O13-2

DETECTING SMALL- SCALE TARGETS BY THE 2D INVERSION OF TWO-SIDED THREE-ELECTRODE DATA: APPLICATION TO AN ARCHAEOLOGICAL SURVEY

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The superior detecting capability of the two-sided three-electrode array over its co-linear four-electrode counterpart is demonstrated in the quantitative manner. Synthetic apparent resistivity data sets of the three- and four-electrode arrays are calculated for models that simulate buried tombs. The results of two-dimensional inversions are compared in view of the resolution in detecting the exact location, size and depth of the target.

A field survey was carried out at the archaeological site known as 'Alacahoyuk' located in the northern part of the central Turkey. The objective of the geophysical survey was to locate the city-wall. An area having dimensions of 20x28 meter was chosen in view of the prior information, based on the previous excavation results obtained from the chief archaeologist of the area. The survey area consists of 15 profiles each being 20 m long and spaced 2 m apart. The direction of the survey lines is from west to east. The distance between measurement stations is also 2 m that constructs 11 measurement stations along each survey line. Apparent resistivity measurements were made for AB/2 spacings of 3, 5, 7, 9, 11, 13, 15 and 17 m (n=1 to n=8). Totally 2640 apparent resistivity values are obtained. The current electrodes A and B are located on the western and eastern side of the array centre, respectively.

The survey area was excavated one year later from the field survey. The exposed wall is buried at a depth of 1.8 m. The width is 1 m. The height of the wall is 1.5 m at the northern side, but it becomes thinner gradually towards south and decreases to 0.5 m. We compare the final archaeological findings and the geophysical interpretation made without knowing the excavation results. The 2D inversion of the apparent resistivity data was applied to all profiles. The available computer memory has limited the number of meshes applied in the modelling. Using a homogeneous half-space model having intrinsic resistivity of 100 and 10 ohm-m, respectively has allowed performing two independent iteration processes. These differing initial guesses produced the same final model. The desired misfit and the maximum limit of iterations were set at a relative error value of 0.001 and 10, respectively. But, all inversions were terminated before satisfying the above conditions. The convergence criterion stops the algorithm since no further improvement of the data misfit is achieved by performing extra iterations.

A representative example is presented for the estimated model that is solved from the data measured over line 12. The inversion of the four electrode data has ended at ninth iteration with a RMS error of 0.91 m. The location of the wall is well estimated, but the depth of the target seems to be incorrectly determined giving an impression that the target is very close to the surface. The block that matches with the wall has less inverted resistivity value (118 ohm-m) in comparison with the resistivity of the top block (204 ohm-m). The inversion of the two-sided three-electrode data is ended at sixth iteration giving RMS value of 0.83. The location of the target is correctly determined. Moreover, the bottom depth of the target is determined correctly as 3 meter. However, initial examination of the inversion results gave an impression that the size of the target was larger than its actual dimensions. Because, the resistivity values of the lower block (130 ohm-m) is slightly less than the inverted resistivity value of the top block (200 ohm-m). The majority of the inversions performed for remaining profiles produced similar results. Since the inversion results clearly indicated the existence of high resistivity surface layer, we have decided to check the validity of inversion results by a synthetic model. The model consists of a very high resistivity block was embedded into low resistivity host medium. A horizontal layer overlies the target and the host medium. The resistivity of the surface layer is less than that of the target. But, it is very high in comparison with the resistivity of the host medium. The synthetic data obtained over this model has been computed and then are given as the input to the 2D inversion algorithm. The results of inversions were similar to the model derived from the inversion of the field data. The resistivity of the target derived from the four-electrode array is estimated as being less than that of the surface layer. The two-sided three-electrode array produced intrinsic resistivity values that are slightly less than or close to the resistivity of the surface layer. This indicates the better resolution of this array in comparison with its four-electrode counterpart. Then, in view of the experience obtained from the inversion of the synthetic data, we have interpreted the high resistivity block beneath the surface layer as an indicator of an ancient wall.

The 2D inversion results of two-sided three-electrode apparent resistivity data for all profiles are presented as resistivity maps by contouring the intrinsic resistivity values of blocks that sharing the same depth range. The purpose of this type of presentation is to examine the lateral resistivity variations in a specified depth. The resistivity distribution for the blocks that lie in the depth range between 0.41 m and 1.83 m is represented by high resistivity values and then is interpreted as the covering soil. The existence of the wall is clearly indicated in the block depths between 1.83 m and 3.11 m. The shape and extension of the target could be well determined. The examination of the highly resistive zone suggests that the wall exists from the first profile in the north until the profile 16. However, the results of the 2D inversion of the four-electrode data are slightly different. The wall is straight and it ends at the profile 12. We outline the wall by considering the detecting capability of the three-electrode array that is superior to the four-electrode array. The resistivity values in the next block range (3.11-5.2) vary monotonously except in the narrow trace of the wall and inside the high resistivity small region at southwest of the survey area. Since the resistivity values are very small in comparison with the overlying blocks, the resistivity values of these blocks have interpreted as being equal to that of the host medium. This interpretation indicates that the bottom of the target is limited inside the preceding block depth range. Then, the estimated depths of the top and bottom of the target are 1.83 m and 3.11 m, respectively. The expected width of the target is 2 m. It should be kept in mind that all these estimations are limited by the block sizes that are prescribed by the available computing facilities.

A sketch of the expected wall is plotted to aid the archaeologists for the excavation works. Since the archaeological works should be carried with extreme care, a limited area that could be examined in one excavation season has been requested. The suggested area has been excavated and the exposed wall helped us to check the validity of the interpretation. Archaeologists dated the city-wall as belonging to Stratum II that corresponds to 1500-1200 BC, the period of Hitite Empires. The width of the wall is 1 m that is less than our interpretation. The correct determination of the width was possible if we would take into account only very high resistivity values. The depths of the top and bottom of the wall are exactly the same as our interpretation in the northern side of the area. The match between the height of the wall and the mesh dimension is not fully incidental. Because, the modelling mesh has been constructed in view of the information obtained from the qualitative interpretation, e.i. visual inspection of pseudosections and the gradient transformation of Karous and Pernu (1985). The direction change in the left-hand side of the excavated area is also well estimated from the 2D inversion of the two-sided three-electrode data.

Conclusion

The 2D inversions of the synthetic and measured apparent resistivity data also prove that the two-sided three-electrode array has better resolution for the detection of small-scale targets in comparison with its four-electrode counterpart. Although the results don't differ drastically from the each other, the improved results that produced by the two-sided three-electrode array could become important to detect the relatively small targets. It should be noted that our tests are not sufficient to compare the detecting capabilities of the mentioned arrays in deriving of the large-scale structural information. However, we feel that the choice between three-electrode systems and conventional arrays should be made depending on the purpose of the survey. For example, if the intention is to obtain a general structural view of the survey area, then the conventional arrays can be preferred because of its lesser measurement requirements.

Acknowledgment

This work was supported by the Scientific and Technical Research Council of Turkey (TUBITAK) under grant no. YDABCAG-553.