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Geophysical Study of Matsukawa Geothermal Area, Northeast Japan*

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As the geological background of Matsukawa is clear in the paper presented by NAKAMURA and SUMI, the writers would like to skip to explain again about geological matters to avoid duplication. Regarding some of their geophysical studies, HAYAKAWA, one of coresearchers already explained at the International Symposium on Volcanology in New Zealand, December 1965. Thereafter they have also been continuing the geophysical studies. This paper includes the previous geophysical study too.

During last eight years since 1958, they have conducted seismic and electrical prospectings and geophysical logging in some test wells. Besides these, HAYAKAWA has also calculated the underground temperature distribution under the assumption of some geophysical states. Paralleling to the geological studies described in another paper, they started with laboratory experiments including density, porosity, and ultrasonic wave velocity measurement by using the specimens of outcrops at and adjacent of this geothermal field.

From these results tentatively they presumed by combining geological data as follows. Matsukawa andesite might correspond to the first cover-rock because of the high velocity and low porosity, while the subsequent dacite tuff formation probably might be the first reservoir of hot water because of low velocity and high porosity. Likewise the dacite lava beneath the dacite tuff might correspond to the second cover-rock and the underlaid marine sediments correspond to the second reservoir.

1. Seismic Prospecting

Consequently the reflexion seismic method instead of refraction method was preferred because the velocity might not increase with depth. For the seismic prospecting, FR-1 magnetic tape recording system was utilized and after several trials of playback, some nice reflexion records were obtained. Fig. 1 shows one of the examples by variable area expression which was obtained by such a way. In Fig. 1, the vertical axis shows the depth from the surface in meter and the horizontal axis shows the lateral distances between shot and detectors. The scale of both horizontal

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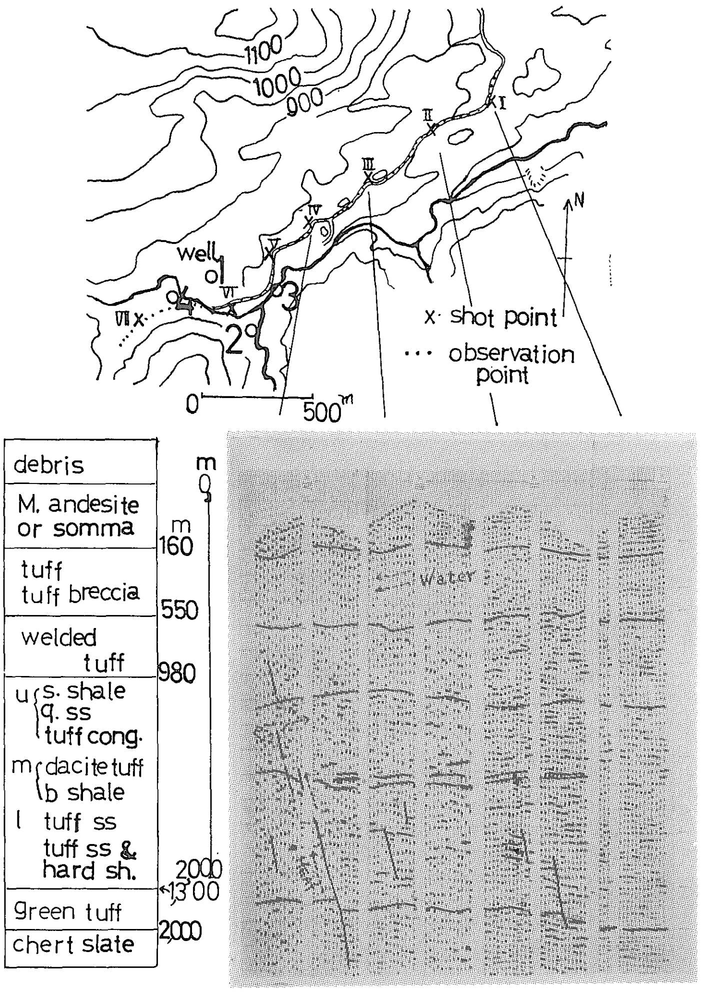

Fig. 1 Result of seismic prospecting

and vertical directions is the same to each other.

As the result of seismic records, depths of reflexion interfaces from the surface were obtained, and they are 160, 550, 980, 1300, and 2000 meters. By taking the geological events into consideration, these reflexion interfaces should correspond to the boundaries between different formations. As explained before, the first layer consisting of hard andesite may be the cover-rock. Below this from 160 to 550 meters in depth, there are possible reservoir for hot water. The layer between 550 and 980 meters corresponds to the dacite formation and as already explained before, this formation was named the second cover-rock. But the writers have found that this is not so complete cover-rock as the first one, as it includes some cracks according to the seismograms. NAKAMURA and other geologists called these "Tamagawa welded tuff formation". Below the Tamagawa welded tuff formation to 1300 meters, there may be sedimentary

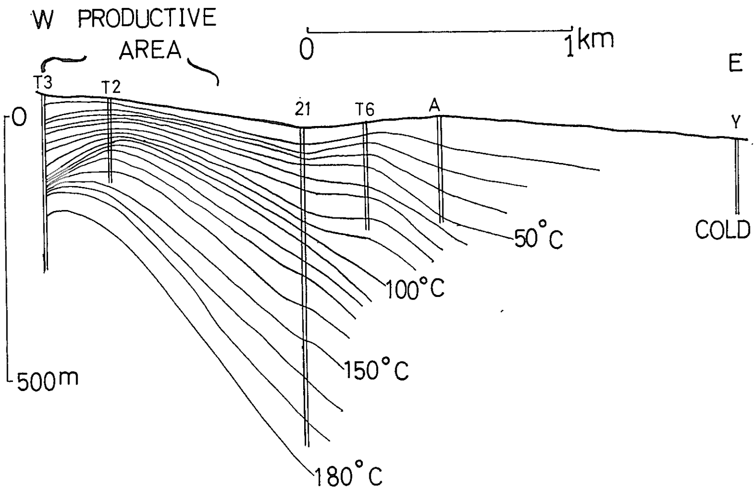

Fig. 2 Underground temperature distribution

formation. Below the sedimentary formation to 2000 meters, there may be so-called Greentuff formation. From seismic records it is easy to predict vertical fissures in it, which may provide steam and gas paths. Deeper than 2000 meters the material would correspond to chert or slate of Paleozoic formation.

2. Underground Temperature Distribution

Some test bore-holes were drilled from which we could obtain the temperature distribution in the shallow part of this area. Fig. 2 shows temperature profile which is parallel to Matsukawa river that corresponds to the seismic traverse. It was very effective for the writers to know the temperature distribution in the shallow part of this field. This result did not contradict with the presumed fault structure in seismic profile. Also the result of the temperature calculation did not contradict with the present shallow temperature curves.

3. Electrical Prospecting

In the case of seismic survey, the traverse line was set along the Matsukawa river. In the electrical prospecting, the traverse lines were set not only to the same direction of seismic one but also to the perpendicular direction of it. The vertical electric sounding of Schlumberger method was applied. The maximum distance between two current electrodes was 4 kilometers. Although many resistivity data were obtained, one of them is shown in Fig. 3. Generally speaking, all of such curve show more or less the same character. In the abscissa the half of current electrode distance——AB/2—— is put in meter, and in the ordinate the apparent resistivity in ohm-meter. Both of them are expressed in logari-

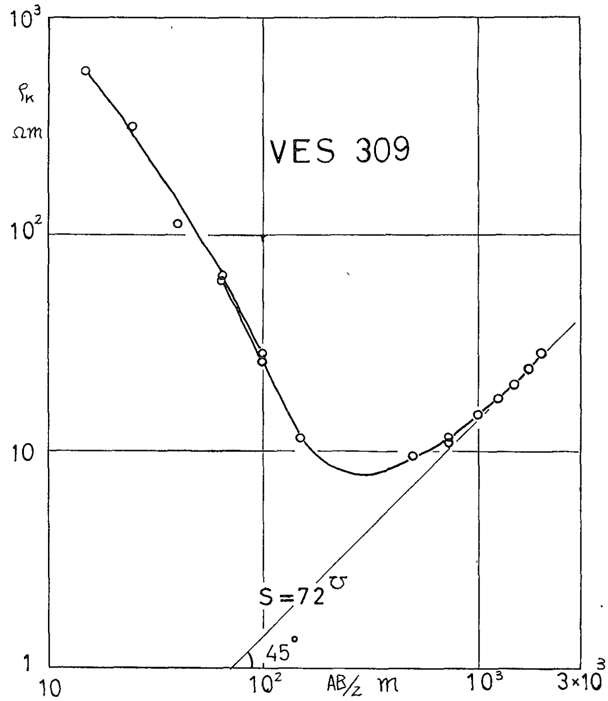

Fig. 3 Example of vertical electric sounding curves

thmic scale.

As shown in Fig. 3, the apparent resistivity curve shows higher value in the shallow part and it shows low value in the intermediate. Again in the deep part there is high resistivity.

The first high may correspond to the surface debris or the first cover as in the seismic prospecting, the first low to the first reservoir, and the second high may correspond to the so-called second cover. Some of curves show the second low resistivity part at deeper part. Probably this may indicate the existence of marine sediments.

Fig. 4 shows a resistivity profile with some of resistivity logging data which correspond to the perpendicular direction to the seismic traverse. As is in the case of seismic profile, the vertical lines show the depth from the surface and the scale of both horizontal and vertical directions is the same to each other. As the maximum spread electrode distances were not enough at three points in the profile of Fig. 4, it was impossible to decide the depth of surface of the second high resistive part there.

In the vertical electric sounding of this profile, it was difficult to detect the second low resistive part, though in some cases of other profiles it could be detected as mentioned before.

As is seen easily in the profile of Fig. 4, near the surface there is debris or the first cover, below it the first reservoir, and finally the so-

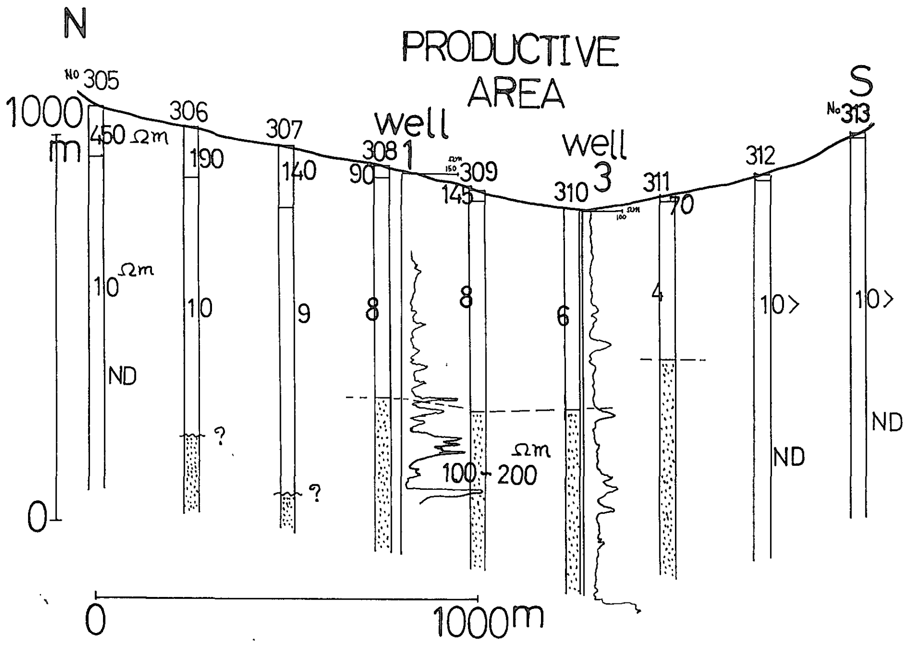

Fig. 4 Result of electrical prospecting

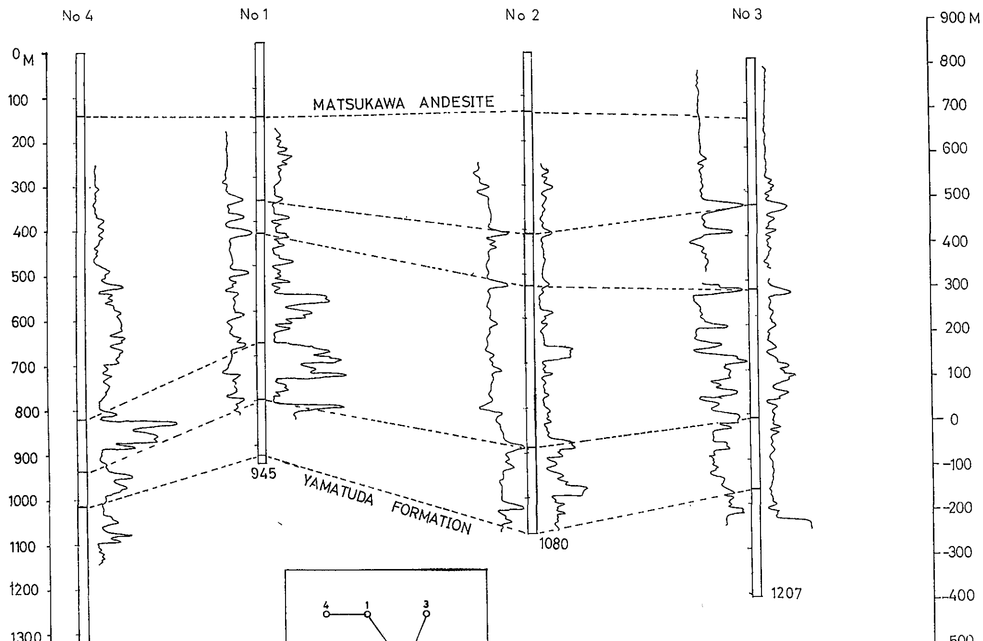

Fig. 5 Electrical log cross section

called second cover. The so-called second cover part has comparatively high resistivity as shown 100～200Ωm. It means that this formation does not contain clayey material and is more compact formation than overlain formation.

As will be described later, however, it has been found that this part can feed a lot of steam and hot water through the wells at present productive area, so that the name of the second cover-rock is not suitable.

The resistivity logs are put in the profile of Fig. 4. It can be easily seen that the high resistivity part in the profile just corresponds to the high resistivity part of logs. Especially the log of the first well shows good correspondence. And it can be easily found that there are the minute low resistivity values among the high resistivity domain especially in the log of the first well which may indicate the existence of fissures in the compact lava.

4. Logging

Fig. 5 shows electric logs of four productive wells. The vertical lines indicate the depth from the surface in meter. On the right side of the axis the resistivity values are shown in ohm-meter, while on the left side self-potentials are shown in milli-volt. In the case of resistivity logging, normal curves of a=1 meter and 0.5 meter were obtained, and the former is shown in Fig. 5. The dotted lines indicate the boundaries between Matsukawa andesite and dacite tuff, and dacite lava and marine sediments respectively obtained by geological core analysis. In between two dotted lines above-mentioned, three dotted lines which connect each other the similar characteristic part of each curve can be put.

By using the data obtained from the test wells, it was found that the surface cold water might flow seasonally into the so-called first reservoir. On the other hand, the resistivity logs show small value in the shallow part about until 550 meters, while at deeper part than the depth resistivity shows high value for instance, in well No. 1. So synthesizing the above phenomena, it was decided to set the casing pipe until the depth of 550 meters to avoid the surface cold water flowing, into the well. Later this arrangement was proved to be good. Anyway in the deeper part than the depth the slotted pipes were set. In another three wells, the resistivity logs were utilized, as in the well No. 1, when the pipes were set.

5. Temperature in the Wells

Fig. 6 shows the temperature recovery curves in the first well as example. In vertical line the depth from the surface is shown in meter as in the former case and in the horizontal line temperature is shown in

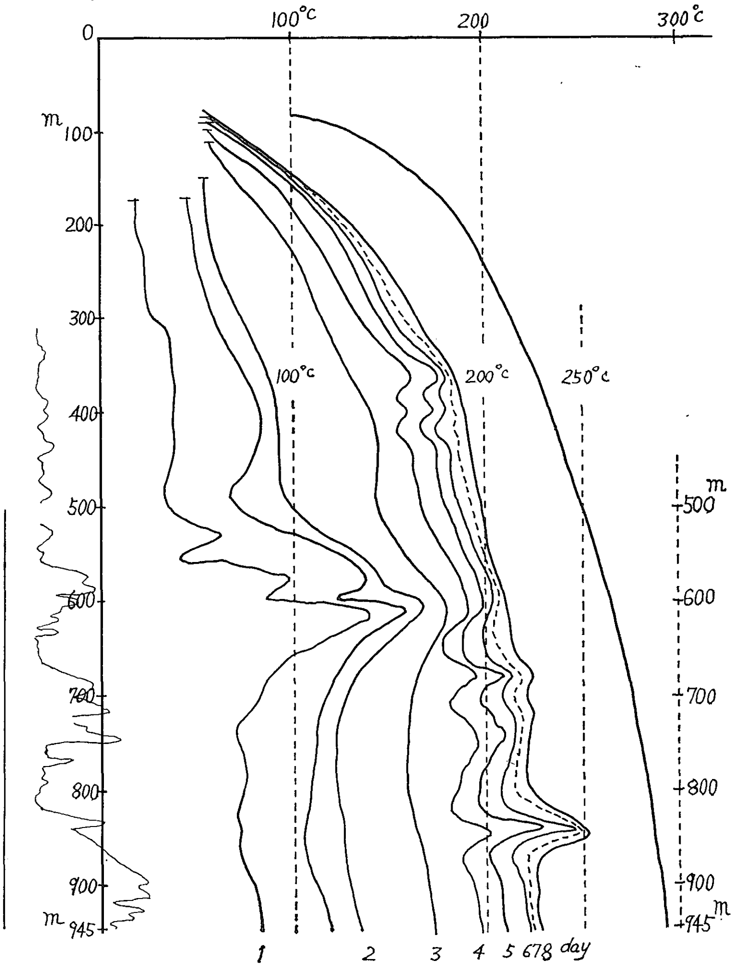

Fig. 6 Temperature recovery curves in the first well

degree centigrade. Immediately after the completion of the well, the mud water used for drilling was replaced by the pure cold water. One day after this arrangement the temperature distribution in the well became as shown in Fig. 6. The temperature distribution changed as shown in Fig. 6 day by day.

From HAYAKAWA's calculation of underground temperature distribution it was expected that the temperature of 300°C at the depth of 1,000 meters, so it was expected as if the temperature might increase a little more than the final curves in Fig. 6, however, the measurement could not be continued because of a financial reason.

Consequently some amount of water was taken out from the well and suddenly a lot of steam were gushing out from the outlet of this well with the amount of 60 tons per hour under about 5 kg/cm^2 gauge pressure which might correspond to about 6,000 kW from this only one

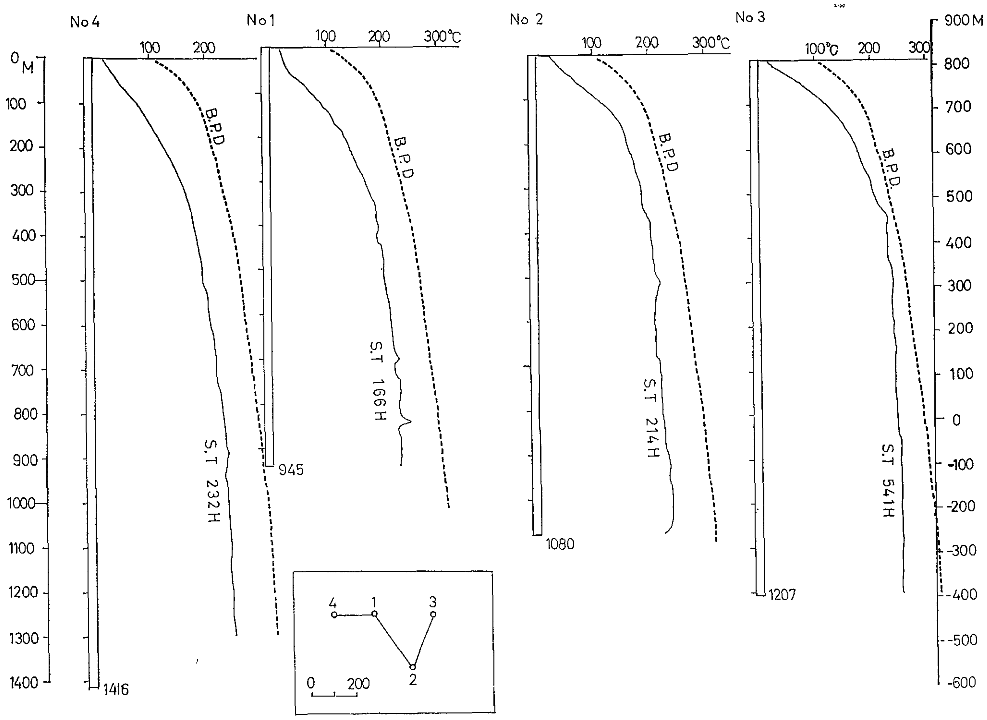

Fig. 7 Temperature log cross section

well.

Likewise another three wells began to discharge steam and water also immediately after excluding some amount of water from the well head. Fig. 7 shows the results of the final temperature measurement conducted just before making them to discharge steam and hot water. The broken lines mean boiling point depth curves.

The very interesting fact can be found out in the comparatively high temperature parts as shown in Fig. 6. They showed the rapid rise in the later stage of one week. By comparing those parts with the resistivity logs, it can be supposed that hot water or steam were penetrating from the country formation into the well through fissures.

6. State of Hot Water Underground

Finally by taking those above-mentioned facts the writers arrived at the following conclusion regarding the state of hot water or steam underground.

At the beginning stage of the study they thought that the so-called second cover-rock formation could not supply a lot of steam and hot water for the well which penetrated it. But finally it became clear from evidences just written here that hot water or consequently steam might come from the deep heat source through the faults, fissures or cracks into the narrow pockets in the lava of the so-called second cover.

The rocks which form the first reservoir are more porous than the so-called second cover-rock, of course, but the reservoir does not contain hot water and steam enough to supply for the productive wells because it does not possess many cracks and fissures, and furthermore the surface cold water may flow into it as mentioned above.

Consequently, it can be concluded that the hot water and steam are now being tapped from the hard formation named firstly as the second cover. The hard formation has plenty of cracks and / or fissures, and it also acts as the cover-rock against the surface cold water. But the character of the primary acquifer below the hard formation has not yet been confirmed in detail.

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松川地熱地域における地球物理学的研究

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要　旨

発電利用のための天然蒸気生産井が4本，松川地熱地域で掘削された。この報告はその坑井の掘削に至るまでと掘削の過程で行なわれた地球物理学的調査研究結果に関するものである。

この地域の地下構造を知るため反射法による地震探査および比抵抗法による電気探査が適用された。これらのほか試錐孔や開発井を利用して電気検層および温度測定も行なわれた。そしてまた岩石試料についての諸測定も行なわれた。

以上の結果地下に存在する熱水蒸気のあり方について次のようなことが明らかになつた。

凝灰岩質の地層の上を覆う松川安山岩類は帽岩の役割をはたし凝灰岩質地層中上部の割目をみたしている熱水蒸気の自然の地表への流出をさまたげている。しかしさらに優勢な熱水蒸気の存在が当初熱水貯溜層になりえないと考えられた固い凝灰岩質地層中の下部に明らかになつた。現在生産井からえられている多量の熱水・蒸気はこの部分からのものと考えられる。その下部の当初優勢な熱水貯溜層と考えられていた部分の詳細についてはまだよくわからない。