Compound evaluations method of some geophysical explorations by self-organizing maps

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Compound evaluations method of some geophysical explorations by self-organizing maps

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In Japan, in the high economic growth period in 1960's, a great number of slopes were formed to construct many roads. Now, the slopes have been aging, it is important to estimate the health of the aging slopes and maintain slopes effectually. So we usually carry out seismic wave method, surface wave method, electric method and so on. However, there is not the technique to compound and interpret the result of each geophysical exploration. Therefore, we notice to self-organizing maps (SOM) used widely in a field of the information processing engineering, and tried to interpret multidimensional data by integrating. In this paper, we classified the ground property by self-organizing maps. The classification result is relatively conformal with boring data. Therefore, it is recognized that it can be used to improve the interpretative accuracy of compound geophysical explorations. And, it can be shown that this technique is effective to estimate of the ground property of the aging slope.

1. INTRODUCTION

In the investigation of the soundness of the aging slope, the method to evaluate overall by using plural geophysical explorations is paid to attention. However, the technique to interpret plural geophysical explorations synthetically is not established, and the high judgment to be based on technical knowledge and experience of the engineer is demanded, and it is the present conditions that unevenness may produce for the interpretation of the geophysical explorations. Therefore, in this study, the data of plural geophysical explorations measured in situs clustered by SOM[1)~3)] widely used in the field of information processing engineering, and the proposal of the technique for interpreting them overall was tried. There were only a few example of ground evaluation by SOM, such as danger evaluations of rock slope[4)], the physical properties along the plate boundary decollement in the Nankai[5)] and the classification of soil properties in levee[6)]. And the authors[7)] tried an application to the ground property evaluation of the aging slope last year. In this paper, k-means method[8)] was applied to perform an objective classification. The result of the classification by SOM was related to RQD (Rock Quality Designation), the rock types and the rock class division that had become clear in the boring investigation. Therefore, it was able to be shown that this method was effective for the compound evaluations of geophysical explorations to understand rock properties of the aging slope.

2. GEOLOGICAL CONDITIONS IN THE RESEARCH SITE

An object slope in this study is cutting ground slope along the national road No.9 in Omi district in Fukuchiyama City in Kyoto in Japan, as shown in Figure-1. The shotcrete slope is area-A (Figure-2), non-support slope is area-B (Figure-3). These are located in the south of the national road, and comparatively large-scale slopes of about 200m in length and about 50m in height. In area-A, there are a lot of cracks due to aging, and a lot of vegetation from the cracks and the swells are seen. In area-B, there are open-cracks. Geological features are in Tanba strata at Triassic in the Mesozoic-Jurassic Period, and are chiefly composed of a part of sandstone layer, a sandstone shale alternation of strata, and a green rock layer.

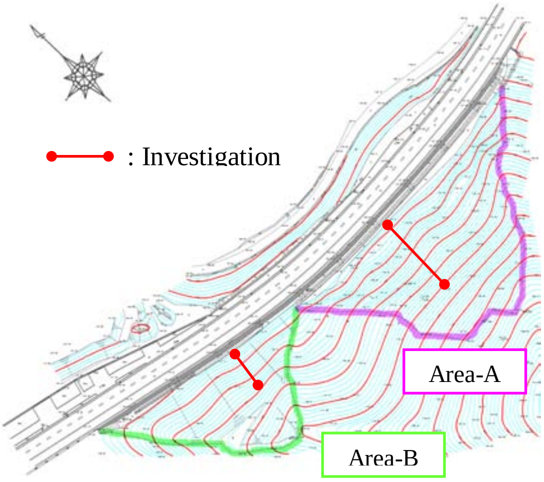


Figure-1. Topographic features of the slope

Figure-2. View of the shotcrete slope (area-A)

Figure-3. View of the non-support slope (area-B)

3. ANALYTICAL METHOD

(1) Geophysical explorations

The Geophysical explorations that were used for examination are a seismic tomography method, a surface wave method, and resistivity tomography method, and in total six times of them are executed from September, 2008 to March, 2011. From each method P wave velocity, S wave velocity, resistivity are obtained. They were executed in both areas. However, in area-A, geophysical data is not sensitive very much because of the influence by the shotcrete and metal bodies behind the shotcrete. Therefore, the evaluation by SOM is carried out on the result of the area-B.

Figure-4~Figure-6 show the result of measurement in summer from 2008 to 2010.

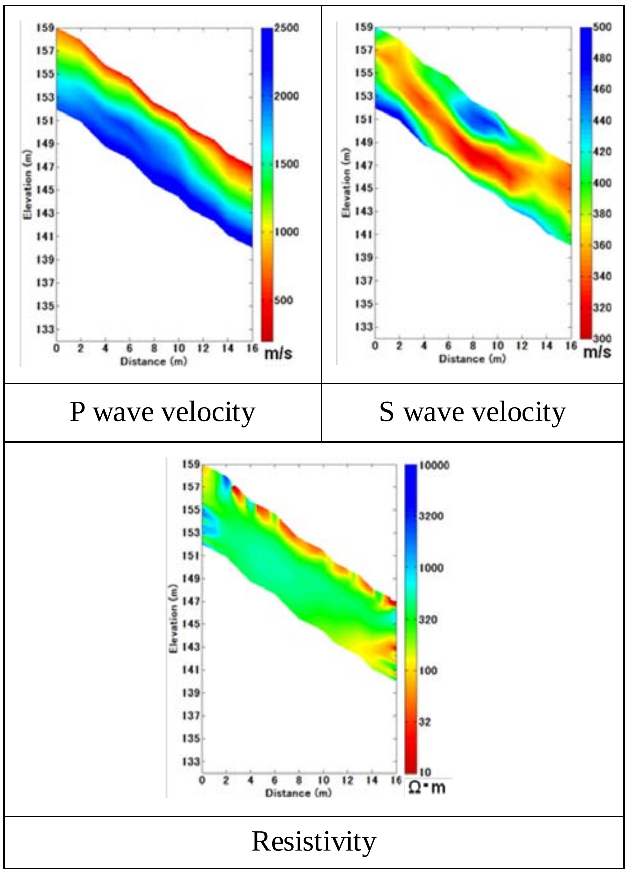


Figure-4. Measurement result (2008)

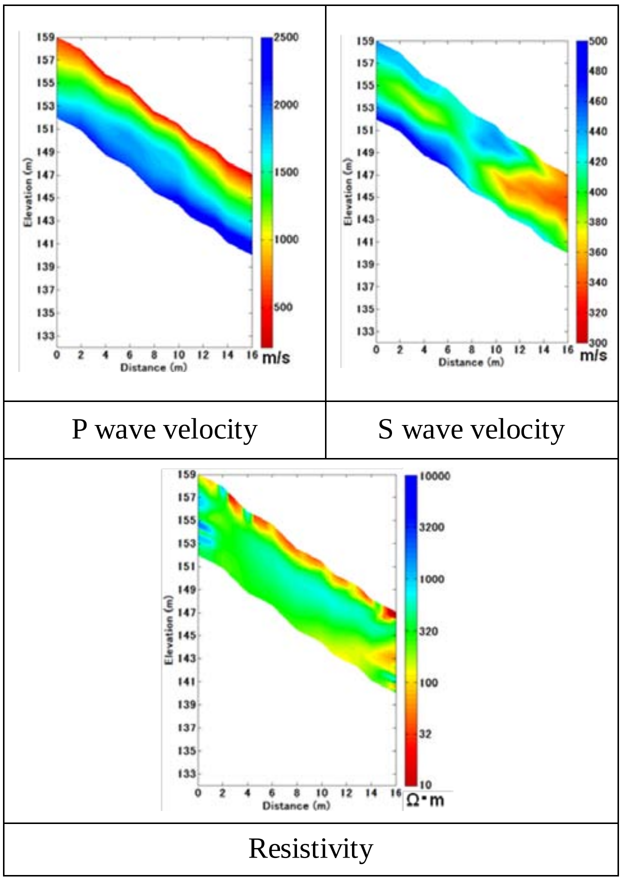
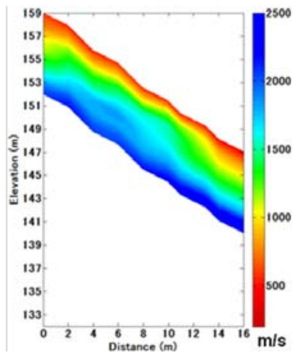
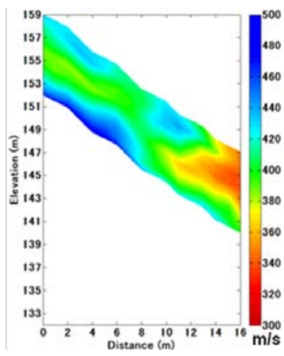
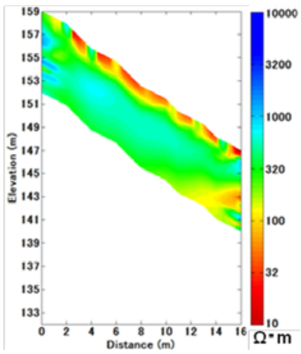


Figure-5. Measurement result (2009)

	
P wave velocity	S wave velocity



Resistivity

Figure-6. Measurement result (2010)

The P wave velocity shows a tendency that the speed transmitted in the ground quickens as depth becomes deep. The S wave velocity was low in the lower part of slope, and it was presumed that there was an intense weathering in the area. And low-resistivity was shown at the surface of the slope and the part deeper than the depth of 4m in B-4. The resistivity was estimated to be influenced by the weathering and the groundwater.

(2) Self-organizing maps (SOM)

SOM is a kind of the neural net work developed in 1979 by professor Kohonen of Helsinki University. This has the feature in which the input data of higher dimension data can be mapped to SOM plane of two dimensions in proportion to the degree of similarity. In a word, data with a different feature has the feature in which the map arranged at a position away can be made so that data with a similar feature is near. The classification was conducted in the map we made to read and evaluate the characteristics of each class qualitatively. The algorithm of SOM is shown in Figure-7.

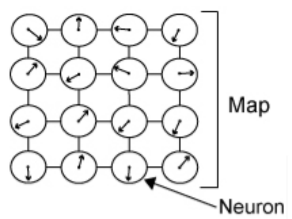
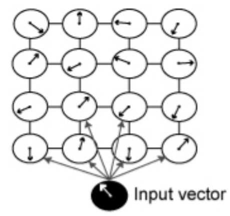
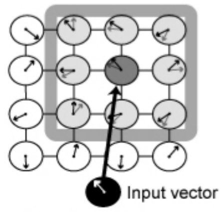
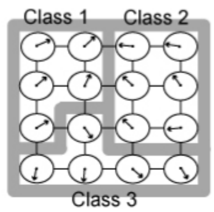
First of all, the two-dimensional map is initialized. An individual neuron with the same dimension as the input vector is arranged in two dimension SOM plane at random besides the input vector (Figure-7(a)).

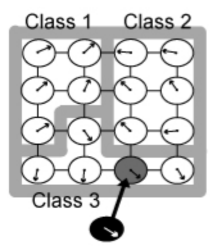
Secondarily, it searches for the champion vector. The champion vector is a vector to which Euclidean distance that shows the degree of similarity shown in the expression (1) is minimized. In a word, it looks for the most similar reference vector to the input vector (Figure-7(b)).

$$d = \left\| x_i - m_j \right\| = \sqrt{\sum_{k=1}^{n} \left[x_{ik} - m_{jk} \right]^2} \qquad (1)$$

d: Euclidean distance, x_i: the input vector, m_j: the reference vector.

Thirdly, according to the expression (2) ~ (5) shown below, the champion vector and the circumference unit near the champion vector learn the input vector. The neighborhood size reduces the size with learning (Figure-7(c)).

 	
(1) Initialization of SOM map	(2) Search for champion vector
 	
(3) Learning of champion vector and unit near it	(4) Clustering of SOM map



(5) Class separation of input vector

Figure-7. The basis of the algorithm of SOM

$$w_i(t+1) = w_i(t) + h_{ci}(t)[x_i(t) - w_i(t)] \quad (2)$$

$$h_{ci}(t) = \alpha(t)\exp\left(-\frac{d^2(t)}{2\sigma^2(t)}\right) \quad (3)$$

$$\alpha(t) = \alpha_0\left(1-\frac{t}{T}\right) \quad (4)$$

$$\sigma(t) = \sigma_0\left(1-\frac{t}{T}\right) \quad (5)$$

$w_i\,(t)$: information processing ability, $h_{ci}\,(t)$: the update rate, $x\,(t)$: the input vector, $\alpha(t)$: the learning coefficient, $d(t)$: the distance from the champion vector, $\sigma(t)$: the learning radius from the champion vector, α_0 : the initial value of the learning coefficient, σ_0 : the initial value of the learning radius, t : the learning frequency, T : All learning frequency.

Fourthly, the SOM map is clustered. Repeating the search and the study of the vector a number of times, the vector with high similarity is arranged on the SOM map. And, considering those Euclidean distances makes it possible to classify the SOM map (Figure-7(e)).

Finally, the input vectors classify. By applying the input vectors to the clustering SOM map, it is understandable which class the input vectors are classified.

(3) K-means clustering

K-means clustering was used for the objective classification in this study. In the k-means clustering, the number of class is set as k beforehand and each data is assigned to the class at random. The center of each class is calculated based on the assigned data. Average value of each element of assigned data is usually used for the calculations. The distance between each data and the center of the class is calculated, and each data is reassigned to the nearest central class. When the assignment of the class of all data does not change through these processes, the processing finishes. If not so, the center is calculated again from the class assigned newly and a series of processing is repeated. As a characteristic of this calculation, some differences occur in the last classification result depending on an initial value. Therefore Davies-Bouldin Index (DBindex) [9] is used as evaluation function to evaluate the last classification result shown in the next expression.

$$DBindex = \frac{1}{k}\sum_{i=1}^{k}\max_{i\neq j}\left\{\frac{\Delta(X_i)+\Delta(X_j)}{\delta(X_i, X_j)}\right\} \quad (6)$$

k: the number of the class, $\delta\,(X_i, X_j)$: Euclidean distance between the class center in (X_i, X_j), $\Delta\,(X_i)$: The average value of the Euclid distance between the center of class X_i and each class.

We try multiple types of classifications by k-means clustering and decided a result that takes DB Index to a minimum as an appropriate classification result.

4. RESULTS

The SOM map of each geophysical datum that is classified by k-means is shown in Figure-8. The SOM map is not the one where the vertical direction and the horizontal direction of two dimensions plane show the coordinates but only similar vectors arranges in neighborhood. Therefore, it is necessary to read how the geophysical values are distributed in the SOM map.

Table -1 shows the relative amount of physical data that each class has in by the map. Figure-9~Figure-11 show the comparison of a classification result and the result of boring investigation.

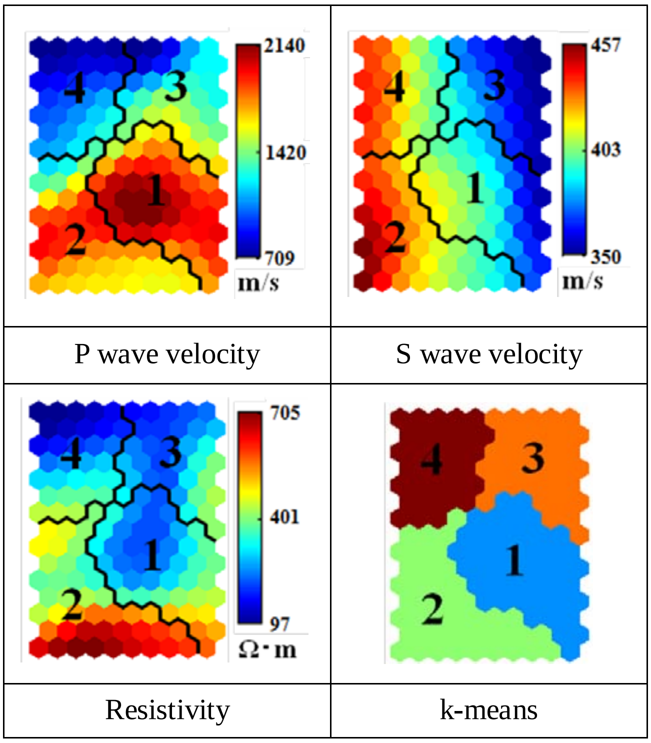


Figure-8. SOM maps of each geophysical datum that is classified by k-means

Table-1. The relative amount of physical data

	P wave velocity	S wave velocity	Resistivity
Class 1	●●●	●●	●●
Class 2	●●	●●●	●●●
Class 3	●●	●	●●
Class 4	●	●●	●

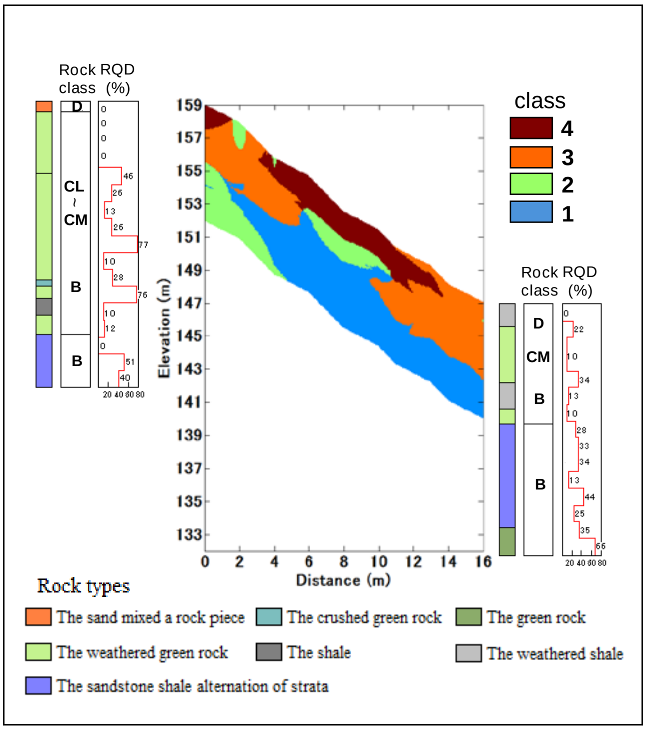


Figure-9. Classification result (2008)

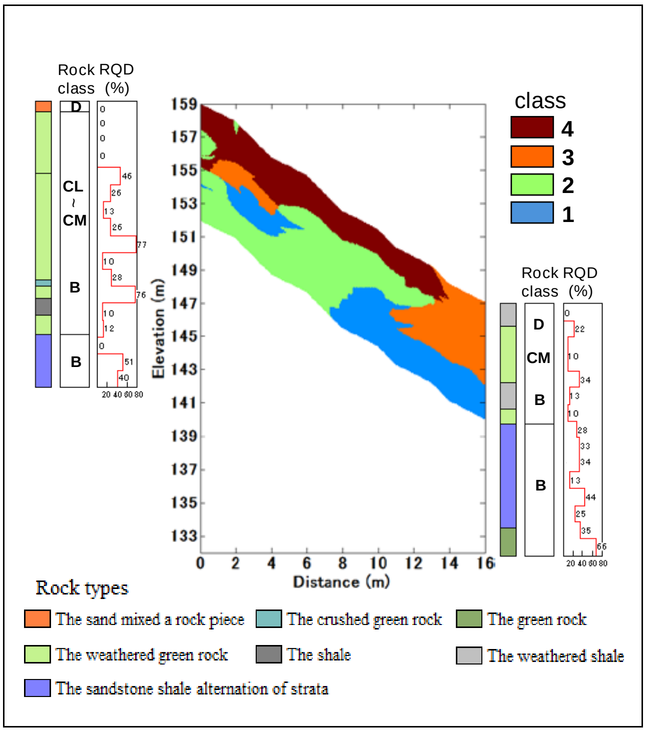


Figure-10. Classification result (2009)

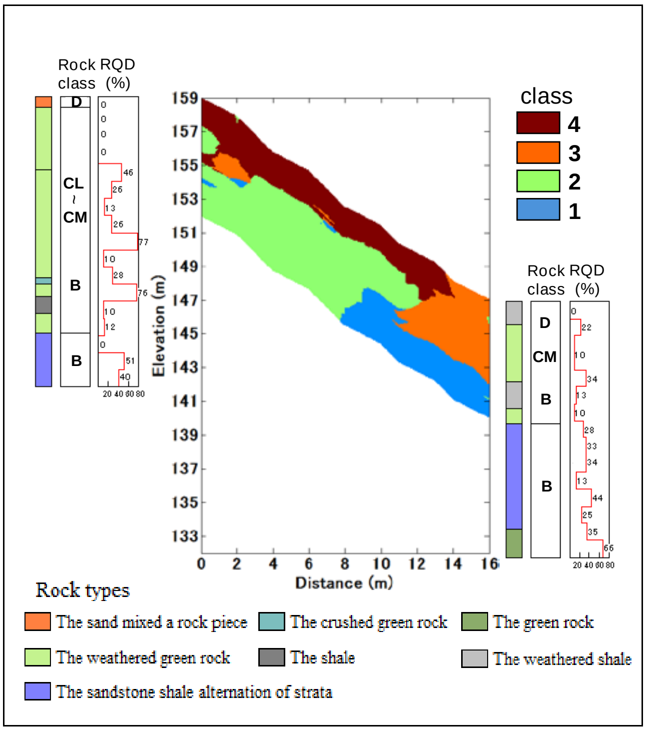


Figure-11. Classification result (2010)

First, the rock properties of each class are estimated from the map in Figure-8. It is thought that class 1 and class 2 are comparatively hard since the speed of P wave and S wave are high-speed. In addition, class 1 is estimated to contain a large amount of water, because the P wave has a property to become fast when there is water in rock. On the other hand, it seems that there is low water content in class 2 because resistivity is high. It is thought that class 3 and class 4 are weak areas since both P wave and S wave are low-speed. Class3 seems to have a high water content, because the resistivity is low and the P wave velocity is slightly higher than one of class 4. Class 4 is distributed over the surface in the all classification results (Figure-9~Figure-11), and it is thought that the Class is influenced by the weathering greatly.

Next, the classification result is compared with the result of boring investigation. In all classification results, class 3 or class 4 are distributed over the surface, and they are almost the same as the points where RQD of B-3 is 0%. In B-4, there is a border of weathering greenstone and the weathering shale at the spot of 5m from the surface, which is also a border of B class and the CM class in the rock class division. At this spot, there is also a border of class 1 and class 3 so that it is shown that the result is consistent.

Finally, the change of the classification result is shown as follows. In the classification result of 2008, class 1 is widely distributed deeper than the depth of 4m from the surface, but in 2009 and 2010 class 1 changes into class 2 sequentially. Therefore, it can be estimated that the water-retaining condition is easy to change in the area. In class 2 distributed over the slope central area, it is thought that the area has low-permeability and is hard because the change is not seen there. It seems that weakening by the weathering is worse because the area where class 4 is distributed over spreads out in the surface.

4. CONCLUSION

In this study, the geophysical data was characterized and classified to four classes by SOM that widely used in the field of information processing engineering to interpret the result of two or more geophysical explorations comprehensively. The opinions obtained from this study are shown as follow.

1) The geophysical values of different dimensional (the P wave velocity, the S wave velocity and the resistivity) that had been obtained from three kinds of geophysical explorations were classified into four classes considering those characteristics by SOM and k-means method.
2) We got the result that is roughly corresponding to RQD taken from the boring investigation, the rock class division and the stratum structure.
3) It will be thought that we can catch a change of the state in the ground such as the weathering and the water-retaining condition by measuring regularly in the future. In the evaluation of each class after the classification, quantitative evaluation technique is demanded in the future because it is qualitative evaluation at this stage.

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