ESTIMATION OF GROUNDWATER FLOW USING MULTIVARIATE ANALYSIS AND GEO-ELECTRICAL METHOD

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1.INTRODUCTION

The significance of groundwater flow is well-known for various purposes such as identification of recharge area, groundwater contamination, and water resources management.

In this work, the implementation of multivariate analysis of groundwater chemistry, in the prediction of groundwater flow, and its comparison with those results obtained through geoelectrical resistivity sounding is reported.

2.STUDY AREA

The investigated area is a part of kumamoto plain which is located in the eastern part of Kumamoto city, southwest of Japan. The plain is mainly covered by the upper Quaternary unconsolidated deposits, particularly, the pyroclastic flow deposits. Fig.1 shows the investigated area.

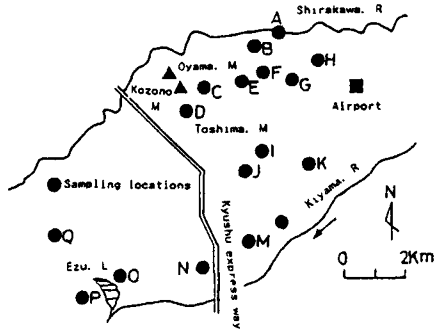

Fig. 1 Investigated area

3.GEOELECTRICAL RESISTIVITY SOUNDING

For this purpose MCOHM 2115, which implements the offset system of electrical resistivity sounding with a multicore cable (Barker 1981), was used. This method has made the Wenner array more efficient for assessing the top most 100m or so. Soundings were performed at 30 stations. The sounding curves were interpreted using a manual technique by utilizing the nearest boring data to the sounding.

The soundings were generally good with low observation errors and reasonably low with random offset errors. Fig.2 illustrates the sounding results for one of the locations.

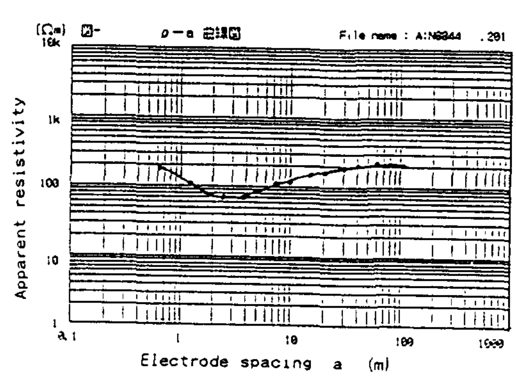

Fig. 2 Resistivity sounding for one of the stations

4.CLASSIFICATION OF WATERS USING MULTIVARIATE ANALYSIS

Four times through out the course of one month, water was sampled from wells in different location (Fig.1). The samples were analyzed for water chemistry parameters.

The data were analyzed seperately using principal component analysis (PCA) for each sampling time. The data were standardized to a mean of zero and variance of one in order to give equal weights to all variables. In all of the cases, the cumulative proportion for the first and second principal components was greater than 85%, which accounts for almost all

Table. 1 Results of principal component analysis

Variables	Average	Standarad Deviation	Z1		Z2	
			E.V	F.L	E.V	F.L
EC	207.222	52.289	0.446	0.96	0.21	0.19
HCO_3^-	63.180	12.497	0.397	0.86	-0.31	-0.28
Cl^-	8.117	3.858	0.312	0.67	-0.71	-0.63
Na^+	10.550	2.396	0.380	0.82	0.58	0.52
Ca^{2+}	14.311	4.613	0.448	0.97	-0.06	-0.05
Mg^{2+}	7.761	2.291	0.447	0.96	0.12	0.11
	Eigenvalue		4.648		0.793	
	Cumulative. p		77.47%		90.69%	

of the variations. Table 1 shows one of the obtained results.

In order to clarify the similarity of the waters, cluster analysis was conducted. The majority of the analyses revealed a dedrogram such as the one given in Fig.3, and classified the waters into four groups.

5. ESTIMATION OF GROUNDWATER FLOW

For estimation of groundwater flow, the data from April to September during which the water shows higher electrical conductivity (EC) were used.

For each group again principal component analysis was performed seperately. The water chemistry parameters were $SO4^{2-}$, Na^+, K^+, Ca^{2+}, Mg^{2+}. For group a, the first principal component accounts for 81.1% of the total variability and the second principal component for 11.3%. The associated plane, which accounts for 92.4% of the variability, is thus sufficient to interpret the results. The eigenvectors of the first principal component, Z1 are positive, and those of Z2 are positive for Na^+ and K^+, and negative for Ca^{2+} and Mg^{2+}. This reflects the fact that the dissolution phenomenon and ion exchange are in correspondence to the Z1 and Z2 respectively.

A contact between sediments and flowing water causes dissolution of ions into the water. On the other hand, ion exchange between Ca^{2+} and Mg^{2+} in the water and Na^+ and K^+ in the clay minerals causes reduction of Ca^{2+} and Mg^{2+} and an increase of Na^+ and K^+. This fact was utilized to estimate groundwater flow. For a certain group, for example group a, moving from right to left is considered to be the direction of groundwater flow (Fig.4).

The same analysis was performed for group b. Fig.5 illustrates the final results obtained by the two above mentioned methods. The two methods in general showed good agreements. Disagreements existed for the northern part of the investigated area which is attributed to the complex structure of the area. Uncertainty of the sounding results might be due to that fact.

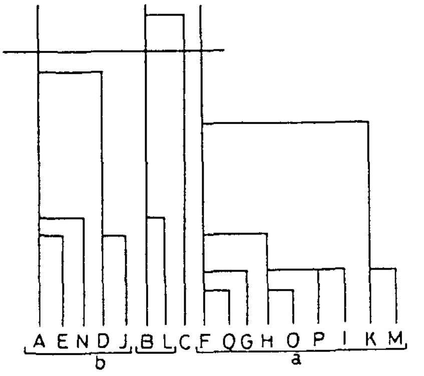

Fig. 3 Dendrogram of water locations

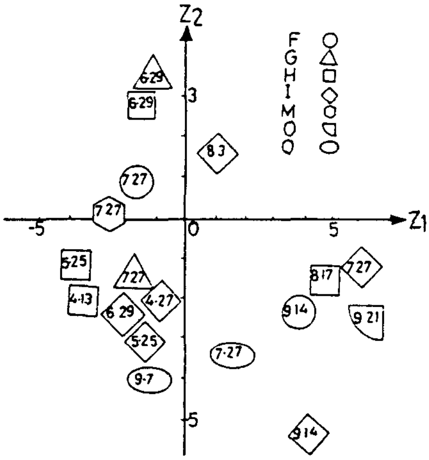

Fig. 4 Z1 and Z2 scores for group a

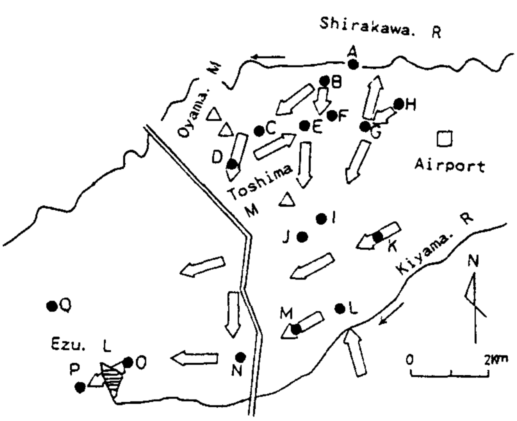

Fig. 5 Groundwater flow for the area

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