

Integration of polyhedral and voxel-based inversion strategies

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SUMMARY

Geophysical inversion of magnetic and gravity data provides an effective method for replacing or supplementing tedious manual methods of modelling field data. Since there can be no unique inversion for any given potential field data set, manual effort is still required to provide inversion constraints in order to extract realistic geological information.

A lot of research literature is devoted to developing automated methods that incorporate a constraint style that avoids the need for manual interaction with the data. The objective is to produce the best, unbiased inversion possible, with the least manual intervention. The output of automated inversions usually requires a high level of interpretation of the output results and an awareness of the strengths and limitations of the inversion method. By contrast, manually constrained inversions include the interpretation as part of the process with a subsequent knowledge of the quality of the result. Our industry emphasises the use of physical measurements from drilling and outcrop to provide a-priori information for inversion, but geological inference can provide a surprising amount of control without a single measurement being required.

A comparison of polyhedral model inversion with voxel-based inversion strategies provides insights into the benefits of both methods. Integration of the two methods provides the opportunity to embed geological knowledge derived from polyhedral modelling within a voxel model. This geological information is then used to constrain the inversion and provide new information not available to the methods when used in isolation.

The San Nicolas deposit in Mexico is used as a case study of inversion methodologies and the use of a-priori information in constrained inversion. The deposit has been extensively drilled and the limits of the deposit are well defined. The gravity and magnetic methods have been chosen for a practical evaluation of inversion strategies and the quality of the geological outcomes by comparison with the drilling results.

The study results show that the polyhedral inversion strategy would have produced the best precision for siting of the first drill hole, but the constrained voxel inversion would produce the best method for optimizing the location of subsequent holes.

Key words: gravity, constrained, inversion

INTRODUCTION

The San Nicolas volcanogenic massive sulphide deposit was discovered in 1997 near Zacatecas, Mexico by Teck Corporation. Geophysical and drilling data from the deposit

have been used for the evaluation of the UBC GRAV3D voxel inversion using constraints derived from the ModelVision Pro polyhedral forward and inverse modelling system.

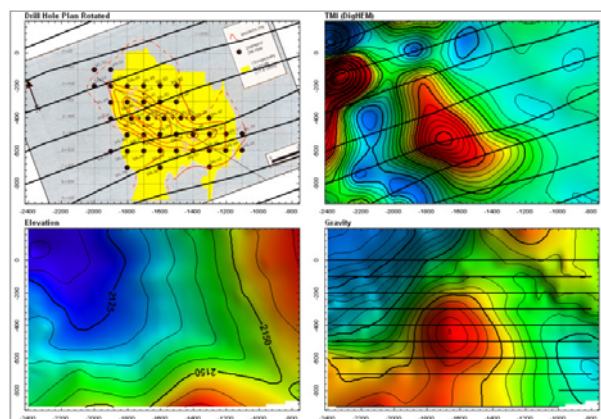


Figure 1. Map images (clockwise) of drill patterns, total magnetic intensity, Bouguer gravity and terrain.

A variety of geophysical data sets has been collected over this deposit including airborne magnetic data, ground magnetic data, induced polarisation, CSAMT, DIGHEM and gravity. The gravity method has been selected to show how polyhedral modelling can be used to improve the voxel inversion results by embedding geological constraints within the voxel model.

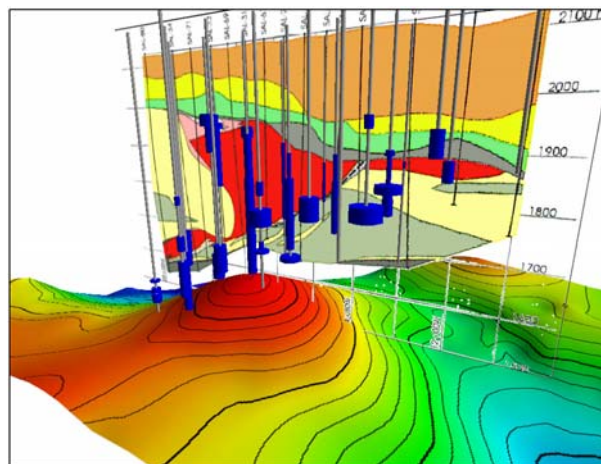


Figure 2. Bouguer gravity, geological section and Cu assay (blue) drilling data for the San Nicolas deposit, Mexico.

Geophysical inversion of gravity data provides an effective method for replacing or supplementing manual methods of modelling field data. Since there can be no unique inversion for any given potential field data set, manual effort is still required to provide inversion constraints in order to extract realistic geological information.

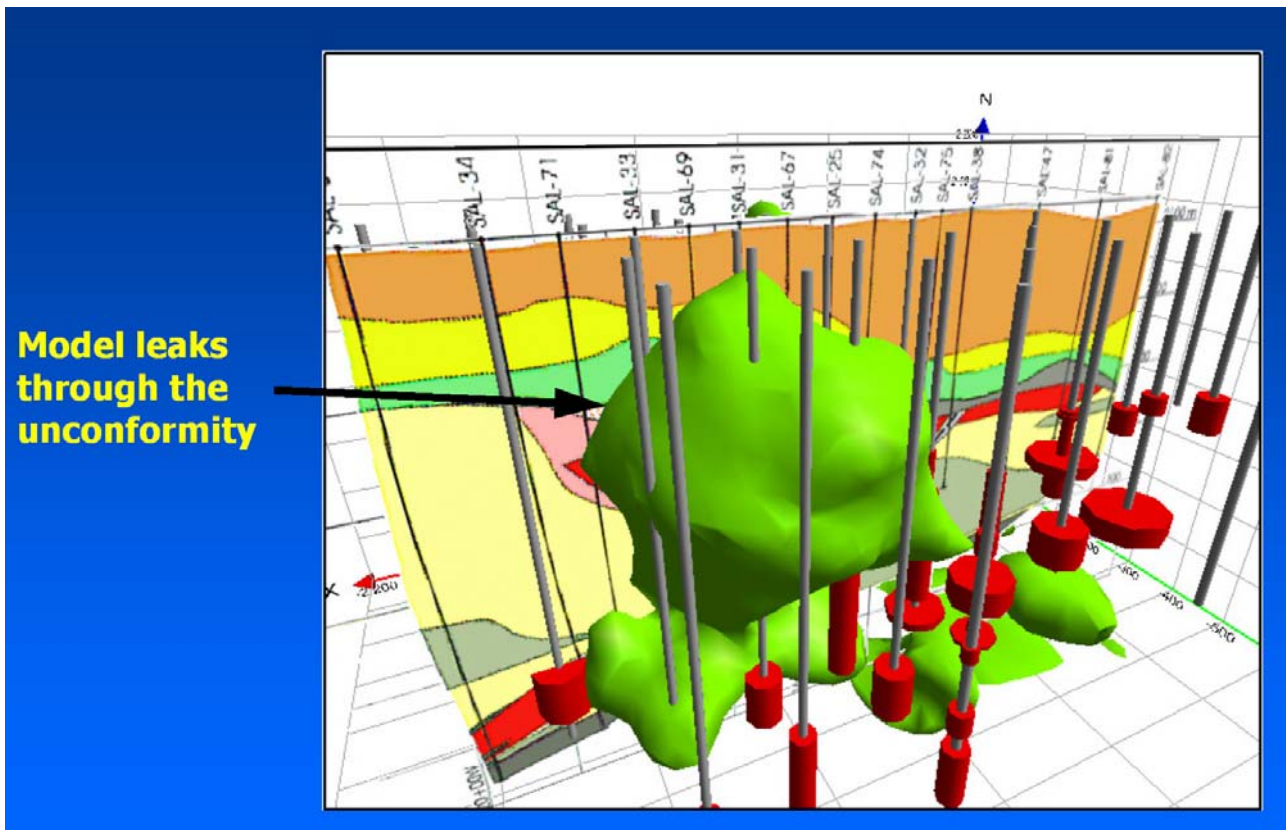


Figure 3. Unconstrained voxel inversion results from GRAV3D

The unconstrained voxel inversion of the San Nicolas gravity data shown in the above figure illustrates the fundamental problem of an unconstrained inversion. The high density massive sulphide deposit is located beneath an unconformity about 160m below the ground surface and the unconstrained voxel inversion shows that the high density core leaks through the unconformity.

How can we improve the outcomes before we have any drilling data? Soft a-priori geological information can be derived from polyhedral-based modelling of the gravity with the application of simple geological inference principles. “The deposit has a high density contrast and is localized/terminated by an unconformity surface.”

Inversion modelling in ModelVision Pro was used to derive the depth and approximate distribution beneath the postulated unconformity using an initial density contrast of 1.9 g/cc. The polyhedral model was then used to populate the UBC GRAV3D voxel model with appropriate density contrasts. Note that the initial polyhedral modelling overestimated the depth to the unconformity by approximately 10%.

The modelling process was also used to model and remove the regional gravity field in a manner consistent with the presence of the unconformity surface. This process is very important for achieving realistic outcomes from the voxel inversion. Figure 4 illustrates the interpretation elements used in polyhedral modelling where the anomalous density material is suspended in a uniform density background.

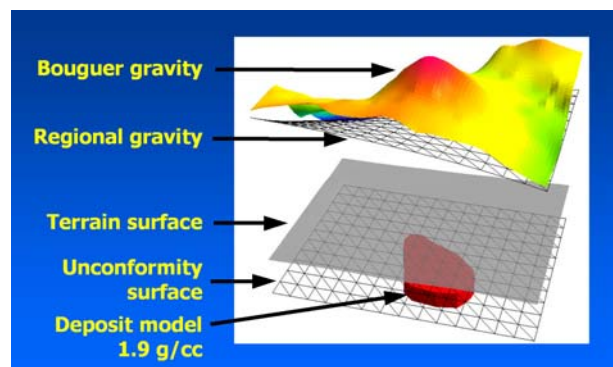


Figure 4. ModelVision Pro 3D display showing the primary elements used to seed the UBC voxel inversion.

The model was then used to create a starting model for the voxel inversion with different density bounds assigned to the overburden, deposit and host rock. Table 1 list the values used to set the density bounds

Table 1 Density Bounds	
Lithology	Density bounds
Cover	-0.05 to +0.05 g/cc
Deposit	+0.3 to +3.0 g/cc
Host	-2.0 to + 2.0 g/cc

Figure 5 illustrates the distribution of the lower bound density values as distributed within the voxel model. Note the polyhedron representing the deposit has been converted to the high density group of voxels shown in red.

The initial polyhedral model derived by ModelVision Pro produces a more realistic outline of the deposit than the unconstrained voxel inversion (Figure 3). The drill holes shown in Figure 5 are used to provide a framework for the quality of the predicted location of the deposit and are not used to influence the modelling process.

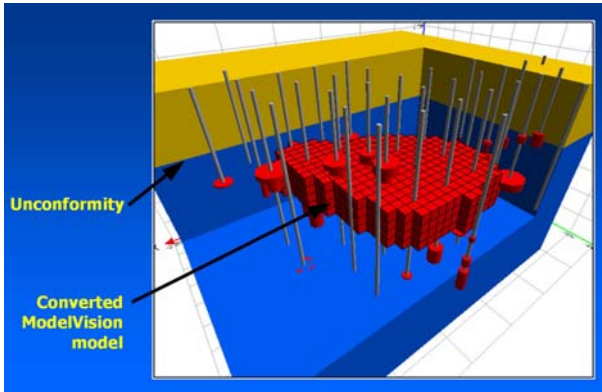


Figure 5. A UBC-GIF, GRAV3D model of the ModelVision physical property constraints (presented in Profile Analyst).

The voxel inversion results (Figure 6) show a more useful outcome than unconstrained inversion (Figure 3). The high density material is forced laterally beneath the unconformity and the distribution reflects more accurately the ultimate shape of the deposit established by drilling.

Importantly, this result was established without the need for a single drill hole constraint.

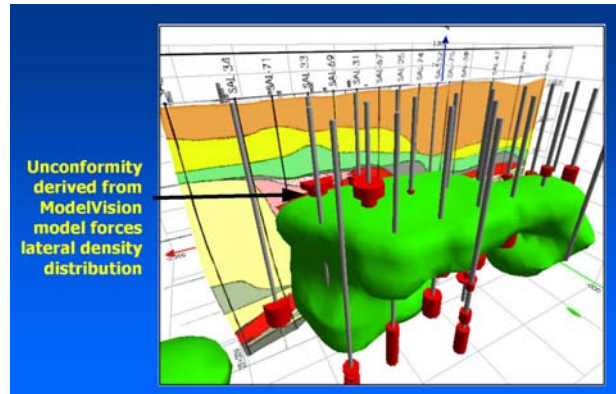


Figure 6. The GRAV3D inversion used constraints derived from a ModelVision Pro polyhedral model.

Superimposition of the polyhedral model with the voxel inversion as shown in Figure 7, provides a method for visualizing the confidence in the voxel inversion outcomes.

The polyhedral model (blue) would provide a high confidence zone for targeting the first drill hole, while the lower confidence extension provides some indication of the possible extent of the deposit. The first drill hole will provide new information such as density and unconformity depth for revision of the ModelVision Pro model. The refined constraint model could then be used to re-run the UBC voxel inversion.

This method provides a logical approach to reducing risk, while improving the probability of success with greenfield exploration from the voxel inversion.

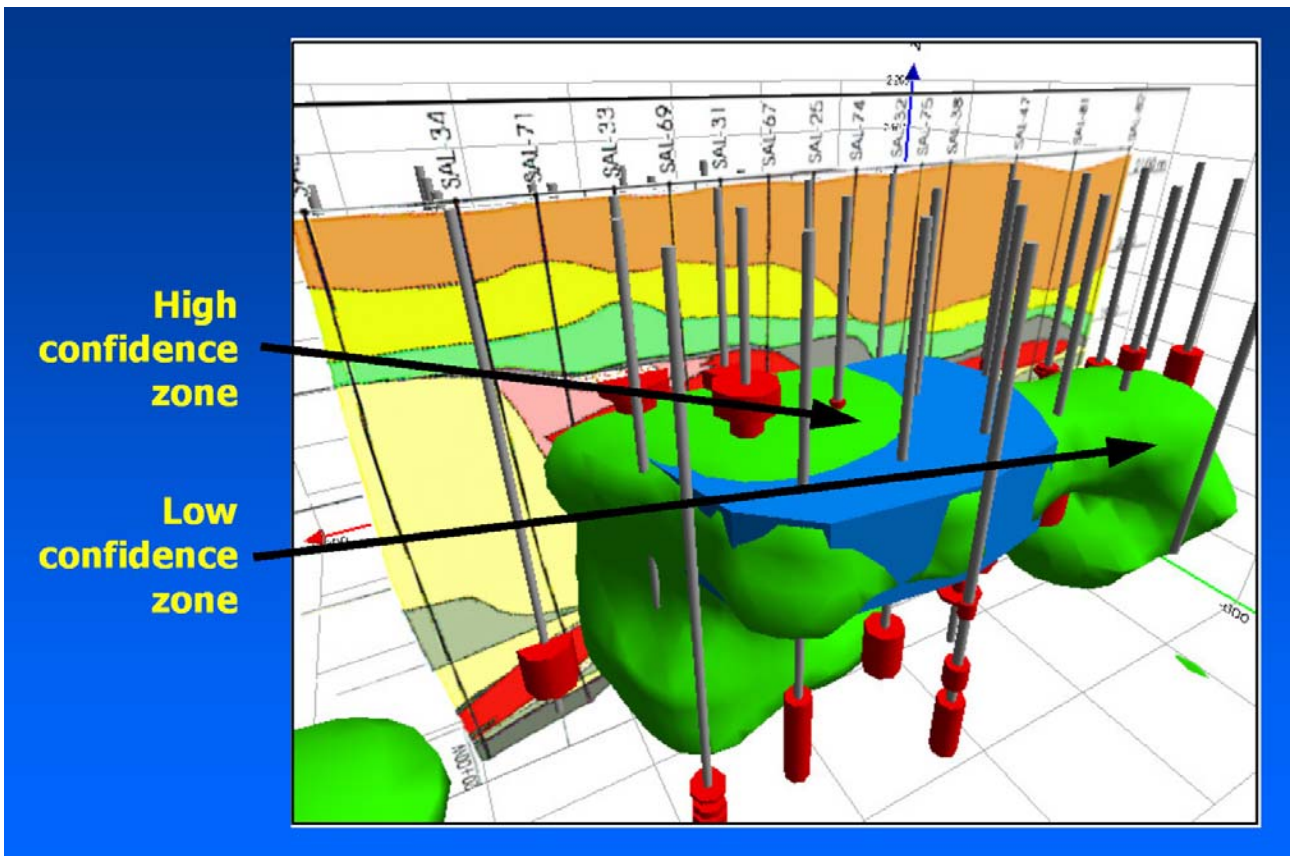


Figure 7. The GRAV3D voxel inversion (green) used constraints derived from a ModelVision Pro, polyhedral model (blue).