Electromagnetic Phenomena in Complex Geological Environments: Lessons from MultiLoop III

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Abstract:

MultiLoop III is used to illustrate that the response of a syncline can be equivalent to the response of two plates. Since plate models are typically the model of choice when interpreting data, the interpreter will naturally be mislead into believing the plate models are a realistic representation of the geology encountered. The consequences of such a misinterpretation will be an erroneous geological model: For the case illustrated, faulting rather than folding will be interpreted to be the cause of the electromagnetic response.

Introduction:

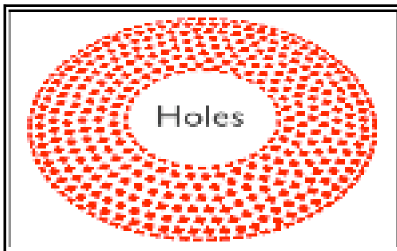
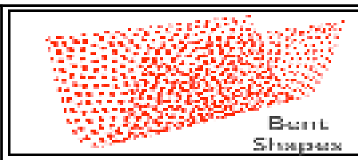
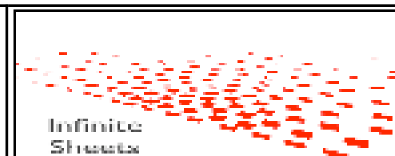
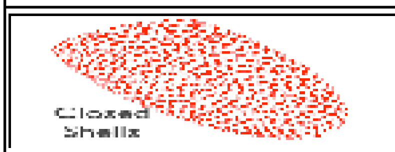
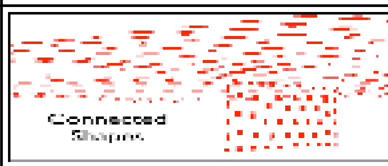
The foundations of modern interpretation theory stem from work done in the 1950s through to the mid-1980s, but not much work in the field has been done recently. Early understanding of interpretation theory was largely the result of computations using analytical and numerical models of simple shapes in free space. Later efforts were based on numerical models, in which the effects of conductive background and overburden on plate and block models were examined. Since that time, exploration has shifted to increasingly complex geological environments and away from the ones where the simple models fully apply. As a consequence, the paradigms and methods used to interpret data from these early studies have failed to keep pace with the new challenges of complex environments.

Of the many models that have contributed to our understanding of electromagnetic phenomena, the thin plate model has arguably been the most significant. Early work with plate models helped to solidify our understanding of induction, while later work contributed to our understanding of overburden shielding effects and current channelling. Today, free-space plate modelling software is a standard tool in any interpreter's tool kit. The model is easy to understand because it forms the basis of existing interpretation theory. Many implementations of the model exist, and commercially available software can compute models quickly and reliably.

MultiLoop III models the scattering using the thin sheet approximation in free space, and so follows the basic theoretical principles of the plate model. Like existing plate software, models can be computed quickly and reliably. However, MultiLoop III differs from existing plate modeling software because it is a mesh based solution, and so can model a diverse range of shapes to represent folded, faulted and intruded structures.

Extensions to thin sheet scattering theory permit MultiLoop III to simulate scattering from shapes that cannot be handled by the plate model. These include holes, junctions between sheets, closed shells, variable resistivity and sheets extending to infinity. Some of this capability is illustrated in Figures 1 through 5.

Many of the concepts developed for interpreting electromagnetic scattering in simple environments can be transferred to complex environments, but care is definitely needed. In the example presented below, we examine the effect of interpreting the response of a synclinal structure using standard interpretation methods; synclinal structures are typical of more complex geological environments into which exploration has recently been pushed.

 Figure 1: Internal holes	 Figure 2: Bent surfaces	 Figure 3: Infinite or semi-infinite sheets
 Figure 4: Closed shells	 Figure 5: Connected surfaces	*MultiLoop III can simulate the response of connected surfaces containing any of the characteristics illustrated. As such, its modelling capabilities are very general*

Example: (Mis)Interpreting the response of a simple syncline

The UTEM response of a simple syncline was computed using the geometry illustrated in Figure 6. The loop was offset from the syncline a distance of 100 metres and the top of the syncline was located 100 metres below the surface. This model could represent a large fold.

Figure 7 shows the stream potential calculated in the inductive limit, just after the current in the transmitter has been stepped off. Equipotential contours of the stream potential show the direction of current flow, and the gradient in the stream potential (rate of colour change) is indicative of its magnitude. It is clear that the dominant part of the current excitation lies on the limb of the syncline closest to the loop, with a smaller return current in the opposite direction located in the other limb. This is a general characteristic of current excitation in a syncline that has been observed in MultiLoop III modelling.

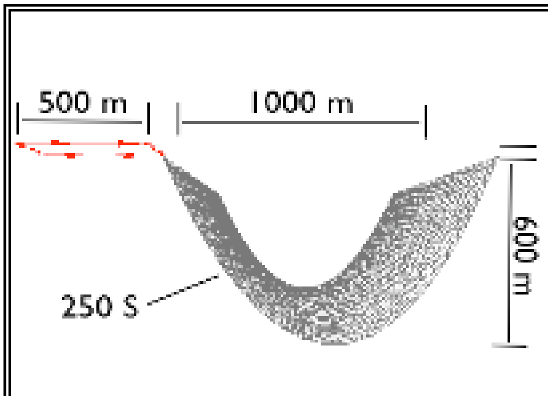


Figure 6: Model geometry

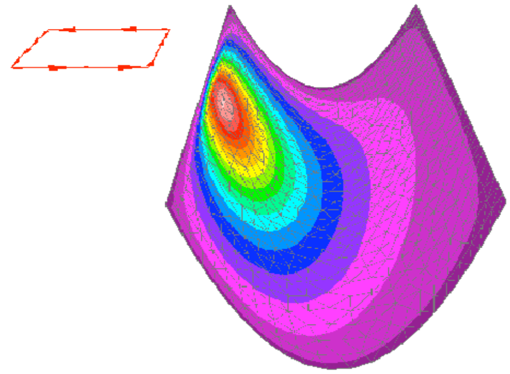


Figure 7: Stream potential: inductive limit

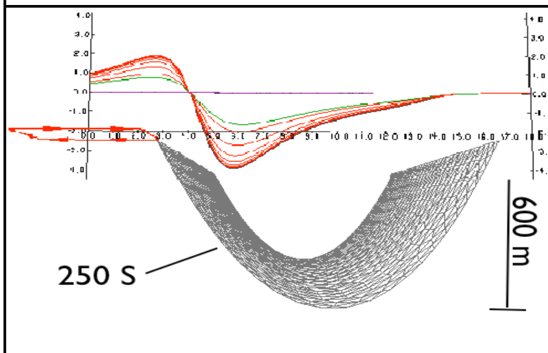


Figure 8: Response of the syncline

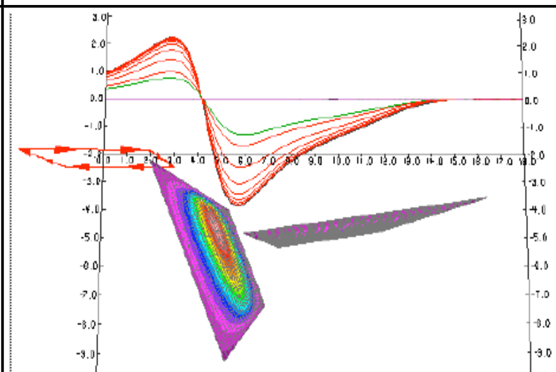


Figure 9: Equivalent plate model

Figure 8 illustrates the profile response over the conductor, while Figure 9 illustrates the response calculated using plates. An interpreter fitting the data would have a difficult time differentiating the models as illustrated in Figure 10: Many of the characteristic traits of the model profiles are virtually identical, and would be indistinguishable in the presence of noise (geological or otherwise) and sparser sampling typical of survey data.

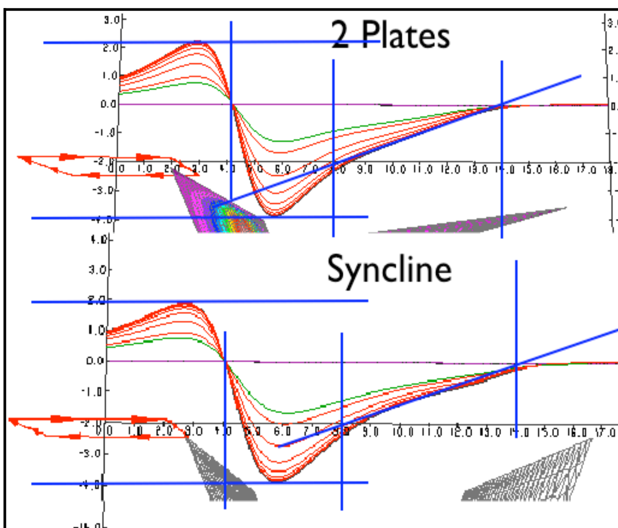


Figure 10: Equivalence between the plate and syncline models. The equivalence of important characteristics of the two responses is highlighted by the blue lines.

Conclusion:

There is no doubt that much of our understanding of interpretation theory results from the work done with the plate model, and that plate modelling software is a necessary tool in any interpreter's tool box. However, the model does have its limitations, and these limitations can result in the use of the model in situations where it does not apply.   Much of our knowledge of interpretation theory is based on such models. As a consequence, the framework in which modern interpretation theory and exploration methods have been developed often does not fully apply to complex geological environments.

An example has been presented to show that model fitting using multiple plates can lead to interpretations in which the modelling fits the data but where the geological interpretation can be quite misleading. This effect could partially explain the increased difficulties encountered when targeting anomalies complicated geology.

MultiLoop III has the capability to accurately simulate the response complicated distributions of thin conductors. This is not only important for fitting data where the geology is complicated, it also provides an important tool for advancing interpretation theory to the next step, beyond the well understood cases for scattering by a simple plate and into the domains now only occupied only by field data. Better interpretation theory will undoubtedly result in better survey design and interpretation, better target prioritization and location, and ultimately improved exploration success rates.