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RECENT EXPLORATION AND DEVELOPMENT OF THE OKUAIZU GEOTHERMAL FIELD. JAPAN

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ABSTRACT

The Okuaizu Geothermal field is located on the northern part of Honshu in Japan. The Okuaizu Geothermal Company **Ltd**. (OAG), a subsidiary of Mitsui Mining and Smelting Co..Ltd.(MMS), has done geological, geochemical and geophysical surveys since 1983. and has drilled 20 wells during 1984-1988. In a period of numerous flow tests, downhole pressure, temperature and spinner surveys have been conducted and fluid samples from wells and hot springs have been analyzed. There are two major production zones controlled by the fault system in the Okuaizu Geothermal field: one is the Chinoikezawa zone and the other is the Sarukurazawa zone. In 1987. a simultaneous flow test of five wells in the Chinoikezawa zone was made for four months and the total consistent steam flow rate was more than 200 t/h at a separating pressure of G.5kg/'dfG. In 1988, a simultaneous flow test of three wells drilled into the Sarukurazawa zone will be held. The computer simulation indicates that it will be possible to expand production to 100 MWc, meanwhile OAG plans a 55MWe development in the near future.

Introduction

The geothermal survey in the Okuaizu geothermal field located on 200km north of Tokyo (Fig.l), was commenced in 1974 by Mitsui Mining and Smelting Co., Lid. and was followed with a shallow hole (NY-1) from 1976 to 1977 by a governmental agency. After several years of no work, the field was surveyed by the New Energy Development Organization (NFDO) from 1982 to 1983 under the Ministry of International Trade and Industry; as a part of this survey. 6 shallow temperature-gradient holes (T-l through T-6) and 7 deeper test holes (OA-1 through OA-7) were drilled. These wells showed that a geothermal reservoir with commercial potential existed within the Okuaizu area.

The Okuaizu Geothermal Company Ltd. which is jointly composed of MMS, Mitsui Construction Co., Ltd. and Toshiba Corporation, has since drilled 20 wells at Okuaizu (It, 2t, 3t, 4r, 5t. 6T, 7T. 8T. 9T. 10T, 11T. 12t, 13t, 14T. 15T. 16T. 17T. 18t. 19R. 20R; here t means slim size test well and r means slim size reinjection well, while T means large diameter test well, and R means large diameter reinjection well). Fig.2 shows the locations of these wells.

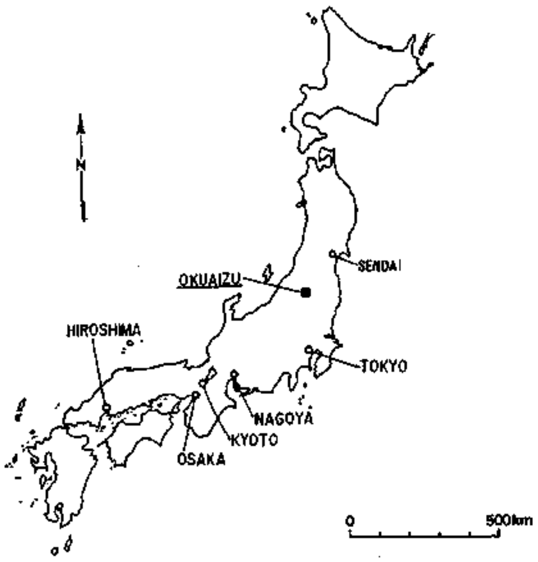


Fig.l LOCATION MAP OF THE OKUAIZU GEOTHERMAL FIELD

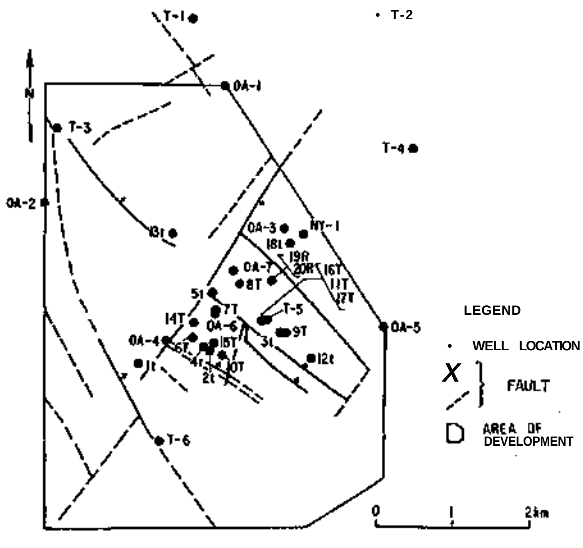


Fig. 2 WELL LOCATION MAP

Geology

The basement of the area seems to be composed of Paleogene to Cretaceous granites and Mesozoic to Paleozoic sediments. Paris of the basement are exposed and can be seen north to south direction (Fig.3). According to an interpreted gravimetric information, top of the basement could be expected to be more than 1500m in depth from surface in the area (Fig.4).

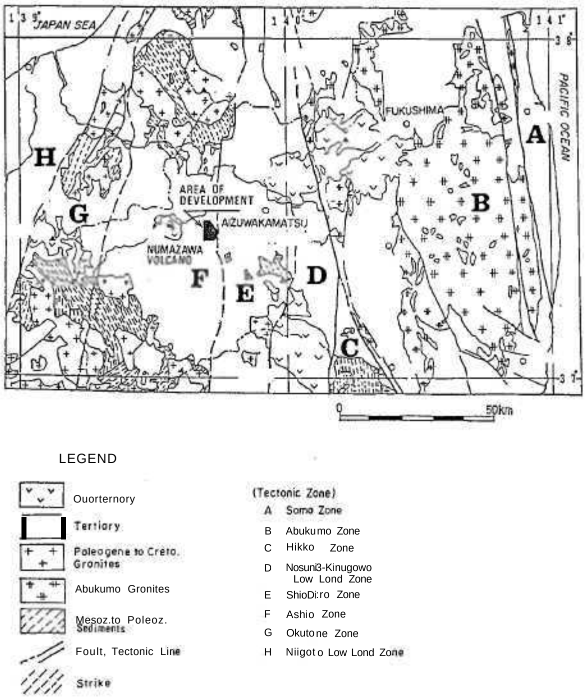


Fig.3 REGIONAL GEOLOGICAL MAP

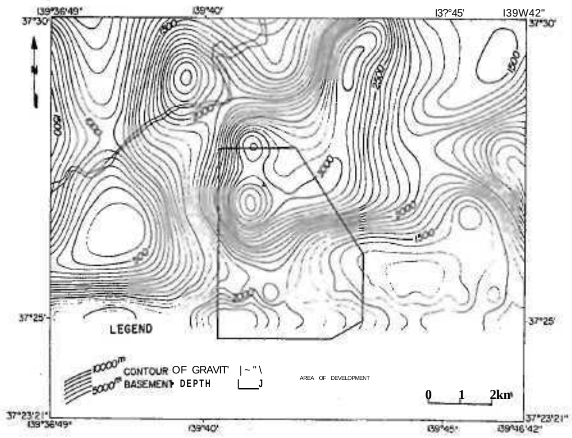


Fig. 4 ESTIMATED BASEMENT DEPTH from GRAVITY SURVEY (4/>=0.3g/cm³)

Drilling revealed shale fragments and granodiorite cobbles in the lower part of the drill core, though drilling did not cut into basement rock. The region is mainly occupied by Neogene volcano-sediments, the Takizawagawa formation, the Ogino formation and the Urushikubo formation (Fig.5). The Takizawagawa formation consists of rhyolitic pyroclastics with interbedded rhyolite lava and its total thickness ranges from 1.000 to 1.300 meters. The Ogino formation consists of rhyolitic pyroclastics, partly dacitic lava and andesitic to basaltic lava, and its total thickness ranges from 200 to 300 meters in the area. The Miyashita mudstone member with several tens meters in thickness lies at the bottom of the Ogino formation; it is useful as a key bed. Because of their characteristic colors the Takizawagawa formation and the Ogino formation are commonly cal led "Green Tuff" and it is well

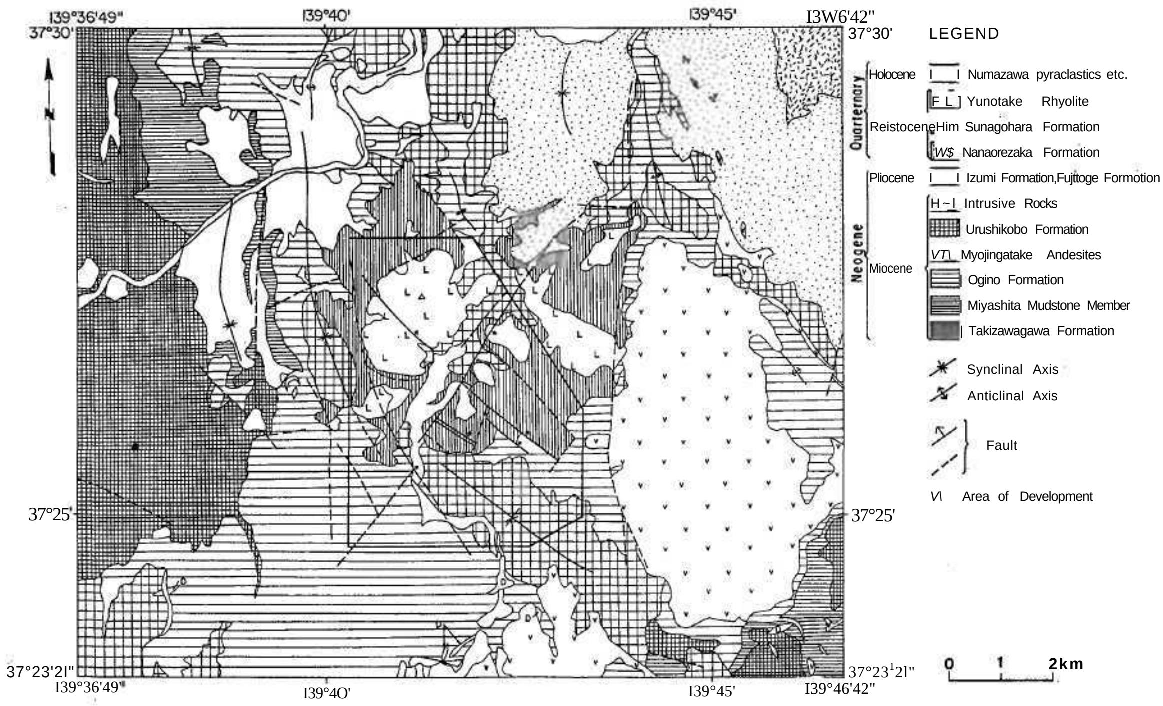
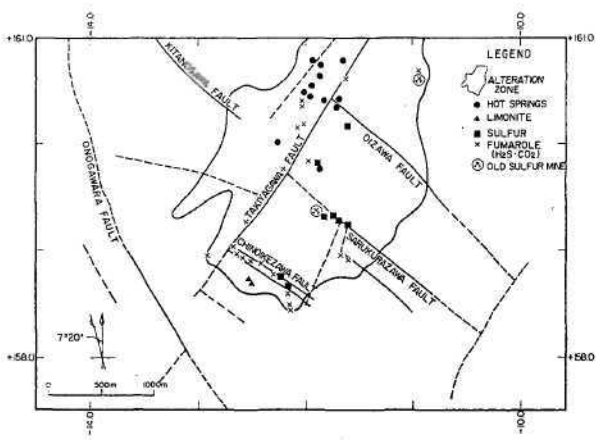


Fig. 5 GEOLOGICAL MAP

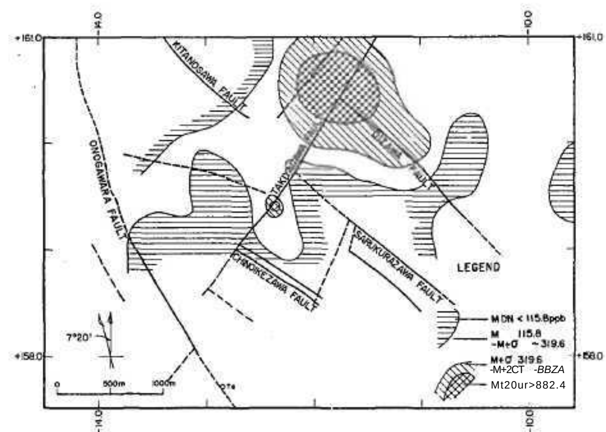
known as containing vigorous submarine volcanic sediments and sometimes Kuroko deposits distributed extensively in Northeast Japan. The Urushikubo formation consists of characteristic sediments formed in an epoch of splitting from a large sodimental basin into several small basins. The formation consists of conglomerate, sandstone, mudstone, siltstone and rhyolitic and basaltic pyroclastics. and their total thickness ranges from 200 to 600 meters in the area. The main Quarternary volcanoes in Northeast Japan stretch from north to south in a volcanic front that runs western side parallel and facing the Japan Trench. Some of the Quarternary volcanoes are also distributed on the inland side opposite to the front and there are two types of Quarternary volcanic sediments in the area. One is the Sunagohara formation, closely related to the volcanic activity of Yunotake rhyolite. The Sunagohara formation consists of mainly tuffaceous sandstone, siltstone and conglomerates, and is a lake deposit of more than 150 meters in thickness. From its pollen fossil and existence of characteristic biotites, it is believed to be of lower to middle Quarlernary. The Yunolake rhyolile with perlite facies intrudes and inter-beds inlo the Sunagohara formation, and K-Ar and fission truck ages of the several rhyolites range from 0.59 to 0.21 Ma. The other is the youngest volcano, the Numazawa Volcano which is located about 10 km west of the area and its pyroclastic flow has a radiocarbon age of 5,150 ±110y. B.P. and il covers terraces in the area. The geological structure of the area is mainly controlled by block movement of the basement rock. There are G main faults in the area, they are the Onogawara. the Chinoikezawa. the Sarukurazawa. the Kitanosawa and the Oizawa fault of a NW-SE strike and the Takiyagawa fault of a NNE-SSV strike (Fig.6). The geothermal production zones are located along the Chinoikozawa fault and the Sarukurazawa fault of in a NW-SE trend on a slope of the gravity high in the south of the field.

Ceotheraiai manifestation

The Okuaizu geothermal field does not look very active at a glance but the existence of high temperature hot springs and a large hydrothermal alteration zone encouraged the exploration of this area (Fig.6). More than fifteen high temperature hot springs (up to 93 ℃) occur in an area of two kilometers in length, and 500 meters in width along the Takiyagawa fault tending to the NNE to the SSW in the north of the field. A measured outflow from these hot springs is rather small at 267J? /min., but more hot water leaks out into a nearby river without ever being measured. Almost all springs have a similar chemical component of chloride water (up to 2,800 *mg/8*) bearing an H_2S component. Many fumaroles occur along the Chinoikezawa fault and the Sarukurazawa fault running from the NW to the SE in the south of the field. A strong hydrothermal alteration -zone can be recognized with an area of 4.5kra [2] covering from the hot spring zone in the north to the deeper geothermal production



P1B.B DISTRIBUTION MAP OF CEOTHERMAL. MANIFESTATION



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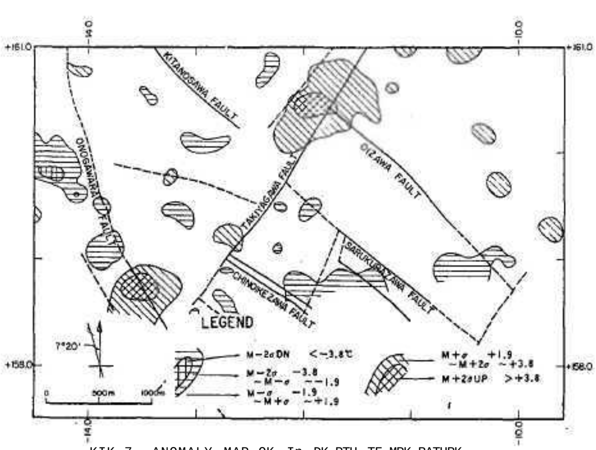

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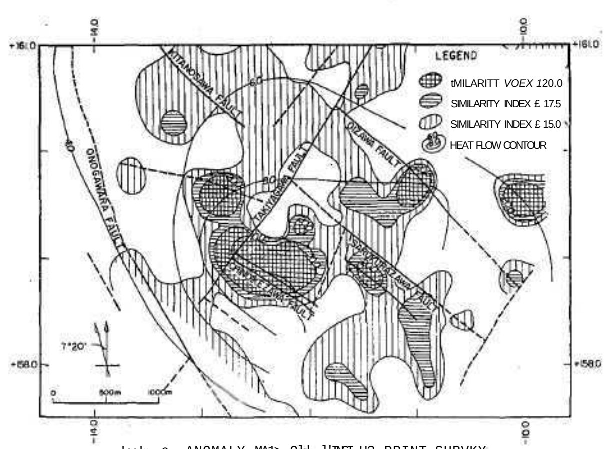

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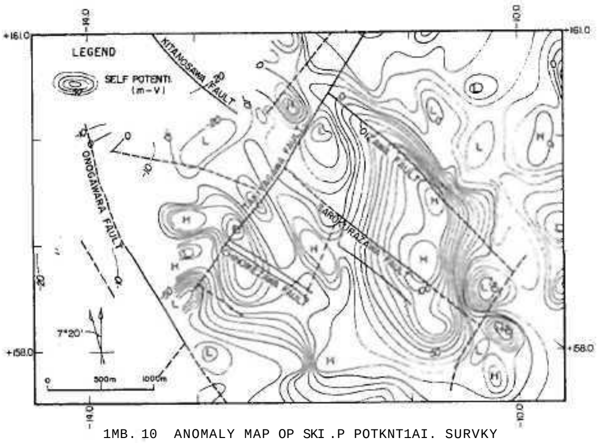

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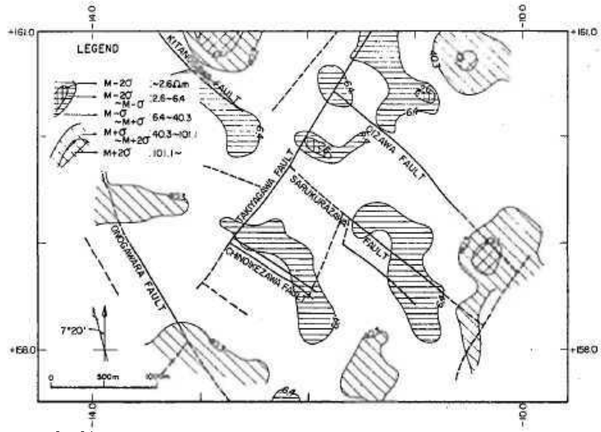


PlK.li APPARENT RESISTIVITY ANOMALY MAP Op KI.P-MT SURVKY

zone in the south. The alteration zone consists of mainly montmorillonite with sericite. raordenite and kaolinite. There are two possible geotherraal heat sources in the field: one is activity of the Yunotake perlite lava dome (0.6-0.2 Ma) and the other is the Numazawa volcano located 10 km west of the field. The Numazawa volcano erruptted about 5.000 years ago and formed a caldera lake.

Geophysical and geochemical exploration

A number of surveys were conducted in the field by NEDO and OAG. A subsurface temperature survey at i meter in depth (Fig.7) and a mercury survey (Fig.8) show a distinct anomaly in the hot spring zone rather than the geothermal production zone. A Finger Print geochemical survey (Fig.9) and a self-potential survey (Fig.10) assigned anomalies not on the hot spring zone but on the geothermal production zone. Apparent low resistivity anomalies (<M-a; <6.4Qm) by ELF-MT survey (7.8 Hz) were recognized in the hot spring zone and along the fault fractured zones in the Nk'-SE strike, which indicate the geothermal production zone (Fig. 11). Low resistivity anomalies (<14 Qm) revealed by TDEM survey related to the Miyashita mudstone member as a caprock of geothermal reservoir on the section (Fig.12) and also indicated an elongation of the Chinoikezawa production zone toward the SE into an unsurveyed area by drilling.

Temperature distribution

At shallow levels, the temperature anomaly has a NL' trend, parallel to the Takiyagawa fault (Fig.13). The relatively high

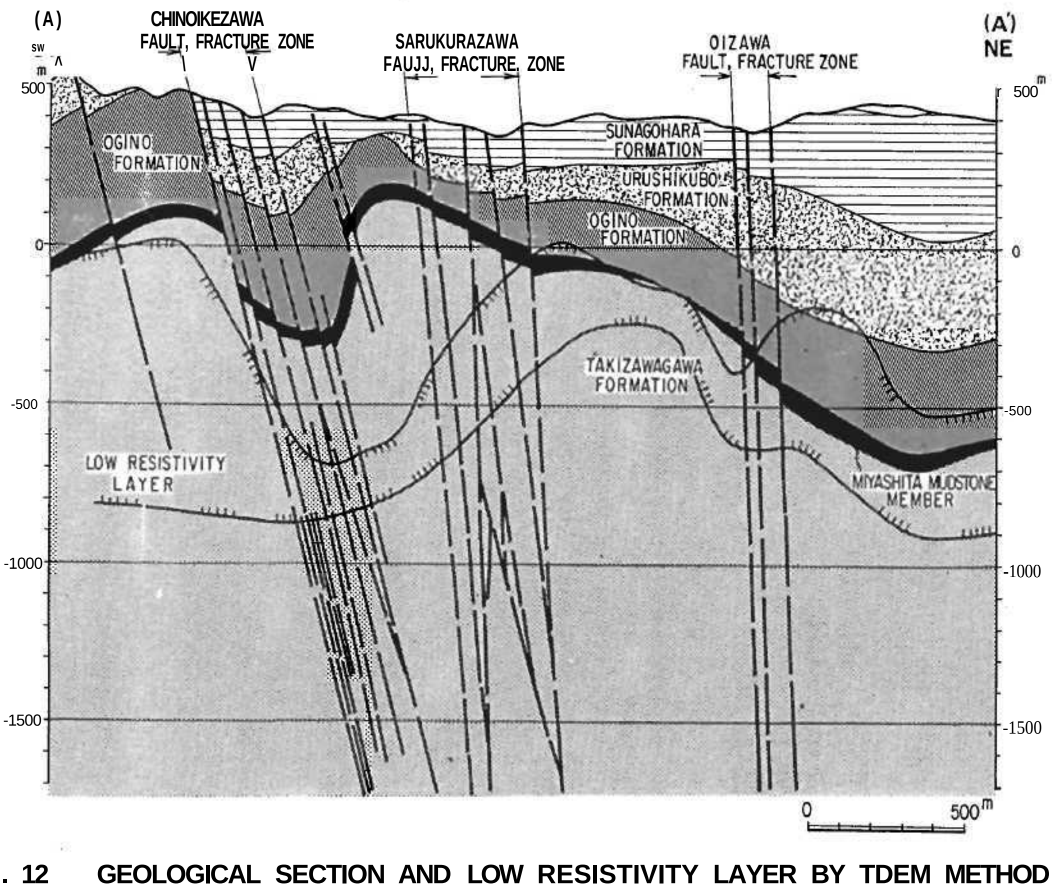
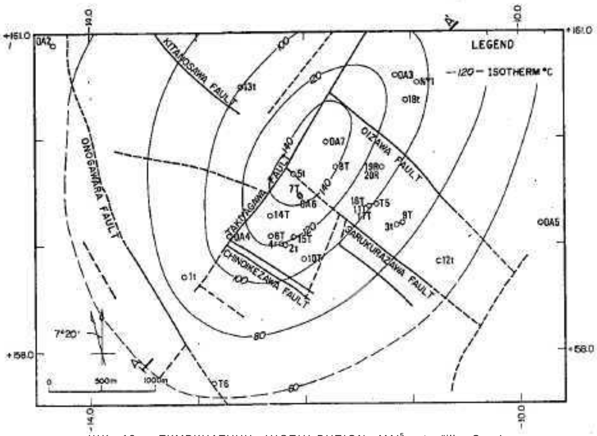


Fig. 12 GEOLOGICAL SECTION AND LOW RESISTIVITY LAYER BY TDEM METHOD



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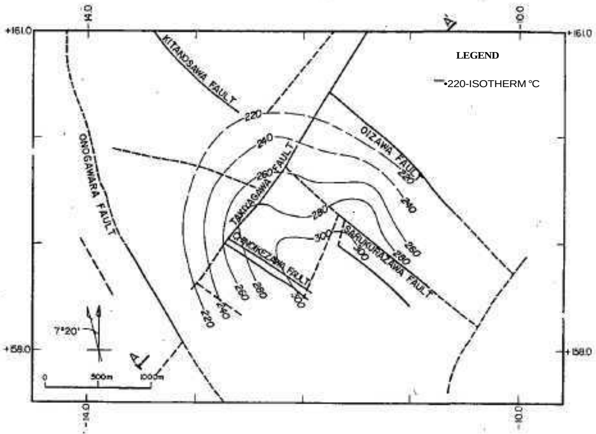

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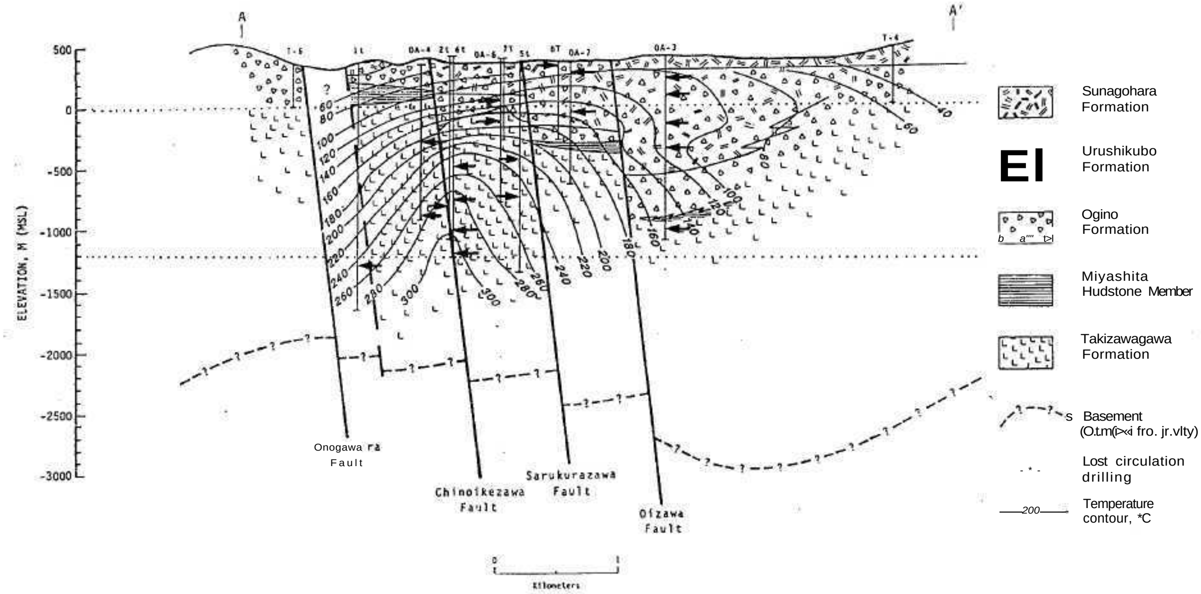

Fig.15 TEMPERATURE CROSS SECTION (A-A')

temperatures at shallow depth on the Nli side of the area suggest that the thermal fluid is outflowing towards the NE on the E side of the fakiyagawa fault. The location of hot springs and the existence of temperature reversals (Fig.15) support this interpretation. Deeper in the system, a NW component of flow was observed (Fig.14). This trend is parallel to the Chinoikozawa and Sarukurazawa fault zones. At these deeper levels, the temperature anomaly is closed on the NW side and open on the SE side. L'pflow is occurring within the Takizawagawa formation along the Chinoikezawa fault in the central production area(Fig.l5). Recharge to the Okuaizu field is supplied by upward and north or northwestward flow of hot fluids from the S or SE of the main production area. The absence of temperature reversals indicates a strong component of upflow in the production area.

Permeability distribution

The surface distribution of the alteration zone is similar to the temperature anomaly pattern at shallow levels and the altered rocks near the surface show very low permeability and act as a caprock for the outflow of the thermal fluid at shallow levels. In the perlite lava beds of the Yunotake rhyolite and the conglomerate beds of Urushikubo formation, lost circulation drilling indicates outflow of thermal fluid at shallow levels. On the other hand, in the Ogino formation there is a very little lost circulation drilling. This is probably because the Miyashita mudstone member and the other mudstone members act as a caprock for the deeper geothermal reservoir. The matrix of Takizawagawa formation does not show high permeability in general otherwise a number of the lost circulation drilling is shown at the fault fracture zone. The analysis of the data from interference tests suggest that the average reservoir flow capacities in both Chinoikezawa and Sarukurazawa production zones are similar, with values ranging from 500 to 3,000 md-m. These values are relatively low for a geothermal reservoir, but a favorable well skin factor (-2.8 to -4.6) caused by the fault cracks conp-ensates and the production wells show high productivity.

A long term flow test

A long terra flow test involving a number of production, reinjection and pressure observation wells was conducted during the latter half of 1987 and early 1988. The discharge parameters for the production wells, based on this test, are summarized in Table 1. The test ended successfully showing a total productivity of more than 20MWc by 5 production wells as was expected before the test. Well 15T showed especially high productivity (>11.5 MWe) even though the well head valve could not open fully due to excess. This was because the equipment used in this test had a capacity of only 100 t/h of steam.

Table 1 Summary of flow test data

Well	Wellhead Pressure(kscg)	Steam Flowrate (t/h)	Water Flowrate (t/h)	Output (MWe)
2t	6.6	12.3	0.8	1.3
6T	7.2	43.1	12.8	4.6
I0T	37.7	20.7	18.8	2.4
14T	7.4	36.4	7.4	3.9
15T	57.2	101.9	67.6	11.5
Total		214.4	107.4	23.7

(At a separating pressure of 6.5 kg/crfG)

Chemistry of the geothermal fluid

Wells 2t. 6t and 15T produce Na-CI water typical of the central production area, with Cl concentrations ranging from about 8.800 to 9.600 mg/H . Other wells produce Na-CI water with less Cl concentrations. The well-to-well variations in Cl can be correlated with changes in other chemical components and explained as the result of mixing and boiling in the reservoir. An isotopic study of oxygen and hydrogen indicates that some portion of old sea water of the Green Tuff period contributes to the geothermal fluid and the existence of a small amount of tritium in the fluid indicates a contribution of meteoric water.

Scaling

Because of a high concentration of silica, carbonate and sulfide in the fluid, there is primarily silica scaling and secondarily carbonate and sulfide scaling.

Silica scale generally occurs in surface equipments and in reinjection wells. To avoid this problem, the single flash system and reinjection of high temperature (160 °C) water are used.

Carbonate scale was found in only well I0T and this seems to be caused by the mixing of rather cold water with a high I1C0 (component from the shallow feed zone. To resolve this problem a flow tost was conducted at different well head pressures to find a suitable well head pressure for control of scaling. In future production wells shalower feed points will be cemented.

Sulfide scale was recognized in the well bore of 2t and in the surface equipment of well 15T. The scale consists of high concentrations of gold, silver, copper, lead, zinc, arsenic and antimony, and it is now under study.

Reservoir engineering assessment work

Volumetric reserve estimates indicated that the most likely value of the maximum capacity for the Okuaizu area is **94MW** with a standard deviation of 31MW. The prediction runs show that it will be possible to expand production to lOOMWe.

Future plan

The OAG plans a 55MWe development in the near future to sell steam to a private electric company. In 1988 a simultaneous flow test of three wells drilled into the Sarukura/ava /one will be held to ascertain commercial power plant capacity.

Acknowledgement

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