3D Imaging of Keyhole Tomb by Electrical Prospecting

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1. Introduction

As the range of applications of geophysical methods has increased, particularly with respect to the investigation of near-surface horizon of interests has developed on providing solutions to specific problems in a geologically difficult where target depths make a backhoe and drill competing technologies. Geophysical methods are cost-effective and large areas can be quickly surveyed at relatively low cost. The most productive geophysical techniques are those for which the target exhibits the greatest physical contrast with respect to the surrounding formations. However, the engineering geophysics is very difficult to predict the sub-surface using conventional geophysical methods. These geophysical techniques have required upgrading of data acquisition accuracy of the methods using the multichannel resistivity tool. They were able to show a good correlation between GPR and ARM data sets from the test site at Saitobaru Kofun area. Geoelectrical methods has the economic advantages to solve various archeological problems. However, there was no successful 3D computer program required for interpreting observed apparent resistivity data. In the present paper, a robust 3D computer program has been developed for an archeological prospection.

2. Electrical Resistivity Method

The purpose of electrical resistivity method is to investigate the change of the formation with horizontal distance (Horizontal Mapping) or with depth (Vertical Sounding). The electrode configuration most commonly used is the four electrode array such as Schlumberger and Wenner electrode arrangements as shown in Fig. 1.

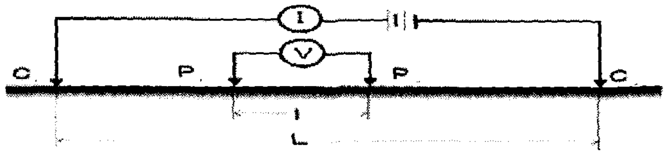

Fig. 1. Four electrode configuration for resistivity measurements.

In this array, the four electrodes are positioned symmetrically along a straight line, the current electrode on the outside and the potential electrodes on the inside. For a homogeneous earth, an electric potential due to a point source on the ground surface is inversely proportional to distance from a current electrode. In order to change the depth of measurements, the current electrodes are displayed outsides for Vertical Electrical Sounding (VES) measurements. For the actual case where the subsurface is not composed of a uniform resistivity material, the measured resistivity derived from the formula is termed the apparent resistivity:

3. Resistivity Inversion

Procedure of data processing of geophysical data consists of model calculation (forward modeling) and the inverse interpretation called as the inversion. The forward problem is calculating the response of an assumed model by solving the boundary value problem. The inverse problem is mathematical adjustment of the model so that the response fits the observed data in a least squares sense by using Marquardt's algorithm as shown in Fig. 2.

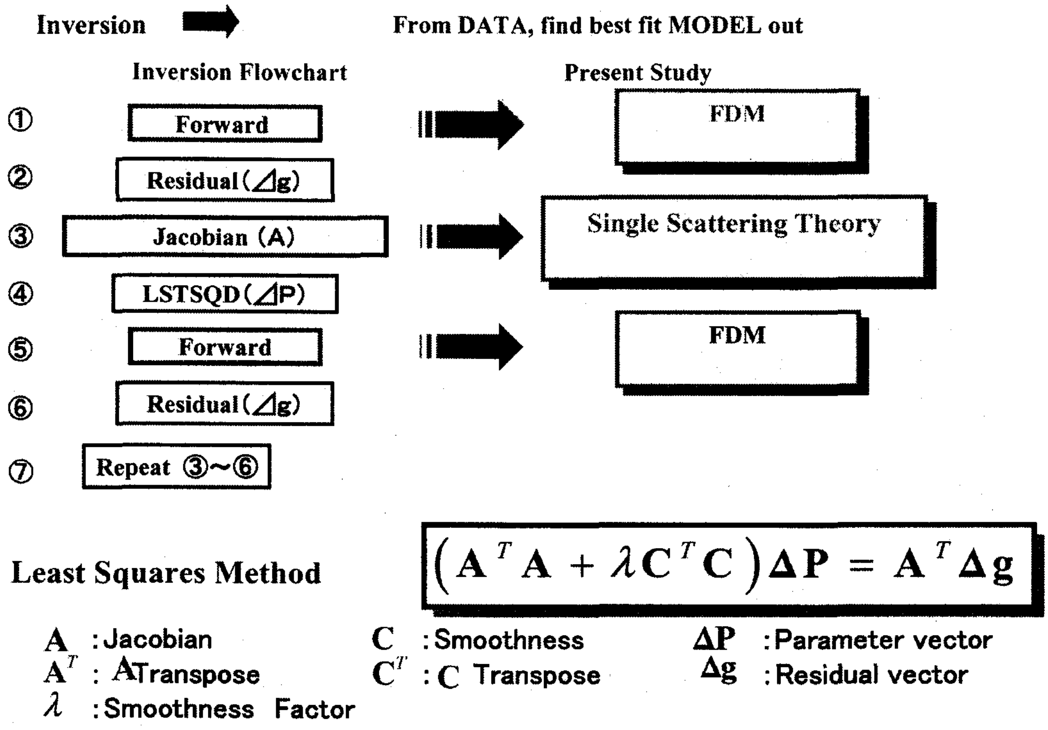

Fig. 2. Data processing of geophysical data by a non-linear least squares method.

4. Case Study (Keyhole-shaped Tomb)

Various geophysical surveys such as ground penetrating radar (GPR), very low frequency (VLF) electromagnetic and electrical resistivity methods have been conducted by the archaeometry group of the Archaeological Prospection Society of Japan. We have conducted Schlumberger VES surveys at the keyhole-shaped tomb named as Iwabaru-Futagozuka Kofun as shown in Fig. 3 located in Kumamoto Prefecture. The tomb is the one of the biggest one in Kyushu island and the total length is 102 m, the diameter of the circular mound is 57 m and the height is 9 m. Resistive anomalies were detected over the circular mound of the tomb by the horizontal mapping survey with Wenner electrode array. Therefore, detailed vertical electric soundings with Schlumberger array were conducted with 2 m grid interval at 67 VES stations as shown in Fig. 4 including the anomalous zones detected by the previous horizontal mapping survey. The observed VES data were carefully interpreted by the inversion programs based on 1D and 2D models.

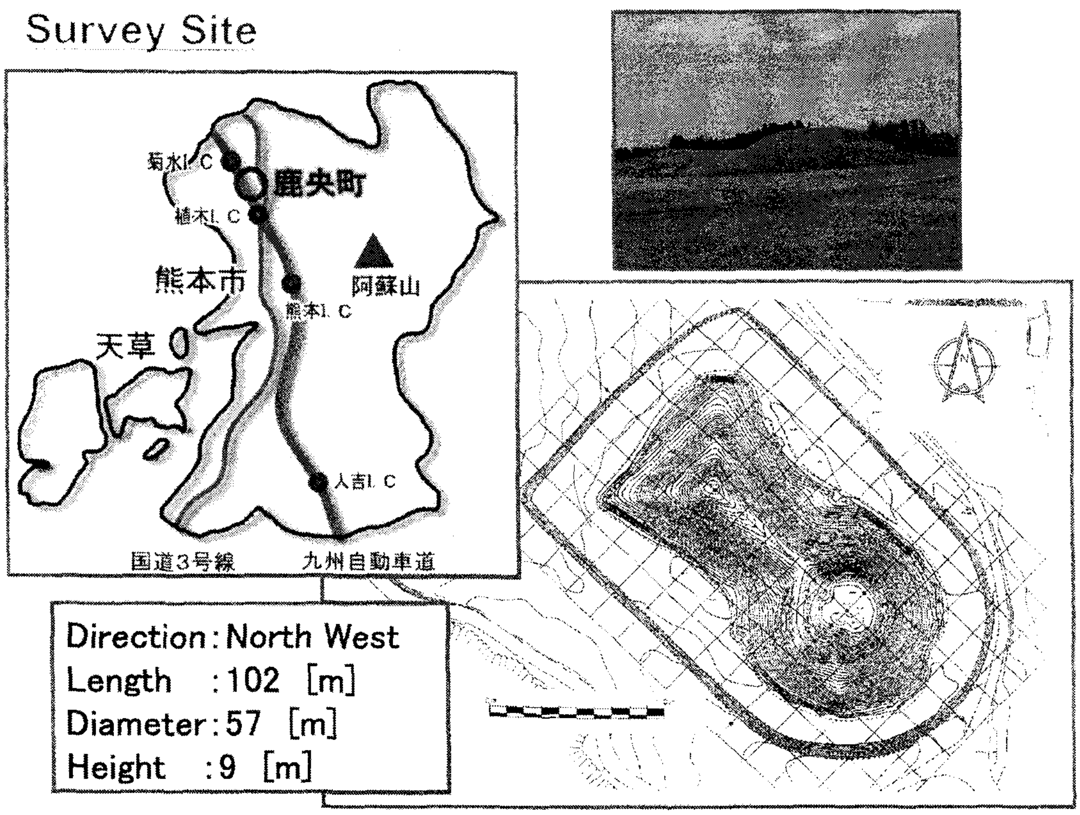

Fig. 3. Location map of Iwabaru-Futagozuka Kofun in Kumamoto Prefecture.

Vertical Electric Soundings

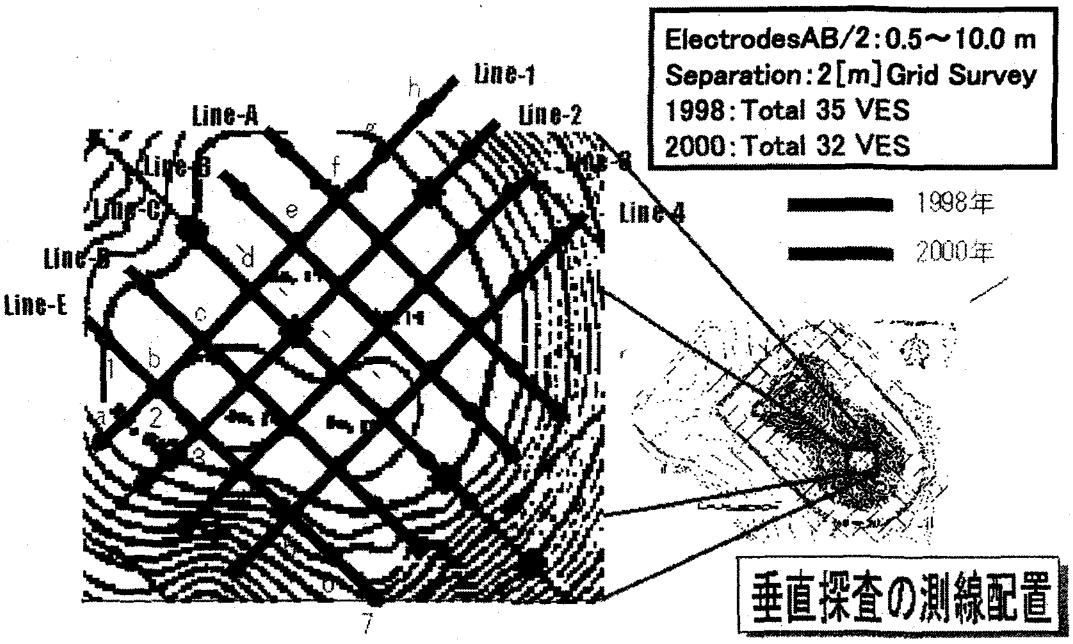

Fig. 4. Vertical Electric Sounding stations at Iwabaru-Futagozuka Kofun.

3D Inversion Result 3 (Depth Sliced Resistivity)

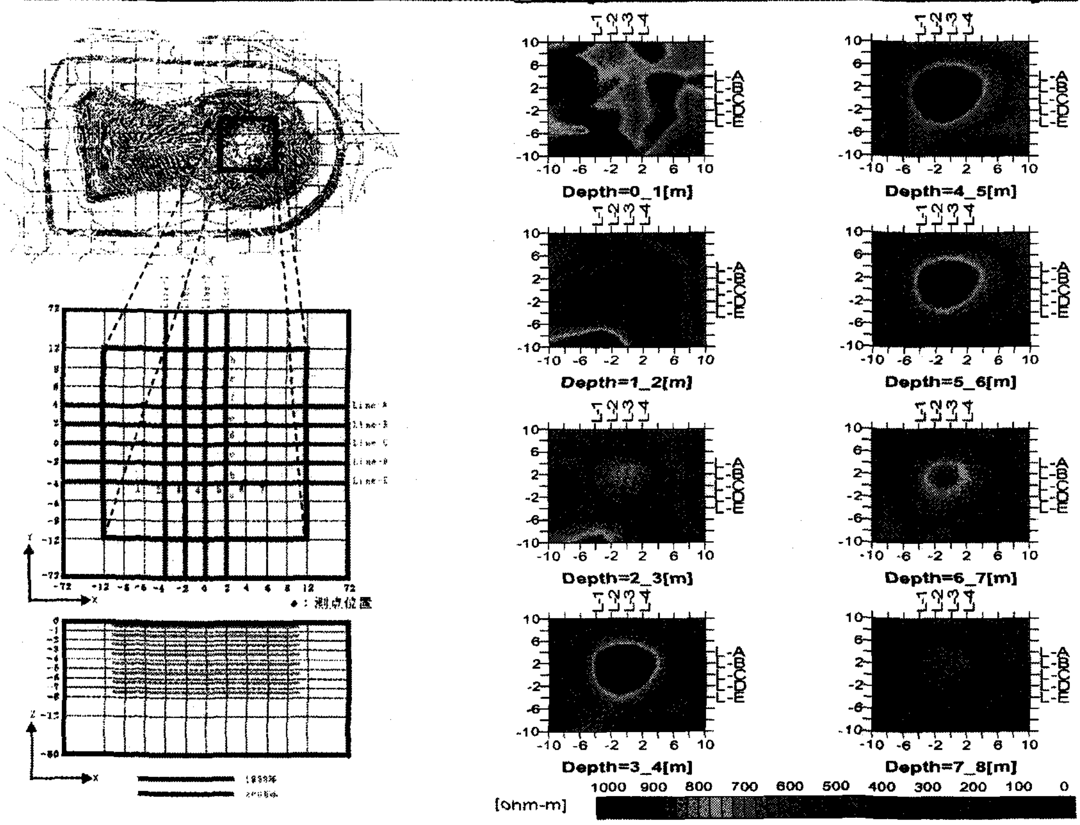

Fig. 5. Depth sliced resistivity contour map derived from 3D inversion.

Depth sliced contour maps derived from 3D inversion results clearly indicated the existence of high resistivity body which corresponds to the stone cavity. The present 3D computer program was also applied to interpret using 67 VES data. The detected 3D anomalous body was evaluated as an ancient tomb by Dr. Yasuhi NISHIMURA who was the President of Archaeological Prospection Society of Japan.

5. Concluding Remarks

(1) Practical 3D inversion program has been developed in the present study.

(2) Resistive anomalies greater than 1000 ohm-m was detected by 2D and 3D inversion of apparent resistivity data.

(3) Detected resistive anomaly was evaluated as stone chamber in the Iwabaru Futagozuka Kofun by the archaeologist.

(4) Multichannel resistivity meter (Handy-ARM) has been developed for an archaeologist by the joint research of Kyushu University and OYO Corporation.

(5) Automatic interpretation of apparent resistivity data can be done during the field survey on the archaeological prospection using a personal computer.

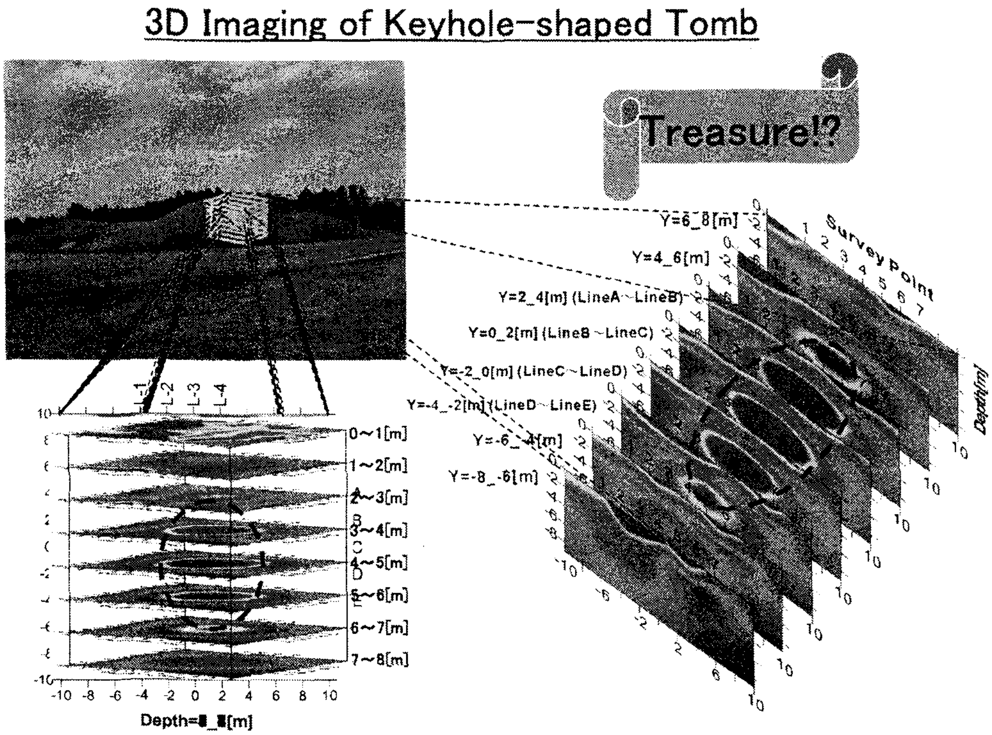

Fig. 6. 3D imaging of keyhole-shaped tomb at Iwabaru-Futagozuka Kofun.