"FINGERPRINT" GEOCHEMICAL SURVEY APPLIED TO ONIKOBE OKUNOIN GEOTHERMAL AREA

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1. INTRODUCTION

Onikobe geothermal area, situated in northeastern Japan, is characterized by the large hydrothermal alteration zones named Katayama, Okunoin and Arayu. "Fingerprint" geochemical survey[1] at 134 stations in two survey lines was conducted in Okunoin area, where faults are detected by other studies (there are papers concerning to the faults, one of which is Abe and Harada(1985)[2]). In this survey the soil-gas absorbed by activated charcoal was analyzed by mass spectrometry. Thus obtained geochemical data show that there are two types of soil-gas anomalies indicating fault/fracture, one of which is high gas emission and the other is low gas emission. Several anomalous zones of the latter type are sandwiched by anomalous zones of the former type, forming the sequence of anomalous zones as high gas emission-low gas emission-high gas emission. Considering all geological and geophysical information, the soil-gas anomaly of the latter type, which has not been found in the other fields, was interpreted to indicate highly altered zone corresponding to top part of fracture zone sealed by clay of hydrothermal origin and the sequence of the anomalous zones was inferred to indicate migration of the passage for geothermal fluid from the center of sealed fractured zone to the outside.

2. DATA ANALYSIS

By cluster analysis, 134 mass spectral patterns obtained by mass spectrometry were classified into 16 clusters which were grouped into four groups (Fig. 1) as described bellow.

Group i: Relative intensity (R.I.) of at least one peak in the range of mass number (m/z) $\geqq 120$ exceeds 0.5.

Group ii: Relative intensity of over one peak in the range of $75<m/z<120$ exceeds 0.6 and relative intensity of peaks in the other ranges is less than 0.6. This group consists of only one cluster (cluster 9) and contains more than a half of all samples. Therefore it is interpreted to show mass spectral pattern of background in this area.

Group iii: The highest peak is in the range of $m/z<120$ and relative intensity of the other peaks is less than 0.3.

Group iv: Relative intensity of peaks in both ranges of $m/z \leqq 75$ and $75<m/z<120$ exceeds 0.6. Mass spectral pattern of this group is most anomalous because this group is most distantly related to group ii (Fig. 2).

To distinguish clearly anomalies indicating fault/fracture from the background, "gas feature diagram"[3] was prepared (Fig. 3). This diagram shows that "total modified ion count"[3] correlates with "high mass gas ratio"[3] and that there is a clear nonpopulated zone which divides the swarm of the samples into two. Almost all of the samples on the right hand of the nonpopulated zone, which show anomalously high gas emission and represent possible fracture, belong to group i. On the left hand of the nonpopulated zone samples of group ii, which represent background, distribute widely. Samples of group iii and iv are concentrated in the left of the diagram. Based on this occurrence, they are interpreted to be anomalously low gas emission.

Locations of the classified samples of the three types, anomalously high gas emission, background and anomalously low gas emission, are shown in Fig. 4. The widest zone of high gas emission F, indicating the prominent fracture running NNW to SSE, appears in the center of the area. An active fumarole occurs on the northwest extension of this zone, suggesting this fracture is presently active as a passage for geothermal fluid. The widest zone of low gas emission H indicates the presumed fault ③ (Nu). Top part of the fault ③ (Nu) above a depth of about 300m is inferred to be greatly

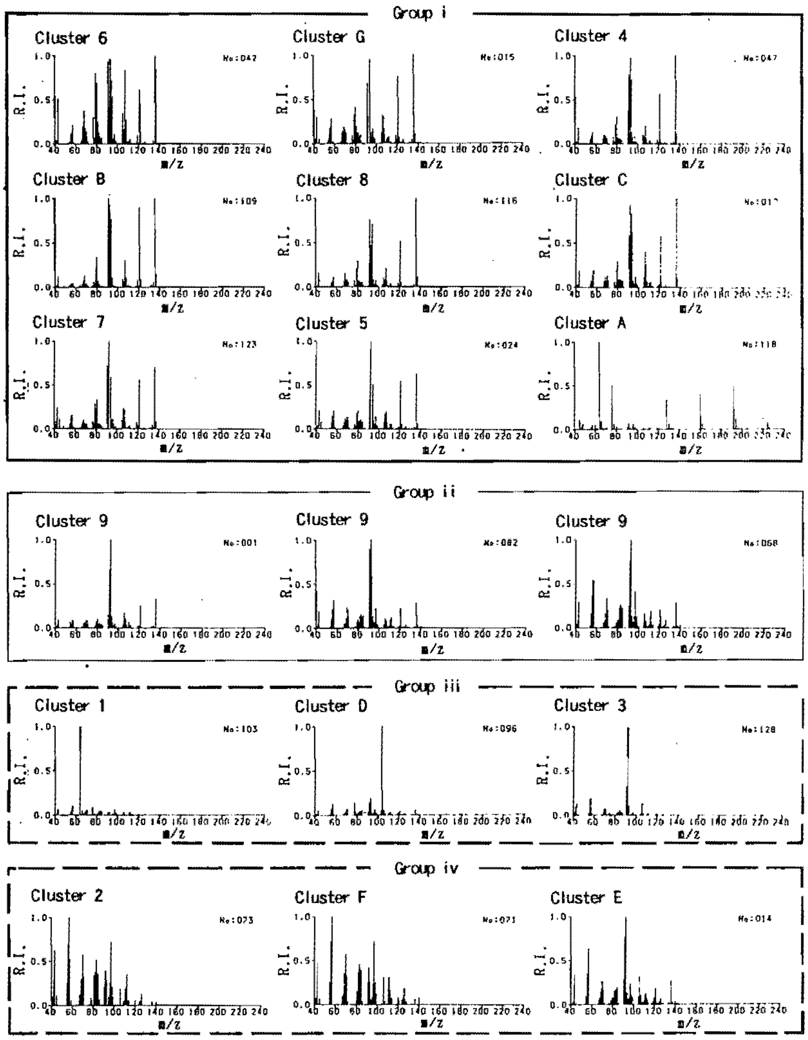

Figure 1. Mass spectra of 16 clusters and 4 groups.

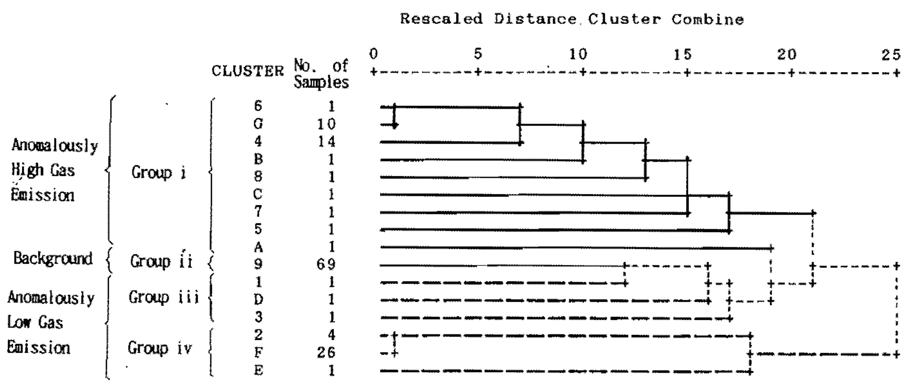

Figure 2. Dendrogram showing the relationship of clusters.

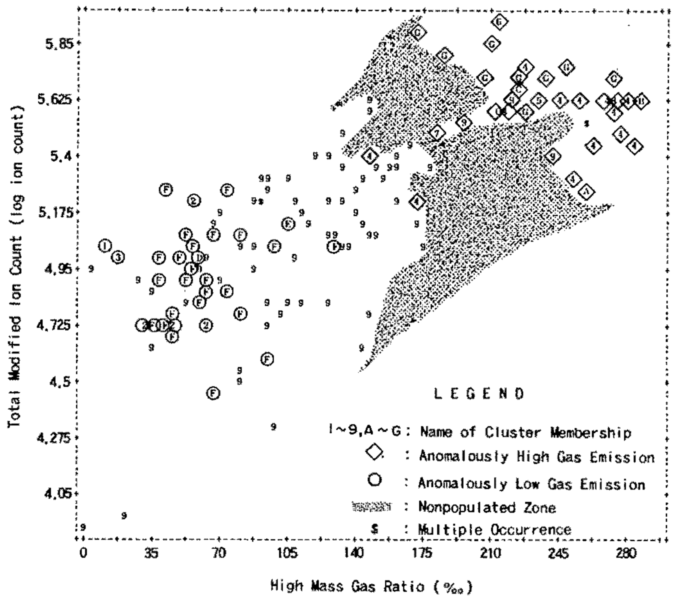

Figure 3. Gas feature diagram.
Total modified ion count: equivalent to the amount of all gases excluding the principal atmospheric components such as N_2, O_2, CO_2, H_2O, Ar, CH_4, ...
High mass gas ratio: ratio of the heavy gas (m/z≧120) to total modified ion count.

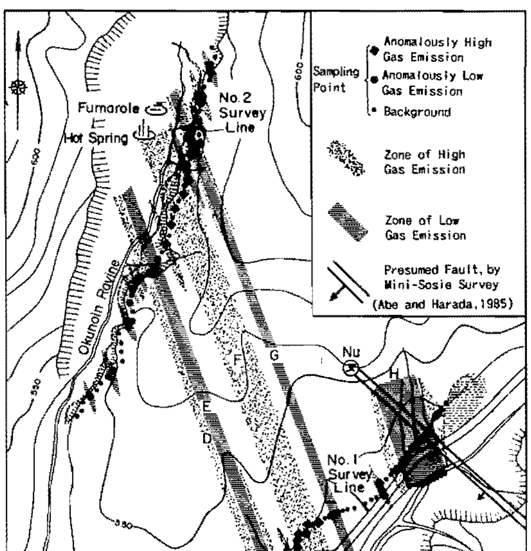

Figure 4. Distribution of the classified types of gas anomalies.

argillized[2]. It is also observed that both of the zones of low gas emission B and H occurring around the presumed faults by the seismic survey are sandwiched by zones of high gas emission, forming a sequence of gas pattern as high-low-high.

3. DISCUSSION

The highly altered zone is indicated as zone of low gas emission in this survey. The process forming the hydrothermal alteration zone in this area has been inferred as follows[4].

Stage 1: By ascending geothermal fluid along fractures, fumaroles and high temperature hot springs are formed on the surface, and a "umbrella" shaped hydrothermal alteration zone is formed above a depth of 30 to 60 m along the fracture.

Stage 2: The fracture, played as a passage of geothermal fluid, is gradually sealed with clay minerals produced by hydrothermal alteration.

Stage 3: Then a new passage for geothermal fluid is formed outside of the alteration zone, and fumarole activity is resumed.

Stage 4: By repeating the above process, the alteration zone develops gradually outwards.

On the basis of the above model, soil-gas anomalies are geologically interpreted as bellow.

Among the above process, stage 1 corresponds to the zone of high gas emission (Fig. 5). Stage 2 corresponds to zone of low gas emission, and stage 3 corresponds to zone of low gas emission sandwiched by zones of high gas emission (Fig. 6), that indicates the geothermal activity of this area is still active and the alteration zones are developing.

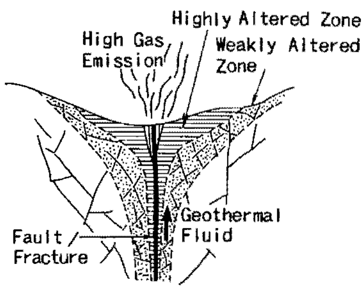

Figure 5. Schematic profile showing spouting out of geothermal fluid along fault/fracture (after Abe, 1985; with some modifications by the authors).

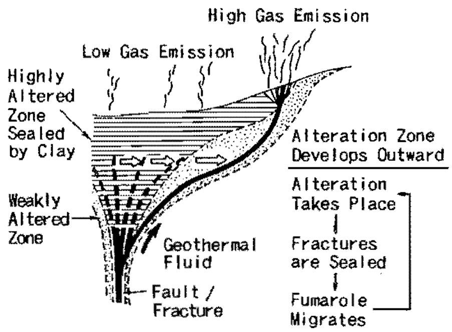

Figure 6. Schematic profile showing development of alteration zone and migration of fumarole (after Abe, 1985; with some modifications by the authors).

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