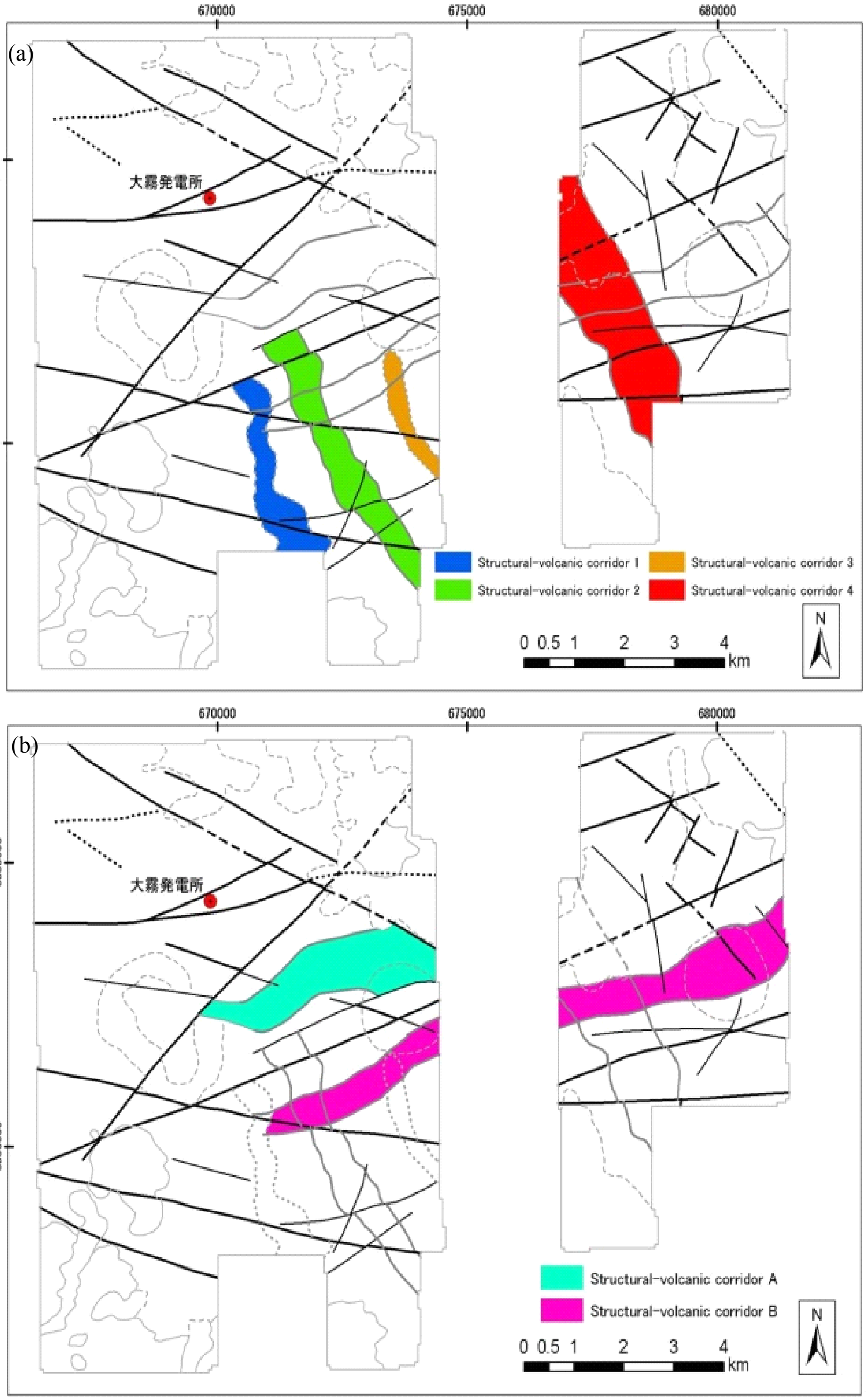

Figure 7. Interpretation Map of the Kirishima Area, (a) ENE-WSW structure with a low gravity response, (b) NNW-SSE structure with a low gravity response.