GEOLOGIC MODEL OF THE GINYU RESERVOIR IN THE KIRISHIMA GEOTHERMAL FIELD, SOUTHERN KYUSHU, JAPAN

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ABSTRACT

The Ginyu area is one of the active geothermal zones in the Kirishima geothermal area. The Ginyu fault running through the center of the Ginyu area, which is the target of the geothermal development, provides a high angle passage for the geothermal fluids moving from the deep reservoir, which means that the reservoir of the Ginyu area is the typical fracture type. The features of the Ginyu fault reservoir are summarized as follows. 1)Direction of the fault; ENE-WSW strike, dipping steeply NW. 2)Width of the fault; all of the penetrated point are projected to a width of about 150m . 3)Character of the cuttings collected from the fault zone by drilling; formed by highly altered rocks mainly composed of quartz, wairakite, and adularia. It is assumed that most of the geothermal fluids are derived from meteoric water around the Kirishima area. Descending water has percolated downward along cracks and circulated to the base rock of the Shimanto group, becoming heated and flowing up through the fault-fissure system and then restored in the volcanic rocks and lacustrine sediments of the Quarternary period.

INTRODUCTION

The Kirishima geothermal area, generally ranging in altitude from 800m to 1000m, is located on the southwestern slope of the Kirishima volcano in Kagoshima Prefecture. Exploration of the Kirishima geothermal area was commenced in 1972 with surficial geological surveys, electric soundings, heat measurement surveys and 30m deep heat holes by Nittetu Mining Company(NMC). Following the results obtained, 21 exploratory wells of about 1,000m to 2,000m in depth have been drilled by Nippon Steel Corporation(NSC) and NMC to the present time. At the same time, 15 exploratory wells were also drilled by the government. The accumulated data indicated that active geothermal resources are extensively distributed in this area. After 1985, the geothermal exploration has been focused on the Ginyu area which occupies a northern section of the Kirishima area, covering an area of approximately 1km by 2km. The exploratory wells drilled at the Ginyu area confirmed the existence of a dominant geothermal reservoir. Also, based on the investigation, geological and geothermal structures of the Ginyu area in the Kirishima area have been revealed.

GENERAL GEOLOGY

The Kirishima geothermal area is situated in a volcanic-tectonic depression, the Kagoshima graben which was proposed by Tsuyuki(1969). This graben is a marginal basin and a back-arc depression at the western extension of the Ryukyu subduction system. In the vicinity of the Kirishima volcano, especially on the western flank, surface manifestations such as fumaroles, hot springs, and altered zones are widely developed. The geologial map of the investigated area is shown in fig.1. Vigorous volcanic activity took place in the Pleistocene epoch and has continued until the present, depositing a thick pile of volcanic rocks, such as andesitic lava

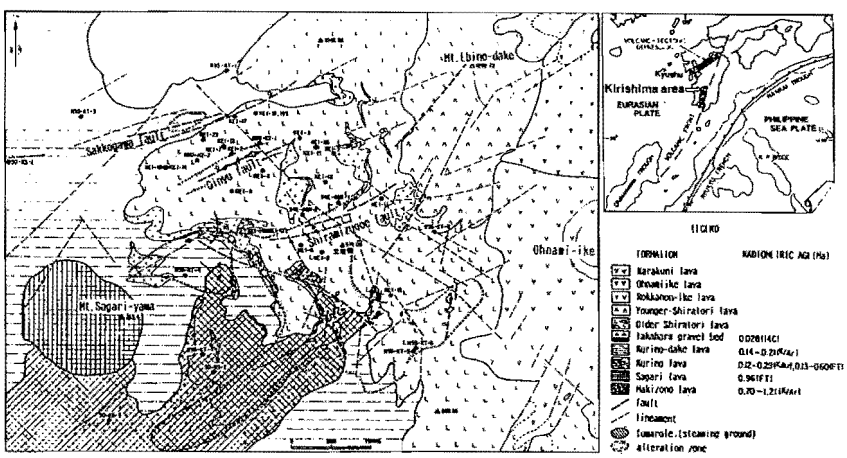

Fig. 1 Geological map of the Kirishima geothermal area.

flows and pyroclastics with minor lake deposits, reaching 2,000 meters and more in thickness in the area. These volcanic rocks overlie the Pre-Neogene basement rock of the Shimanto group. The Shimanto group is the basement of the Kirishima area, which crops out at the southeastern end of the Kirishima volcano. This group is highly decomposed, mainly consisting of sandstone and shale. This group was first encountered in well N56-KT-7 at a depth of -1,070m, drilled by the government. A correlation between the outcroping of the Shimanto group (300 ~400m above sea level) and exploratory well N56-KT-7(-1,070m below sea level) indicates that the basement of the Kirishima geothermal field is depressed to a depth of more than 1,300m.

FRACTURE SYSTEM

Most of the lineaments found in this area run in a direction of NW-SE and ENE-WSW(Fig.2). The NW-SE direction is the same as that of longer axis of the Kirishima volcano. Most of the younger craters and parasitic cones are arranged in parallel with the longer axis. On the other hand, thermal manifestations are aligned along the direction of ENE-WSW. The features described above suggest that the Kirishima geothermal area is controlled by a system of faults and fractures oriented along two main directions; NW-SE and ENE-WSW. Surface investigation and exploratory wells recognized the existence of several faults. The principal fault systems which we have named are as follows; 1)The Sakkogawa fault; ENE-WSW strike, dipping to NW. 2)The Ginyu fault; ENE-WSW strike, dipping to NW. 3)The Ginyu subfault; ENE-WSW strike, dipping to SE. 4)The Shiramizugoe fault; ENE-WSW strike, dipping to SE. Of which the recognized fault, The Ginyu subfault is a buried one intercepted by well KE1-4.

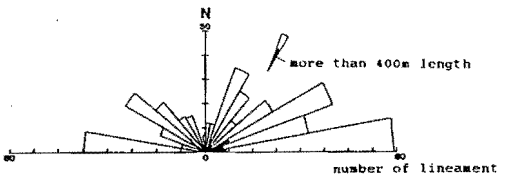

Fig. 2 Distribution of lineaments from large scale air photograph.

HYDROTHERMAL ALTERATION

Many markedly altered zones, such as Sakko-gawa, Ginyu, Ohra, Kinyu, Shiramizugoe, Yunoike, Torijigoku, Yamanjou, and Tearai, formed by geothermal fluid, are distributed on the surface of the Kirishima area. Until now the fumarolic activity has continued within these altered zones except in the Sakko-gawa zone. Generally, these zones are aligned along the fault systems of ENE-WSW and NW-SE. Each altered zone shows zonal arrangement with kaolin-quartz zone, kaolin-cristobalite zone, and montmorillonite zone from the interior to outside. The subsurface alteration taken from the information of the exploratory wells is classified into 4 subzones on the basis of its clay mineral assemblages; montmorillonite-interstratified clay mineral-chlorite and/or sericite. The chlorite-sericite zone occurs in the deeper part of the well with increasing temperature. The upper level of the crystallization of quartz and wairakite coincides with the present isotherms of 100 ~180 ℃ and 190 ~240 ℃ respectively, which suggests that the hydrothermal system in the Kirishima area is now active .

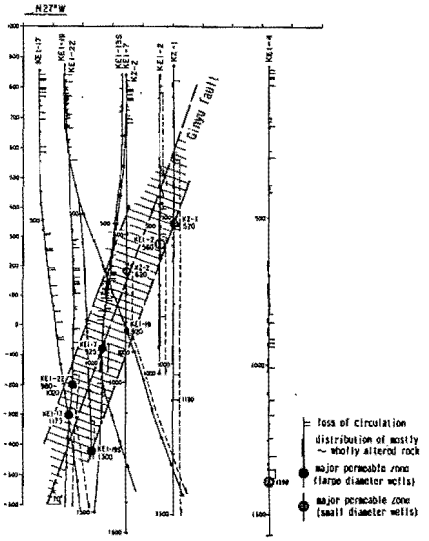

Fig. 3 The intercepted poinsts of wells at the Ginyu fault (projection to N27 °W strike cross section).

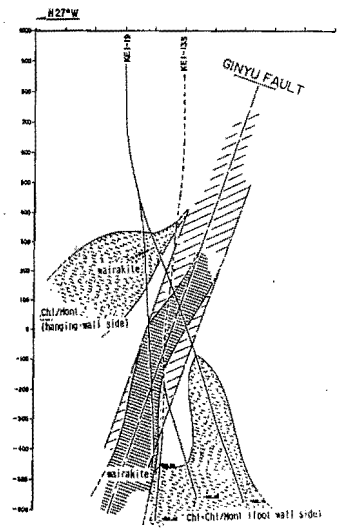

Fig. 5 Subsurface distribution of wairakite and chlorite/montmorillonite mixed layer mineral

IMPERMEABLE ZONE

It is worth noting that the impermeable zone which makes a role of cap rock has developed in the entire area investigated. The impermeable zone is produced by self-sealing, mostly caused by the deposition of clay minerals, zeolites, calcite, and other minerals. The impermeable zone around the Ginyu fault has a width of 200m to 400m vertically, coinciding with a temperature of 100 ~200 ℃, and covering the Ginyu fault reservoir convexly. In the eastern part of the Ginyu area, the impermeable zone develops horizontally with a width of 400m~500m and prevents meteoric water from percolating to any significant depth. The development of the thick impermeable zone is one of the reasons that active geothermal resources are extensively developed in the Kirishima area.

SUBSURFACE FEATURES OF THE GINYU FAULT

The surface trace of the Ginyu fault has a general strike of N63°E, So, the intercepted points of the Ginyu fault are projected at the N27°W strike cross section. According to the fig.3, all of the points of the Ginyu fault intercepted by wells are restricted to a width of about 150m.

The first small diameter well KE1-2 located in the Ginyu fault zone, with a depth of 1,000m, penetrated a high permeable zone at 560m , and has a production rate of 15t/hour of geothermal fluids, about 70% of which is steam and remaining 30% is water. Strongly altered cores that are found at around 560m, are corroborative evidence of a tension fault. The mineral assemblage of cores at around 560m, which is mainly composed of quartz, wairakite and sericite, is presumed to intercept the Ginyu fault. The orientation of the hydrothermal vein at around 560m shows an ENE-WSW strike, dipping to NW steeply from the measuring thermoremnant magnetism of the cores (This method was firstly estblished by Hayashi and Furutani, 1982) The results obtained from KE1-2 enabled us to outline the shape of the Ginyu fault and led to the discovery of the Ginyu fault reservoir. Following the results of well KE1-2, wells KE1-7,17,19S,and 22, all with a large diameter, were drilled to the north of well KE1-2 to intercept the Ginyu fault at the deeper part and successfully penetrated through the high permeable zone at 925m,1,173m, 1300m and 1,000m respectively with a uniform temperature of around 232℃. The drilling results from well KE1-17, which is a typical exploratory well which intercepted the Ginyu fault reservoir, are shown in Fig.4. Judging from the drilling conditions, geological and geophysical logs, it is revealed that well KE1-17 presumably intercepted the Ginyu fault reservoir at 1,173m. The feature of the cuttings at around 1,173m is characterized by the highly silicified cuttings containing quartz, wairakite, adularia, and small amounts of epidote, prehnite, chlorite, and sericite. The temperature estimated by a fluid inclusion study indicated around 230℃, which corresponds with the temperature obtained from the temperature recovery tests.

All of the alteration minerals observed at the Ginyu fault zone are the neutral~faint alkaline type, promising the presence of a neutral~faint alkaline solution with a pH value. Medium rank hydrothermal alteration, which is characterized by the presence of chlorite-chlorite/montmorillonite interstratified mineral is found in the foot wall and hanging wall of the Ginyu fault, whereas high rank alteration minerals, characterized by chlorite-wairakite along the Ginyu fault, suggests that most of the ascending geothermal fluid is limited along the Ginyu fault(Fig.5).

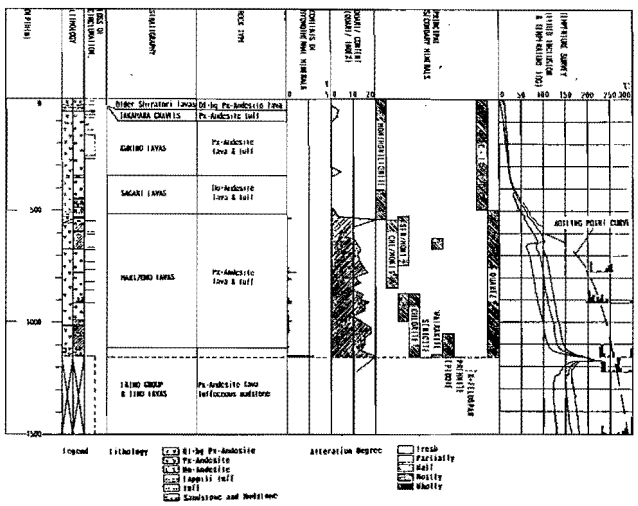

Fig. 4 Columnal section of well KE1-17

GEOLOGIC MODEL

Using such items as geological sections, electric and temperature logs, and drilling logs, from all the wells, we have developed the predominant geologic model shown in Fig.6. Features of the geothermal resources in the Kirishima geothermal area are of the typical fracture type. From north to south, several faults such as the Ginyu fault, the Ginyu subfault and the Shiramizugoe fault have been recognized. In the Sakkogawa fault zone, a number of lineaments were observed along the surface of the Sakkogawa fault, and ground isotherms decreased rapidly. So, the Sakkogawa fault is presumed to be a recharging zone. The maximum temperature encounted by drillings in the area increases from west to east, which is the same direction as toward the center of the Kirishima volcano. Accordingly, it is presumed that the present activity of the Kirishima geothermal area represents the post volcanic action of the Kirishima volcano which possibly extruded recently. In the Ginyu production area, the temperatures of the feed points show a uniform temperature of 232 ℃, which postulate the existence of a high permeable reservoir. It is assumed that most of the geothermal fluids are derived from meteoric water that falls within the Kirishima graben. The fluids have percorated downward along cracks, faults and through permeable volcanic rocks, and may finally circulate to the base rock of the Shimanto group (1-2km below sea level), becoming heated and migrate upward again through the fault-fissure systems and then be restored by the volcanic rocks and lacustrine sediments of the Quaternary period.

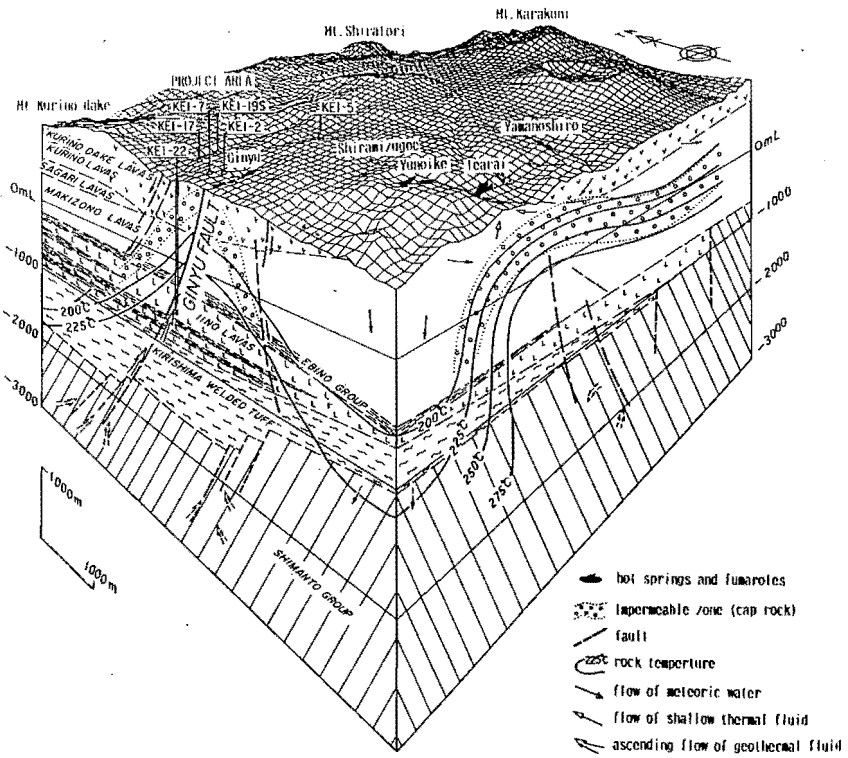

Fig. 6 Conceptial model of the Kirishima geothermal system (bird eyes view)

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