STEREOGRAPHY OF GEOLOGICAL AND GEOTHERMAL STRUCTURE

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INTRODUCTION

Geothermal energy is relatively clean. For this reason, it is one of the important energy resources for us, although the scale is not so large. The usable energy is stored generally as hydrothermal fluid occupying underground fractures and/or pores. This implies that it is the most important to know the 3-dimensional shape of the geological and geothermal structures for the exploration of it. Many geological and geothermal data collected during the exploration are analyzed by various procedures, and are displayed as geological and isotherm maps, and so on. Each map is always drawn on a 2-dimensional sheet. The 3-dimensional shape of the accurate structure is constructed only within the brain of the exploration engineer who treated most of data. If the other engineer wishes to know the 3-dimensional structure, he must spend a lot of time to understand the presented maps. On the contrary, if the engineer can use the suitable stereographic tool, he should easily understand the 3-dimensional structure.

A computer system for the stereography has been developed for the above purpose. The system possess functions necessary to observe interactively 3-dimensional geological and geothermal structures. That is, it can display quickly desirable figures from all directions. The application of this system to the Nishiyama geothermal filed is stated in the following chapters.

NISHIYAMA GEOTHERMAL FIELD

The Nishiyama geothermal field is located 30 km west of Lake Inawashiro, Fukushima, northeastern Japan (130°42'E and 37°27'N). The geology and geothermal structure is described by Nitta et al. (1987).

The geology consists mainly of Tertiary and Quarternary volcanic rocks. Any drilling has not cut the basement. The rock is considered, however, to be Pre-tertiary granitoid. The sedimentary rocks including lava and pyroclastics are divided into five formations. They are the Takizawagawa, Ogino and Urushikubo formations of Miocene age, the Fujitoge formation of Pliocene age, and the Quarternary Sunagohara formation.

The Takizawagawa formation consists mainly of rhyolitic pyroclastic rocks with intercalating rhyolitic lave flows. The Ogino formation also consists of mainly of rhyolitic pyroclastic rocks, and partially of andesitic to basaltic pyroclastics. The lowest horizon of this formation is characterized by a bed of black mudstone. This mudstone plays an important key to distinguish the Ogino formation from the Takizawagawa one. For this reason, the bed is particularly named as the Miyashita mudstone. Urushikubo formation is lithologically various in

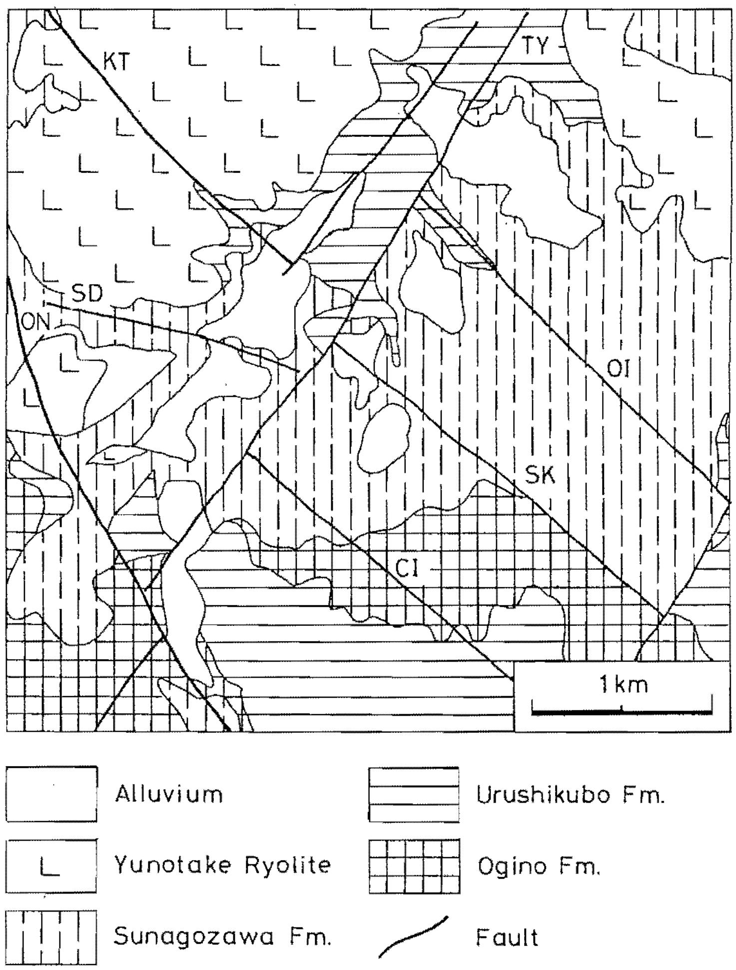

Fig. 1. Geological map of the Nishiyama geothermal field (simplified from Nitta et al., 1987). Abbreviations of faults: CI=Chinoikezawa, KT=Kitanosawa, ON=Onogawara, OI=Oizawa, SD=Sudarezawa, SK=Sarukurazawa, TY=Takiyagawa.

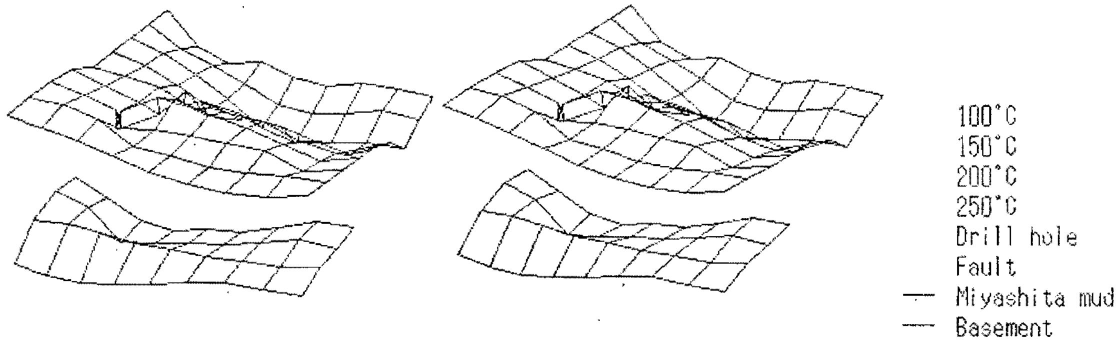

Fig. 2. A stereoimage pair of the surfaces of the basement and Miyashita mudstone. The north is rightbackward.

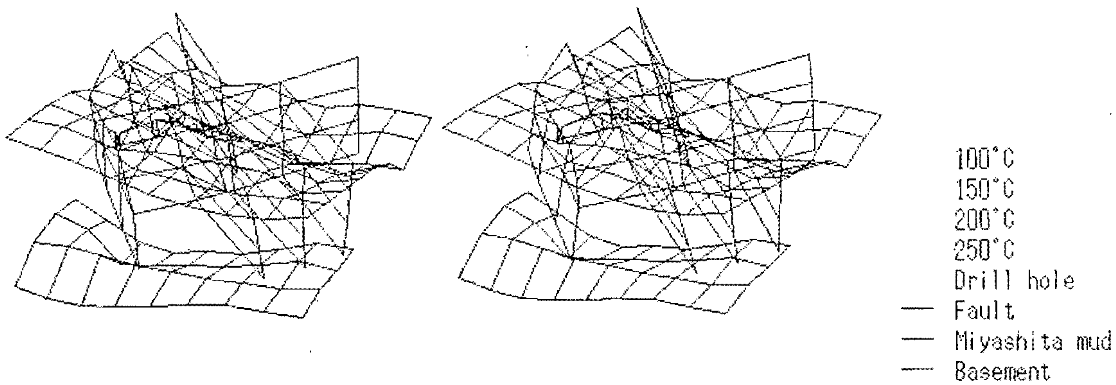

Fig. 3. A stereoimage pair of the surfaces of the basement and Miyashita mudstone, and the faults. The north is rightbackward.

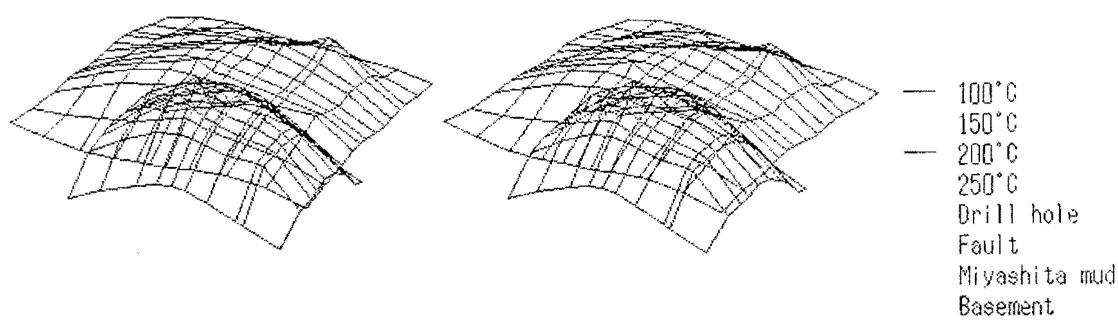

Fig. 4. A stereoimage pair of the isothermal planes of 100°C and 200°C. The north is rightbackward.

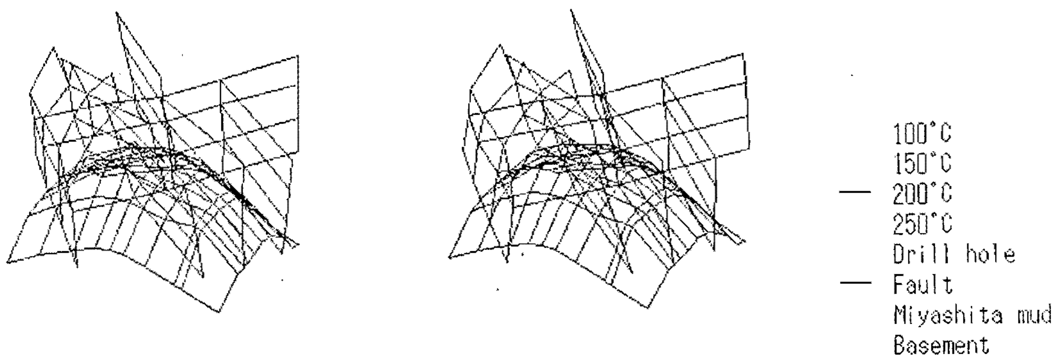

Fig. 5. A stereoimage pair showing the relation between the 200°C isothermal plane and the fault. The north is rightbackward.

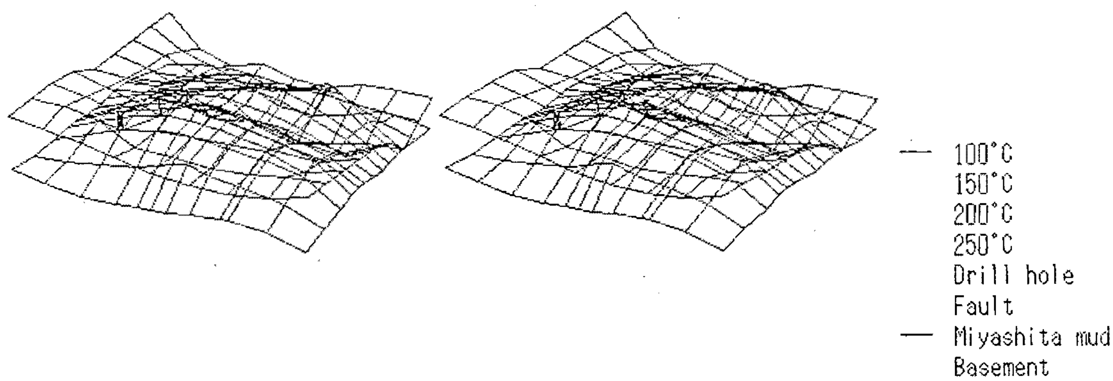

Fig. 6. A stereoimage pair showing the relation between the 100°C isothermal plane and the Miyashita mudstone. The north is rightbackward.

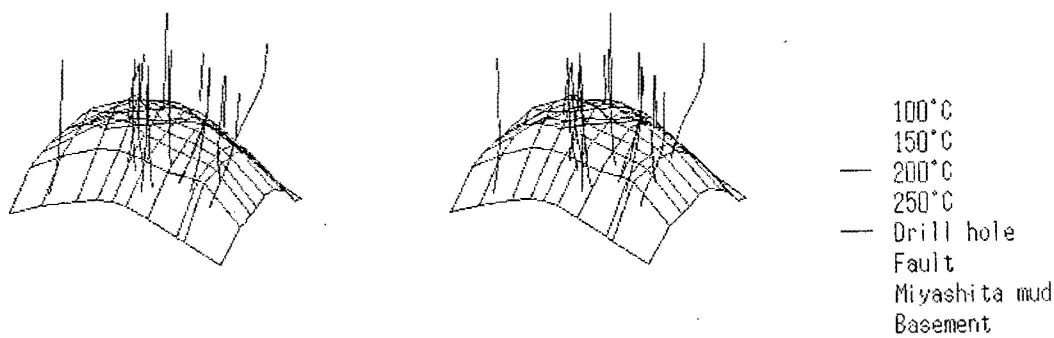

Fig. 7. A stereoimage pair of the 200°C isothermal plane and the drill holes. The north is rightbackward.

places. It consists of mudstone, siltstone, tuffaceous sandstone, tuff breccia, pumice tuff, tuff, basaltic pyroclastics, rhyolitic lava, and limestone. The Fujitoge formation consists mainly of sandstone, and tuffaceous sandstone and mudstone, and pumice tuff of lake sediments, and partially of welded tuff. The Sunagohara formation of a lake deposit is composed of tuffaceous sandstone, siltstone and conglomerate. The Yunotake rhyolite is a product of a volcanic activity which took place at the late stage of the sedimentation of the Sunagohara formation.

The gravity data suggests that the basement is shallow in the southeastern area, and deep in the northwestern one. Roughly speaking, the formations shows the same trend. However, the structure does not always coincide with that of the basement. The formations are folded, and form locally many domes, basins, anticlines, and synclines. The largest basin is situated in the northeastern quarter.

The fracture system consists of two groups. The one strikes northwestwards, and the other northeastwards. The Onogawara fault cutting all structures runs toward north-northwest near the western end in this field. The Takiyagawa fault divides the area lying east of the Onogawara fault into northwestern and southeastern blocks. The Sudarezawa fault and the Kitanosawa fault run in the northwestern block, while the Chinoikezawa fault, the Sarukurazawa fault and the Oizawa fault in the southeastern block. All of them strike northwestwards, and end at the Takiyagawa fault, except the Kitanosawa fault.

The geothermal structure was analyzed using the data obtained from 32 drill holes. According to the result, the high temperature zone of the main heat anomaly is localized along the Takiyagawa fault at shallow levels, and along the Chinoikezawa fault at deep levels. A small heat anomaly occurs at the center of the northeastern quarter. Nishiyama hot spring is located in this anomaly.

STEREOGRAPHY

The personal computer system of the interactive stereography is almost the same as that for the crystal structure (Shoji, 1987). As compared with the system for crystals, the user can easily display or erase each object in this system. On the contrary, it is impossible to draw or delete a line between two designated points. The stored objects are the surfaces of the Miyashita mudstone and the basement, the faults, the isothermal planes of 100°C, 150°C, 200°C and 250°C, and the drill holes. We cannot recognized 3-dimensional pattern from the stereoimage pair in which all objects are displayed, because of the complexity. In Figs. 2 to 7 are shown some examples of stereoimage pairs which indicate interest geological and geothermal structures. They are black and white, because they are the hardcopies on a plotter. Their practical images are colored on a computer display. Consequently, the stereographic recognition in the interactive observation is still easier than the observation of Figs. 2 to 7. All figures are viewed from the southeast direction.

Fig. 2 shows all objects. It is impossible to recognize the shape of each object even on the computer display, because of the complexity. Fig. 2 shows both of the basement and the Miyashita mudstone. The Miyashita mudstone form a basin in the northeastern quarter. Fig. 3 shows the faults as well as the objects shown in Fig. 2. The Miyashita mudstone is clearly displaced by the Takiyagawa fault.

Fig. 4 shows the isothermal planes of 100°C and 200°C. Both of planes are approximately parallel to each other in most places, form a domal structure. The geothermal reservoir is situated at the center of the dome and its vicinity. The parallelism between two isotherms is disturbed in the northeastern quarter, where only the 100°C isotherm has a peak. The Nishiyama hot spring is located at this peak. Fig. 5 shows the relation between the 200°C isothermal plane and the faults. The high temperature zone elongates along the Takiyagawa fault. The highest site in the zone is localized near the crossing line between the Takiyagawa and Chinoikezawa faults. Fig. 6 shows the relation between the 100°C isothermal plane and the Miyashita mudstone. The 100°C isotherm coincide finely with the Miyashita mudstone around the above crossing line. This implies that the Miyashita mudstone plays a caprock of the geothermal fluid in this area. On the other hand, both trend reversely in the northeastern quarter where the Nishiyama hot spring is situated. The hydrothermal water of the hot spring seems to be reserved in the basin of the Miyashita mudstone.

Fig. 7 shows the 200°C isothermal plane and the drill holes. Most of drilling reach the 200°C isothermal plane. The number of them, however, is too few to draw the isotherm near the northwestern corner.

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