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EXPLORATION OF GEOTHERMAL ZONE IN MT. ASO WEST AREA IN KYUSHU, JAPAN

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ABSTRACT

This is an introduction of results of Geothermal Development Promotion Survey done during 1991-1993 in the west half of Aso caldera. Several hot springs and some wells blowing dry steam are distributed across the gently sloping area with an altitude of 400-1000m above sea level. Geological and geochemical survey, electrical and electromagnetic exploration, drilling, heat flow survey and environmental survey have been conducted in support of the project. After such preliminary exploration, it was estimated that favorable heat zones were concentrated within the caldera area. Two deep holes encountered heat zones showing more than 200 degrees centigrade of vapor and water. These two holes hit extraordinary low water levels suggesting imbalance of underground pressure due to the existence of hidden vapor dominant type reservoir.

1. LOCATION

Geothermal Development Promotion Survey was done in Asosan-Seibu Area (West Slope of Mt. Aso) during 1991-1993. The exploration area lies in the west half of Aso caldera and occupies approximately 70 km^2 extending within Chouyou village, Kugino village and Ohtsu town in Kumamoto Prefecture, Kyushu. (Refer to Fig.1).

2. GEOGRAPHY

The area is surrounded by two drainages, Kurokawa and Shirakawa along the caldera rim which merge near Tateno and run out to the west of the caldera. The eastern part of the exploration area lies in gently sloping area with an altitude of 400-1000 m above sea level and corresponds with western slope of Aso Central Cones. The caldera rim includes steep topography with altitude of 600-1200 m above sea level. (Fig. 1)

3. GEOLOGY

The surface geology of the area is comprised of Pre-Aso volcanic rocks of middle Pleistocene, and volcanic products of Mt. Aso, which was active from middle Pleistocene to Holocene. Active geothermal occurences such as high temperature hot springs and fumarole are distributed in several areas, such as Yunotani, Yoshioka, Tarutama and Jigoku. In the Yunotani area, which is located in eastern part of the exploration area some geothermal wells drilled by the Aso Resort Hotel are producing dry vapor with energy equivalent to more than 2 megawatts (MW) generating capacity. The hotel is making use of the vapor for it's own air conditioning by using an absorption heat exchanger. Other than those mentioned above, several low temperature hot springs exist in Akamizu, Tochinoki, Kugino etc. (Refer to Fig.2)

4. HISTORY OF EXPLORATION

4.1 Past Exploration

Nation-wide Geothermal Resources survey

During 1988-1990, the "Nation-wide Geothermal Resources Survey Project Phase" was conducted by the New Energy and Industrial Technology Development Organization (NEDO) in the Aso area and included this area. The exploration done included: Distribution of Volcanic Rocks, Geochronologic Survey, Fluid Geochemical Survey, Precise Gravity Prospecting, Electrical Resistivity Survey (MT,ASMT), General Analysis

Geothermal Development Promotion Survey

The following was carried out by NEDO during 1991-1993.

1.Surface survey

Survey of geology and hydrothermal alteration, Geochronologic survey (K-Ar and F.T), Geochemical survey (Hg, CO_2 in soil gas, 1 m depth soil , temperature, analysis of hot spring and surface water), Electromagnetic prospecting(MT), Electric prospecting(Schlumberger)

2. Well survey

Heat flow survey drill holes (3 wells x 400 m), Exploratory wells (1 well x 1,000 m, 3 wells x 1,200 m, 2 wells x 1,700 m, 1 well x 1,800 m), Core tests.

3. Environmental impact assessment

Weather, air, water quality, flora/fauna, landscape, hot spring and microearthquake.

4. Temperature logging

5. Hydrothermal water survey

Pumping by swabbing method and bailer method, Sampling and analysis of hydrothermal water

5. RESULT OF EXPLORATION

5.1 Summary

The five drill holes suggested promising heat sources are concentrated within caldera area. In 1993 exploration was concentrated in potential heat source zones within caldera area. Two deep exploratory wells (N5-AS-6 and N5-AS-7) were drilled in the potential heat source area near Yoshioka and Tarutama in the western part of caldera area. Temperature logging was carried out several months after drilling work finished. N5-AS-6 showed 216.6 degrees centigrade and N5-AS-7 showed 203.3 degrees centigrade. (Refer to Fig.1 and 3).

5.2 Interpretation

Geological Structure

Basement of the Aso Volcano is composed of metamorphics, Cretaceous granites, and Pliocene to Pleistocene volcanics. Aso volcanic products erupted 0.3 million years ago and are composed of pyroclastic flows and volcanic products from central volcanic cones, which extruded in a later stage. Pyroclastic flows are recognized to have 4 flow units, Aso-1 to Aso-4. The Aso-4 flow unit is observed in a few drill holes, such as N4-AS-3, N4-AS-6 and 7 and is used as the key bed in the caldera. A major tectonic line in this area is the ENE-WSW Oita-Kumamoto Tectonic Line, which crosses Aso caldera and the WNW-ESE Kuratake Fault Zone, which is located in the north-north western portion of the caldera. The size of collapsed structure of Aso caldera is 12 km in EW, 19 km in NS direction and 1.2 km in average collapsed depth (Refer to Fig.2).

Thermal Structure

Volcanic activity in this area is interpreted as follows. During middle Pleistocene (0.7-0.35 million years ago) extrusion activity of Aso Volcanic Rocks occurred around the intersection of the Oita-Kumamoto Tectonic Line and Kuratake Fault Zones. During middle to late Pleistocene (0.3-0.08 million years ago) volcanic activity of Mt. Aso started. During late Pleistocene (0.08-0.02 million years ago) both deposition of caldera sedimentary facies (Shiramizu Layer) and extrusion of volcanic rocks occurred at almost same time. These extrusions resulted in a series of 18 volcanoes, which are classified as old central volcanic cones. From late Pleistocene to Holocene (0.02million years ago to present) extrusion of volcanic rocks occurred along the fracture zone of the Kuratake Faults. These are classified as late central volcanic cones. Among them Mt. Nakatake is still active. The remaining magma, yielded old volcanic cones erupting 0.07 million years ago, and still has enough heat capacity to serve as a heat source for the geothermal activity of the area. Computer reservoir simulation suggests this remaining magma present at 3-4 km from the surface is capable of serving as a heat source. (Refer to Fig.2).

Geothermal alteration

The area is classified into 6 alteration zones, such as the non-altered zone, halloysite zone, smectite, mixed ore zone, sericite-chlorite zone and epidote-chlorite zone. Montmorillonitization is continuously observed in sericite-chlorite zones of N3-AS-1 and 2 and N4-AS-3 and 4. This phenomenon is understood to be retrograde alteration, which suggests a lowering temperature due to decline of geothermal activity. On the other hand no alteration minerals related with retrograde alteration are observed in N5-AS-6 and 7, which suggests these drill holes are located near the current geothermal reservoir. (Refer to Fig.4).

Geophysical exploration

An extraordinary low resistivity zone is recognized by MT method right under the altered zone in Yunotani, Yoshioka and west Yunotani. It suggests alteration extends downward in a vertical direction. An extraordinary low resistivity (less than 5 m) zone is recognized by electrical exploration method (Schlumberger) in Yunotani, Yoshioka and west Tarutama area. The SW disposition is concordant with distribution of the alteration zone near surface. (Refer to Fig.4).

Temperature logging

A convection zone is observed at 200-600 m depth in N3-AS-1 and 2, N4-AS-3, N5-AS-6 and 7. At greater depths, a steep temperature gradient (13-15 degrees centigrade/100 m) zone is observed. This phenomena shows thermal structure in this area is of conductive type. Temperature logging carried out several months after drilling work finished showed 216.6 degrees centigrade in N5-AS-6 and 203.3 degrees centigrade in N5-AS-7. (Refer to Fig.3 and 5).

Hydrothermal Water Structure

The isotopic ratio of δD in hydrothermal water from N5-AS-6 and 7 is very small. This suggests the source of this water is the water that infiltrated from higher elevation near the area. Some portion of meteoric water supplied from volcanic central cones and from other geographically high places infiltrates deep underground and forms a deep hydrothermal water reservoir heated by volcanic heat source. The reservoir is filled with neutral to weakly alkaline deep hydrothermal water at 220-300 degrees centigrade. Vapor and gas derived from this deep hydrothermal water reservoir ascend along fracture zones and form a vapor-dominated reservoir showing 210-220 degrees centigrade at a shallower depth of around 400-500m. Vapor and gas ascending further infiltrate into the shallow ground water zone and form an acidic sulfate (SO_4) type hydrothermal aquifer showing about 150 degrees centigrade. Some portion of high temperature hydrothermal water ascends upward from deep reservoir. It reacts with surrounding rocks, mixes with ground water, lowering its temperature and forming a neutral to weakly alkaline sulfate or bicarbonate (HCO_3) type hot spring reservoir showing about 100 degrees centigrade in shallow underground zone of Shimoda, Shiramizu and Kugino area etc. (Refer to Fig.6 and 7).

Pressure Structure

The water level observed in N5-AS-6 is extraordinarily low, showing -290 m sea level (SL), while its collar elevation is 709 m SL. Water level observed in N5-AS-7 is again quite low, at 160 m SL, while its collar elevation is 630 m SL. (Refer to Fig.3). One of the possible reasons for this phenomenon might be a pressure imbalance occurring at depth due to a hidden vapor dominated reservoir that reflects steam static pressure within the reservoir. Within the reservoir, pressure at depth is as low as at shallow depth, which may give a considerable pressure gap with the surrounding water static zone. It is assumed that these two drill holes are located close to boundary of these two zones. A conceptual model (Refer to Fig. 8) was considered with the idea of a hidden vapor-dominated reservoir and at the same time a natural state reservoir simulation was done by using the Sing simulator developed by NEDO. The result of the simulation was concordant with the conceptual model including a vapor-dominated reservoir and possibility of the existence of a hidden reservoir east of Tarutama and Yunotani seems to be quite high. Possibilities suggested by simulation are:

①existence of vapor dominated reservoir

②existence of hydrothermal water dominated reservoir under the above vapor dominated reservoir.

(Refer to Fig.3 and 8).

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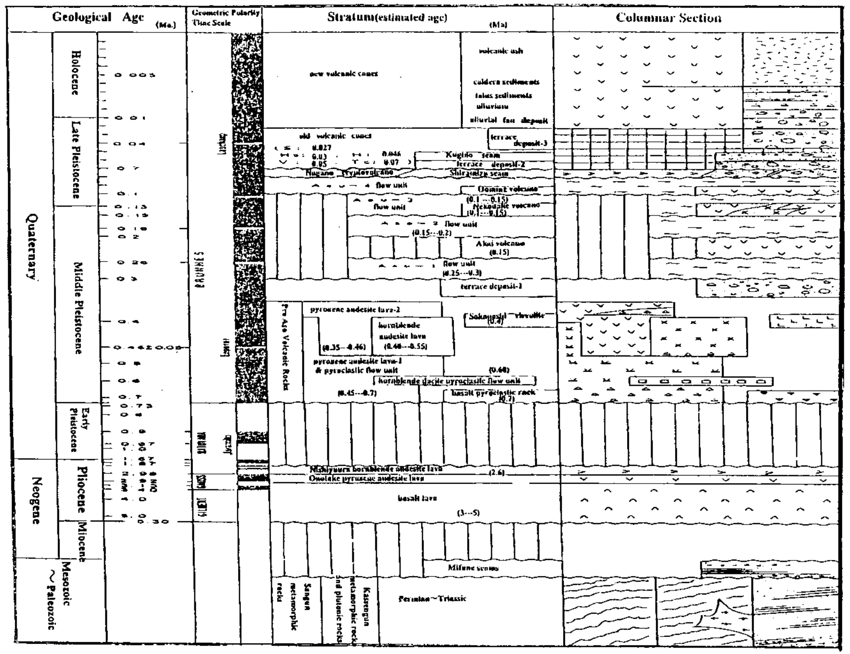
Fig. 2 Geologic Columnar Section



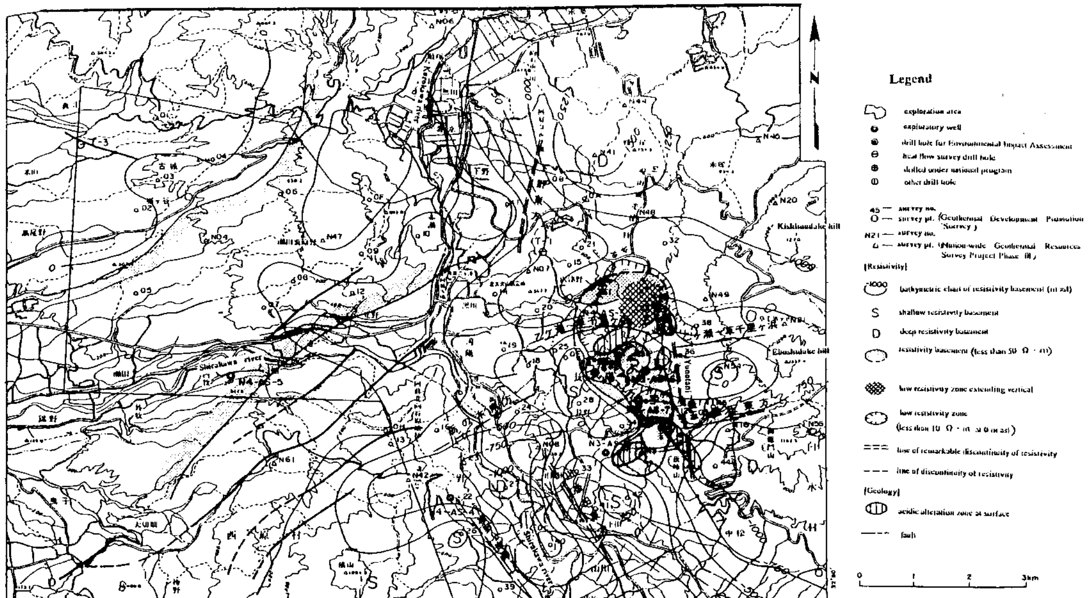


Fig. 4

Plane of Comprehensive Analysis

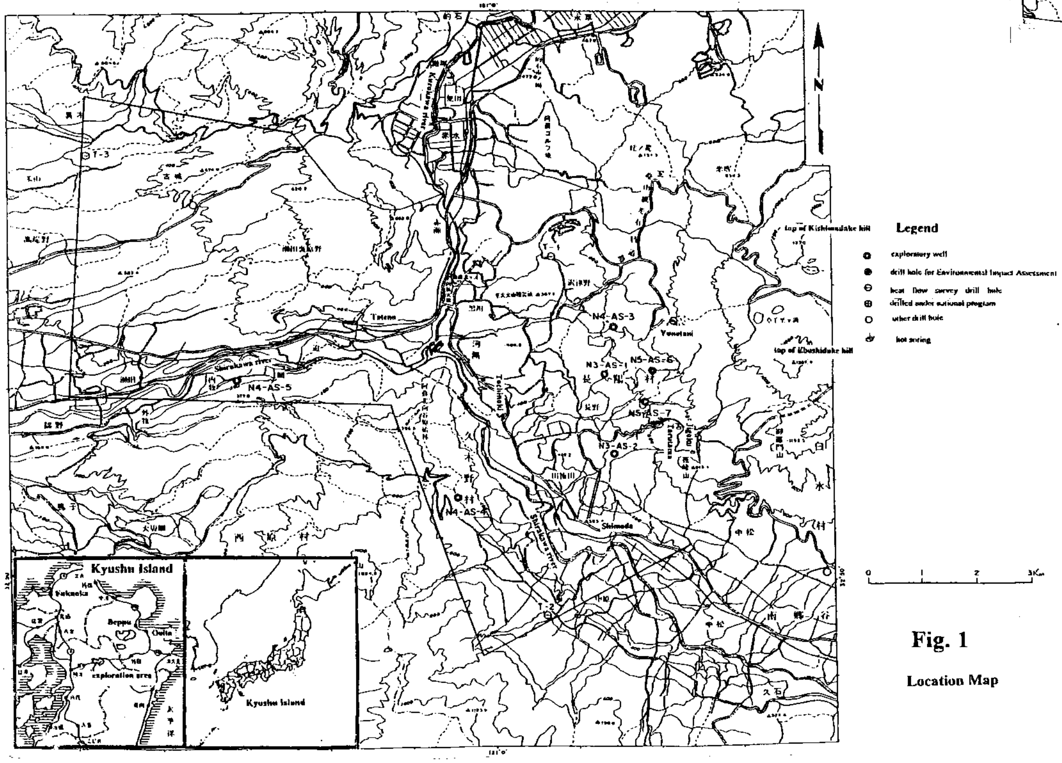


Fig. 1

Location Map

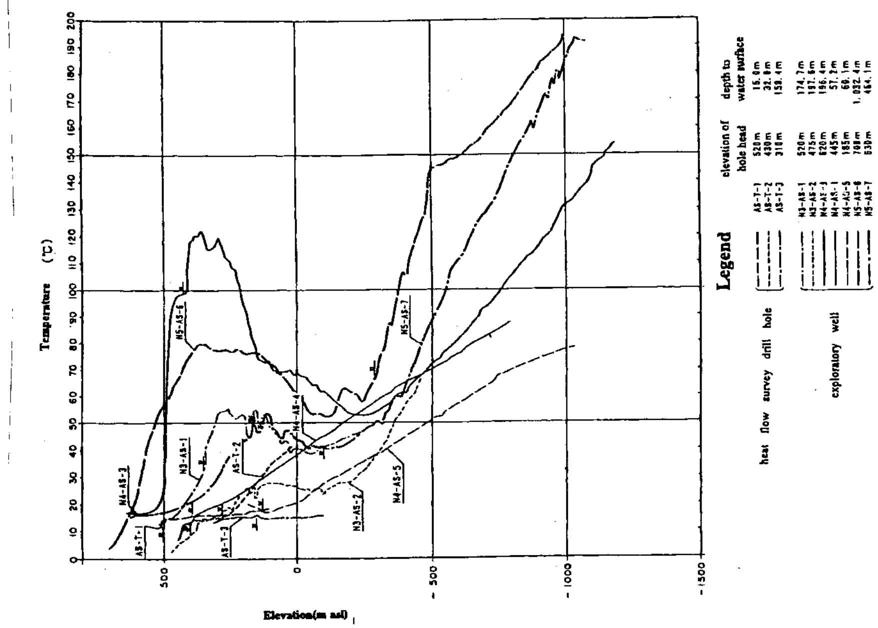


Fig. 3 **Temperature Logging(120 Hrs)**

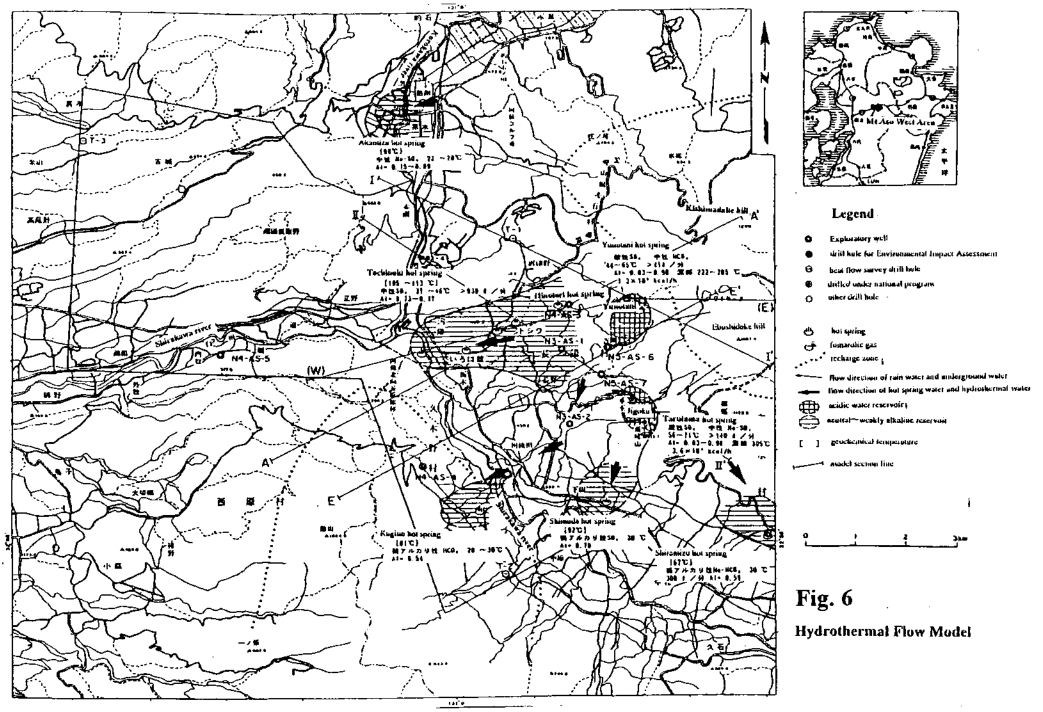


Fig. 6

Hydrothermal Flow Model

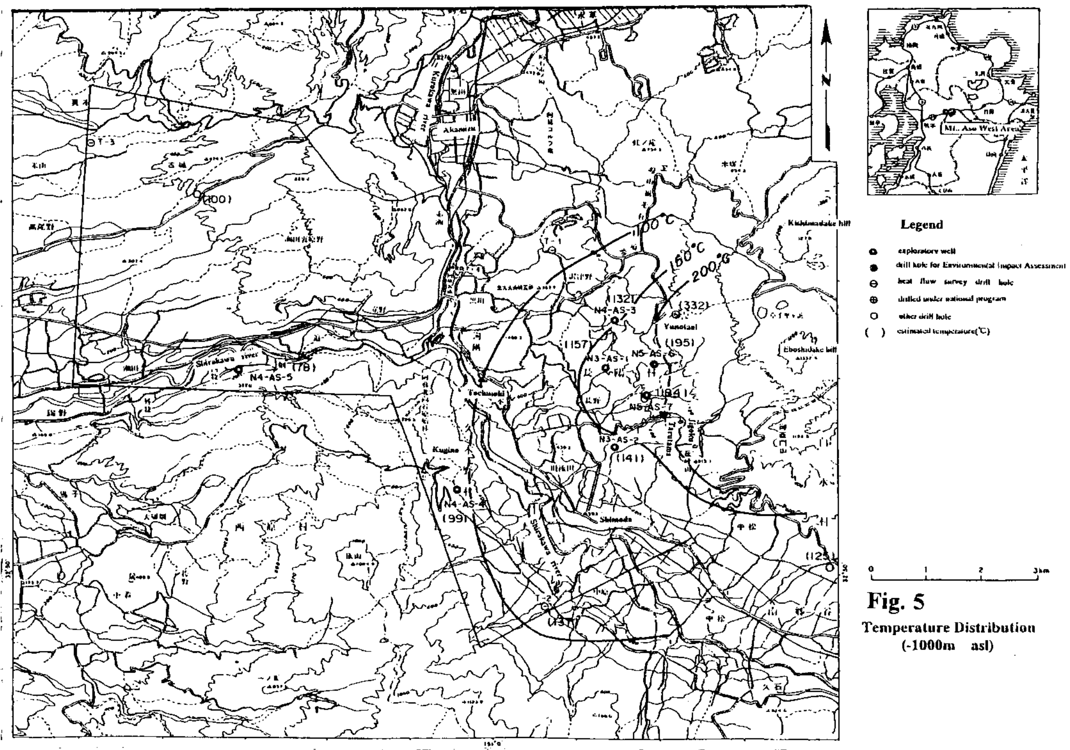


Fig. 5

Temperature Distribution
(-1000m asl)

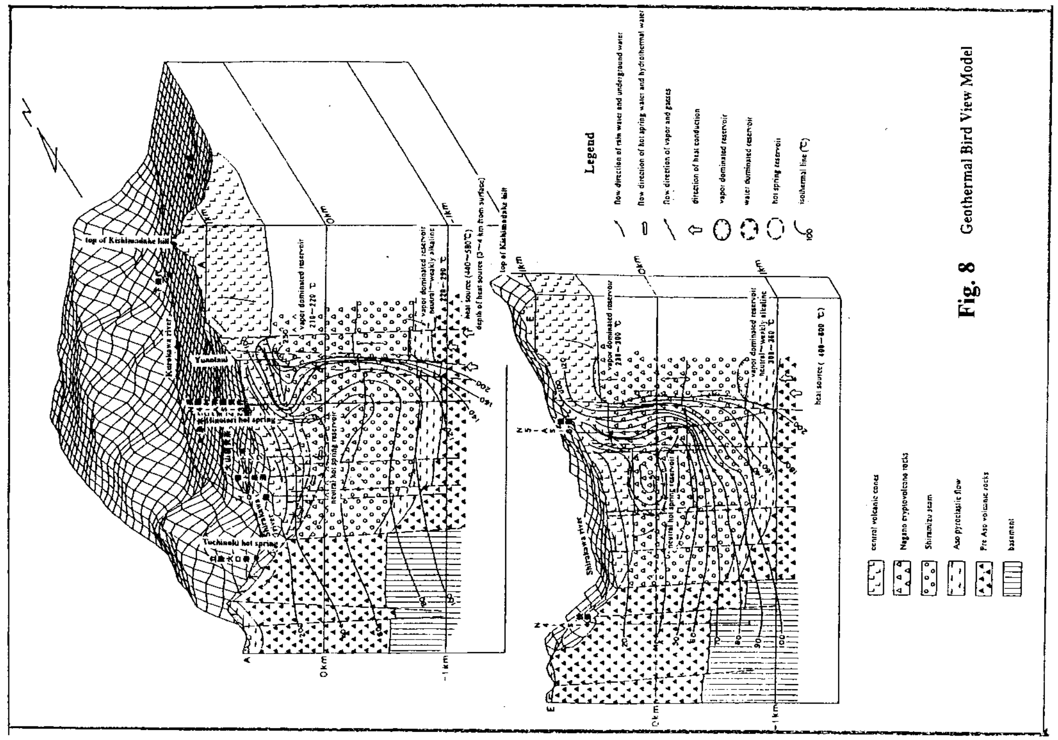


Fig. 8 Geothermal Bird View Model

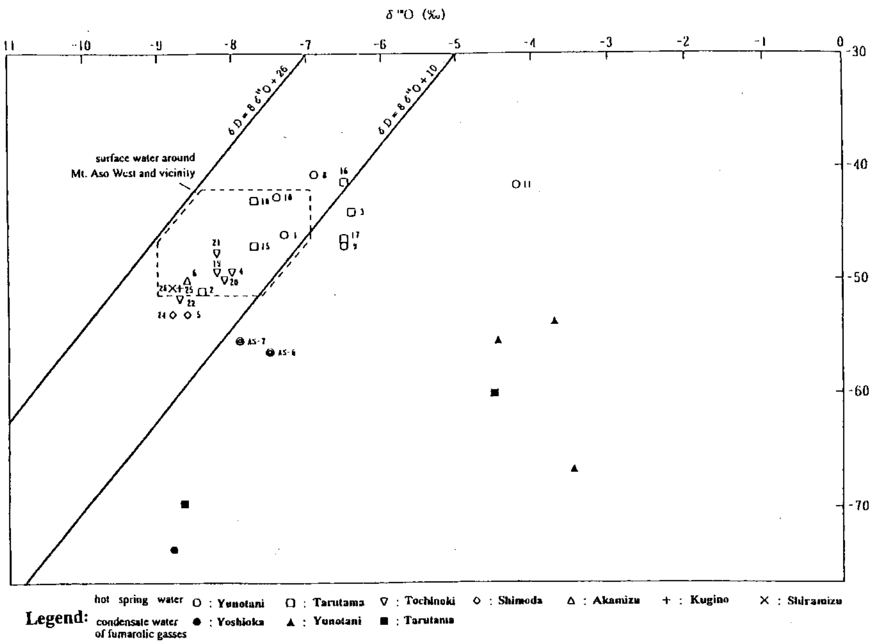


Fig. 7 **Relation Between δD and δ18O in hydrothermal water of N5-AS-6 and N5-AS-7**