CONCLUSIONS

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Developments during the last decade show that large discoveries from exploration and production of conventional nonrenewable energy sources are becoming more elusive and expensive. This should encourage the increased utilization of nonseismic methods (mainly the potential field methods—gravimetry, magnetometry, and electromagnetic methods) aiming at reducing average exploration costs. The search for higher effectiveness is valid not only for energy and mineral resources exploration, but also in the broader study of the Earth's crust and lithosphere structure. From this perspective, there exist several important challenges in the area of potential fields: acquisition, processing, and interpretation—some of them are well analyzed in Li and Krahenbuhl (2015). In general, we state that when performing accurate gravity field interpretation and modeling, we must introduce reliable corrections to the acquired data in order to exclude all nongeological signals.

The chapters presented in this book are intended to contribute to the scientific developments connected with terrestrial gravity data processing, mainly with the discussion of the Bouguer gravity anomaly definition. Although the evaluation of Bouguer anomaly values is one of the most important (and standard) steps in anomalous gravity field representation within applied geophysics, there still exist open questions and conflicting aspects. Of course, the presented themes do not cover all the actual problems, connected with precise and correct Bouguer anomaly evaluation (many of those themes are well described in several textbooks, published during the last years, e.g., LaFehr and Nabighian, 2012; Hinze et al., 2013; Fairhead, 2016). Instead, our work in these chapters focuses on several specific aspects, as deemed important by the editors of this volume.

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The most important outputs of this publication are as follows:

- At global scales, the Bouguer gravity anomaly evaluation should be based on ellipsoidal heights. Only an approach with this vertical datum yields the correct evaluation of the gravitational effect of all masses below the topography surface that differ from the density of the reference Earth (Chapter 2, The Physical Meaning of Bouguer Anomalies—General Aspects Revisited). This was pointed out also by the authors of one of the important papers for the Society of Exploration Geophysicists (SEG) community (Hinze et al., 2005). Comment: For some regional and the majority of local surveys, a sea level datum, which is often used conventionally, can be still used as the vertical datum, without undue errors.
- At local and regional scales, the Bouguer gravity anomaly can be regarded to be harmonic in planar approximation everywhere above and on the topo-surface (Chapter 2, The Physical Meaning of Bouguer Anomalies—General Aspects Revisited). The scalar representation of the anomalous gravitational acceleration in Bouguer anomalies is justified for local and regional studies, but it can be associated with considerable errors at larger scales.
- The truncation of topographical masses during gravity terrain corrections (to the standard distance of 166.7 km) is justified only for local- to regional-scale investigations. However, the distant relief effect is important at large scales and even sometimes at regional scales at specific locations (Chapter 2, The Physical Meaning of Bouguer Anomalies—General Aspects Revisited), which was shown also by Mikuška et al. (2006). To some extent, topographical and ocean masses are compensated by crustal thickening and thinning, respectively. Hence, isostatic far-field effects may have to be considered as well (Chapter 2, The Physical Meaning of Bouguer Anomalies—General Aspects Revisited) as they reduce the distant relief effect effectively as shown by Szwillus et al. (2016).
- From the analysis of historical sources, it follows that Pierre Bouguer himself in fact did not introduce the “Bouguer slab” or “Bouguer plate” correction as it could be generally interpreted (Chapter 3, Some Remarks on the Early History of the Bouguer Anomaly). Similar conclusion holds also for the so-called “free-air” or “Faye” correction—it was not suggested in any of the fundamental works of Faye. The term “Bouguer reduction” is likely correctly attributed to Helmert (1884) who used it for describing his relocation of the measured gravity values to sea level datum—a step which

Bouguer, in fact, neither did nor proposed. However, the authors of Chapter 3, Some Remarks on the Early History of the Bouguer Anomaly, concluded that Pierre Bouguer had indeed laid the foundations of the present-day Bouguer anomaly evaluation.

- In this publication, one important methodical approach is presented (Chapter 4, Normal Earth Gravity Field Versus Gravity Effect of Layered Ellipsoidal Model), namely calculating the normal (theoretical) gravity entering into the Bouguer anomaly evaluation: not as the standard solution of the Laplace equation (e.g., Helmert's or Somigliana's formulae), but calculating it as the gravity effect of a layered ellipsoidal model. Despite the fact that some important unanswered questions remain, this approach could be an alternative way to understand and work with the normal gravity field in the future. The main goal of the authors in Chapter 4, Normal Earth Gravity Field Versus Gravity Effect of Layered Ellipsoidal Model, however, was to initiate a broader discussion, rather than to give any definitive solution.
- In the calculation of the topographic effects (or the terrain corrections) as a part of Bouguer anomaly evaluation, there exist a large number of approaches, using different approximations and divisions of the calculation point vicinity into zones (where the nearest relief plays the most important role). In the approach in Chapter 5, Numerical Calculation of Terrain Correction Within the Bouguer Anomaly Evaluation, four circular zones with outer radii of 250, 5240, 28,800, and 166,730 m, respectively, are used within a newly developed software Toposk. The involvement of a 3D polyhedral body in the nearest calculation zone is the best state-of-the-art approximation. Such a concept of polyhedral bodies or a sum of triangular prisms approximation is supported also by other authors (e.g., Tsoulis, 2003; Cella, 2015). Another important aspect of the presented approach is the concept of interpolated heights of calculation points (instead of measured ones) within the nearest zone.
- Another aspect in the evaluation algorithms for topographic effects is their computational speed. This is linked with modern highly detailed and large-scale digital elevation models (e.g., those originated from laser scanning procedures and LiDAR technologies)—using them can make the terrain correction process time-consuming, although of much higher accuracy. This drawback can be overcome by means of a dynamic refinement of the elevation grids during calculation according to the geostatistical properties of topography in the studied area (Chapter 6, Efficient Mass Correction Using an Adaptive Method).

- As a case study of Bouguer anomalies in the evaluation for larger datasets, a practical example from the Slovak Republic is given in Chapter 7, National Gravimetric Database of the Slovak Republic. The former regional gravimetric database (212,478 points) was supplemented with detailed gravity data (107,437 points), and today, it represents one of the most densely covered Bouguer anomalies map of an individual country in the world. In this chapter, several practical aspects are discussed and one newly detected regional linear structure was verified by detailed in-situ measurements. In addition to this, a new software CBA2G_SK is developed, where a reverse calculation method is realized—from the Bouguer anomaly values the value of gravity acceleration in a calculation point is reconstructed. Such estimated values can play a role in various geophysical and geodetic applications, as discussed in Chapter 7, National Gravimetric Database of the Slovak Republic.

Naturally, in addition to the above-mentioned outcomes, the reader can find other interesting comments and ideas within the seven chapters of our monograph. On the other hand, there are still many open problems and questions, which have not been fully covered by the chapters in this monograph and remain for future discussions:

- Why is the standard radius for topographic effect (or gravity terrain corrections) evaluation equal to approx. 166.7 km (opening half-angle of $1^\circ 29' 58''$)? We know empirically that this distance is very well selected, but do we really know the physical reasons for it?
- Should the standard formulae for the normal (theoretical) gravity (e.g., Helmert's or Somigliana's formulae) be used, or should we develop a concept of normal gravity using the gravity effect of a well-defined reference layered ellipsoidal model? The discussion was initiated in our monograph in Chapter 4, Normal Earth Gravity Field Versus Gravity Effect of Layered Ellipsoidal Model.
- Regarding the topographical effect evaluation: how we can best account for discrepancies between the measured heights of the calculation points and those coming from their projections on the used digital elevation model? Some solutions were offered in Chapter 5, Numerical Calculation of Terrain Correction Within the Bouguer Anomaly Evaluation (i.e., the use of interpolated instead of measured heights for within the nearest zone), but this question remains open.
- Should we use the ellipsoidal approximation for outer and distant zones during the topographical effect evaluation? Or is it enough to

stay with the actual spherical approximation (with desired accuracy for different kinds of surveys)?
- Which of the distant effects (ignored in the standard Bouguer anomaly evaluation) play an important role in the interpretation of large scale (or global) geology? Distant relief effects (Mikuška et al., 2006) are relatively well known and also analyzed by different authors (e.g., also here in Chapter 2, The Physical Meaning of Bouguer Anomalies—General Aspects Revisited), but there still remain other distant effects, which should be analyzed in more detail in the future (e.g., Szwillus et al., 2016).
- Do we fully and properly understand the role of the Bouguer reduction (correction) density in Bouguer anomaly evaluation? Is the commonly used value of 2670 kg/m^3 really some average density of upper crust? Hinze (2003) gives us some thoughts about the historical reasons for this choice, but the topic is deeper and much more interesting....

As we have mentioned in the Introduction, the compilation of this small monograph was strongly motivated by the meeting of several experts at the workshop: "Bouguer anomaly—what kind of puzzle it is?" held in Bratislava in 2014. Perhaps, the time has come for a follow-up meeting, where these unanswered topics and new problems could be discussed and pursued. It may be useful for this next meeting to be covered by one of the professional associations such as European Association of Geoscientists and Engineers or Society of Exploration Geophysicists.

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