3D Gravity, FTG and Magnetic Modeling: the new IGMAS+ Software

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Summary

Three-dimensional (3D) interactive modeling with the IGMAS+ software provides means for integrated processing and interpretation of geoid, gravity and magnetic fields and their gradients (full tensor), yielding improved geological interpretation. IGMAS+ fully three-dimensional models are constructed using triangulated polyhedra and/or triangulated grids, to which constant density and/or induced and remanent susceptibility are assigned. Interactive modifications of model parameters (geometry, density, susceptibility, magnetization), access to the numerical modeling process, and direct visualization of both calculated and measured fields of gravity and magnetics, enable the interpreter to design the model as realistically as possible. IGMAS allows easy integration of constraining data into interactive modeling processes, visualization and combination of geodata with density/susceptibility models. These visual overlays of different 2D and 3D datasets enables quantitative comparison and adjustment and results in models that are constrained by as much independently derived information as possible.

Introduction

'State of the art' geophysical interpretation requires an interdisciplinary approach, particularly when considering the available amount of information contained in comprehensive data bases. A combination of different geophysical surveys employing seismics, gravity and geoelectrics, together with geological and petrological studies, provide new insights into the structures and tectonic evolution of the lithosphere and natural deposits. Interdisciplinary interpretation is essential for any numerical modelling of these structures and the processes acting on them (e.g. Breunig et al., 2000; Schmidt and Götze, 1999; Ebbing et al., 2006; Fichler et al., this issue).

To avoid ambiguity, the interpretation of potential fields by three-dimensional (3D) modelling requires data from other independent sources. Various geophysical methods are used to interpret geophysical data, yielding an increasing number of models – some 3D, most still two-dimensional (2D), and some even one-dimensional (1D). Examples include seismic 2D-raytracing models, 2D and 3D density modelling, four-dimensional (4D = time dependent) stress modelling, and 1D/2D magnetotelluric resistivity modelling. Even geological modelling, which provides a variety of 3D and even 4D models faces limitations. These modeling procedures, and others, are often restricted by single physical parameter interpretation due to limited hard- and software capabilities.

Additionally, these models consist of mostly independently derived information, which must be evaluated to ensure that it is of the highest quality for undertaking complex interpretation. To conduct geophysical modelling, we deal with the following "loop" of knowledge acquisition:

1. Compilation of an initial model that fits concepts and data.
2. Comparisons with other models or data and, if necessary, depiction contradictions and open questions.
3. Interdisciplinary model-driven discussions of inconsistencies.

4. Model improvement by automated algorithms (eg. Sæther, 1997; Alvers, 1998), interactive computer graphics, and incorporation of independent information by visualisation techniques.
5. Return to step 2 until a satisfying model has been found (joint interpretation).

Against this background, we are working towards a 3D interactive software tool which will ease the interpretation of gravity and magnetic data bases. The software IGMAS+, an acronym standing for "Interactive Geophysical Modelling Application System" bases on the existing potential field modelling software IGMAS (http://www.gravity.uni-kiel.de/igmas), a tool developed during the past twenty years. The new IGMAS+, however, will comprise the advantages of the "old" IGMAS (e.g. flexible geometry concept and a fast and stable algorithm) with automated interpretation tools and a modern graphical GUI based on leading edge insights from psychological computer graphics research and thus provide optimal man machine communication.

The Kernel

IGMAS+ uses triangulated polyhedrons or gridded surfaces to approximate areas of constant density and/or susceptibility within the Earth's crust and mantle. The numerical algorithms were developed by one of the authors (Götze), published in Götze and Lahmeyer (1988) and allow the calculation of geoidal undulations, gravity components and all its gradients (FTG), as well as remanent and induced magnetic field components and all its gradients in one program step.

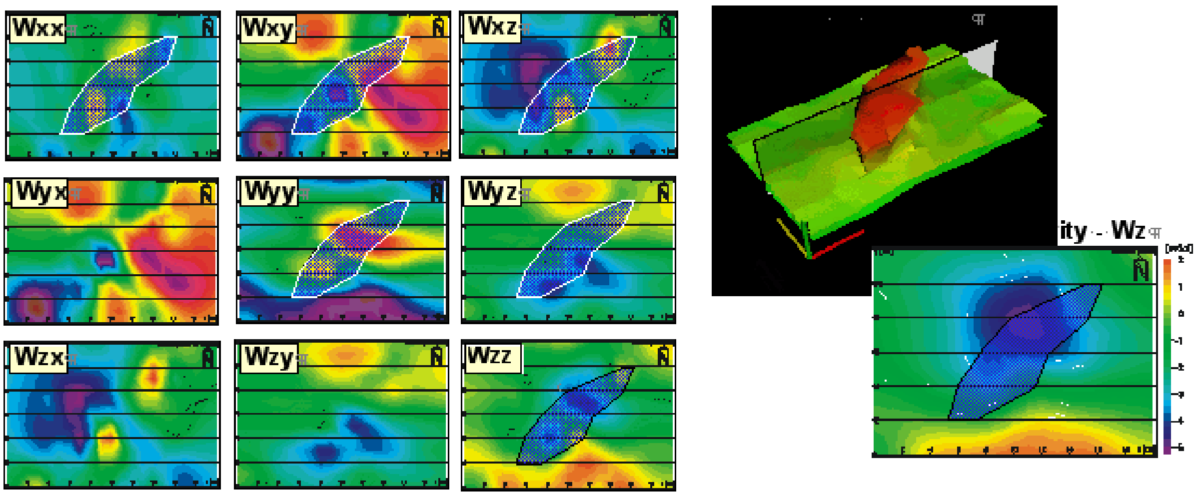

Figure 1. This IGMAS modeling of a typical salt dome in Northern Germany emphasizes the advantages of FTG interpretation: On the right hand side the conventional gravity (Wz) of the density model is shown, on the left the full gradient tensor, identifying much more structural details. The outline of the salt dome is highlighted.

Visualization and Integration of Constraining Data

Highly sophisticated interactive 3D modelling tools are essential for dealing with complex geological structures. The profit for geoscience is indisputable; Today, software tools allow visualisation of complicated geometries , and enable users to observe and to interact with the model (Figure 2).

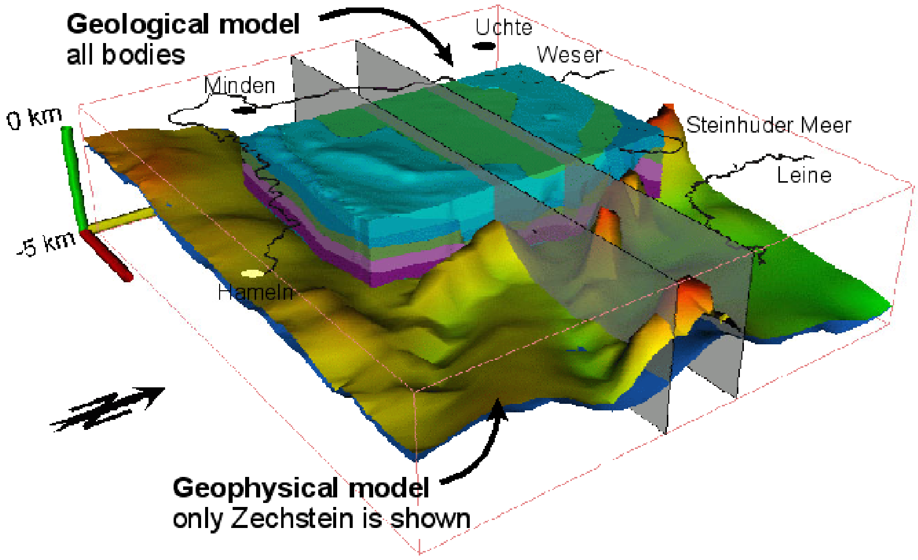

Figure 2. The southern part of Northwest-German basin. The high resolution geological model (central cube) was constructed by the Gocad modelling software and combines information from borehole data and geologic data from the surface. This model is embedded in a 3D geophysical model – here the Zechstein horizon and domed salt diapers are visualized – constructed by a combination of seismic and forward modelling of the gravity field. Geographical information overlain on the model provides orientation and location.

Modern interpretation tasks in a complex working environment, however, create higher demands on the software than just computer graphics:

- The flexible creation and qualitative or quantitative comparison of different kind of maps ease the work with different data types and levels of details
- Easy and intuitive interactive input and graphical modification of geometry, physical parameters as well as settings of the general project environment - usability is an essential feature of a software.
- Interoperability is achieved through a huge variety of interfaces and data exchange formats. Special emphasis is placed on an appropriate XML definition.

Conclusions

The approach of joint geological and geophysical 3D modelling leads to a better understanding of subsurface geology. Iterative exchange of intermediate results between working groups enriches the process of multidisciplinary investigation which as a result will lead to faster and more reliable solutions.

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