Reply to Comment on: 'A numerical comparison of 2D resistivity imaging with 10 electrode arrays' by T. Dahlin and B. Zhou

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Reply to Comment on: 'A numerical comparison of 2D resistivity imaging with 10 electrode arrays' by T. Dahlin and B. Zhou

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Candansayar (2005) has misunderstood some issues of our paper (Dahlin and Zhou 2004). For example, he states that 'inversion results depend strongly on the number of data', but we believe this is not the whole truth. Adding more linear-correlated data or low signal-to-noise-ratio data for inversion may not lead to improvement in the resolution and reduction of multi-solutions of inversion. The more such data, the more difficult it may be to arrive at a satisfactory level of the data fit, and the more artefacts in the image may be obtained; see: inversion theory (Menke 1984) and real examples (Zhou and Dahlin 2003). The inversion result depends strongly on data quality, not just the number of data! For noisy data and linear-correlated data, the number means little for the inversion. The data 'quality' means a high signal-to-noise ratio, good coverage of the model (depth penetration and horizontal extension) and independent data.

A central issue is the 'number of data' in Table 1 of our paper (Dahlin and Zhou 2004). The number of data for Wenner configurations can be greater than the number of data for PD and SC arrays for the same multi-electrode system, if subsets of data of the PD or SC arrays are compared with the whole data set of WN. We made an effort in carefully choosing the configuration parameters *n* and *a* for the 10 arrays and gave three possible measurement scenarios with different data densities (Table 1) for an 81-electrode system (Survey 3, Survey 2 and Survey 1 with increasing numbers of data points). The data densities for Survey 3 in Table 1 actually have comparable features in such aspects of the 'data quality'; for example, they have similar subjective depth penetration, horizontal coverage and data-acquisition efficiency (a relatively small difference in the number of data points), so it was natural to use them for inversion comparisons.

We used the same gridding and inversion parameters for all electrode arrays, with a grid size equal to the minimum electrode distance in the *x*-direction. Later practical experience from surveying with the multiple gradient array has shown that it is generally better to use a grid size equal to half the electrode spacing, and it is possible the results for, for example, the 'dipping blocks' model could be improved if that were used. Possibly the higher data densities would give a clearer advantage with a finer model grid.

Furthermore, the arrays may have different levels of noise-contamination in the data, which is correlated with the magnitude of the measured potential. A potential-dependent error model was used in this study that had been obtained by statistical analysis of several large field data sets with normal and reciprocal measurements (Zhou and Dahlin 2003). The error property of an array is another cause for different inversion results with the 10 arrays. However, the experiments performed by Dahlin and Zhou (2004) show that the data density of Survey 3 can produce results that are in many cases as good as those of Survey 1 or Survey 2, because Survey 3 in most of the cases studied contains enough information to image the five models with reasonable quality. Thus, these measurements are examples of efficient survey schemes for the arrays and the five models. There might, however, be scope for making use of more data for different resistivity distributions and/or with other inversion procedures. Recently, Stummer, Maurer and Green (2004) presented an experimental procedure for efficient surface surveying schemes that provide optimum subsurface information; they show the importance of using optimized data sets, and also conclude that larger optimized data sets produce better images than smaller data sets.

Candansayar argues about the number of data points in each data set, and that we favour Wenner by having more data points for that array. The fact is that we tested three different levels of data density, but (as also pointed out by Candansayar) there is an upper limit for some arrays (as for example the Wenner). When a measurement protocol is created for a particular cable layout, certain systematic strategies are used, and it will generally not result in exactly the same number of data points for the different arrays unless some

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measurement combinations are truncated arbitrarily. Nevertheless, our study clearly shows that even with the lowest data density, where for example the pole-dipole and multiple gradient arrays have smaller numbers of data points, these arrays perform better than the Wenner. Furthermore, even if we, for reasons of space limitation, could not show the inverted sections for all the tested options, we summarized them in Figs 13 and 14, and based our conclusion on them. Therefore, we do not understand Candansayar's objection.

Candansayar is very concerned that we are trying to favour the Wenner array by the way we designed the modelling experiment and selected inversion parameters. He writes: 'they forced the inversion of Wenner configuration data to give better results than the inversion of other configurations', because more data were used for WN, but on the contrary our study clearly shows that it is preferable for the survey resolution to use other arrays, for example pole-dipole, instead of Wenner. We state very clearly in the conclusions and abstract that the results show that surveying with pole-dipole, dipole-dipole and multiple gradient arrays can give better resolution than, for example, Wenner and pole-pole for the modelled cases (the pole-dipole was modelled with forward and reverse measurements as stated in Table 1).

The program Res2dinv was used for the inversion, and the inversion parameters from a batch control file are shown in the Appendix. It would probably have been better to use a smaller increase in the damping factor with depth, i.e. 1.05, and to use full recalculation of the Jacobian matrix.

REFERENCES

Candansayar M.E. 2005. Comment on: 'A numerical comparison of 2D resistivity imaging with 10 electrode arrays' by T. Dahlin and B. Zhou. *Geophysical Prospecting* **53**, 853–854.

Dahlin T. and Zhou B. 2004. A numerical comparison of 2D resistivity imaging with 10 electrode arrays. *Geophysical Prospecting* **52**, 379–398.

Menke W. 1984. *Geophysical Data Analysis: Discrete Inversion Theory*. Academic Press, Inc.

Stummer P., Maurer H. and Green A. 2004. Experimental design: Electrical resistivity data sets that provide optimum subsurface information. *Geophysics* **69**, 120–139.

Zhou B. and Dahlin T. 2003. Properties and effects of measurement errors on 2D resistivity imaging. *Near Surface Geophysics* **1**, 105–117.

APPENDIX

Batch control file used

The following batch control file was used for L_1-norm inversion using Res2dinv (for L_2-norm inversion, the same parameters were used except that robust data and model constraints were not chosen):

```
DATA FILE 1
pp-bc1-d3e3.dat
pp-bc1-d3e3-l1.INV
0.15
0.03
ALWAYS - LINE SEARCH
1.0
0.4
6
1.00
10
2
NO - APPLY FLATNESS FILTER DIRECTLY ON MODEL VALUES
YES - REDUCE NUMBER OF TOPOGRAPHICAL DATUM POINTS
YES - CARRY OUT TOPO CORRECTIONS
END - TYPE OF LINEAR TREND TO SUBTRACT
LIMITED RECALCULATION - JACOBIAN MATRIX DETERMINATION
INCREASE OF DAMPING FACTOR WITH DEPTH
1.10
TYPE OF TOPOGRAPHICAL CORRECTION (1 = SC,2 = FEM)
1
USE ROBUST DATA CONSTRAIN?, CUTOFF FACTOR FOR DATA CONSTRAIN
YES
0.10
USE ROBUST MODEL CONSTRAIN?, CUTOFF FACTOR FOR MODEL CONSTRAIN
YES
0.001
ALLOW NUMBER OF MODEL BLOCKS TO EXCEED DATUM POINTS?
YES
USE EXTENDED MODEL?
NO
REDUCE EFFECT OF SIDE BLOCKS?
NO
TYPE OF MESH (0 = STANDARD, 1 = FINE, 2 = FINEST)
1
OPTIMISE DAMPING FACTOR AT EACH ITERATION
YES
```

Legend

Type of information	*Value in RESIS.BTH*
Header	DATA FILE 1
Name of input data file	RATHCRO.DAT
Name of output data file	RATHCRO.INV
Starting damping factor	0.15
Minimum damping factor	0.03
Line search option to be used	ALWAYS
Convergence limit	5.0
Percentage change for line search	0.4
Number of iterations	6
Vertical/horizontal flatness filter ratio	1.00
Thickness of model layers increase	10
Finite-difference grid size	4
Include smoothing of model resistivity	NO
Reduce number of topographical datum points	YES
Carry out topographical correction	YES
Type of linear trend to remove	END-TO-END
Type of Jacobian matrix calculation	LIMITED RECALCULATION