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THESES OF PHD DISSERTATION

GRAVITY AND MAGNETIC DATA PROCESSING AND MODELING FOR A BETTER-KNOWN GEOLOGICAL ENVIRONMENT

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1. Introduction

The geo-environment, including its deep structure is exceptionally important from point of view of sustainability of the life on the Earth, but this question is not in the centre of the everyday life. The Earth sciences already revealed many of secrets of the Earth and attained huge progress in the exploration of the subsurface. The humanity — unfortunately — does not use adequately all this knowledge. We erect buildings in inadequate places, and we destroy treasures, which can be exploited only once, in spite of fact that we should be able to predict the natural risks with considerable reliability. My work is aimed at a better knowledge about the composition, structure and processes of the Earth crust. Questions about raw material exploration and about natural risks (earthquake, volcanism) are discussed, and even the mutual the dependence of geo- and biospheres is emphasized.

The primary aim of my dissertation is the processing of magnetic and gravity data. I also deal with mapping data, but the main emphasis is put on data processing along regional profiles.

I compare these results with various other geophysical data (like seismic and magnetotelluric), and I interpret them collectively, in order to get a more accurate knowledge about the geo-environment.

2. The methods and the competed work

I selected such regional / country-size geophysical profiles, where seismic or magnetotelluric data were already available: for example the CEL-7 and CEL-8 lines measured in framework of the CELEBRATION project in Hungary.

CELEBRATION 2000 (Central European Lithospheric Experiment Based on RefrAcTION) was an international lithosphere research program. The aims of the program from Hungarian viewpoint were as follows:

- Studies about the formation of the Pannonian Basin, and also if its sub-basins;
- Construction of a three-dimensional model of the lithosphere in the whole studied area;
- Development and assessment of geodynamical models, describing the region's tectonic evolution.

Interpretation of deep and regional profiles, having first-arrival seismic tomography data (like CEL–7 and CEL–8 lines) is not a simple problem. Control borehole data are available only from the uppermost 5 km. Other geophysical measurements could provide useful additional data to the geological interpretation, but only magnetic and gravity data are available, which cover the whole area of Hungary. Along the CEL–7 seismic profile the ELGI and the HAS-GGRI carried out magnetotelluric measurements with the point density of the seismic measurements. By now, due to seismic and magnetotelluric measurements we have got a data base, which is appropriate not only for lithosphere studies.

The basement depth, the upper crustal structures, the places of magmatic intrusions and other information are important elements of the Earth's crust. All these elements can be determined in a much more reliable way from the joint interpretation of seismic, magnetotelluric, gravity and geomagnetic measurements, than from individual measurements.

The two-dimensional (x, z, where x is profile direction, z is the depth) measurements are generally unsatisfactory. The natural processes (the change of the physical parameters or of the geometry of the bodies) should be expressed, if possible, in three (x, y, z) or even more four (x, y, z, t) dimensions. All active processes are permanently changing — in long scale —

our geo-environment. For practical reasons I have dealt mainly with two-dimensional interpretation, all the time I took into consideration the three-dimensional environment. A joint interpretation of profiles and maps fits better to the nature's three-dimensional changes.
Due to ELGI Mapping Division, I have access to the geophysical data in the whole area of the selected regional profiles, including the potential field parameter maps and database of Transdanubia. ELGI CELEBRATION Working Group provided me the results of the seismic processing; the magnetotelluric soundings were carried out in frames of a joint (HAS-GGRI and ELGI) research project (Hungarian National research Fund, T37694 and TS40848).
From the mapping data the abrupt lateral changes in the physical parameters can be detected, providing a picture about the plan-view of formation boundaries and structural elements. From the profile measurements I could give estimation about the vertical extension and the inhomogeneities of the geological formations along the profile.
As magnetic and gravity data processing I used automatic processing techniques (Euler-, Werner-, Multiple Source Werner-, Naudy-deconvolution, Cordell-Henderson depth inversion and Spector-Grant depth estimation), which were used to detect boundaries, structural interpretations, both in maps and along profiles.
The solutions of automatic data processing were compared with the magnetotelluric and seismic data. I studied in details the similarities and the reason of the differences between the results of the applied methods, which were jointly visualized.
Besides studying geophysical data, I analyzed the spatial distributions, the changes and potential interactions among petrophysical parameters (like density, magnetic susceptibility, seismic velocity and electric resistivity):

- I examined the effect of extra high magnetic susceptibility to magnetotelluric measurements — because of the so-called Hopkinson peak, near the Curie temperature. I illustrated the effect of magnetic susceptibility to the magnetotelluric measurements by using one- and two-dimensional modeling;
- I examined the possibility of magnetic anomalies, which can be caused by telluric quasi-direct currents;
- I examined the "velocity anomalies" of the seismic velocity section obtained from seismic refraction measurements, taking into account that decreasing the pressure or increasing the temperature leads to the decreasing of velocity;
- I investigated the possibility of transformation one physical parameter into another one (for example I calculated a density distribution from the velocity distribution) and how this transformed parameter (pl. density) can be used in further processing and modeling.

Most of the proposed data processing methods with detect geological structures, representing a drastic change in the subsurface geology. However, it is worth comparing the obtained results with other environmental parameters, and examining the interactions among them. One of the examples is the occurrence of water-lily wetland habitats related to the gravity anomaly field. I could identify in that case hydrogeological (or hydraulical) phenomena via geophysics and botany (KISS and SZALMA 2007). The close relationship between the gravity field and the wetland habitats can be explained indirectly by laws of subsurface water flow regime.

3. New scientific results

My work led to the following new scientific results:

T1. Introduction of automatic processing methods (inversions) into the potential field interpretation

Introduction of automatic processing methods (Euler-, Werner-, Naudy- and Cordell-Henderson methods) into potential field interpretations, by using profile measurements (CEL–7 and CEL–8). The depth focusing of the automatic processing is carried out with size of the sampling window, with transformation of the components and with upward continuation of the anomalies. It made possible a sounding-like interpretation of the single-point data (interpretation of deep bodies and structures of geological section).

T2. Joint geological interpretation of gravity, magnetic, magnetotelluric and seismic measurements

Joint geological interpretation of seismic, magnetotelluric and potential field inversion results: basement depth determinations, structural interpretations and identification of volcanic roots along regional CEL profiles.

T3 Introduction of seismic velocity anomaly

Filtering out the velocity depth trend, I constructed a new velocity anomaly section from the available seismic velocity distribution. The obtained velocity anomaly shows a very good agreement with the solutions of automatic gravity inversions. The highest velocity jump is always observed between the basin and the basement formations, thus the basement surface usually appears in an explicit way. Where this velocity jump is not identifiable, the basement is fractured or transformed, indicating tectonic features or relating thermal anomalies and other secondary changes. The velocity anomaly indicates obtrusive velocity changes compared to the environment (velocity inhomogeneities), which are related in most cases to density discontinuities, detected by gravity.

T4. Detection of magnetic anomalies caused by telluric steady currents

Magnetic anomalies may be due to two kinds of component. One is coming from the natural magnetic susceptibility of rocks, the other one is the effect of telluric quasi steady currents.
This effect can be somewhat estimated from magnetotelluric specific resistivity profiles (Cull 1985, Geophysical Prospecting, 33, 460–467). An alternative solution is comparison the pseudogravity field due to magnetic sources with the real gravity anomaly field. If there is a pseudogravity maximum in a basin area, it may originate, depending on depth, from telluric steady current, or from deep magnetic source body. If spectral depth estimation results in a shallow depth (a depth value within the basin), then the effect is probably due to telluric currents. If the magnetic anomaly originates from the below the basement surface, the telluric effect can be excluded, and the source of the anomaly is probably metamorphic or some kind old magmatic formations. Correlating the pseudogravity and gravity anomalies, I localized all potential places along the CEL-7 profile, i.e. where gravity has minimum (so it is a basin), but the pseudogravity has maximum.

T5. Consequences of magnetic phase transition just below the Curie temperature

Based on a recent solid-state physics experiments (RÜDT et al. 2002, Phys. Status Solidi A, 189), I assumed that the magnetic susceptibility of ferromagnetic materials can be increased one or two orders of magnitude in the Earth's crust.

The magnetic susceptibility of the ferromagnetic material may be enhanced significantly at the state of magnetic phase transition (HOPKINSON effect), just below the Curie temperature, which may be the source of geomagnetic anomalies of crustal origin. My hypothesis, that Hungary's long geomagnetic wavelength, and small amplitude magnetic anomalies, lying along geological structures are caused by small-sized, but very strongly magnetized causative bodies at the Curie depth.

T6. Consequences of magnetic phase transition in magnetotellurics

The high magnetic susceptibility/permeability, if it is created by the magnetic phase transition — which is neglected routinely by magnetotellurics — has to be taken into consideration at the interpretation of MT profiles.

I demonstrated this effect by using the basic homogeneous half-space formulae, and by carrying out one-dimensional calculations.

4. Utilization of the results

The gravity and the magnetic methods are the oldest and cheapest geophysical techniques. I started to use in Hungary the profile-oriented automatic processing and interpretation methods — on basis of ELGI's national digital database — to solve geological problems. I presented how the existing gravity and magnetic digital databases, equipped with new automatic processing techniques, can be directly used in geological interpretation. It is shown in my publications: papers, methodological and research reports, and other results in potential field data processing and interpretation, achieved together with my colleagues in frames of various projects of ELGI.

In 2003, in connection with the exploration program „The definitive placement of little and medium radioactivity wastes of atomic plant" (FANCSIK et al. 2003), I compared the processing results of potential field data with results of magnetotelluric soundings and seismic measurements along some profiles. The result was surprising: the gravity processing results corrected the structural interpretation results of deep geophysical exploration methods, like magnetotellurics and facilitated the identification of different seismic levels.

The modern application of gravity and magnetic methods offer a new opportunity in deep geological studies. I have refined and improved the data processing methodology, and I applied it in a complex geophysical interpretation along lithosphere-investigating CELEBRATION (CEL-7 and CEL-8) lines.

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