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Evaluation of Reliability in Computerized Geotomographic Image Model Selection by Electrical Methods

by

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Abstract

The recent development of the geoelectrical methods has been able to extract reliable subsurface information from its applications to the earth structure and the environmental earth field data obtained under more complex geological structure environments. This would include weathered overburden layers, vertical contacts, faults, fracture zones, deep bed rocks or host rocks, near-surface lateral or local inhomogeneities and various topographies.

The most commonly used controlled source electrical methods, including direct current resistivity measurements for exploration and evaluation of the earth structures and their environments, may be those in which a great variety of electrode arrays may be grouped into two main systems: the surface electrode array system and the solid electrode array system. The surface electrode array system can be divided into vertical sounding and horizontal profiling techniques. The solid electrode array system may be divided into hole (or tunnel)-to-surface and cross-hole measuring techniques. The vertical sounding technique has extended its two-dimensional (2D) interpretation ability by use of continuous vertical sounding (CVES). The horizontal profiling has extended its ability for automatic, high resolution inversion. The solid electrode array measuring has become a new useful tool as an aid to extraction and enhancement of signals due to small or deep, and complex target inhomogeneities.

In the resistivity interpretation method, including the so-called computerized geoelectrical image model construction, such as resistivity tomographic section reconstruction and computer animation of resistivity maps, it is worth special mention that evaluating the extraction and enhancement of subsurface information due to target inhomogeneities, or evaluating the effects of electrical arrays found to be sensitive to the reasonable subsurface model reconstructions. Especially, it is very important that one analizes and integrates the effective elements for the reliable evaluation of resistivity interpretation procedures.

In this paper, at first, a significance of traditional and newly developed electrical geophysical pseudosections based on sensitivity distributions of the surface and solid electrode array systems are described. Next, we reviewed a model optimization in electrical prospecting by use of Akaike's Information Criterion, which can be considered as the statistical estimator of the entropy or the Kullback-Leibler information measure. Finally, two field examples of evaluation

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of the computerized image model selection procedure by using pseudosection and *AIC* are discussed.

1. Introduction

Recent geoelectrical interpretation procedures require more careful and reliable subsurface information[19,22-27,31-34]. The most commonly used direct current methods for the exploration and evaluation of the target inhomogeneities and their environments may be those in which a great variety of electrode arrays may be grouped in two main systems: the surface electrode array system and the solid electrode array system. The surface electrode array system can be divided into vertical sounding and horizontal profiling techniques. The solid electrode array system may be divided into hole(or tunnel)-to-surface and cross-hole measuring techniques.

The vertical sounding technique has extended its two-dimensional interpretation ability by use of continuous vertical sounding (CVES). Beard (1987)[4] has investigated an assessment of 2D resistivity structures using a 3D inversion, and detected unreasonable results in the vertical sounding. He has suggested that one may often obtain a more reliable interpretation of subsurface information from the pseudoscections than from the exact results by the so-called VES inversion. Mundry (1984)[8] has also pointed out the 2D resistivity structure problems in the VES inversion. van Overmeeren and Ritsema (1989)[10] and Molano, Salamanca and van Overmeeren (1990)[11] have developed the CVES technique and applied it to groundwater exploration, monitoring environmental groundwater quality, in which high density interpreted 2D models can be obtained continuously.

The horizontal profiling has extended its ability for an automatic, high resolution inversion. Two-dimensional resistivity inversions have been developed by Tripp, Hohmann and Swift (1984)[15] who have proposed a concept of resistivity tomographic image reconstruction by use of surface resistivity data. Smith and Vozoff (987)[16] have reported Dipole-Dipole 2D resistivity and induced polarization inversions by use of its pseudosections. Furthermore, as an aid to more reliable interpretation elements, original and extended various sensitivity distributions including Frechet or partial derivatives have been defined and developed by Sugano et al. (1988a, 1989a)[19,22], Bazinet and Berube (1988)[20] and McGillivray and Oldenburg (1990)[21]. Sugano et al. (1989a)[19] have newly proposed the sensitivity distribution in the nontarget inhomogeneities. McGillivray and Oldenburg (1990) have studied the methods for calculating Frechet derivatives and sensitivities in the case of a 100 ohm-m conductive prism buried in a 1,000 ohm-m half space.

The solid electrode array measuring has become a new useful tool as an aid to extraction and enhancement of signals due to difficult target inhomogeneities. Sugano and Sassa (1988a, 1988b, 1989a, 1989b, 1989c, 1989d, 1990)[19,23~27] and Sugano (1980, 1990a, 1990b, 1990c)[31~34] have investigated the evaluation of extraction and enhancement of response due to target inhomogeneities in the solid electrode array system. They also investigated the evaluation of its solid electrode array effects in the computerized section construction (subsurface imaging) techniques.

Thus, the direct current electrical prospecting method by use of surface electrode arrays has long been applied as an effective aid to mineral and energy resources, groundwater reserves, civil engineering geotechnical and environmental explorations and evaluations[28~30]. Also, electrical methods using subsurface electrodes may become increasingly more useful exploration tools for detecting deep or hidden mineral deposits, energy or groundwater resources and geological fractures for monitoring groundwater contamination, nuclear waste repository and various dynamic changes of earth structures. Furthermore, in geophysical prospecting, some tomographic reconstruction algorithms have been investigated. Especially, the tomographic analysis of seismic data has lately become a powerful tool for geophysical researches. In such researches, investigating the techniques utlizing the large numerical modeling, the high density three-dimensional data, simulation analysis, the visualization such as imaging and computerized section reconstructions has been developed.

However, the effective and reliable evaluation methods of the various interpretation procedures have not been fully developed.

The present study suggests that the electrical geotomographic image reconstruction procedure using the computerized section construction linear digital filter, the pseudosection based on sensitivity provides reliable interpretive advantages. At first, this paper begins with a brief review of the pseudosection method based on the sensitivity distribution developed by the author, and examples of pseudosection construction in Section 2. The basic concept of the relation between pseudosection and sensitivity has been discussed by the examples of the Wenner surface, hole-to-surface, and cross-hole solid array systems. Next, Section 3 presents a model optimization problem in the resistivity interpretation and effect of AIC. Section 4 discusses two kinds of field examples for evaluations of computerized section procedures using resistivity pseudosection and AIC. The first evaluation of the computerized section model has been studied as a groundwater reservoir exploration geophysics under the condition of near surface geologic noises. The second evaluation has been discussed about an example of exploration conducted in the groundwater bearing area with a vertical fault. In these evaluations, the pseudosections of the field model and computerized model, the percentage difference pseudosections between the field resistivity model and computerized model, and the investigated results by the AIC method have been systematically described. Consequently, Section 5 gives conclusions.

2. Significance of pseudosection based on sensitivity distribution and examples of resistivity pseudosection analyzed by FEM 2D-3D algorithm

2.1 Significance of pseudosection construction

As is well known, the surface resistivity array pseudosection which was already shown by Hallof (1957)[41], Marshall and Madden (1959)[42] has proven to be a very useful expression for investigating resistivity information obtained for various geoelectric structures. The most common interpretation technique in the one-dimensional (1D) problems is the linear digital filter method developed by Koefoed (1979)[7].

In the two dimensional (2D) problems, it is conventionally common to depend on the pseudosection method. Unfortunately, a direct interpretation of subsurface resistivity distributions from general pseudosections is difficult. One can only use surface electrode array pseudosections, but one can not use solid electrode array pseudosections because the latter have not yet been introduced. Applying the sensitivity distribution method, the resistivity pseudosection constructions can easily provide very effective information for subsurface resistivity distributions, as Sugano et al. (1989b)[19] have newly introduced. The recent most important developments in electrical techniques include the use of computer 2D-3D or 3D high density modeling, continuous large data processing with visualization and electrical solid arrays such as cross-hole (or hole-to-hole) and hole-to-surface (and surface-to-hole) configurations, often used in electrical tomography techniques. An important objective of the solid electrical array method is to maximize, extract and enhance the response due to target inhomogeneities by using subsurface electrodes in boreholes or tunnels. As mentioned above, up to the present it has been considered that the pseudosection method cannot be applied in the case of the risistivity method using the solid array electrical tomography procedure, where the area of exploration is surrounded by the line of electrodes. Therefore, the author has also developed the solid array pseudosection method for a more useful application of pseudosections.

Generally speaking, if the computerized resistivity tomography inversion result is not perfectly equal to the true resistivity distribution, the subsurface information may be considered to be a pseudosection. Finally, we must effectively use pseudosections according to the stage of resistivity interpretation procedures. Today, an effective element as an aid to evaluate the resistivity inversion including electrical geotomography has not yet been proposed. It can be seen that both the traditional

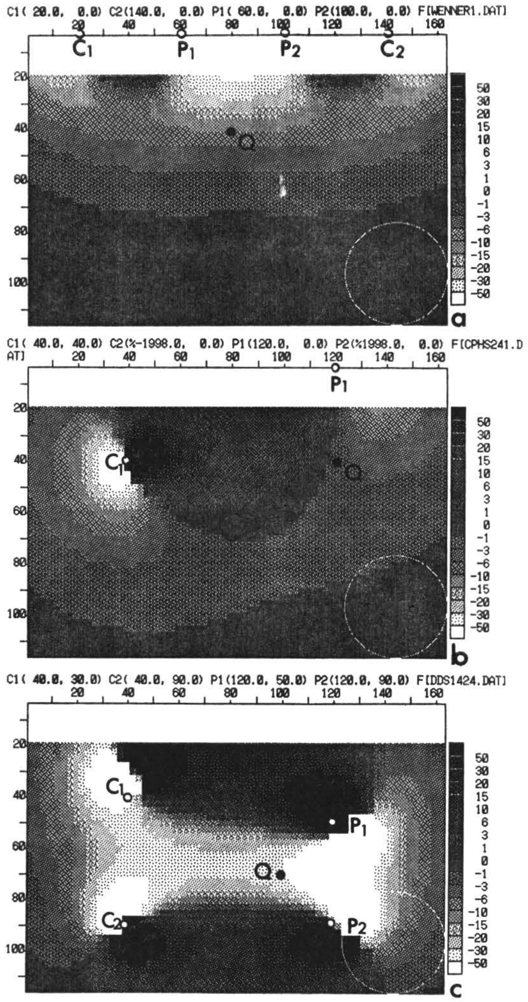

Fig. 1. Examples of sensitivity distributions and pseudosection assignment points for typical surface and subsurface solid electrode array systems.
(a): CPPC (surface) Wenner electrode configuration,
(b): C (subsurface) P (surface) Pole-Pole hole-to-surface electrode configuration,
(c): CC (subsurface) PP (subsurface) Dipole-Dipole cross-hole electrode configuration.

pseudosection and the newly defined one are very nice in potential data analysis for this inversion such as electrical geotomographic image reconstruction procedure.

Figures 1a, 1b and 1c are examples of illustrations showing the relation between pseudosection plotting points and sensitivity distributions. Figure 1a shows an example of sensitivity distribution for a typical Wenner surface electrode array configuration, including its assignment point Q. The point Q plotting its apparent resistivity data for its pseudosection construction is conventionally defined at the x-directional center of the array and at the depth of electrode spacing. From the view point of the sensitivity characteristics, the assignment point Q locates at the position in the rather normal high sensitivities, where, by the author's definition, the sensitivities S_k in the cases of $S_k \lesseqgtr 0$ for the relation of $\rho_k \lesseqgtr \rho_N$ between the target resistivity ρ_k and the environmental earth resistivity ρ_N. It can be supposed that sensitivity characteristics lead to provide more accurate subsurface resitivity information and its resistivity environments.

2.2 Pseudosections for surface electrode array

Various surface electrode arrays, such as Pole-Pole, Pole-Dipole, Wenner (or alpha Wenner), Schlumberger, Eltran (Electric transient or beta Wenner), Dipole -Dipole, Staggered (or Cascade, gamma Wenner), etc., have their own resistivity pseudosections for each earth structure. It has been well known that one can often obtain some good fitness between the type of surface electrode array configurations. For typical examples, the Wenner or Schlumberger array has the ability to extract the subsurface information due to the horizontal conductive or vertical resistive structures. Also, the Eltran or Dipole-Dipole array has the ability to extract the information due to the vertical conductive and horizontal resistive structures. The Staggered array has the more sensitive ability to extract the anomalies due to the horizontal conductive and vertical resistive structures than the Wenner array.

2.3 Pseudosections for hole-to-surface solid arrays

Various kinds of hole(or tunnel)-to-surface solid arrays may be designed in the practical fields. Figure 2 illustrates the solid electrode combination pattern of C (subsurface, drill hole DH-1) P (surface) hole-to-surface configuration. Here, the current electrode C_1 is driven in the borehole DH-1 from the depth of 0 m to 800 m and the potential electrodes P_1 on the surface from 200 m to 1,600 m in the x-direction. The remote electrodes C_2 and P_2 are set far from the bore-

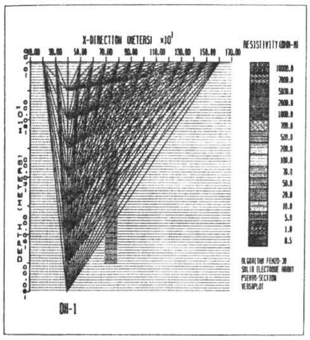

Fig. 2. Electrode combination pattern designed by C (driven in the borehole DH-1 from the depth of 0 m to 800 m with a spacing of 100 m) P (driven on the surface from the distance of 200 m to 1,600 m in the x-direction) hole-to-surface array configurations. With the 24 electrodes, the 135 unique potential data can be obtained for resistivity pseudosection construction.

hole. There are 9 electrode positions (100 m spacing) along the borehole DH-1 and 15 electrode positions (also 100 m spacing) on the surface. With these 24 electrodes, one can obtain 135 unique potential or apparent resistivity data. Figures 3a and 3b show the hole-to-surface solid array pseudosections which are made by the assignment point Q (See Figure 1b) in the cases of a conductive (the target resistivity is 10 ohm-m and its surrounding nontarget inhomogeneity is 100 ohm-m) vertical orebody and a conductive horizontal orebody. Both the case of the conductive vertical orebody shown in Figure 3a and the case of the conductive hori-

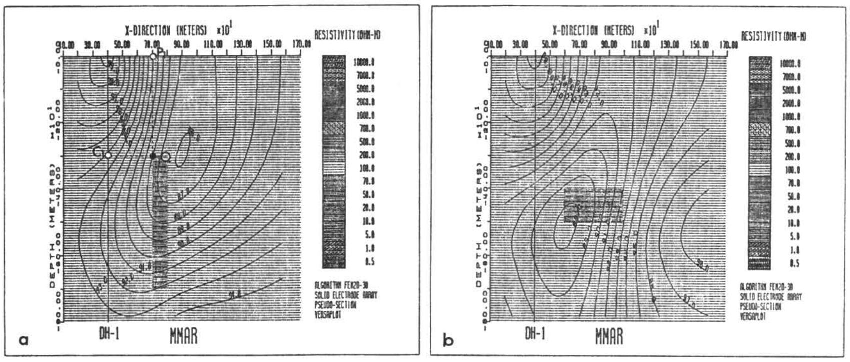

Fig. 3. Examples of resistivity pseudosection change calculated by FEM 2D-3D algorithm for the C (borehole DH-1) P (surface) solid array by the cases of conductive vertical and horizontal target inhomogeneities (the target resistivity is 10 ohm-m and its surrounding nontarget background is 100 ohm-m).
(a): Resistivity pseudosection for a conductive vertical structure, (b): Resistivity pseudosection for a conductive horizontal structure.

zontal one shown in Figere 3b present anomalies of low apparent resistivities at each structure, respectively. Comparing the vertical case with the horizontal case, the latter anomaly appears at a deeper position than the former one. It can be said that the difference of the subsurface structure type directly contributes to the anomalies and then one can obtain the interesting macro-anisotropy information of the earth structures and their environments on the resistivity pseudosections.

2.4 Pseudosections for cross-hole solid arrays

Many cross-hole (or tunnel) solid arrays using two or multi drill holes may be designed for the field electrical data aquisitions. Figure 4 illustrates the solid electrode combination pattern of *CC* (subsurface, drill hole DH-1) PP (subsurface, drill hole DH-2) cross-hole configuration, in which the current bipole electrodes C_1C_2 are set in the borehole DH-1 at the depth of 400 m, 500 m and 800 m. The potential electrodes P_1P_2 are set in the borehole DH-2 from the depth of 0 m to 1,300 m with electrode spacings ranging from 100 m to 900 m. For an example of measurement with the C_1C_2 electrodes at the depth of 400 m and 800 m, there are 2 electrode positions (400 m spacing) along the borehole DH-1 and 12 electrode positions (100 m spacing) along the borehole DH-2. With these 14 electrodes, one can obtain 63 unique potential difference or apparent resistivity data. Figures 5a and 5b show the cross-hole solid array pseudosections which are made by the assignment point *Q* (See Figure 1c) in the cases of the C_1 (400 m) C_2 (800 m) long spacing pair and the C_1 (400 m) C_2 (500 m) short spacing pair for a conductive (the target resistivity is 10 ohm-m and its surrounding nontarget inhomogeneity is 100

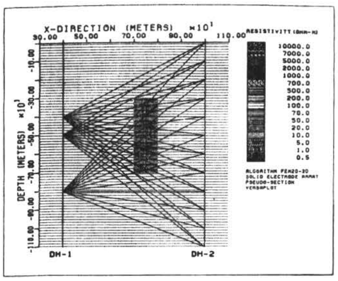

Fig. 4. Electrode combination pattern designed by CC (setted in the borehole DH-1 at the depths of 400 m, 500 m and 800 m with spacings of 100 m and 400 m) PP (driven in the borehole DH-2 from the depth of 0 m to 1,300 m with electrode spacings of 100 m, 200 m, 300 m, 400 m, 500 m, 600 m, 700 m, 800 m and 900 m) cross-hole array configurations With the 14 electrodes, the 63 unique potential difference data can be obtained for resistivity pseudosection construction.

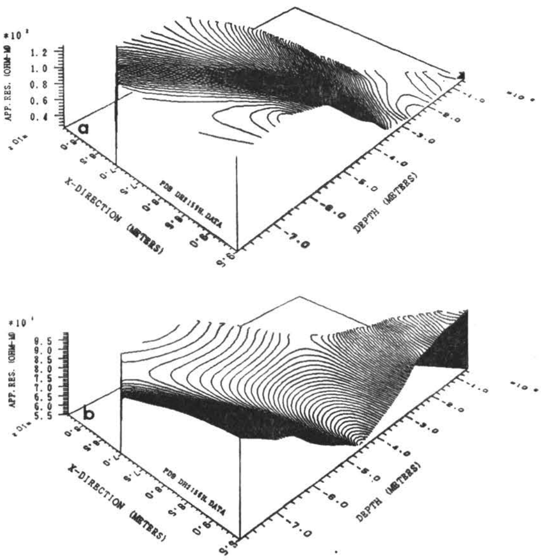

Fig. 5. Examples of resistivity pseudosection change calculated by FEM 2D-3D algorithm for the CC (borehole DH-1) PP (borehole DH-2) solid array by the case of CC (at the depths of 400 m and 800 m, long spacing) and CC (at the depths of 400 m and 500 m, short spacing) for a conductive vertical target inhomogeneity (the target resistivity is 10 ohm-m and its surrounding nontarget background is 100 ohm-m).
(a): Resistivity pseudosection for a setting of the long spacing CC current electrodes, (b): Resistivity pseudosection for a setting of the long spacing CC current electrodes.

ohm-m) vertical orebody. Although the two cross-hole resistivity pseudosections are made of the same conductive vertical orebody as shown in Figure 4, they have presented almost different anomalies of low apparent resistivities at the target position. The anomaly in the former pseudosection constructed with long spacing (400 m) of the C_1C_2 appears near the surface, but the latter anomaly appears at the center of of the target inhomogeneity. It can be said that the difference of the subsurface solid array directly contributes to the anomalies, as one must be careful about designing the effective solid array combination patterns as an aid to obtain the target information for the resistivity interpretation.

3. Use of *AIC* and its problem in model optimization for resistivity interpretation

Various statistical methods have been tried to estimate optimum models. The Kullback-Leibler information measure, which was defined by Kullback and Leibler (1951)[3], is not a practical estimator, because in the prospecting problems true models are unknown. Akaike (1974)[1] defined an information criterion, the so-called AIC (Akaike's Information Criterion), which can be applied to the cases of unknown true models.

In electrical prospecting, model selection in the resistivity interpretation depends on the geological character of the subsurface structure. Considering the facts, it may be a matter worthy to be considered that *AIC* is a useful statistical estimator, but not for a model identification problem. High resolution resistivity inversion requires many parameters such as a number of resistivity blocks and a combination of various resistivities for target and nontarget inhomogeneities. For example, 1D inversion techniques usually adapt a model divided by horizontal multilayer structures. 2D inversion techniques often adapt a model divided by multiblock structures with rectangle sections. Therefore, if the higher resolution inversion requires a greater number of multilayers or multiblocks, the number of their model parameters becomes a great deal. If to solve this difficult resistivity problem one applies *AIC* to every case, one can not accomplish the performance of model optimization. Under the predetermined or the limited interpretation conditions, the evaluation by *AIC* is adaptive for successful electrical prospecting techniques.

4. An evaluation of computerlized resisivity section construction procedure

The examples discussed here were conducted by the well used surface Wenner electrode system as the groundwater reservoir exploration and their environmental geophysics.

4.1 Field example 1: example of exploration conducted in a groundwater bearing area with near surface geologic noise.

The estimation of the groundwater bearing zone was investigated by a geological survey too. As a result of the geological approach, the groundwater bearing zone consists of gravel and sand layers surrounding weathered granite formations. Figure 6a shows the surface Wenner electrode array combination pattern designed for the field application.

Figure 6b shows the result of the computerized resistivity section after 30 iterations by the linear digital filter and the vector area methods.

The linear digital filter method is based on the following fundamental equations,

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial V}{\partial r}\right)+\frac{\partial^2 V}{\partial z^2}=0, \qquad (1)$$

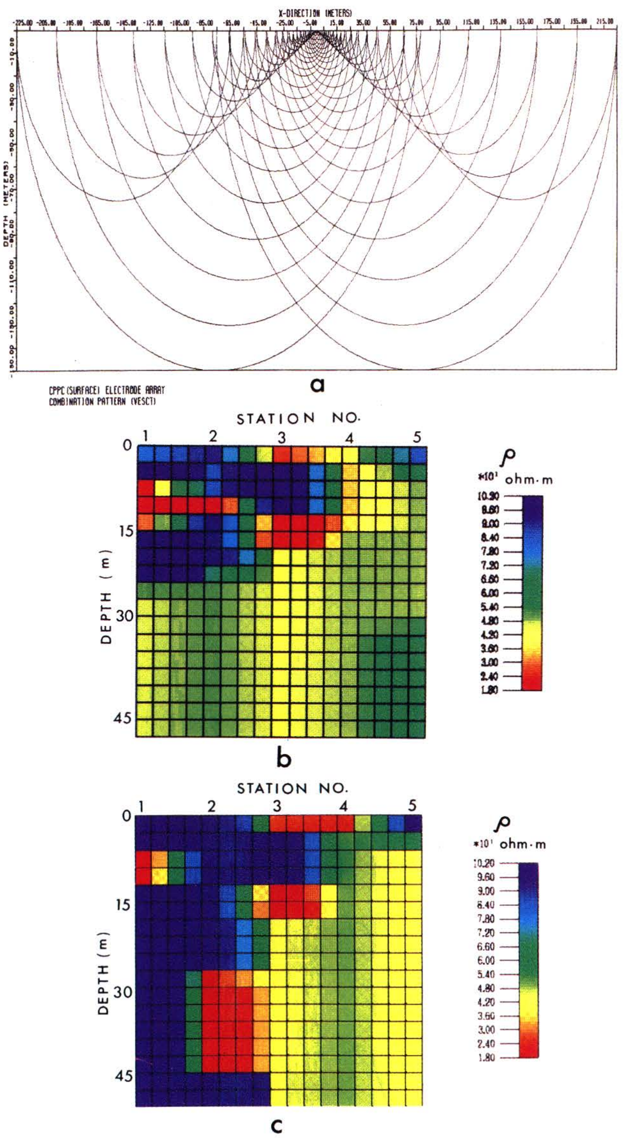

Fig. 6. Designing surface electrode array combination pattern and the selections of computerized resistivity model in the cases history of groundwater exploration under the condition with near surface geologic noise.

(a): An example of designing surface electrode combination pattern by use of CPPC (surface) Wenner array configurations,

(b): Computerized resistivity section model selected for groundwater exploration.

(c): Computerized resistivity section model selected for groundwater exploration.

where $V(r, \phi, z)$ is the potential expressed with the cylindrical coordinate. In the Wenner system, the apparent resistivity is expressed as follows,

$$\rho_{aw} = 2a\int_0^\infty T(\lambda)[J_0(\lambda a) - J_0(2\lambda a)]d\lambda, \tag{2}$$

where $T(\lambda)$ is called the resistivity transform. J_0 is the Bessel function. By use of the linear digital filter f_j,

$$f_j = \int_{-\infty}^{\infty} 2\frac{sin[\pi(-\eta+x-y_0-j\Delta y)/\Delta y}{\pi(-\eta+x-y_0-j\Delta y)/\Delta y}[J_0(e^\eta) - J_0(2e^\eta)]e^\eta d\eta$$

$$\eta = x - y \tag{3}$$

we can obtain the computed resistivity

$$\rho^c{}_{aw} = \sum_{j=-\infty}^{\infty} f_j\ T(y_0 + j\Delta y) \tag{4}$$

The vector area method is based on the theorem introduced by Karplus (1958)[58].

Figures 7a and 7b illustrate examples of evaluation of the computerized section reconstruction procedure by use of *AIC*, which presents the performance of the computerized model in comparison with the true model in the field. *AIC* is expressed in the following relation,

$$AIC = N\ log\ \hat{\sigma}^2 + 2n + C, \tag{5}$$

where N is the number of resistivity data and n is the number of inverted layers, also, $\hat{\sigma}^2$ is the variance calculated by ρ_{ai} (the apparent resistivities of the true model) and ρ_{ci} (the apparent resistivities of the computerized model).

The model shown in Figure 7a includes the unreasonably low resistivity layer and it is impossible to estimate the earth structures in the field. From the evaluation of the resistivity interpretation procedure by use of an automatic inversion, the six-layer model shown in Figure 7a can be selected by 30 iterations with the indicator *AIC*. However, *AIC* indicates an anomaly value at about 28 iterations. Therefore, it can be said that from the even evaluation by use of *AIC*, the reasonable true layers model can not be selected in this interpretation procedure. Then, we use a concept of the resistivity equivalent layer theorem for the selection of an optimum model. Figure 7b shows the reasonable model selection using the equivalent layer theorem.

AIC as a criterion of objective model selections may be useful for monitoring and the evaluation of a reasonable interpretation procedure if those are applied to the optimum resistivity distributions and the determination of layer thickness under the same parameters. Therefore, the use of *AIC* for resistivity interpretation may be effectively applied to select the inverted model parameters in the case of which the value n is variable. In these examples, it can not be said that the typical use of *AIC* has been carried out. It may be an interesting future problem and

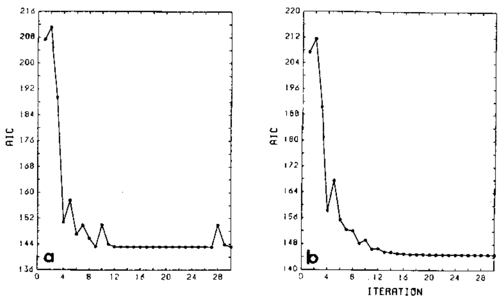

Fig. 7. Examples of evaluation of computerized resistivity section reconstruction procedure by use of AIC.
(a): AIC model selection at the station No. 1 after an automatic inversion, (b): AIC model selection at the station No. 1 after revision using equivarent layer theorem.

more important that one set a reasonable relation among electrical model parameters.

Figures 8a and 8b show the resistivity pseudosection for the field data ρ_{ai}, and the pseudosection constructed by the computerized model data ρ_{ci}. FIgure 8c shows the percentage difference $(\rho_{ci}-\rho_{ai})/\rho_{ai}\cdot 100(\%)$ between the apparent resistivity data of the field model shown in Figure 8a and the apparent resistivity data of the computerized model shown in Figure 8b.

Comparing the field model resistivity pseudosection shown in Figure 8a with the computerized model resistivity pseudosection shown in Figure 8b, it is clearly seen that both pseudosections present almost completely similar patterns. The fact suggested that a successful model selection was acomplished. The percentage resistivity difference pseudosection shown in Figure 8c may confirm the good fitness, in which local residuals may indicate a more detailed improvement of the resistivity distribution or unreasonable analysis errors by the 1D inversion. Finally, the groundwater bearing zone under a near surface geologic noise environment can be detected in the medium low resistivity area at the depth of about 15 m under the station of No. 3 of the computerized resistivity section shown in Figure 6b.

4.2 Field example 2: example of exploration conducted in a groundwater bearing area with vertical fault

Figure 6c shows the inverted result into a computerized resistivity section after 30 interations by the linear digital filter and the vector area methods. In this example, the resistivity interpretation procedure is evaluated from the initial model to the simulated model after 30 iterations. Figures 9a, 9b and 9c illustrate

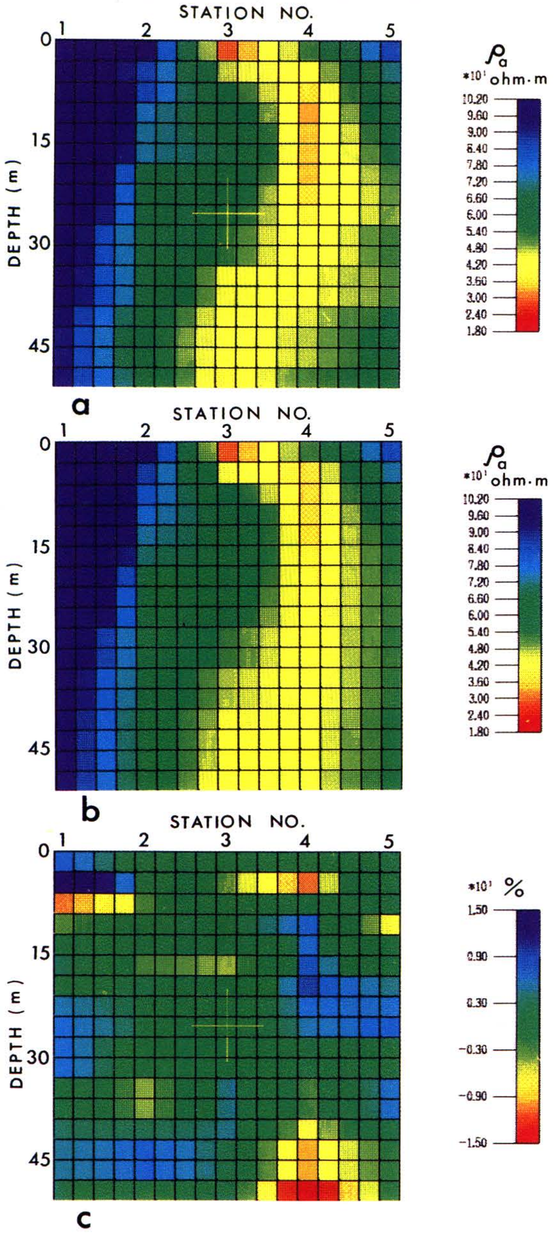

Fig. 8. Examples of evaluation of computerized resistivity section reconstruction procedure by use of pseudosections.
(a): Resistivity pseudosection for the field data ρ_{ai}, (b): Pseudosection constructed by the computerized model data ρ_{ci}, (c): Percentage difference $(\rho_{ci}-\rho_{ai})/\rho_{ai}$ 100(%) between the apparent resistivity data of the field model shown in Figure 8a and the apparent rsistivity data of the computerized model shown in Figure 8b.

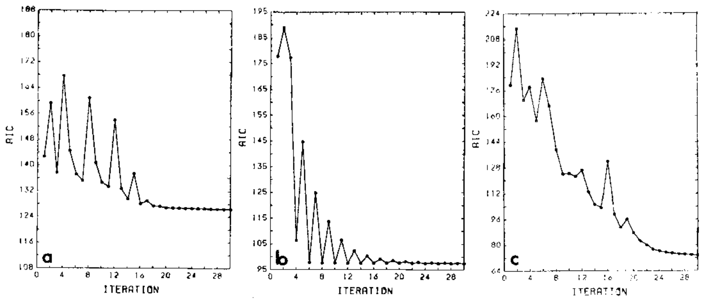

Fig. 9. Examples of evaluation of computerized resistivity section reconstruction procedure by use of AIC.
(a): AIC model selection at the station No. 1, (b): AIC model selection at the station No. 2, (c): AIC model selection at the station No. 5.

examples of evaluation of the computerized section reconstruction procedure by use of *AIC*, which present the performance of the computerized model in comparison with the true model in the field. The reasonable four layer model shown in Figure 9a can be selected by 20 iterations, the six layer model in Figere 9b by 22 iterations and the three layer model shown in Figure 9c by 30 iterations. Figures 10a and 10b show the resistivity pseudosection for the field data ρ_{ai} and the pseudosection constructed by the computerized model data ρ_{ci}. Figure 10c shows the percentage difference $(\rho_{ci}-\rho_{ai})/\rho_{ai}\cdot 100(\%)$ between the apparent resistivity data of the field model shown in Figure 10a and the apparent resistivity data of the computerized model shown in Figure 10b.

Comparing the field model resistivity pseudosection shown in Figure 10a with the computerized model resistivity pseudosection shown in Figure 10b, it is clearly seen that both pseudosections present almost completely similar patterns as well as the example shown in Figures 8a, 8b and 8c for the exploration of the groundwater reservoirs under the near surface noise. The fact suggested that a successful model selection was acomplished by the result as shown in Figure 6c. The percentage resistivity difference pseudosection shown in Figure 10c may confirm the good fitness, in which local residuals may indicate a more detailed improvement of the resistivity distribution or an unreasonable analysis error by the 1D inversion.

Generally, as the true earth structure is unknown before exploration or excavation, it is impossible to compare the computerized model with the true earth structure. However, one can evaluate the performance of the resistivity interpretation procedure with the aid of the pseudosection method.

Finally, the groundwater bearing zone surrounded by a vertical fault environment can be detected in the medium low resistivity areas at the depths of about

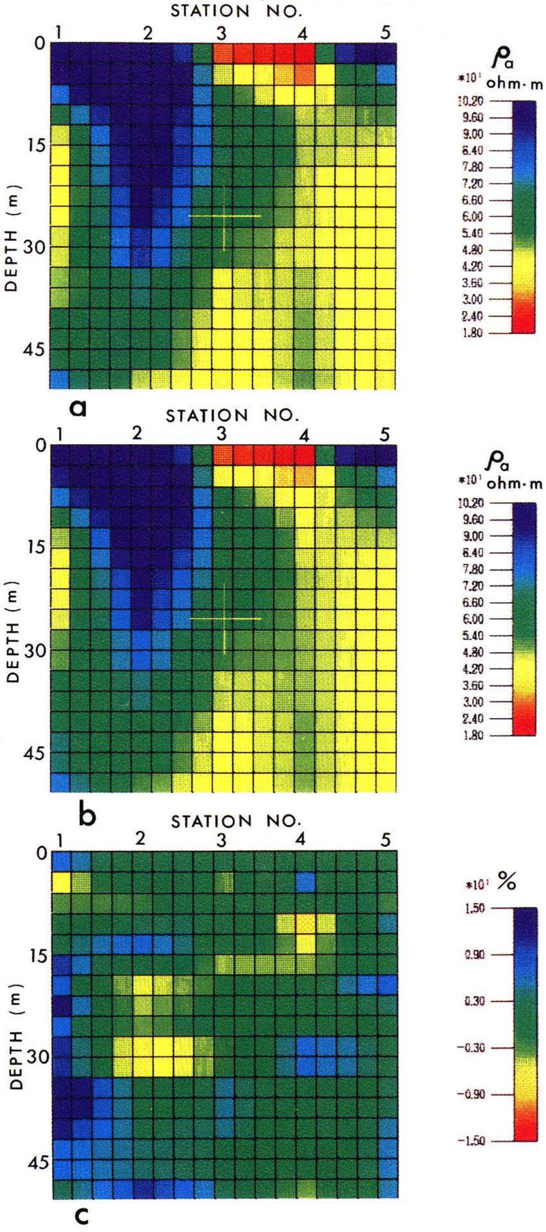

Fig. 10. Examples of evaluation of computerized resistivity section reconstruction procedure by use of pseudosections.
(a): Resistivity pseudosection for the field data ρ_{ai}, (b): Pseudosection constructed by the computerized model data ρ_{ci}, (c): Percentage difference $(\rho_{ci}-\rho_{ai})/\rho_{ai}$ 100(%) between the apparent resistivity data of the field model shown in Figure 10a and the apparent resistivity data of the computerized model shown in Figure 10b.

15 m and 40 m under the structures of No. 2 and No. 3 of the computerized resistivity section shown in Figure 6c.

5. Conclusions

The most important recent activities in the electrical measurement of the earth structure and interpretation techniques include the use of large continuous data, high speed computer simulation with effective visualization, and designing and setting of various electrode array combination patterns. Studies on the evaluation of extraction and enhancement of response due to target inhomogeneities and on the evaluation of solid electrode array effects in the computerized section procedure have been carried out as an aid for the improvement of electrical prospecting. The first objective problem in these development activities is how to extract reliable subsurface information under the more complex earth structure environments.

In this paper, a reliability evaluation of the electrical geotomographic image model selection using pseudosection and Akaike's information criterion has been discussed with the case histories of the groundwater reservoirs and the environmental geophysical exploration.

Some results in this investigation are as follows:

1) The reliability evaluation of the geotomographic image model selection was performed by use of the electrical methods.
2) The computer visualization techniques must not be increasingly an effective tool only for subsurface imaging but also for the evaluation of the geotomographic image model selection, which may be a typical future resistivity interpretation.
3) In the evaluation of the computerized resistivity section construction procedure using pseudosection and *AIC* in the field example of the case history of the groundwater exploration under the near surface geologic noise, it has been recognized that the field resistivity and the computerized model resistivity pseudosections are both nearly similar to each other. Also, the percentage resistivity difference pseudosection can become an effective indicator with the residuals between the field apparent resistivities and the computerized model apparent resitivities. Also, it may be worthwhile to investigate if an evaluation of the resistivity model selection by use of *AIC* can be successful under the predetermined multilayers analysis.
4) In the second evaluation of the computerized section construction procedure using pseudosection and *AIC* in the case history of the groundwater exploration

with a vertical fault, the same fact as the first case history can be recognized.

The efficient and reliable solution of the electrical inverse problem mostly depends upon the interpretation method and its successful evaluation technique with new feasibility. The most convenient way of dealing with the resistivity inversion is to use the so-called data percentage residuals misfit versus the number of forward calculations numerically, from which the monitoring or evaluation of the reliable interpretation procedure can be performed visibly. Therefore, it is necessary to provide an objective and easy visualization element of evaluating the electrical geotomographic image model selection.

The author has shown that the use of electrical methods can become effective monitoring and evaluating elements for the improvement of the electrical geotomographic image model selection system. Furthermore, systematical and integrated evaluation methods have been fundamentally investigated for a more successful and reliable geophysical measurement system of subsurface information due to target inhomogeneities under the various environmental earth structures.

Aknowledgement

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