Title:

Detecting Caves Using Microgravimetry: A Study on the Prohodna Cave

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Level of study or work: Master thesis

Information about you (and your team):
I am 23years old and I have recently completed my academic journey, successfully defending my master's thesis on the 7th of July. My professional focus lies in applied geodesy, but my interest extends to various disciplines within geodesy, such as gravimetry, physical geodesy, ellipsoid geodesy, and astronomical geodesy. It was this wide-ranging interest that led me to choose gravimetry as the subject of my master's thesis. Throughout my research, I received invaluable support and guidance from my thesis supervisor, PhD Eng. Severina Dzhorova-Marinova, from the Faculty of Geodesy at UACEG (University of Architecture, Civil Engineering and Geodesy).

Area of interest

The main focus of this study is to investigate the application and effectiveness of microgravimetry in cave detection. Caves and underground cavities have always posed challenges for geologists, geomorphologists, and speleologists due to their hidden and sometimes difficult-to-reach nature. These geological formations provide crucial insights into various environmental and geological phenomena, highlighting the importance of their localization and examination.

Geophysical methods, especially microgravimetry, have gained significant prominence as powerful tools for identifying density variations and gravitational anomalies associated with cave voids. Microgravimetry's relevance also extends to infrastructure-related applications. Its capability to detect subsurface voids and density variations can profoundly impact infrastructure development, ensuring safe construction and effective monitoring. The technique plays a crucial role in identifying potential hazards and ground instability, facilitating informed decisions and appropriate mitigation measures.

Moreover, the application of microgravimetry goes beyond cave detection, proving valuable in detecting other subsurface features such as salt deposits, gold reserves, and various density anomalies within the Earth's crust.

Approach to the problem

The principle of microgravimetry is quite simple. It relies on determining underground density changes through local gravity variations. Voids, whether filled with air or water, have lower density (0 or 1 g/cm^3) than the surrounding rocks (2.7 g/cm^3), which is crucial for the analysis. These density contrasts are detectable on gravity maps like Bouguer anomaly maps, making microgravimetry a powerful tool for cave localization.

For this study, the Prohodna cave in Bulgaria, known for being the country's longest cave tunnel at 262 meters, was chosen as the test site due to its remarkable geological features, such as the captivating "Eyes of God" phenomenon.

To conduct the survey, a total of 42 gravity stations were planned (Fig.1), positioned at an average distance of 20 meters from each other. The stakeout of these points was carried out using a high-precision GNSS receiver, the Hi-Target v100, with the RTK method and CORS (Continuously Operating Reference Stations). Simultaneously, gravimetric measurements were executed using the LaCoste & Romberg Model G gravimeter, known for its accuracy of 0.04 mGal. The measurements were referenced to a gravimetric base point, where readings were taken at the beginning and end of the on-site survey.

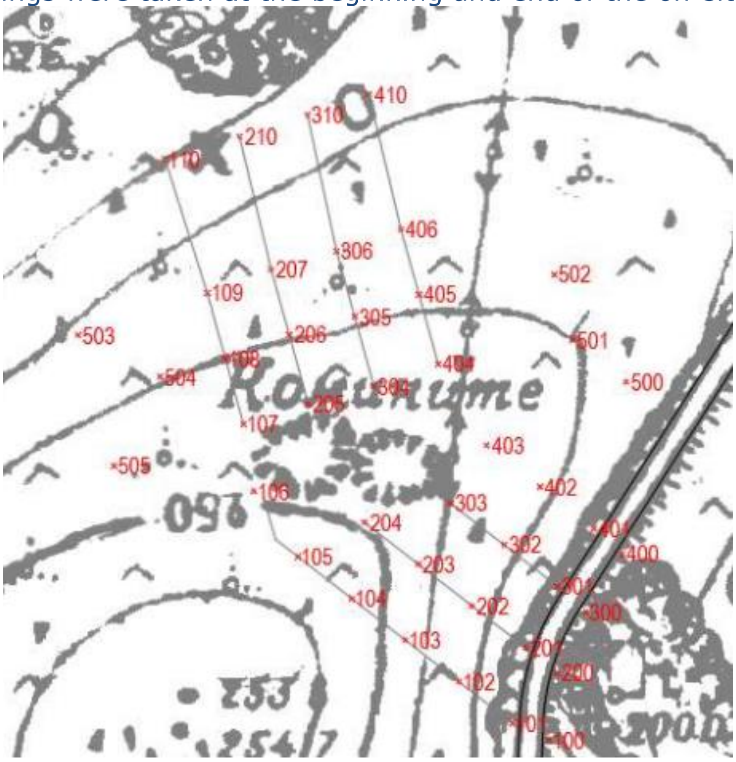

Fig.1 Planned gravity stations

During the data processing steps, several corrections were applied to the measurements. Firstly, the raw readings were converted to milligals (mGal). Subsequently, tidal corrections were calculated to account for the influence of the moon and the sun on gravity measurements. The instrument height correction was determined using the vertical gradient and the instrument's height above the gravity points. Additionally, atmospheric correction was applied to address variations in atmospheric pressure that can affect gravity readings. Lastly, instrumental drift correction compensated for any calibration drift during the survey. These corrections collectively contribute to the reliability and validity of the microgravimetry data.

Results, conclusions and next steps

After all the corrections mentioned earlier were applied, the adjusted readings were used to calculate gravity differences, and gravity values at each gravity station were computed using the gravity value of the gravimetric base. These values revealed anomalies and density variations in the subsurface, providing valuable insights into cave structures and other geological phenomena.

The Free-air gravity anomaly, Bouguer anomaly, and residual anomaly were calculated, and corresponding models were created using Surfer 13 software (Fig.2 to Fig.4). The Free-air gravity anomaly represents the difference between observed and theoretical gravity values, considering only the Earth's shape and rotation. However, it doesn't account for subsurface density variations and wasn't the main map for further analyses. Instead, the focus was on the Bouguer anomaly, which considers elevation differences and subsurface density variations, offering a more accurate representation of subsurface anomalies.

Additionally, residual anomalies were computed, useful for identifying localized subsurface features like ore bodies and geological structures.

Our analysis yielded compelling results, demonstrating the effectiveness of microgravimetry in detecting underground cavities or voids. Graphical visualization of the anomaly field revealed a distinct zone with reduced anomaly values in the surveyed area's central part, suggesting a significant underground feature. The unique negative extremums on the surfaces of Bouguer anomalies and gravity force anomalies provided strong evidence, directly linking these anomalies to the entrance and galleries of the "Prohodna" cave.

Overall, this study successfully showcased the power of microgravimetry as a tool for cave detection and exploration, offering valuable applications in various subsurface features and geological phenomena.

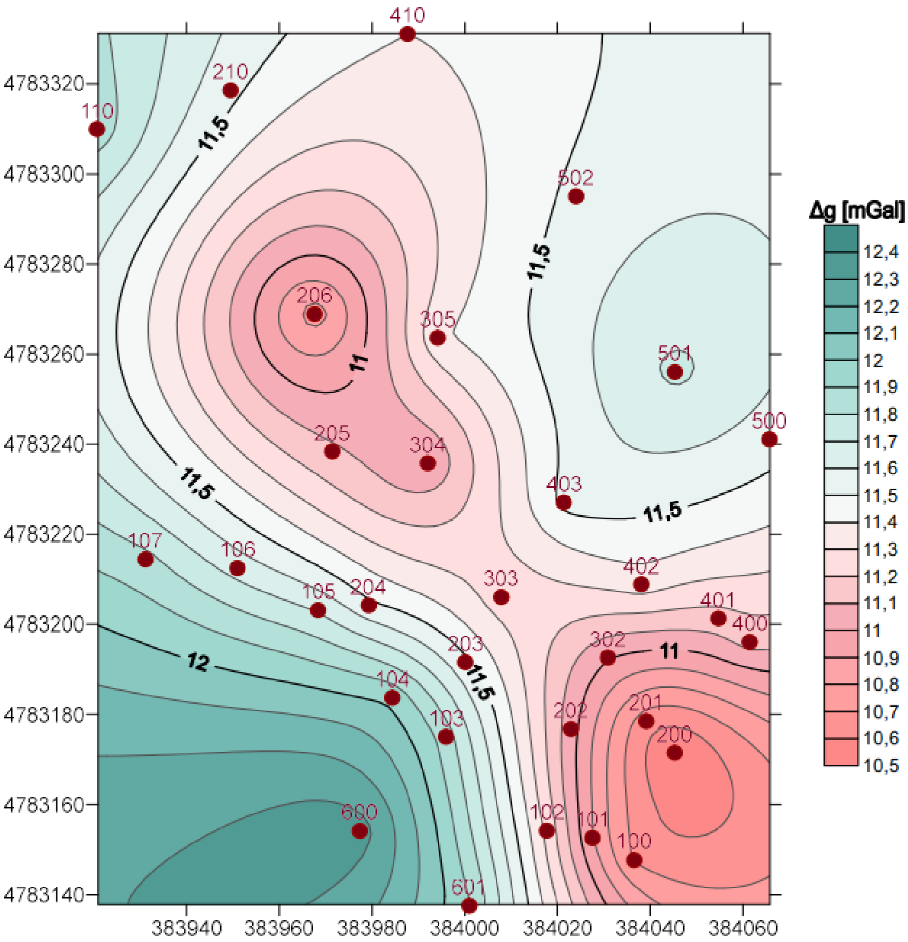

Fig.2 2D visualization of free-air gravity anomaly

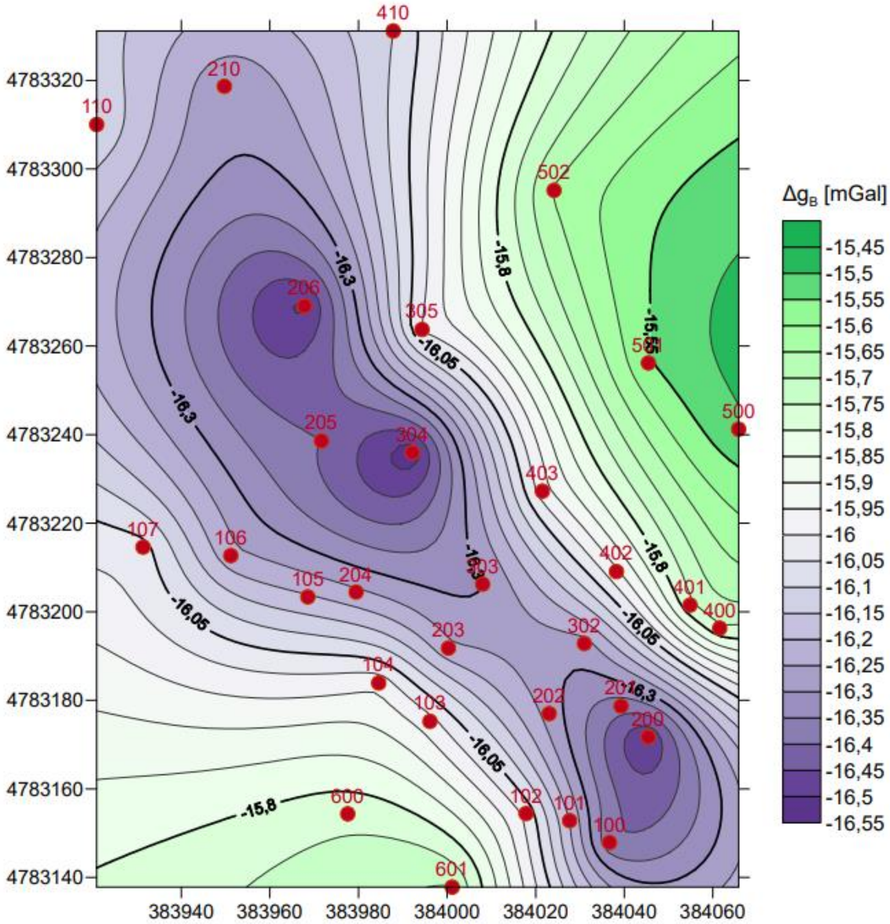

Fig.3 2D visualization of Bouger anomaly

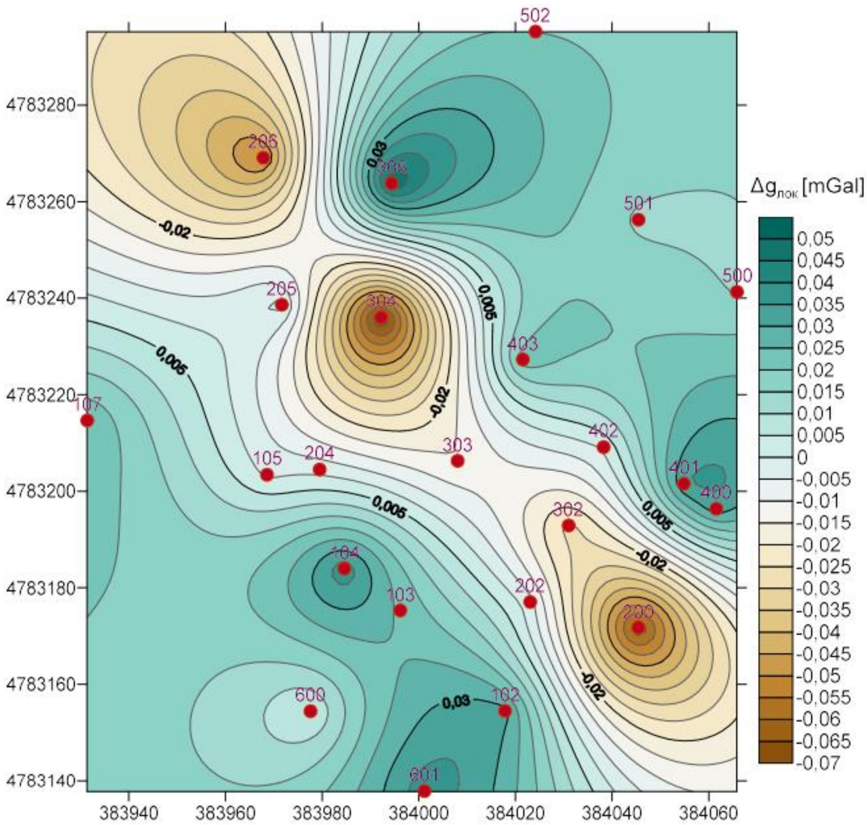

Fig.4 2D visualization of residual anomaly

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