Inversion of long-offset TEM soundings near the borehole Münsterland 1, Germany, and comparison with MT measurements

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SUMMARY

Data from a long-offset transient electromagnetic (LOTEM) survey in northwest Germany around the borehole Münsterland 1 are interpreted using 1-D inversion. Special emphasis is given to the fact that the best-fitting model is not necessarily the most realistic one. We therefore investigate different inversion algorithms in order to obtain a more geologically meaningful result.

The 1-D inversion results using a second-order Marquardt algorithm show a three-layer structure, with a conductor embedded between two more resistive layers. This is in good agreement with the known lithology and the well logs. 'Profile inversion' uses the result from one site as the starting model for the next. The application of the technique yields a smoother section than the individual inversions, and corresponds more closely to the (presumably) layered structure in the area. If desired, using a parameter weighting scheme makes it possible to force consistency at the cost of a larger misfit, yielding a smoother section even in a part of the area where the data are influenced by a 3-D anomaly. Occam inversion is a smoothness-constrained technique which is independent of the starting model. The result of the Occam inversion shows the same features as the Marquardt inversion, including effects which are attributed to 3-D distortions in the data. Joint inversions of the LOTEM data were carried out with magnetotelluric data from the same area. In that case, the LOTEM electric field is recognized as crucial for the resolution of the resistive layer in the section.

Key words: joint inversion, magnetotellurics, Münsterland, Occam inversion, 1-D inversion, transient electromagnetics.

INTRODUCTION

Long-offset transient electromagnetics (LOTEM) has been applied to hydrocarbon and geothermal exploration (Kaufmann & Keller 1983; Keller et al. 1984), deep crustal studies (Strack, Lüschen & Kötz 1990) and coal exploration (Strack 1984; Stephan, Schnigenfittig & Strack 1991). Those studies illustrate that general knowledge of the geology of the area and experience with the method is required for a meaningful interpretation. A crucial step in the interpretation of electromagnetic (EM) field data is 1-D inversion. Fast and reliable 1-D inversion algorithms exist, whereas 2-D or 3-D interpretation methods are the subject of current research (Newman 1989). The 1-D inversion gives a preliminary understanding of the data, and in many cases the horizontally layered earth is already a reasonable approximation to the true situation.

A minimum difference (e.g. in a least-squares sense) between field data and 1-D synthetic data is often taken as an indicator that the 'best model' has been found. The 1-D inversion will arrive at a valid model for field data containing only random noise. However, the model parameters may still be correlated so that equivalent models must be analysed. On top of this, real noise is rarely random, because it consists of external natural electromagnetic noise, man-made noise (cultural noise and system instrument noise) and 'geological noise'. The deformation of the signal by a 3-D response is seen as 'geological noise' in the 1-D inversion. The best-fitting 1-D model can be geologically meaningless. In this paper we use different 1-D
inversion tools to obtain a reasonable compromise between an optimum data fit and a meaningful result. The advantages of each technique are demonstrated with real data to aid in selection and application of those tools.

For this study we interpret LOTEM field data from a sedimentary environment in northwestern Germany, with the objective to extrapolate the geology away from the borehole Münsterland 1 using surface measurements. 1-D inversion is used here, because the lateral resistivity variations can be assumed to be small. Data from magnetotellurics (MT) and controlled source audio frequency magnetotellurics (CSAMT) are also available for joint inversion with the LOTEM data.

LOTEM is a transient EM method which uses a grounded horizontal electric dipole as transmitter. Fig. 1 shows a typical survey layout. The transmitter is kept fixed for many different receiver stations. The distance between transmitter and receiver is comparable to the exploration depth. A horizontal loop receiver records the time derivative of the vertical component of the magnetic field. At present, two horizontal electric field components are routinely measured, but for the earlier Münsterland survey electric fields were recorded only at few stations in order to evaluate their merits for the interpretation.

Figure 2 shows two examples of processing of observed signals. The raw data (top row) are contaminated with 16/2/3 and 50 Hz power line noise and additional sporadic noise. The data is pre-stack processed using digital filters (compare middle row). Depending on the noise level, 50 or more individual transients at each receiver site are selectively stacked. The filtering and selective stacking techniques are described in detail by Strack, Hanstein & Eilenz (1989a).

THE SURVEY AREA

The Münsterland area lies within a large sedimentary basin in northwest Germany. The upper 1500 m belong to the depositional zone of the Cretaceous North Sea Basin. The underlying coal-bearing Carboniferous layers reach a thickness of up to 5000 m and consist of clastic accumulations of Variscan age (Jödicke 1990).

The distribution of LOTEM and MT sites in the survey area is shown in Fig. 3. The borehole Münsterland 1 is located in the centre of the figure, about 20 km WNW of Münster, and about 100 km north of Cologne, Germany. It was drilled in 1962 down to a depth of nearly 6 km. Fig. 4 shows the lithology and the results of laterolog measurements in the borehole. The Cretaceous clay-marl formation has a resistivity between 4 and 6 Ωm down to 1500 m. At 1500 m the resistivity increases, first in the Cretaceous limestone, then continuously down to 5400 m in the interbedded silts and sandstones due to decreasing porosity. The resistivity decreases between 5400 and 5500 m has been investigated by Duba et al. (1988) and by Jödicke (1990). It occurs in black shales of the Lower Carboniferous containing organic matter. At greater depth the resistivity increases again in Devonian sandstones and limestones.

**Figure 1.** Typical survey layout for the LOTEM method. The transmitter is kept fixed for many different receiver stations. In the lower left of the figure the injected current function is displayed. The lower right schematically shows the earth response for the electric field and the time derivative of the magnetic field (after Strack et al. 1989b).
Büchter (1983) processed the raw laterolog data and derived a blocked resistivity log for comparison with 1-D MT inversion results. We use her blocked resistivity log to derive starting models for the 1-D LOTEM inversions.

The LOTEM data were recorded by the University of Cologne in 1987 using the University’s data acquisition system. The stations are aligned along two profiles, which cross approximately at the borehole location. Data sets A08 and A09 are electric field measurements; all others are magnetic field derivatives. The A02, B08, B09 and B10 data cannot be used for interpretation because they are too noisy even after processing. The data set A05, which is a magnetic field transient, includes a sign reversal, which cannot be caused by a horizontally layered earth (Sternberg 1979). It is probably caused by a local conductive anomaly, which is still a subject of current research.

The MT data were measured by the University of Münster in 1981. Büchter (1983) thoroughly interpreted the MT data and found in her analysis that the data do not show 2-D or 3-D effects up to a period of 100 s, which completely covers the depth range of our LOTEM measurements. For larger periods, corresponding to greater depths, the skewness values become larger than 0.5, which means that 2-D or 3-D structures occur. Additional information is available in the form of a north–south seismic line crossing at the Münsterland 1 borehole location. It shows mainly horizontal reflectors typical of a sedimentary basin down to a depth of approximately 4000 m (Meissner & Bortfeld 1990). From this information we conclude that lateral variations are smooth and that 1-D inversion is applicable to the LOTEM data. It is our objective to find these smooth variations starting with the well log.

**INVERSION RESULTS**

For the inversion of the LOTEM data, a second-order Marquardt algorithm with singular value decomposition (SVD) was used. The algorithm and the corresponding tools to analyse the resolution properties are described in detail by Jupp & Vozoff (1975) and Raiche et al. (1985).

Figures 5 and 6 show the inversion results along the east–west profile ML8701 and the north–south profile ML8702. Data from all but one station could be fitted with a three-layer model. In each case the first layer has a resistivity of about 10 $\Omega$m and a thickness between 100 and 300 m except for the eastern part where it appears thicker. It can be correlated with the first few hundred metres of Cretaceous marl (compare Fig. 4).
Figure 3. LOTE&M and MT sites in the Münsterland area (northwest Germany). The LOTE&M stations are aligned along two profiles which cross near the location of the borehole Münsterland 1 (well).

Figure 4. Lithology and results from laterolog measurements in the borehole Münsterland 1. The solid line is a blocked resistivity-depth section which is used for comparison with the inversion results (after Büchter 1983).
The second layer has a resistivity of 4–7 $\Omega$ m and a thickness varying between 1000 and 2000 m. This layer coincides with the Cretaceous clay-marl which is more conductive than the marl in the upper layer. The resistivity of the third layer varies between 12 and 80 $\Omega$ m. This corresponds to a resistivity increase in the laterolog, with strong variations due to the interbedding of limestone and sandstones.

The inversion results along profile ML8701 contain two anomalous regions. For the data set B04 a very conductive layer at 3600 m depth was necessary to fit the data. Apparently, this layer corresponds to the increase in conductivity in the laterolog at 5400 m depth. However, since the area is known to be approximately horizontally layered, a discrepancy in depth to the conductor of nearly 2000 m between the location of the borehole and the B04 site is unlikely. It was not possible to fit the data set with the conductive layer at a greater depth. Jupp & Vozoff (1975) introduced a measure for the resolution of the model parameters which can be derived from the SVD and is called 'importance'. On a scale from 0 to 1 small values correspond to bad resolution, high values correspond to good resolution. In this case the depth to the conductive layer is very well resolved, which means that we do not have a uniqueness problem here (if the model is correct). We will continue the discussion of this layer during the application of Occam inversion below.

The second anomalous region is at the eastern part of the cast–west profile where three data sets (A03, A06 and A07) require a thicker and more resistive first layer than in the rest of the area. The assumption of a 1-D structure may not be valid here, because the lateral resistivity variations between site A03 and A01 are not small. Additionally, the sign reversal at station A05 (between A06 and A07) indicates 2-D or 3-D structures. It is very likely that the three stations are disturbed by the same anomaly which causes the sign reversal at station A05.

One objective of the interpretation is to map the depth to the third layer, which represents the Carboniferous. The depths obtained from 1-D inversion differ by nearly 500 m between sites A04 and B05 (Fig. 5). This is not realistic, because the area is part of a sedimentary basin with largely horizontal reflectors. The 68 per cent error bars (Raiche et al. 1985) for the geoelectric layer boundaries indicate that the depth to layer 3 is not so well determined for site B02. A smoother representation would therefore be more appropriate for the interpretation. One way to achieve this is to use the final model of one station as starting model for the following station, a procedure we call 'profile inversion'.

**Figure 5.** Results of the individual LOTEM inversions along profile ML8701. The upper part of the figure shows the interpreted resistivity section. The shaded area corresponds to the second layer. The vertical lines at the layer boundaries are the error bars for the depth to the corresponding layer. At the bottom of the figure the data (dots) and the inversion results (solid lines) are shown sequentially starting from the west of the profile.

**Figure 6.** Results of the independent LOTEM inversions along the profile ML8702. The upper part of the figure shows the interpreted resistivity section. The shaded area corresponds to the second layer. The vertical lines at the layer boundaries are the error bars for the depth to the corresponding layer. At the bottom of the figure the data (dots) and the inversion results (solid lines) are shown sequentially starting from the north of the profile.
quantified. This is done by defining parameter weights which are a measure of the uncertainty of the a priori resistivities and layer thicknesses. The theory was described in detail by Lawson & Hanson (1974). Here we only give a short outline.

If \( d_1, \ldots, d_n \) are \( n \) measured data points with corresponding standard deviations \( \sigma_1, \ldots, \sigma_n \), and if \( f_i(p), \ldots, f_n(p) \) are \( n \) calculated data points depending on the model vector \( p = (p_1, \ldots, p_n) \) which contains the layer resistivities and thicknesses, the chi-square error between measured and calculated data is

\[
\chi^2 = \sum_{i=1}^{n} \frac{(f_i(p) - d_i)^2}{\sigma_i^2}
\]

(1)

The Marquardt–Levenberg method minimizes the functional

\[
U = \chi^2 + \mu(\|\delta\| - ||\delta_*||)^2
\]

(2)

(Lines & Treitel 1984) where \( \delta = p_1 - p_0 \) is the parameter change vector between the present and the previous iteration, \( ||\delta_*|| \) is a threshold value for the parameter change and \( \mu \) is a Lagrange multiplier. This may be written in the linearized form as

\[
U = ||J\delta - e||^2 + \mu(||\delta|| - |\delta_*|)^2
\]

(3)

where \( J \) is the Jacobian matrix and \( e = f(p_0) - d \) is the difference vector between measured and calculated data points. To introduce a measure for the uncertainty of the model parameters Lawson & Hanson (1974) propose the modification

\[
U = ||J\delta - e||^2 + \mu||F(\delta - \delta_*)||^2
\]

(4)

where \( F \) is a \( m \times m \) diagonal matrix containing the weights for the model parameters.

A large weight for one parameter means that the corresponding parameter change has a large contribution to the functional \( U \). Since \( U \) is minimized, the parameter change will be small if the weight is large. Thus, the weights can be used to quantify a priori information in the inversion process. Since this is a method to impose constraints on the model parameters without using fixed boundaries, we call the parameter weights 'soft bounds'.

Profile ML8701 was inverted using profile inversion and soft bounds, again starting from the western end of the profile. The resistivity of the second layer was given the weight 2, because the starting value of 5 \( \Omega m \) is narrowly defined in the well log. The second layer thickness is not quite as well defined and was given the weight 1. The three other parameters were left floating with weights 0.5. The result of this inversion is shown in Fig. 8. Now the resistivity section is also smooth in the eastern part of the profile. The top of the third layer is consistent with the western part, and we could interpret that the Carboniferous layer is slightly inclined from west to east. However, the lower part of the figure shows that the fit of the early times at the three eastern sites of the profile is much worse than before. Moreover, the error bars for the top of the third layer are now very large. The reason is that the constraints which are imposed on the parameters prevented the inversion from fitting the data. In this example the soft bounds were used as a tool to obtain a 1-D interpretation of data which are in
Figure 8. Results of parameter-weighted 'profile inversion' of the LOTEM data along profile ML8701. The result is now very consistent over the entire profile including the eastern part. However, the lower part of the figure shows larger misfits than Figs 5 or 7.

fact distorted by a 3-D anomaly. The result may not be very reliable. However, we prefer it to the previous ones, because a smooth variation is more likely to represent the top of the Carboniferous. For a complete interpretation, 3-D modelling would be required (Hördt et al. 1992).

**OCCAM INVERSION**

So far we have only dealt with 1-D inversion using layered earth models with well defined resistivity contrasts. Constable, Parker & Constable (1987) introduced a smoothness-constrained inversion algorithm—the so-called Occam inversion—which allows continuous variations of resistivity with depth. We applied their scheme to the LOTEM data. The continuous earth model is approximated by a set of horizontal layers. The layer thicknesses are equidistant in logarithmic space and are kept fixed during the inversion so that only resistivities vary.

Occam inversion minimizes the functional

\[ U = \mu^{-1}(\chi^2 - \chi^*^2) + R \]

(5)

where \( \mu \) is a Lagrange multiplier, \( \chi^* \) is defined by equation (1), \( \chi^* \) is the desired value of misfit, and

\[ R = \sum_{i=2}^{m} (p_i - p_{i-1})^2 \]

(6)

is the roughness of the earth model. In the Marquardt method the size of the parameter change vector is damped, whereas in Occam inversion the roughness of the earth model is minimized under the constraint that the misfit reaches the desired value. Seeking the smoothest possible model avoids overinterpretation, because there will be no structure in the final model which is not required by the data.

As an example, Fig. 9 shows the results of Occam inversion at station B04 in comparison with the layered earth model obtained from Marquardt inversion. The desired misfit of 5 was reached after four iterations. Assuming that the data errors can be determined correctly and that the earth is an ideally layered half-space, the expected optimum value for the misfit is 1. Since the assumptions usually do not hold, we used the misfit from the Marquardt inversion, increased by 10 per cent, as the desired value for the Occam inversion.

In the very shallow part of the section the two inversions give different values for the resistivity. This is not so important since the very shallow resistivities are not well resolved by the LOTEM method. Between 300 and 2000 m both curves show approximately the same structure, the difference being that the Occam result is smooth. The resistive layer between 2000 and 4000 m has a much higher resistivity in the Marquardt inversion. This is not significant because the data used here are magnetic fields, and the resolution of the LOTEM magnetic field for resistive layers is poor (Strack et al. 1989b). Since Occam inversion is looking for a smooth model it takes the lowest possible value for the resistivity. Finally, both inversions show the
sharp decrease of resistivity between 3000 and 4000 m. It is
interesting that the resistivity of the deep conductor after
four iterations in the Occam inversion is even smaller than
in the Marquardt inversion. Here, we are close to the point
where Occam inversion becomes unstable, which means that
the smoothness constraint is no longer important and the
model becomes overparametrized (Constable et al. 1987).
Thus, according to the philosophy of Occam inversion of
finding a compromise between honouring the data and
finding a smooth model, the result after three iterations may
have to be preferred here, although it has a slightly higher
misfit.

Occam inversion was performed for all stations along the
profile ML8701. The results were converted to a
resistivity–depth section (Fig. 10). This section contains
approximately the same features as the result of the profile
inversion, including the anomalous region in the eastern part
of the profile. The important point is that a ‘minimum
structure section’ is obtained, which is not in danger of
overinterpreting the data. When working with real field
data, it is often desirable to have an independent
interpretation tool to check previous results. The example
illustrates that Occam inversion is an appropriate tool to do
that.

We now continue the discussion of the fourth layer at
station B04. In the previous chapter we stated that the depth
to the conductor is well resolved and that the layer does
probably not correspond to the resistivity decrease in the
well log. This is now confirmed by a different inversion
method. Occam inversion shows the layer at about the same
depth as the Marquardt inversion. The very western station
is the only one which shows the conductive deep layer. The
layer depth is larger than the distance to the next station
that does not require an extra layer. This indicates a
non-layered structure which is seen as a deep conductive
layer by all of the 1-D inversion techniques. Consequently,
we cannot find a geological explanation for such a
conductive layer.

**JOINT INVERSION WITH MT DATA**

MT data were also available in this survey area. The
interpretations of the two methods can be combined by joint
inversion of the two data sets. The theory was developed by
Vozoff & Jupp (1975) for MT and Schlumberger soundings.
Later it was applied to controlled-source EM with
Schlumberger soundings by Gomez-Trevino & Edwards
(1983) and by Raiche et al. (1985) for coincident loop TEM
with Schlumberger soundings. The idea of the joint
inversion is to fit data of different methods to a single
resistivity model. This is done by combining the Jacobians
into one matrix, and the data vector and model functions
into one vector while keeping the same parameter vector to
fit the data:

\[
J = \begin{pmatrix} J(LOTEM) \\ J(MT) \end{pmatrix}, \quad f = \begin{pmatrix} f(LOTEM) \\ f(MT) \end{pmatrix}, \quad d = \begin{pmatrix} d(LOTEM) \\ d(MT) \end{pmatrix}. \]

When doing a joint inversion like this one must be aware
of the physical connotations of the methods which are used.
It is well known that in a true 1-D case MT is only sensitive
to horizontal resistivities (e.g. Jupp & Vozoff 1977). The
reason is that MT uses purely inductive sources which
generate only horizontal current systems in the subsurface.
The LOTEM method also involves vertical currents,
because of the grounded dipole source. However, the
magnetic fields at the surface are only sensitive to the
horizontal resistivities. The reason is that the magnetic fields
only depend on the ‘Poloidal Magnetic’ (PM) mode of the
current system in the earth, which contains only horizontal
currents (Boerner & West 1989). This is different for the
electric fields of the LOTEM method. They also depend on
the ‘Toroidal Magnetic’ (TM) mode, which includes vertical
currents. This means that the LOTEM electric fields can
help to resolve resistivity within resistive layers, which the
MT method is incapable of doing.
In the following we will concentrate on joint inversions with the MT site AULE, which is very close to the location of the borehole. Fig. 11 shows the LOTEM data set A01 and the MT data AULE. The MT data consists of two parts: the high-frequency data were measured by the University of Braunschweig with a controlled-source method (CSAMT) using only one transmitter. The low-frequency data were measured by the University of Münster between 1981 and 1982 (Büchter 1983). For 1-D inversion we used a coordinate system where the x direction is parallel to the CSAMT transmitter. The solid lines in the figure show the theoretical curve for the best-fitting model. The inversion results are compared with the well log information in Fig. 12. The LOTEM inversion agrees more closely with the well log in the upper few kilometres, but does not resolve the deeper sections. The result of the MT inversion is considerably different from the well log. In particular the second layer is much thicker than in the LOTEM inversion. In the joint inversion the second layer thickness is approximately the average of the two values of the separate inversions.

We also performed a joint inversion of the AULE data with a LOTEM electric field. The nearest electric field site (A08), is 1 km away from AULE. Since our previous results did not show any local conductivity anomalies in the area around the borehole, we treated the AULE and the A08 data as if they were measured at the same site. The results of the inversions (Fig. 13) show the same basic features as Fig. 12 but now the joint inversion agrees closely with the well log over the entire depth range of the borehole.

In order to investigate the different inversion results in more detail, we will consider the data fits and the resolution of those parameters which are important for the depth to the third layer. Table 1 shows the importances for the second layer thickness and the third layer resistivity that result from the single inversion and from the joint inversions, respectively. The joint inversion with the LOTEM electric field results in a higher importance for the third layer resistivity. Additionally, the data misfits for the different inversions are displayed in the table. For the MTHZ inversion, mainly the data fit of the LOTEM data deteriorates compared to the single inversion. For the MTEX inversion, both data fits (the MT fit and the LOTEM EX fit) deteriorate about the same amount. We conclude that the LOTEM electric field has a larger influence in the result than the LOTEM magnetic field.

Fischer & Le Quang (1982) investigate the behaviour of MT inversions when a larger value for the misfit is allowed. They showed that the variety of possible models can be very large. In the example shown, the LOTEM electric field constrains the variety of possible models. It is a typical example where a weakness of MT is overcome by joint inversion. For MT the resolution of resistivity and top of thick resistive layers is difficult (Fischer & Le Quang 1982). The LOTEM electric field resolves the resistivity increase between second and third layer, because it is also sensitive to vertical currents. However, the LOTEM measurements do not penetrate deep enough and need the MT for the
deeper section. In combination with the MT data the whole depth range is resolved.

In general, however, one must always keep in mind that the basic assumption of a 1-D earth may not hold. This becomes very clear in the joint inversion of two data sets in the very eastern part of the profile. Fig. 14 shows the LOTEM data A06 and the MT data WIEL. The solid line is the inversion result of the best joint inversion which could be obtained. The fit is poor for both data sets which means that it is not possible to find a common 1-D earth model in this case. However, both data sets were easily interpreted with separate 1-D earth models. Unsuccessful joint inversion serves as an indicator of 2-D or 3-D conditions in this area, because they have different effects on different types of measurements.

CONCLUSIONS

Different 1-D inversion techniques are applied to LOTEM field data to find a compromise between realistic interpretation and data fit. They have been used to get a more unbiased interpretation of the data. Each technique has its particular advantages and contributes differently to the final result. Profile inversion yields a smooth section in the western part of the profile which is in agreement with the well log information. Inversion with weighted parameters allows one to include a priori information such as seismics (Strack et al. 1989b). However, in the extreme case it can force the result to become the a priori model. In the example it provides a smooth section even in the anomalous eastern part of the profile. We conclude that the underlying 1-D earth model is also valid in the eastern part, but disturbed by a local 3-D anomaly. In areas where the geology suggests large lateral conductivity variations, this tool cannot be recommended. Occam inversion gives a smooth model independent of the starting model. Here, it results in a 'minimum structure' section which avoids overinterpreting the data and confirms the results of Marquardt inversion over the entire profile.

Joint inversion can be a tool to overcome weaknesses in the resolution of the different methods. The combination of LOTEM electric field and MT data helps to resolve the third, resistive layer in this area better than the joint inversion of LOTEM magnetic field and MT data. This is in good agreement with theoretically predicted resolving powers for LOTEM magnetic and electric fields. In the eastern part of the survey area the separate 1-D inversions were possible while the joint inversion failed, indicating 3-D structures.

**Table 1.** Importances and data misfits for the MT inversion (station AULE) and for the joint inversions MTHZ (station A01) and MTEX (station A08). The second layer thickness is denoted h_2, the third layer resistivity is denoted \( \rho_3 \). The values in brackets are the misfits for the individual inversions.

<table>
<thead>
<tr>
<th>Inversion</th>
<th>( h_2 )</th>
<th>( \rho_3 )</th>
<th>MT</th>
<th>HZ</th>
<th>EX</th>
<th>Misfit X</th>
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<td>MT</td>
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<td>0.11</td>
<td>3.2</td>
<td></td>
<td></td>
<td>3.0</td>
</tr>
<tr>
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<td>0.11</td>
<td>3.4 (3.2)</td>
<td>4.7 (2.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MTEX</td>
<td>1.0</td>
<td>0.32</td>
<td>4.0 (3.2)</td>
<td></td>
<td></td>
<td>4.8 (3.8)</td>
</tr>
</tbody>
</table>
Most of the survey area appears 1-D and the LOTEM data resolve three layers which are in agreement with the well log information. In the western part of the profile a fourth, very conductive, layer is required, but there is no obvious geological interpretation for this. In the eastern part the inversion results are not consistent with those in the rest of the area. It is likely that the 1-D structure also extends to the eastern part of the survey area, but the structure is disturbed by a local 3-D anomaly. The 3-D modelling for these data sets is subject of ongoing research.

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