GEOCHEMICAL MODEL OF THE MATSUKAWA GEOTHERMAL FIELD

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INTRODUCTION

The Matsukawa geothermal field is located in the Hachimantai volcanic region in which three geothermal power plants are now in operation(Fig.1). The Matsukawa power plant commenced its operation in 1966, and is characterized by a vapor dominated geothermal system. Some conceptual models of the Matsukawa area based on the surface survey data and well data were proposed(Hayakawa, 1967; Nakamura,1967;Ide,1985). In addition to these models, a geological structure of the Matsukawa area was explained in detail by Akazawa and Muramatsu(1988).

For the last 22 years, chemical characteristics of steam and production rates of the wells changed with time. This study presents a chemical model of the Matsukawa geothermal system based on examinations of changes in well discharge characteristics with time and the areal distribution of chemical compositions of steam.

GEOLOGICAL SETTING

According to Ide(1985), geological formations in the Matsukawa area are divided into three units, from oldest to youngest, marine sedimentary rocks of Miocene, Pliocene to Pleistocene Tamagawa welded tuffs and Quaternary Matsukawa andesite(Fig.2). Steam feed points exist mainly in lower part of Tamagawa welded tuffs and around the margin of porphyrite intrusive rock. As shown in Fig.3, three faults exist in the Matsukawa area, and they are thought of to form main reservoirs and steam channels of the system(Akazawa and Muramatsu,1988).

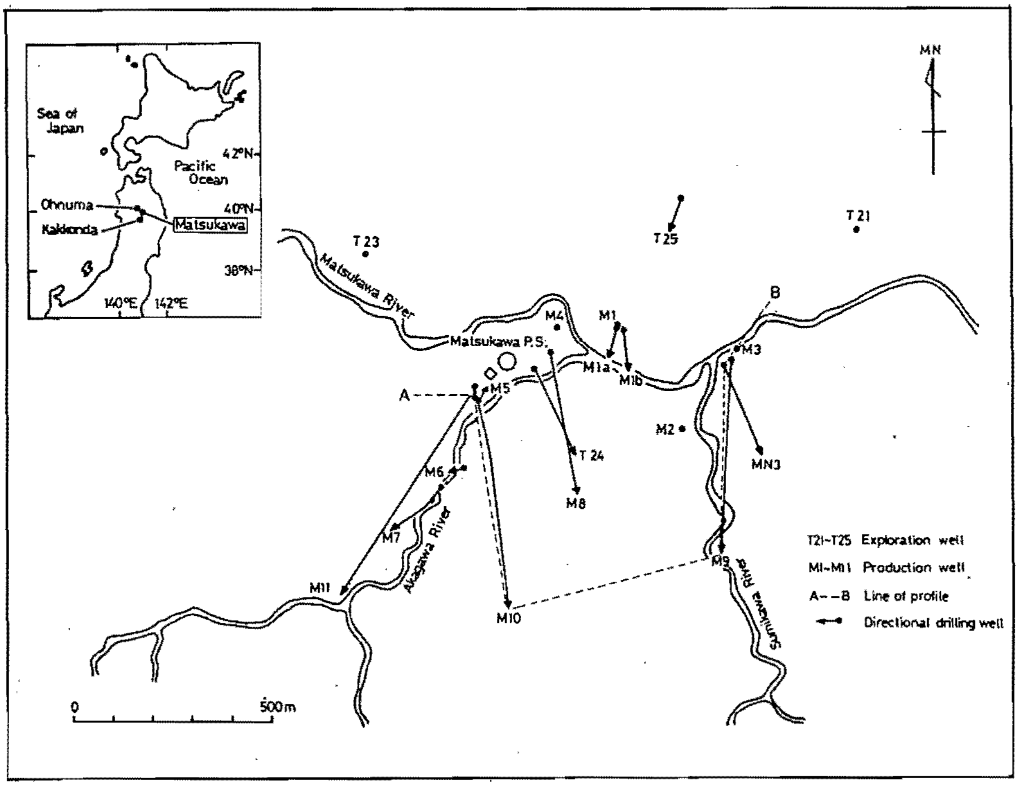

Fig.1 Location map of wells and cross-section at the Matsukawa geothermal field (after Akazawa and Muramatsu,1988)

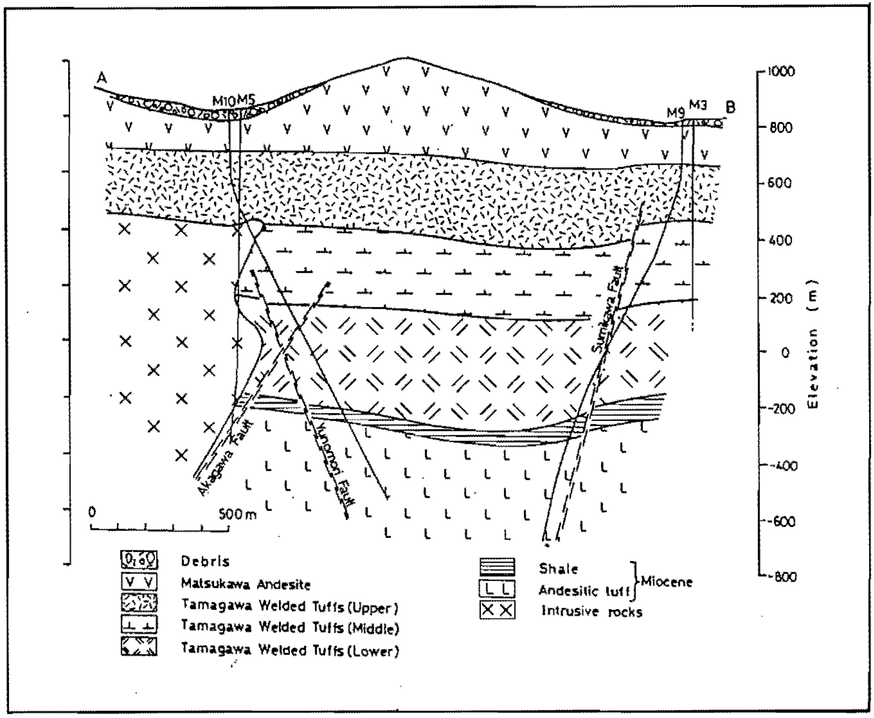

Fig.2 Geological cross-section of the Matsukawa field.Location of the cross-section is shown in Fig.1 (after Akazawa and Muramatsu,1988)

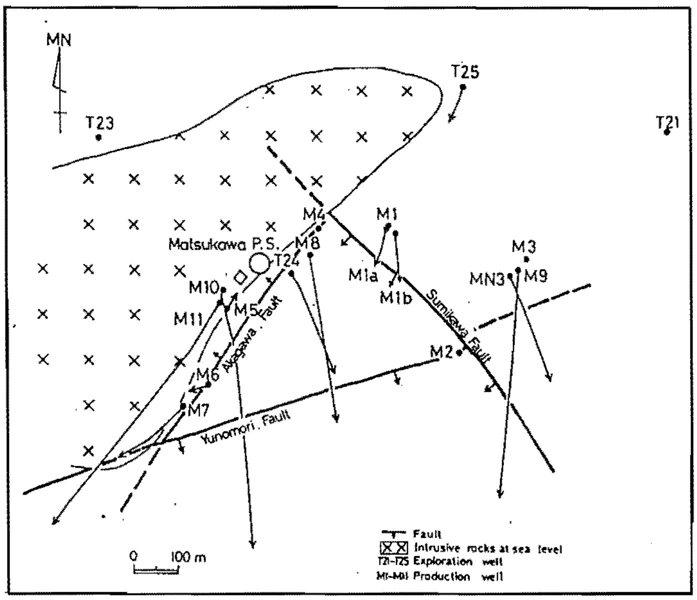

Fig.3 Fracture map at sea level estimated by the distribution of main steam feed points in the Matsukawa geothermal field (after Akazawa and Muramatsu,1988)

CHEMICAL CHARACTERISTICS OF STEAM

Chemical compositions of steam samples collected from production wells of the Matsukawa area are shown in Table 1. Triangular diagram of relative CO_2,H_2S and alkali-unabsorbed gas and relationship between normalized He/Ar and N_2/Ar ratios are shown in Fig.4 and Fig.5, respectively.

Based on the characteristics of the chemical compositions, production wells of the Matsukawa area can be divided into two groups. One is a group of wells of M-1b, MN-3 and M-9, which are drilled into the eastern to southeastern part of exploitation zone. Total gas concentration in steam of this well group is as high as 1vol.%. As shown in Fig.4, steam of this group is rich in CO_2 and poor in H_2S. NH_3 concentration is around 30ppm, and H_3BO_3 concentration is lower than 6ppm. The other is a group of wells M-2, M-5, M-6, M-7, M-8, M-10 and M-11,which are drilled into the central to western part of exploitation zone, which is strongly altered. Total gas concentrations in steams of this group is lower than those of the former group. Concerning CO_2 and H_2S concentrations, steam of western well group shows opposite characteristics to that of eastern well group; more CO_2 and less H_2S in eastern group(Fig. 4). Moreover, NH_3 concentration of western well group is lower than 10ppm, and H_3BO_3 concentration is over than 10ppm.

According to Yoshida(1984a), carbon isotopic composition of CO_2 of M-1b,3,9 group is light and shows wide variation. On the contrary, that of M-2,5,6,7,8,10, 11 group is heavy and constant. However, there is no significant difference of carbon isotopic composition of CH_4 between the two groups. This means that surface water which containes organic carbon contributes to the steam of M-1b,3, 9 group. Wide variation of carbon isotopic composition of CO_2 of this group means that the contribution of steam originated from deep brine is comparatively small. Almost the same values of carbon isotopic compositions of CH_4 suggest that origin of CH_4 of these two group are the same.

Tritium concentration of steam from M-3 and M-9 are from 1.1 to 1.2TR, and those of M-5 and M-8 are from 0.3 to 0.4TR(Yoshida,1984b). This suggests that contribution of recent surface water to steam of M-1b,3,9 group is larger than that to the other group. Thus, this coincides with the interpretation of carbon isotope data.

Based on the He/Ar and N_2/Ar ratios of the Matsukawa geothermal steam, these gases contained in the steam are mixture of deep seated volcanic gas and atmospheric air dissolved in surface water(Yoshida,1986). As shown in Fig. 5, He/Ar and N_2/Ar ratios of steams of all the wells are plotted along the mixing line which connects the point of M-3(highest values of both ratios) and that of dissolved air. Thus, it can be said that M-1b,3,9 group is strongly contributed by the volcanic gas. Combined this result with that of carbon isotopic compositions of CH_4, it can be considered that local variation of He/Ar and N_2/Ar ratios are caused by a different contribution of deep brine, and the contribution for the southeastern well group is larger than that for the other group. This coincides with the two facts that the rate of decrease of steam productivity is lower in the southwestern area and that the shut-in pressure of M-7 obtained from build-up test is much higher than those of M-8 and M-9(Hanano and Sakagawa,1988).

Based on the results discussed above,it can be said that there are two production zones at the Matsukawa area; one is a eastern to southeastern group, and the other is a central to southwestern group. Moreover, it can be said that distribution of chemical andisotopic compositions of the steam is caused by a difference of mixing condition of the steam sources in each area.

Table 1. Composition of geothermal steam from geothermal wells at Matsukawa

			Gas concentration in steam (by volume)								
Well	Date	Total gas	H_2S	CO_2	H_2	N_2	CH_4	Ar	He	NH_3	H_3BO_3
		%	ppm	ppm	ppm	ppm	ppm	ppb	ppb	ppm	ppm
M-1b	4/16,1988	1.01	495	9290	19.0	184	109	1760	38.8	4.5	0.6
M-2	3/17,1988	0.32	435	2660	46.9	36.9	21.3	463	5.28	10.0	19.3
MN-3	3/17,1988	0.96	701	8700	68.5	80.9	51.5	681	16.1	35.0	5.1
M-5	4/16,1988	0.24	358	1950	33.8	39.1	20.3	455	5.52	2.5	5.7
M-6	4/16,1988	0.38	543	3140	39.4	54.9	22.8	665	10.2	6.6	22.2
M-7	4/16,1988	0.19	382	1430	39.6	29.6	16.0	344	5.64	5.9	32.2
M-8	4/16,1988	0.43	688	3500	32.3	49.7	29.3	556	9.39	7.0	12.7
M-9	3/17,1988	1.13	644	10500	103	53.6	46.4	589	7.12	30.2	5.6
M-10	4/16,1988	1.11	2230	8760	24.1	61.8	24.1	940	6.66	1.2	0.1
M-11	3/5, 1988	0.24	415	1880	49.9	43.2	14.3	566	5.29	5.1	25.8

Total gas:Gases other than water vaper.

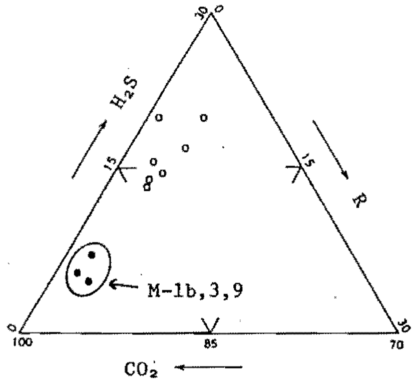

Fig.4 Gas composition of geothermal steam of Matsukawa shown by triangle diagram for CO2,H2S,and R-gas(residual gases):●:M-1b,3 and 9,○:M-2,5,6,7,8,10 and 11.

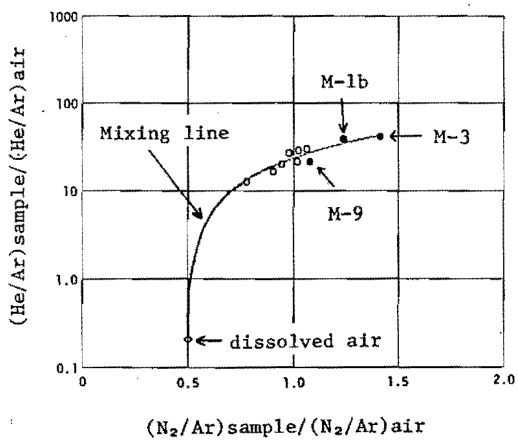

Fig.5 Relationship between He/Ar and N2/Ar ratios of geothermal gases of Matsukawa.●:M-1b,3 and 9,○:M-2,5,6,7, 8,10 and 11.

RELATIONSHIP BETWEEN FRACTURE DISTRIBUTION AND STEAM FLOW

As shown in Fig. 3, three fractures exist in the Matsukawa reservoir (Akazawa and Muramatsu,1988). We think that the fracture distribution controls the flow of geothermal fluids. Concerning wells M-1b and M-9, steam comes along the Sumikawa fault. For the well group of M-7,8 and 11 and M-5,6 and 10, steam comes along the Akagawa fault and Yunomori fault, respectively. Hanano and Sakagawa(1988) suggested that the steam is supplied from southwestern area, based on a trend of the areal pressure distribution. However, from a chemical point of view, two steam sources seem to exist in the area, one is for M-1b, 3, 9 and the other is for M-2, 5, 6, 7, 8, 10, 11.

We can conclude that one geothermal fluid comes from southeast area and flows along the Sumikawa fault, and the other fluid comes from southwest area and flows along the Akagawa fault and Yunomori fault. The distribution of chemical caracteristics of steams are controled by the differences of mixing mechanism which is also controled by the fracture distribution and pressure distribution of the Matsukawa area.

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