3D MODELING IN THE FENNOSCANDIAN SHIELD: PRELIMINARY RESULTS ON BURAKOVSKY LAYERED INTRUSION

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1) Introduction

This work has been carried out in the 3D Geological modeling module of the COCOP/NATO project entitled: ***Creation of a French-Russian Research Hub for the Search and Discovery of Super-Large Metallic Deposits .*** COCOP RUS/3B1/800 and NATO CLG 980145

The general objective of this module is to model the geology and the petrophysical properties of selected areas in the Fennoscandian shield. As referred to in the original project description, the work to be carried out and its objectives are:

(1) model the geometry of key geological structures and volumes using geological data (maps, sections, etc.), (2) perform inverse modeling methods based on available gravimetry, magnetic and seismic data for adjusting model geometry.

The Burakovsky block has been chosen as a first case study.

2) Results

2.1) Data extraction

The modeling process has been achieved on the following selected area:

Burakovsky block lat. 61 55' - 62 20' long. 35 40' - 36 10'
UTM (m) Xmin = 2330000 Xmax = 2400000
Ymin = 6950000 Xmax = 7020000
Zmin = -45000 Zmax = 1000

This zone is interpreted to be part of the Archean. On the geological map level (figure 1) 3 major entities can be distinguished which can be modeled as separate relevant entities at a crustal scale. These are:

1) an ultramafic intrusive body (layered intrusion: gabbro, gabbro-norite, anorthosite, dunite, anorthosite, peridotite, pyroxenite) around 2.5 to 2 Ga. (Sharkov et al., 1995, Higgins et al., 1996).
   This body has a strong metallogenic interest (copper, nickel, chromium)
2) Archean gneiss (tonalite, trondhjemite, granodiorite gneiss, quartzo feldspathic gneiss, enderbite, migmatite) around 3.2 to 2.5 Ga.
3) supracrustal rocks (tholeite, komatiite and Fe-rich basalts, gabbro, dacite rhyolite, conglomerate) around 3.32 to 2.75 Ga.

for modeling all data have to be in the same kilometric projection. Thus, the DEM (Digital Elevation Model), the gravity grid (Bouguer anomaly) and the magnetic grid have been extracted and reinterpolated on a 2.5 km square grid. On a first step, only the Bouguer gravity anomaly is considered (Figure 3a):

2.2) Direct geometric modeling

This task is achieved using the Geological Editor software developed in-house by BRGM.
Geological boundaries of the main geological units are digitized on the DEM. On the basis of Rubin sismic profile, mean depth of lower, middle and upper crust have been estimated and added to te model.
These data are interpolated given some orientation data (Lajaunie et al., 1997)
Then, given the chronology and spatial relationships between units (ultramafic unit is intrusive in supracrustal rocks and in Archean gneiss) it is possible to build a "solid model", i.e to fill the space with geological formations (fig. 2)

2.3) ***Gravity effect***

The gravity effect of this model can be computed by assigning proper densities to different units.
The densities are deduced from the lithologies and have been chosen as follows:

Geological unit	Density	Standard deviation
Mantle	3.30	0.05
Lower crust	3.15	0.05
Middle crust	2.95	0.05
Archean gneiss	2.75	0.05
Ultramafic	3.10	0.05

The reference density for anomaly is choosen equal to 2.95.
The computed effect from the model is illustrated on figure 3. In order to consider the preliminary geometric model as "acceptable". The computed anomaly must meet two criteria:
(1) the range of the computed anomaly must be comparable
(2) the two images must be somewhat "similar" in their variations.

As a first approximation the result (fig.3b) can be qualified as "acceptable" . The main anomaly is respected and seems to be correlated with the geometry of the ultramafic unit. In order to better distinguish if the strong (southwestern) positive anomaly is correlated to a deeper root of the body in this area or to denser rocks a better knowledge of the regional geology in this area and the associated rock density distribution is required.

The main differences in the two images concern the north eastern part where the anomaly is less negative than in the model. This can be due to underlying lithologies which have not been identified for this model or to large scale variations which cannot be taken into account here.

2.4) Inverse gravity modeling

Given the hypothesis on densities and distribution of geological units it is possible to use the preliminary model as a start for gravity inversion. The results will obviously depend on the pertinence of these hypothesis.

Gravity inversion works on a Voxel model of the geology. It deforms both the geometry and the density distribution within the geological units (Bosch et al. 2001) Density modifications are performed matching the given standard deviation and a

Gauss law, so that the observed anomaly is fitted at best. The output is expressed by images of the results of the inversion in any section.

The two main interesting images are those from the probable distribution of geological formations and the density distribution (fig. 4). One can see that the general trend of the anomaly can be explained by variations of the lower crust, middle crust, and mantle attitude, on both density distribution and geological model. The density distribution in the archean gneiss reveals some heterogeneities, this probably means that we should enhance the complexity of the initial model by introducing intermediate layers between upper crust and Archean gneiss with better constrains on densities.
The depth of the ultramafic body until about 7000m is well constrained in southern part if considering a relatively homogeneous density distribution. Thus a better knowledge of internal lihologies and densities should be required to constrain it real depth. It has to be redrawn in the north-eastern part where it probably further expands and flattens under the surface level. This could explain the positive trend in the anomaly in the northeastern area.

3) Conclusion

The objective of this preliminary study was to set up the methodology for the 3D geology/geophysical properties modeling. It is a demonstration of what can be achieved by combinining geological and geophysical data.
From the results of this study, it is concluded that given homogeneous density hypothesis, the high positive anomaly is compatible with a possible depth of the ultramafic layered intrusion about 7000 m. A more detailed study requires an accurate knowledge of internal density and lithologic variations and a higher resolution in gravity map.

An important "light" and thick upper crust is necessary to explain the bulk anomaly, which can be partially represented by the archean gneiss.
In a general way one must better identify and constrain the densities of the crustal layers in the block as well as the density distribution within ultramafic layers. The results of inversion must not be taken as "truth" but must be discussed in the light of the geological/geophysical knowledge of the area.

References

Sharkov, V.E., Bogatikov, T.L., Grokhovskaya, Chistyakov, A.V., Ganin, V.A., Grinevich N.G, Snyder, G.A., Taylor, L.A. 1995: Petrology and Ni-Cu-Cr-PGE Mineralization of the Largest mafic pluton in Europe: the early proterozoic Burakovsky layered intrusion, Karelia, Russia. *International Geology Review Vol. 37. 509-525.*

Higgins, S.J., Snyder, G.A., Mitchell, J.N., Taylor, N.A., Sharkov, E.V., Bokatikov, T.L., Grokhovskaya, Chistyakov A.V., Ganin, V.A., Grinevich., N.V. 1997: Petrology of the Early Proterozoic Burakovsky layered intrusion, southern Karelia, Russia: mineral and whole-rock major-element chemistry. *Can. J. Earth Sci. 34: 390-406.*

Bosch, M., Guillen, A., Ledru, P. 2001: Lithologic tomography: an application to geophysical data from the Cadomian belt of northern Brittany, France. *Tectonophysics, Vol. 331, Issues 1-2, 197-227.*

Lajaunie, Ch., Courrioux, G.,Manuel, L., 1997: Foliation fields and 3d cartography in geology: principles of a method based on potential interpolation. *Mathematical Geology, 29 (4), 571-584.*

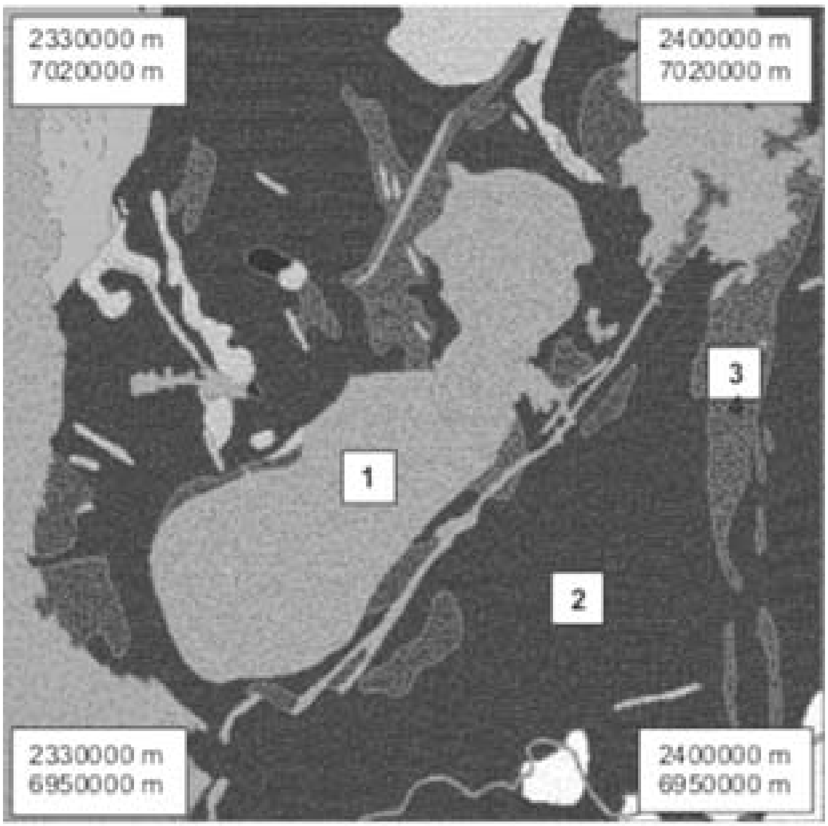

Figure 1. Gological map of the Burakovsky extracted from the 1/2000 000 Geological Map of the Fennoscandian Shield

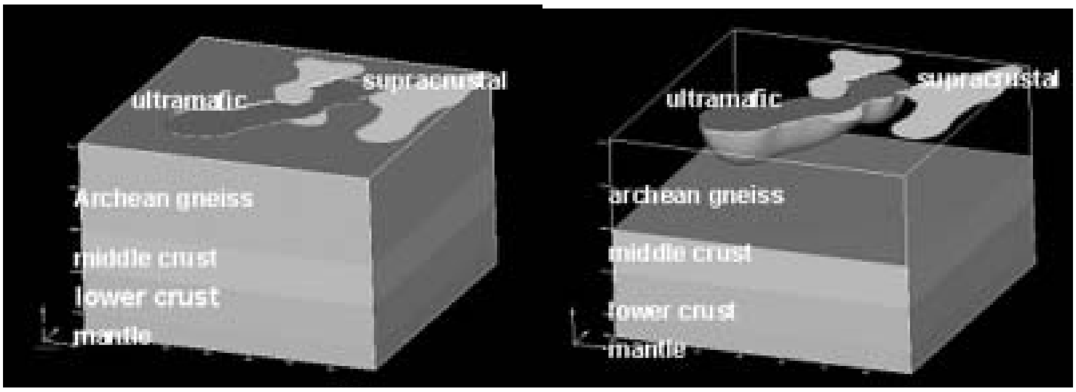

Figure 2. 3D "solid model" of geological units. Archean gneiss has been removed to make the ultramafic unit visible.

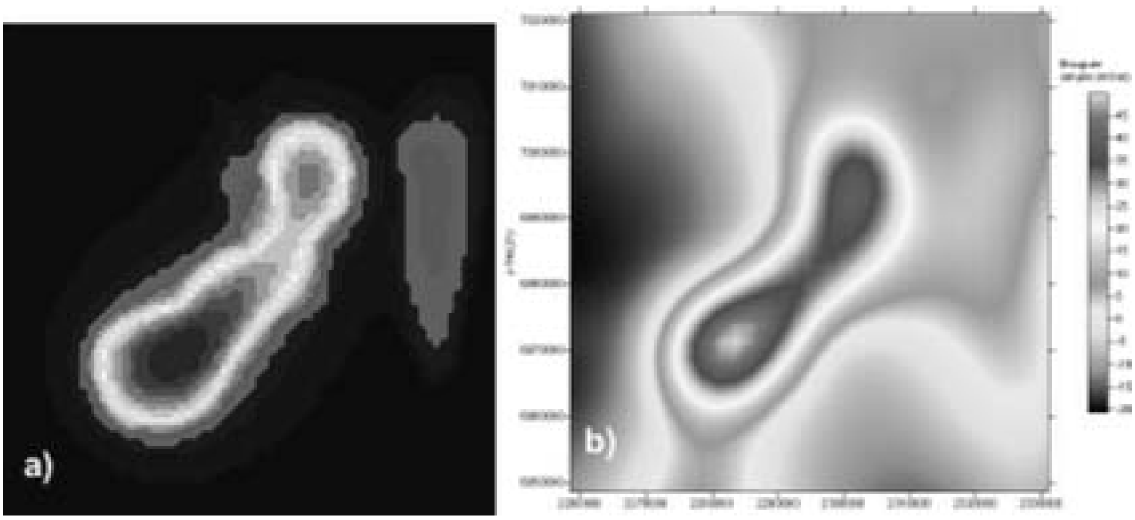

Figure 3. Comparison between the anomaly computed from the model (a) and the observed gravity anomaly (b): 7a: the computed anomaly ranges from -16 mgal (dark blue) to 48 mgal (dark red) ; 7b: the observed anomaly ranges from -20 mgal to 50 mgal.

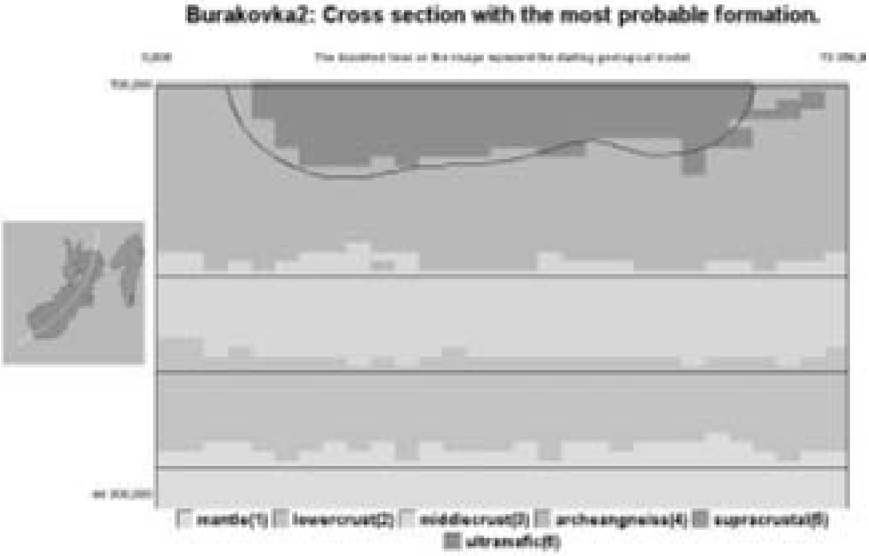

Figure 4 Results of gravity inversion on a profile along the ultramafic unit axis.