MICROGRAVIMETRY

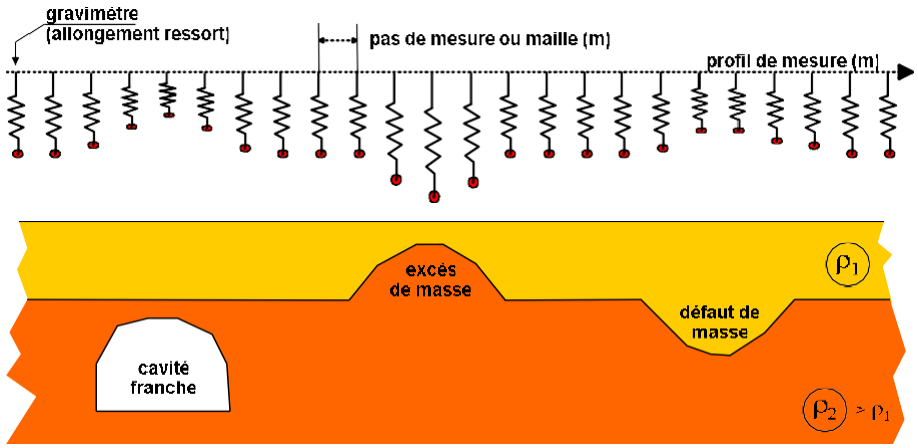
AGAP

Method principle

- The microgravimetric method consists in studying the variations of the local gravitational field by a measurement, on the surface of the ground, in several points of a given area, in order to establish the density distribution of the subsoil (excess and lack of mass).

- The measurement of variation of the local gravity field at the ground surface is carried out using a precision gravimeter, the principle of which is to balance a standard weight by lengthening a spring. Spring elongation is proportional to the variation of the gravity field on the local vertical axis (vertical component of gravity acceleration).

- It is distinguished from gravimetry by the scale of measurements performed. The unit commonly used in microgravimetry is µgal (10^{-6} gal, 10^{-8}m/s2).



Principle diagram of the method

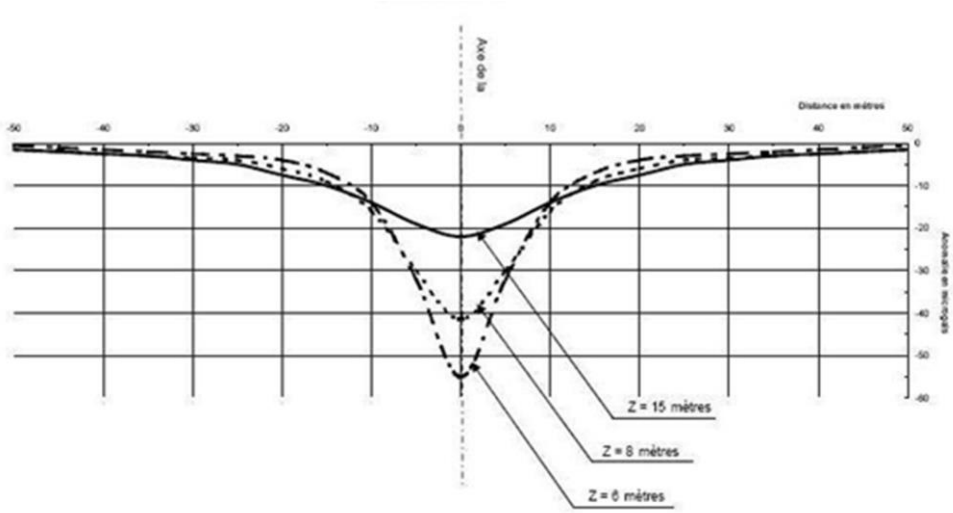
Applications

The method is particularly suitable for the geotechnical diagnosis of the risk of underground cavities, but other fields of application than those of geotechnical engineering can be discussed (hydrogeology, mining, archaeology, etc.).

- Types of problems addressed :
  - Search for anthropogenic and natural cavities.
  - Highlighting specific geological contexts (faults, veins, decompressed zones).
  - Search for buried archaeological structures.

- Common fields of application :
  - Civil engineering.
  - Geotechnics.
  - Archeology.
  - Mines.
  - Hydrogeology.

- Depth of investigation:
  It depends on the volume of the target and the density contrast between target and surrounding.
  It is generally considered that the portion concerned by the method is the portion 0 / 50m.



Gravimetric anomaly due to 2m radius gallery at depth Z
(Cahier de l'Agap microgravimétie)

Traduction : PB / Vérification : CC-JLM / Approbation : MH

Limitations / Constraints / Prohibitions

- It is necessary that there is a sufficient density contrast between what is being sought and its environment. In the case of a cavity search, it is important to know if the cavity sought is flooded or dry. In the case of a geological study, it should be ensured that the density contrast between the different horizons present is sufficient.

- Since the measurement is particularly difficult to achieve, it is imperative to carry out these measurements in a calm environment, without disturbances of the type: co-activity in works phase, meteorological disturbances, proximity to industrial installations. Seismic activity, even distant, may prevent to achieve measurements.

- The surface on which the method is to be applied must not present a too substantial topography (mass correction of the same amplitude as the one from the desired anomaly). The presence of buildings on or near the study area will require special treatment (mass defect corrections).

Modelling may be carried out by the service provider, at the definition stage of the technical program, to justify the use of the method, its detection capacity and its program (number of stations, survey mesh).

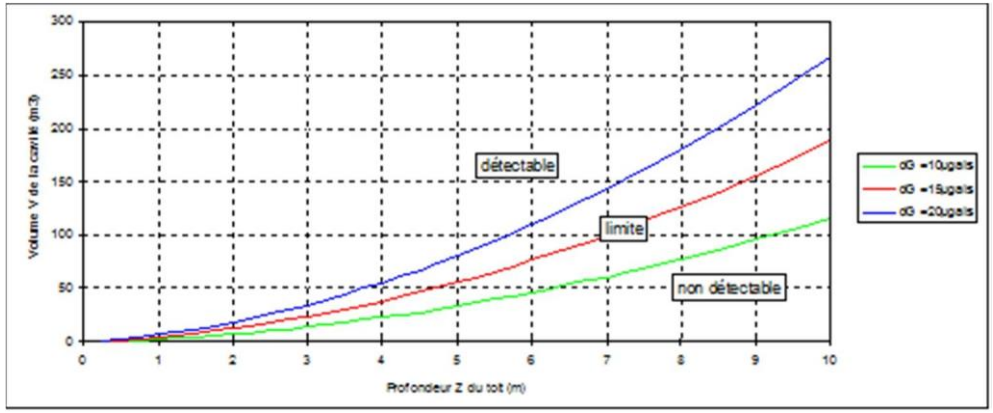


Diagram "detectability of a cavity",
function of vacuum volume, depth and significant threshold

Means necessary for acquisition

- Equipment :
  - The method requires the use of a precision gravimeter. At present, three devices are recognized as having sufficient precision: the LACOSTE & ROMBERG gravimeter, model D, called «microgal», and the SCINTREX gravimeters, models CG5 and CG6. These devices must be checked periodically (maintenance, calibration. See manufacturers specifications).
  - Precise leveling of each of the measuring station is imperative, using a precision leveling tool (level, theodolite). These devices must be checked periodically (maintenance, calibration. See specifications for topographers and surveyors.)

- Personnel and skills:
  - An operator qualified in microgravimetric measurement and precision levelling, for implementation. In general, the operator is accompanied by an aid for implantation and levelling.
  - A qualified geophysicist for processing and interpretation.
  - A qualified senior geophysicist for quality control.

Gravimeter Lacoste & Romberg (left) and gravimeters Scintrex CG5 and CG6 (right)

Implementation

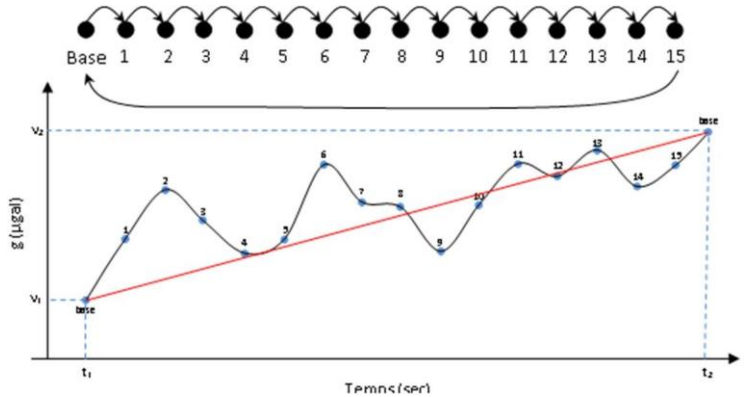
- Establishment of the measurement program:
  - Prospecting mesh sizing by an experienced geophysicist based on the depth and size of the objective and the geological context (development of a detectable target model according to the proposed program).
  - Definition of acquisition parameters related to site constraints (measuring time, return to base, etc.), by an experienced geophysicist.

- Preparatory work:
  - The positioning must be particularly careful, the position of the measuring stations must be identified in X, Y, Z. A reference station must be defined for the study (base), or even several in the case of an extended study area (the bases must then be linked).
  - On soft and unstable ground, topsoil stripping for the stability of the device should be performed at each measuring station.
  - The levelling of the measuring stations must be carried out with an error less than one centimeter at the measurement location. The height of the tripod, or saucer, must be taken into account.

- Quality Control:
  - The measurements are made according to cycles not to exceed 1h00 between two returns to the base. The instrumental drift will have to be checked at each return to the base.
  - At least 20% of the measurements must be taken for quality control. These measurements are carried out randomly. Quality control is based on a statistical analysis of recoveries (standard deviation).

- Production: Depends on the difficulty of moving on the ground and the environment. On average, from 60 to 80 stations/day (excluding site preparation and repeated measurements).

Operators performing measurement (FONDASOL, CEBTP)

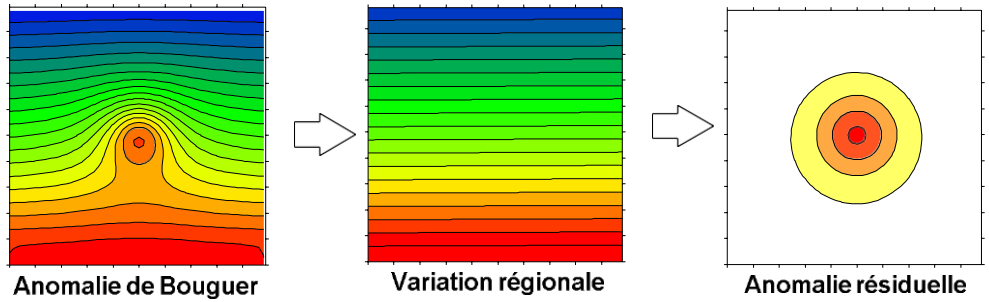


Principle of progression during measurements

Data processing and interpretation

1. Corrections (latitude, luni-solar, topographical, instrumental drift, etc.).
2. Definition of a significant threshold (root mean square error less than half the magnitude of the expected anomaly).
3. Bouguer anomaly mapping.
4. Definition of the regional variation and calculation of the residual anomaly.
5. Vertical gradient mapping, if justified.
6. Individualization of density anomalies and their amplitude in µgals.
7. Possible modelling of the dimensions and depth of the detected anomaly.

Production :
1 processing day for 1 to 2 acquisition days, excluding report writing and mapping.



Principle of establishing the residual anomaly (Residual = Bouguer - Regional)

Results and Deliverables

- Results are typically presented as maps or profiles, Bouguer Anomaly, regional variation, and residual anomaly with specific quantitative interpretation, upon request.

Study report

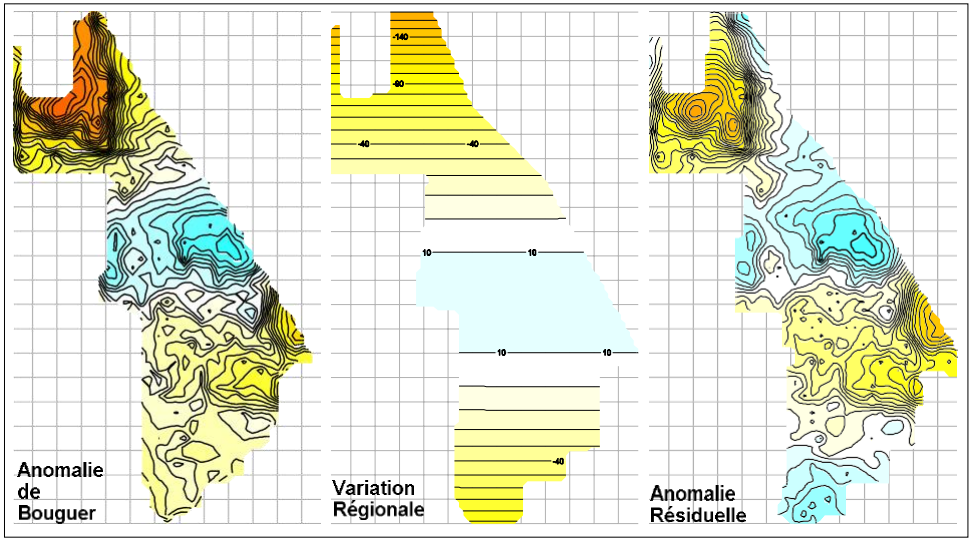
- The study report has several sections. An AGAP document specifying the layout of a standard report can be found on the website (www.agapqualite.org).

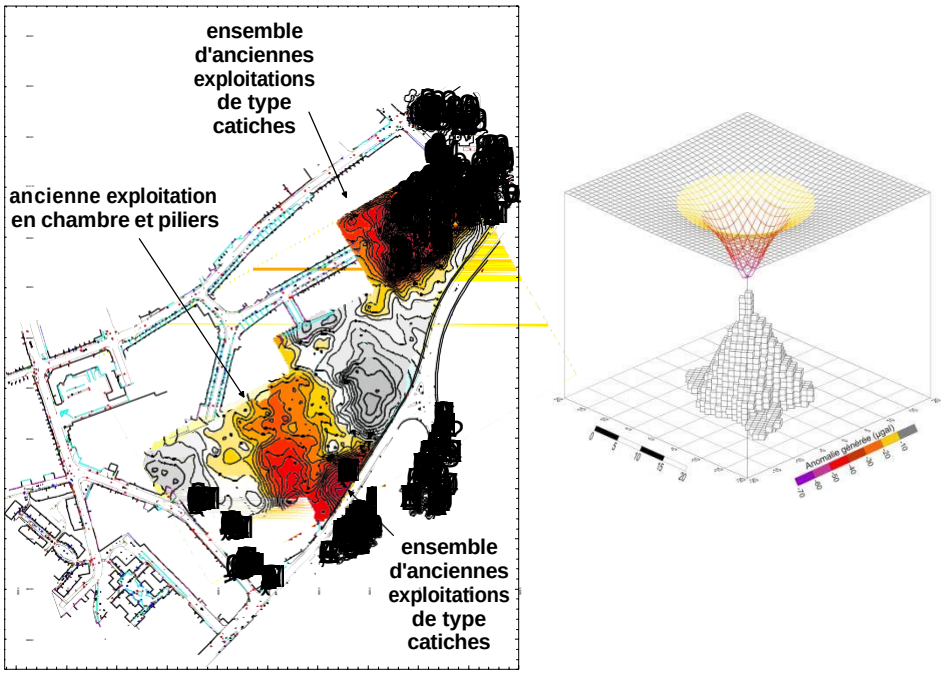
  The General Section reports on the means implemented and the environment, the location, the geological context, the objective, the operating method, the equipment, the interpretation methodology, etc. A chapter must be devoted to the statistical analysis of the revisions carried out and to the determination of the significance threshold (considered as twice the average standard deviation of the revisions).

  - *Specific maps*: location and nomenclature map of the microgravimetric stations, station leveling map, Bouguer Anomaly maps, regional variation map, residual anomaly map showing the proposed geotechnical control surveys. Gravity anomaly maps should take into account the significance threshold (amplitude).

  - *Summary map*: Depending on the objectives of the study, the customer's expectations and the terms of the contract, an interpretation (including an integration of the results with other geophysical methods and/or geotechnical data available) may be carried out. Additional studies may be recommended.

- The report consists of a text volume and a map volume, on paper and/or in digital format. Field data may be provided as a spreadsheet-type data file. Particular attention must be paid to the positioning of the measuring stations, the reference system used and the positioning of the control or calibration surveys proposed in conclusion.





The different steps in a study on cavity search
(data processing, synthesis map, cavity modelling)

Contribution to geotechnical study

- Essential for G5 geotechnical diagnosis missions on anthropogenic cavity problems at shallow depths.

Some densities (related to the nature and degree of alteration of the material)

Air: 0.0
Water: 1.0
Topsoil: 1.3 à 2.2
Silt/loess: 1.6 à 2.0

Clays: 1.6 à 2.4
Chalk: 1.6 à 2.4
Marl: 1.7 à 2.6
Limestone: 2.0 à 2.8
Sandstone: 1.8 à 2.6

Shale: 2.2 à 2.6
Granite: 2.5 à 2.8
Quartzite: 2.5 à 2.7
Massive basalt: 2.7 à 3.3
Concrete: 2.4

Contractor/service provider dialogue

- At the client's responsibility
  - Detailed specifications with clear objective (target, size, depth, origin).
  - Plans and documents relating to the area to be explored.
  - Informations about site access and security, and administrative permissions.
  - Documents relating to any previous investigations (geophysical and/or geotechnical).
- At the responsibility of the service provider
  - Explicit proposal justification of the proposed method, adaptation to the objective, description of benefits and limitations, modelling of the anomaly generated by target, accuracy of measurements and realistic final results.
  - Professional quality study report: review of objectives, applied methodologies, discussion of results, conclusions and practical recommendations in response to the client's request.

For further information

- **1988**, J. Lakshmanan, « traitement et inversion des données gravimétriques : la microgravimétrie, son application aux recherches de vides ». Thèse I.N.P.L.
- **1988**, Lakshmanan, « Application of microgravity to the assessment of existing structures and structural foundations ». Rapport USARDSG-UK.
- **1995**, H.O. Seigel, « a Guide To High Precision Land Gravimeter Surveys ». Document SCINTREX Limited.
- **2015**, J.P.Barron et A.Bouvier, « Microgravimétrie et prospection microgravimétrique : manuel pour la conception et la mise en œuvre". Cahier n°3 de l'AGAP Qualité.

Links

- www.lacoste&romberg.com,
- www.scintrex.com
- www.georeva.eu