CDI – *Conductivity Depth Imaging*

CDI vs Layered Earth Inversions *what is a CDI* ? *a descriptive explanation*

The concept of a CDI is widely misunderstood particularly by users and collectors or airborne EM data. The concept originates in magnetotellurics and was introduced by Niblett in 1960. For decades it was referred to as a CDT – conductivity depth transform. This is a much better terminology for the technique as many individuals think the 'I" in CDI stands for inversion.

Although, there is a type of inversion process in CDI's, it is not a true layered earth inversion. In MT, the concept was to take the phase of the impedance and from this estimate an apparent resistivity. In other words, an apparent halfspace which would explain the phase. From this apparent halfspace resistivity, the apparent depth was calculated as the centroid of the current distribution in such a resistive halfspace at that frequency. Thus, an apparent depth and resistivity were derived from the impedance data at each frequency.

This concept was extended to towed airborne FEM systems in the early 1990's by Sengpiel. This approximation provides useful information for airborne data but not ground data. Essentially, the idea is to determine the apparent resistivity from the quadrature data which is a type of inversion and from there, determine the centroid of current in such a halfspace as in the MT approach. The controlled source methodology is somewhat different in the depth estimate b varies very little from the estimate provided by the MT approach.

But, most importantly, it should be noted that the technique does not attempt to derive a layered earth model. Each frequency determines an apparent depth and there is no attempt to resolve the entire physical response of a layered earth. In TEM data, this type of approach was attempted starting in the 1990's using the equivalent of the quadrature data for FEM, namely the decay of the data. By utilizing, the decay of different sets of windows, apparent resistivities were determined and apparent depths determined by approaches which are analogous in the physics of EM to the frequency domain methods.

In both, CDI approaches, FEM and TEM, attempts were made to estimate a continuous resistivity profile. However, thee attempts are merely approximate as there is no attempt to deal with the interaction between the resistivity of different layers. In both FEM and TEM, the different layers are not independent as at the interface between different layers, part of the electric field transmits through the boundary and part reflects and the reflection wave also interacts with the interface above and so on and so forth.

An inversion, is a very different approach as a the full response of the layers are calculated and inverted for using actual resistivities and depths and not apparent resistivities and depths. For airborne FEM, the use of CDI's essentially disappeared by 2000 as proper and fast 1D inversion codes were available. For TEM, most of the use of CDI's started to disappear around 2005 but some service companies still persist in this approach. This is particularly true of the evolution of towed TEM birds by Fugro and CGG. In-loop systems such as VTEM, had access to a range of software but Fugro and CGG did not have too many choices for out of loop data.

CDI vs Layered Earth Inversions *in EMIGMA*?

For airborne FEM data, EMIGMA still offers historical apparent resistivity and depths estimates but also offers two types of full 1D inversions. Two different types of inversions are offered as there are, today, generally 2 approaches to inversion. The most popular approach to inversion of many types EM and resistivity data, is the so-called Occam approach. In this approach, there are normally more model parameters than data and additionally to provide some reasonable geological model, the resistivity parameters are constrained to vary smoothly with depth. The other approach in EMIGMA, is to utilize the original approach to inversion of data and which has more theoretical support. This is an approach whereby both the resistivity of the layer and the thickness of the layer are determined and the resistivity can vary abruptly but the number of model parameters is less than the number of data.

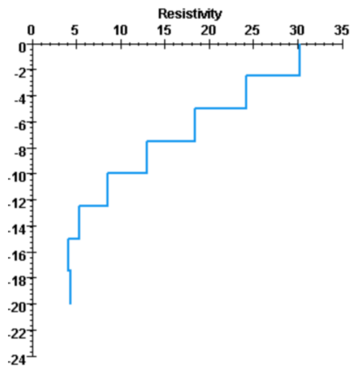
The CDI capability for TEM, however, has been removed as we believe, generally, its results are too often counterproductive. Rather, we have focused on developing accurate but rapid layered earth inversions for airborne data. These inversions are available for both inloop systems such as (VTEM and SkyTEM) but also for out-of-loop systems such as (Genesis, Tempest and older data from HeliTEM, MegTEM and GeoTEM). For out-of-loop data, both the vertical components and the horizontal components may be used in the inversion.

For FEM, we will illustrate first for a synthetic dataset.

CDI vs Layered Earth Inversions *Example from Synthetics*

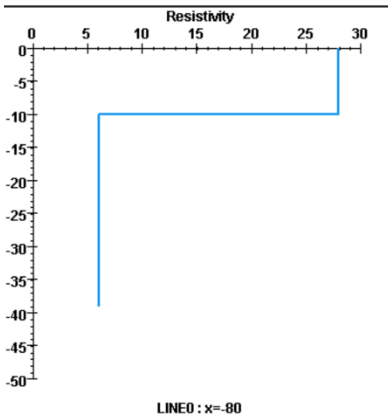
For FEM, we will illustrate first for a synthetic dataset. The model is simple, 10m of 25 ohm-m material over 5 ohm-m and we will utilize and vertical coplanar broadside system using 4 frequencies similar to the fixed wing FEM systems.

Occam Inversion



The model above is a 8-layer over a halfspace smooth inversion which fits the data to less than .001%. While the model shows that the upper resistivity is higher than the lower and that the basement is close to the correct resistivity, we do not know the precise depth to the bottom of the first layer and have a wide range of resistivities for the top 10m.

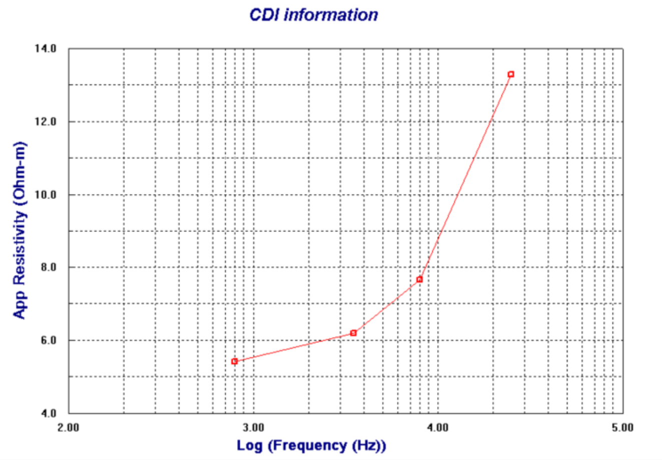
Under Parametrized Model



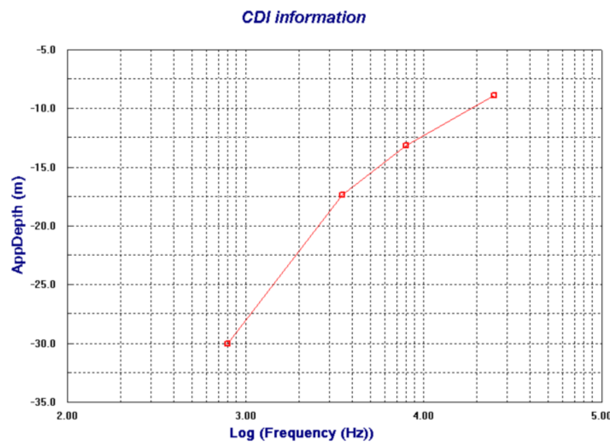
For the underparametrized inversion, we made the inversion work a little harder. We first added 1% noise and then set the starting model to be 2 layers to a depth of 20m with a basement. The resistivity of the top layers was set in the starting model to be the apparent resistivity at high frequency and the basement was fixed at the apparent resistivity of the lowest frequency. The inversion derived the above result. The depth to basement is usefully defined and closely correct while the upper resistivity is somewhat larger but not significantly so. The basement resistivity is a little high but again not significantly. The inversion fit was 0.93%.

CDI vs Layered Earth Inversions *Example from Synthetics*

We have seen the differences between an Occam and underparametrized inversion. But, now lets compare these inversion results to that of a CDI. Remember, the inversion results are for a sequence of layers with each layer having a thickness and a resistivity and the full interaction and propagation and backscattering between layers is considered.



Apparent Resistivity



Apparent Depth

The above figures show all the information available for a CDI. We have 4 apparent resistivities and 4 apparent depths. We have no information on the number of layers, nor the resistivities or thicknesses of any layers. What is does show, is a basement which is close to 5 Ωm and a cover which is 14 ohm-m or higher. The apparent depths indicate a depth to the first interface which is greater than 9m. The other apparent depths bear no information to our model but do indicate that the data is penetrating to a depth of about 30m.

What to do with a CDI? *Example from Synthetics*

As shown on the previous figures, even in simple environments, the CDI's in themselves to not provide an precise information on the resistivity-depth structure. But, can be useful to set starting models for inversion.

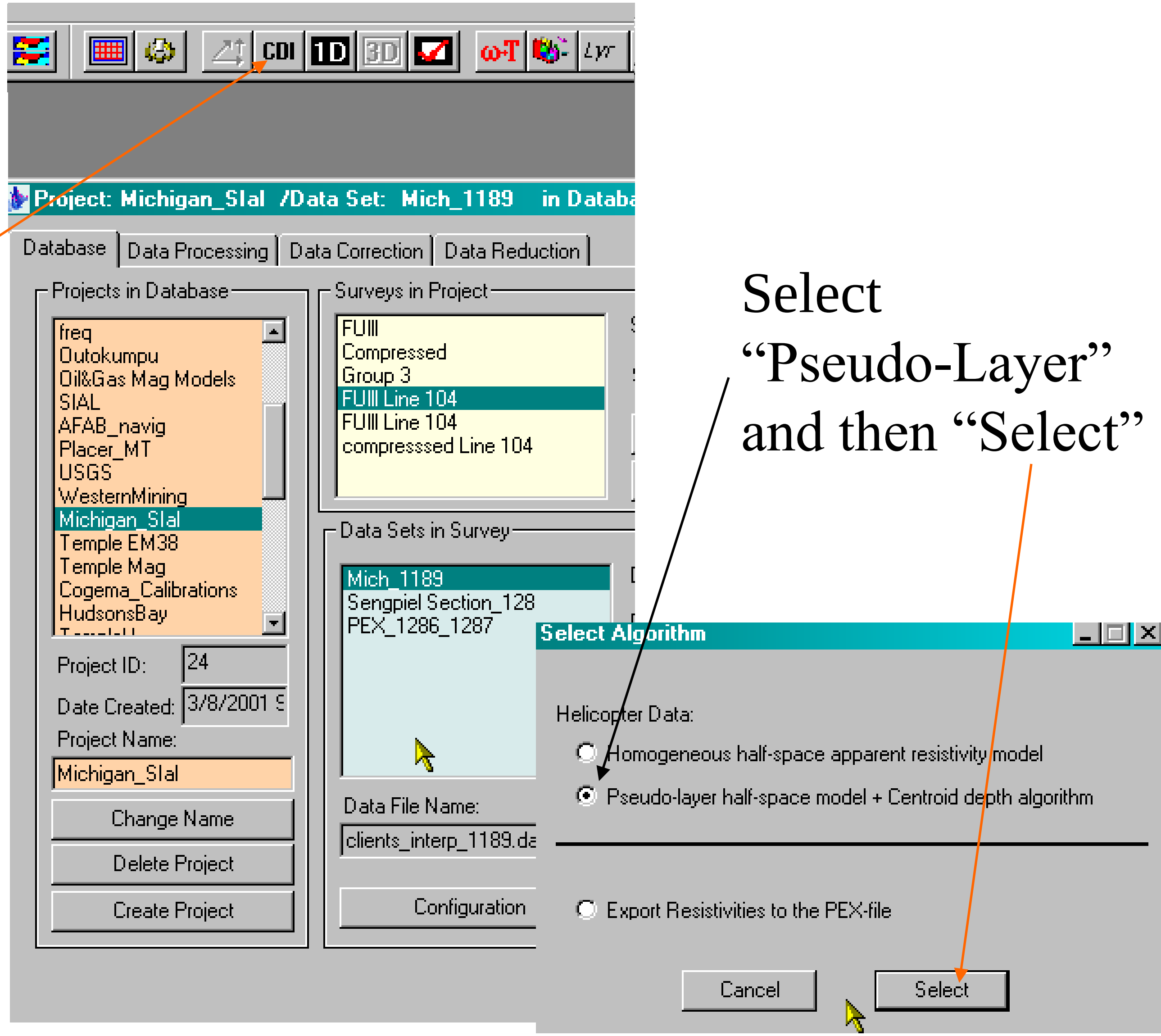
It is quite common for software, to interpolate CDI information into estimates of resistivity-depth structure. This, we also do in EMIGMA. However, much care should be used :

1. There is an automatic interpolation but the user should check with varies interpolations. This is accomplished by unclicking the automatic generation of a PEX file and then the user is asked to define the maximum and minimum depths and the number of intervals.

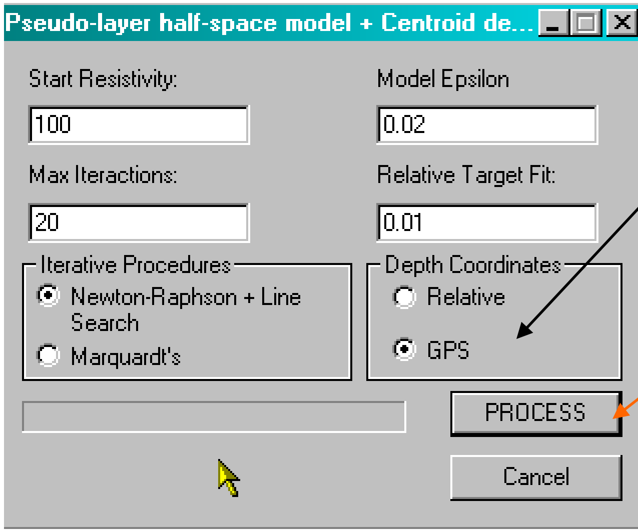
2. The CDI technique will not work in a 2D or 3D environment and in these cases the results can produce wild results. This was the reason for the frantic attempts to develop CDI's in the 1990's with competition between different instrument manufacturers. However, they were fighting a losing battle as the approach is limited.

Sengpiel Depth Sections – in EMIGMA the CDI approach is not exactly Sengpiel's apparach but is very similar.

Select helicopter EM Dataset and then Select “CDI”



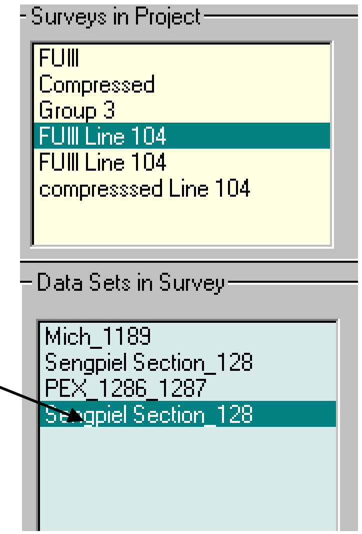
Select “Pseudo-Layer” and then “Select”

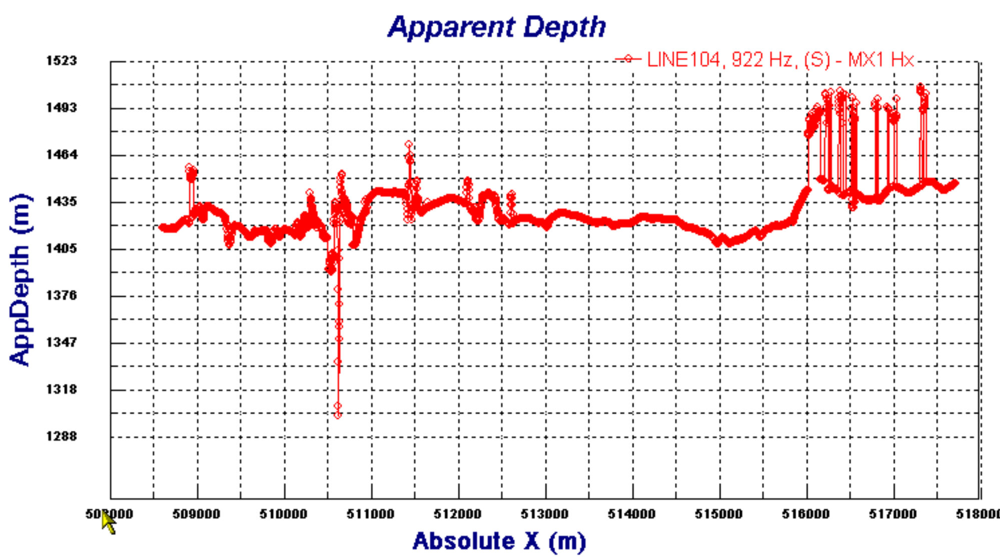


Select Relative or GPS

Then "Process"

A new dataset is created containing apparent depths and apparent resistivities

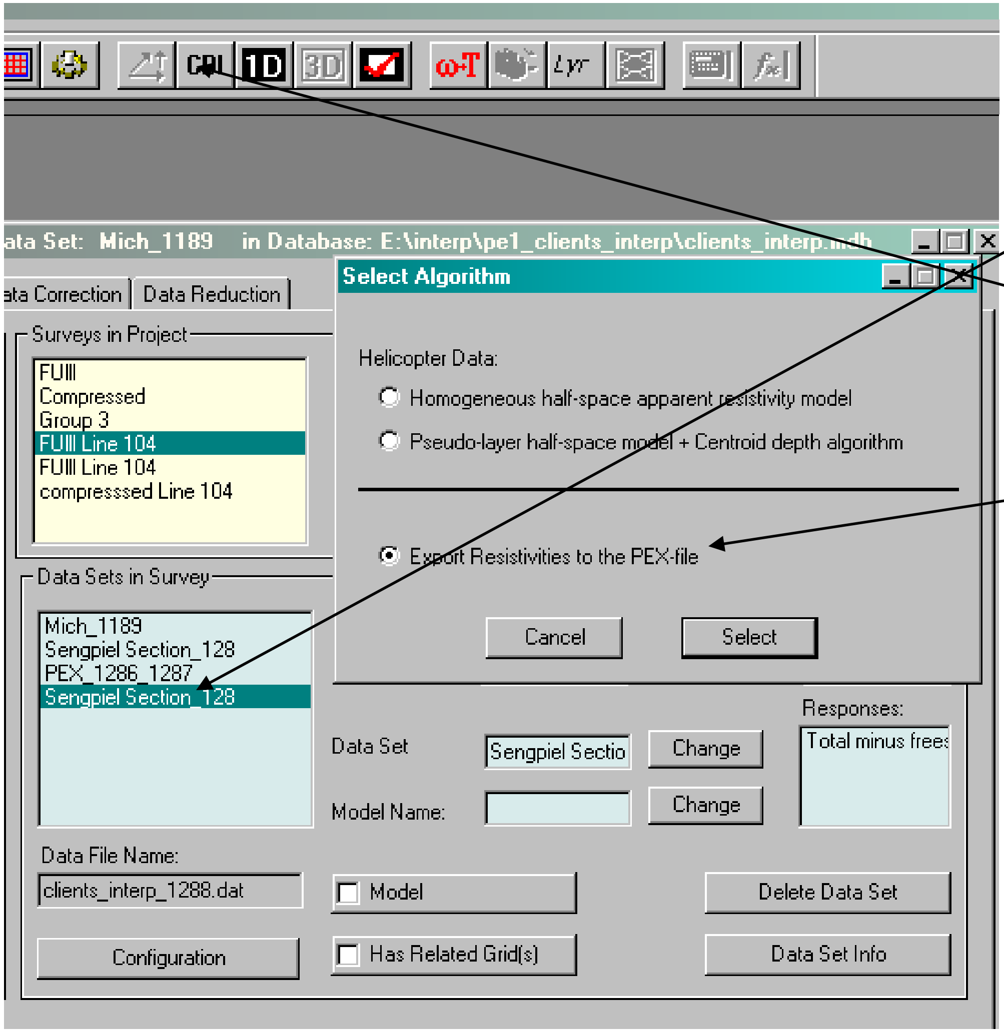




You may plot both Apparent Depth and their Apparent Resistivities in the Plotter

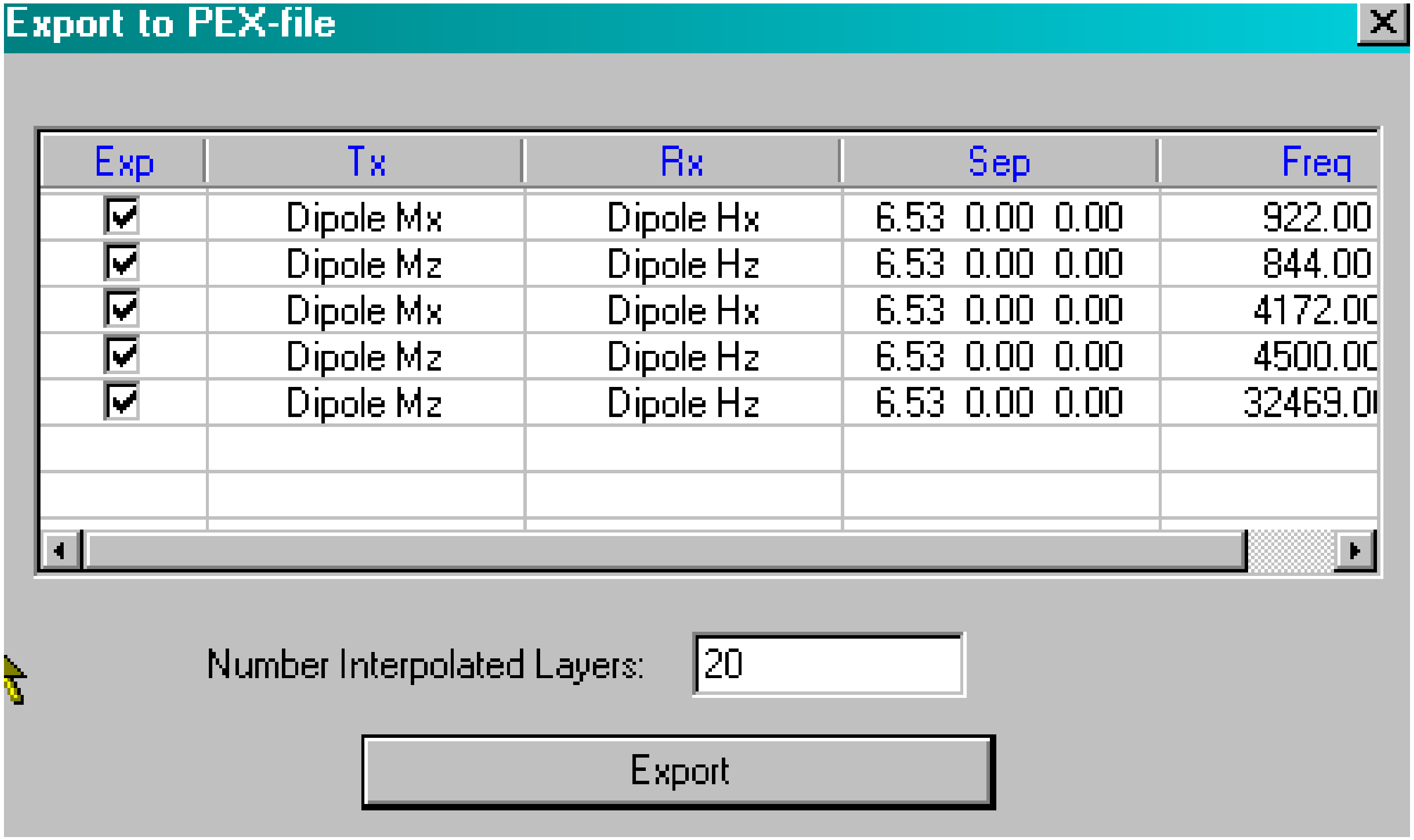
Remember: The technique will not work at all for some data

Exporting to PEX file - 1



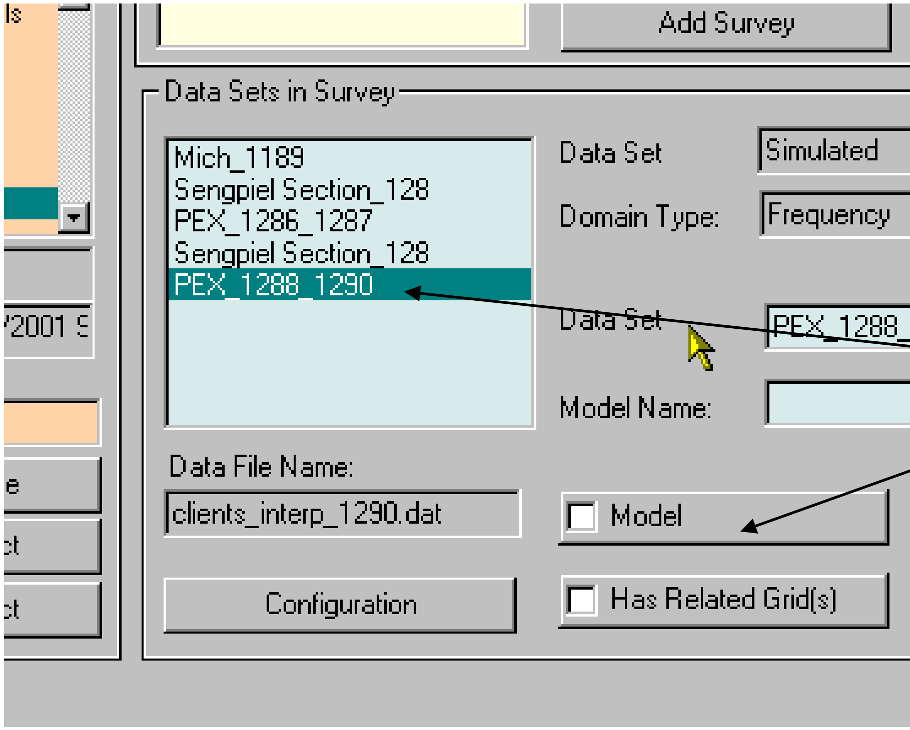
Now select output Sengpiel Section data set, and then click the "CDI" button followed by "Export Resistivities"

Exporting to PEX file - 2

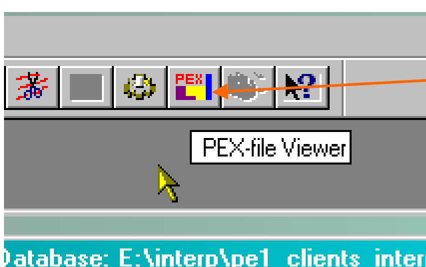


Now select which apparent depth information you wish to use in your image (some of your data components might not be good for some images). Select the amount of resolution you wish. Remember some depths may be very deep (check apparent depth in plotter). Select Export to complete your task.

Exporting to PEX file - 3



You will notice a new dataset and if you click Model you will notice a .pex file associated with it. This .pex file can be viewed or opened in any ASCII editor or spreadsheet.

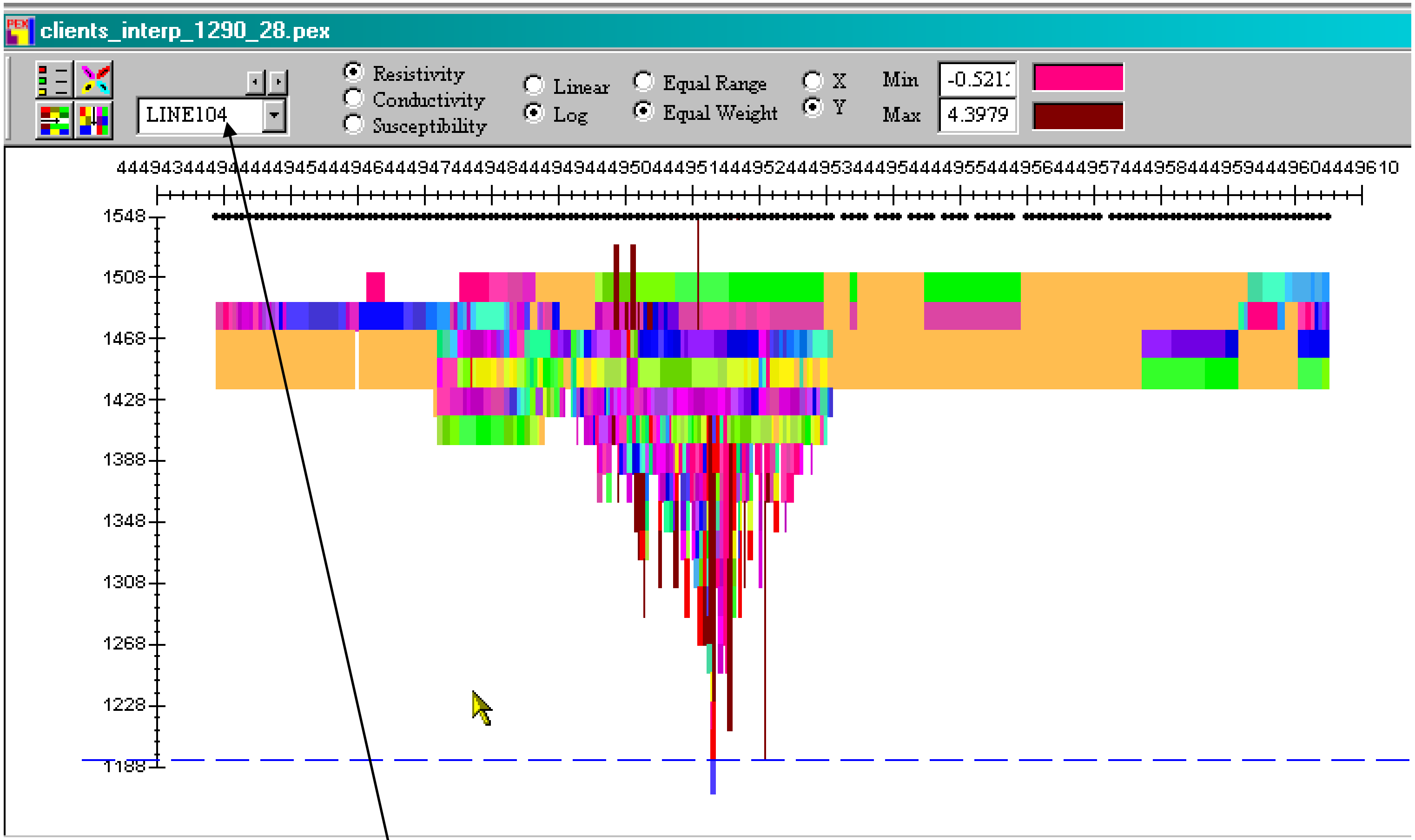


By selecting PEXView you may see these Images

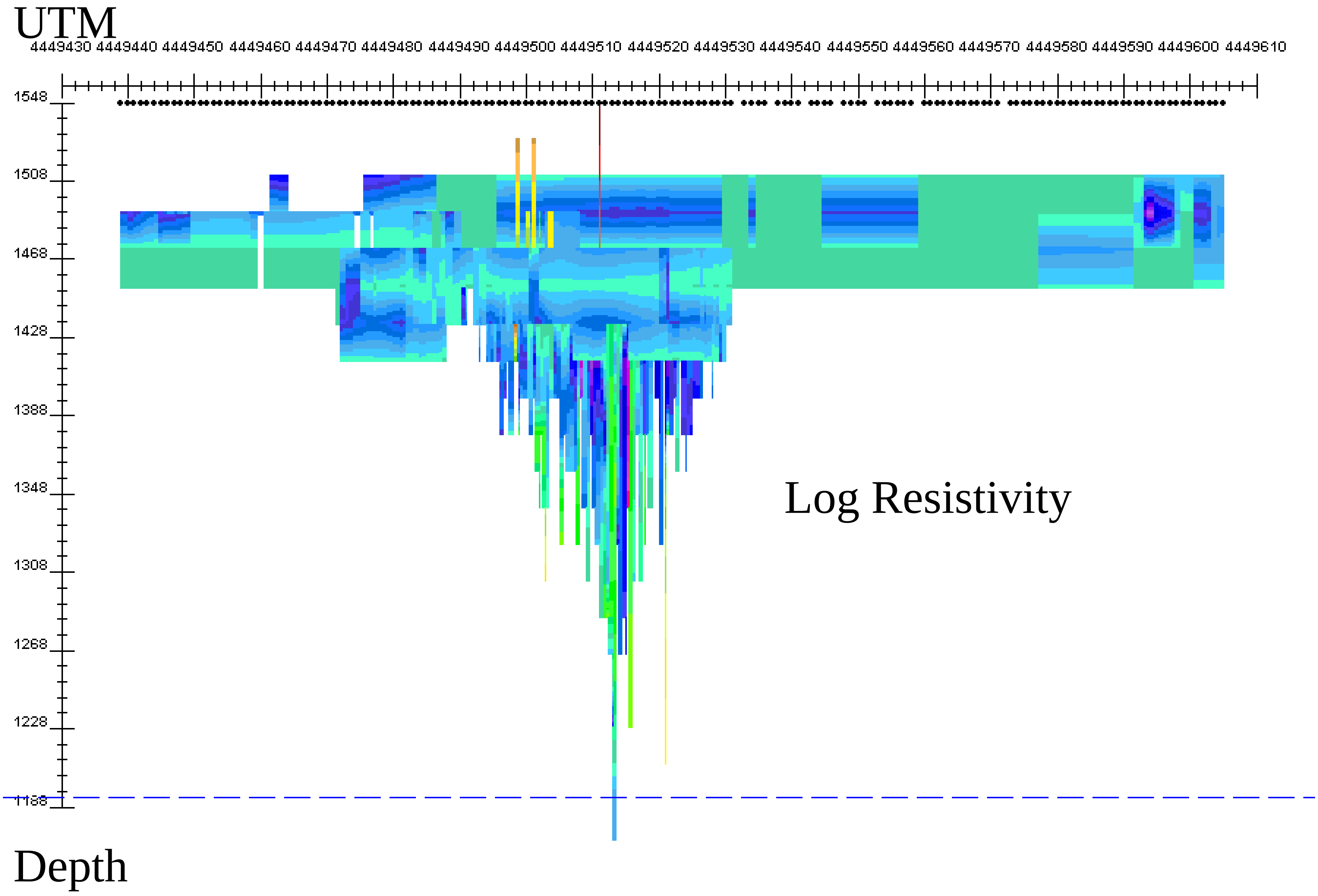
You can also load to Contour (but beware)

PEXVIEW

The purpose of PEXView is to accurately investigate your depth sections.



If you have multiple lines then you may step between lines. There are many other features.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