Airborne Full Tensor Gravity Gradiometry Vs Ground Gravity Data in the search for mineral deposits

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Outline

• History of gravity surveys
• Equivalence principle
• Gravity gradiometers in operation
• A comparison of data – ground and airborne
• Conclude
Airborne Gravity & Gradiometry

“A gravitational timeline…..”

Baron Loran von Eotvos

Torsion Balance Gradiometer
Gravity gradiometry in resource exploration begins with the invention of the Eotvos torsion balance in 1896.

This invention’s application to resource exploration was soon realized and by 1929, 170 torsion balances were used in North America.

Primary application – map salt domes for oil exploration.
• Superseded by the faster gravimeter in the 1930s
• But continued to be of interest – investigation of equivalence principle
Gravity Instrumentation

LaCoste & Romberg Gravity Meter

Worden Gravity Meter
Ground Gravity Timeline
Units

Unit for acceleration is metre per second squared (m/s²)

- \( \mu m/s^2 = 10^{-6} m/s^2 \)
- 1 mGal = 10 \( \mu m/s^2 \)
- 1 gu = 1 \( \mu m/s^2 \)
Units

Gravity gradient is a gradient acceleration: acceleration units divided by distance units: per second squared $\left( s^{-2} \right)$

- $1 \text{ ns}^{-2} = 10^{-9} \text{ s}^{-2}$
- $1 \text{ Eo} = 1 \text{ ns}^{-2}$
Airborne Gravity & Gradiometry

“A gravitational timeline…..”

- Lacoste & Romberg meters
  - Carson & Fugro LCT

- AirGRAV and GT-1A
  - Sander Geophysics & Canadian Micro-Gravity

- Lockheed Martin instruments
  - Falcon, BHPB (Fugro Airborne Surveys), 5 instruments
  - Air-FTG®, Bell Geospace, 3 instruments
  - GGI, ArkeX, 3 instruments

- Instruments under development
  - EGG, ArkeX
  - AGG, Gedex,
  - Rio Tinto,
  - ‘String’ Gradiometer, Gravitec
Advantages

• When performed from space, speed of coverage is an advantage
• Ease of access and uniformity of coverage
• The above result in lower cost
• Airborne gravity is limited by equivalence principle (measurements on board an aircraft cannot distinguish accelerations due to gravity from those due to the motion of the aircraft)
• Gravity gradiometer can make the distinction
Applicability

• proved useful in the search for coal, base metals in iron-oxide copper-gold deposits, porphyries, Broken-Hill type deposits and volcanogenic massive sulphides, iron in massive haematite, nickel sulphides and gold. There have also been useful applications in the search for oil and gas.

• The Santo Domingo Sur copper deposit in Chile is one of the projects that is a gravity gradiometer discovery.
Advantages Gravimeter

- Low capital cost
- Smaller size
- Low weight

Comparisons need to consider accuracy across the entire wavenumber spectrum
Example

KIMBERLITE Gravity Anomaly
**Full Tensor Gradient Technology:**

Tensor components chart the changes in the gravity field as observed by geology.

- **3D FTG data** is the direct measurement of the gravity field in all directions.
- Determines minute changes in density distribution in all Tensor components.
- FTG data measured in Eötvös (E) units:
  \[ 1 \text{ E} = 0.1 \text{ mgal} / \text{ km} \]

**Real Data example from Vinton Dome salt body, Louisiana, USA**

**… Full Tensor Gradiometry for target detection and delineation**
Airborne Gravity & Gradiometry

“...a key tool in the Exploration Toolbox....”

- Need to improve / enhance ground gravity coverage:
  - Land access;
  - Difficult / rugged terrain.

- A Geological mapping technology:
  - Regional and localised surveying capabilities;
  - Structural and lithological contact mapper;
  - Depth to bedrock / Overburden issues.

- A Target Prospector:
  - Direct: Kimberlite (Diamonds), Porphory systems (Copper etc), Massive sulphides (Base Metals), Geothermal;
  - Indirect: Structural / Stratigraphic (hydrocarbons), Salt (hydrocarbons), Palaeochannels (alluvial diamonds / gold / uranium, sand & gravel, ground water).
Gradiometers in Operation
FALCON AGG

- Restricted in its use by the US State Department
- May only be used in countries approved in the applicable export license approvals
- Been used in Australia, Botswana, Canada, SA, …Zambia
- Newton System services North and South America
- Einstein-Southern Africa, Galileo-Australia
- Strict limits on access to unprocessed data
Bell Geospace

- 1998 – Bell Geospace took delivery of an FTG built by Lockheed Martin for ship borne gravity – 3D-Full Tensor Gravity
- Later modified for airborne use (Air-FTG)
Region of useful measurements

Adapted from Frank van Kann – University of WA
Region of useful measurement

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Airborne Vs Ground data
Desampled Ground Vs Airborne
Upward continued versus Airborne Tzz
Airborne Vs Ground
TZZ at 80m survey height

Ground gravity
Conclusion

- Airborne gravity data has contributed in the discovery of large deposits.
- For smaller type deposits, it is recommended to follow-up airborne work with ground gravity.
- Variation in anomaly mapping may be a result of poor elevation data.
• Thank You
Gravity Gradient Instrument:
Rotating accelerometers and GGI

Gradients measured as the difference across opposing pairs of accelerometers;

Accelerometers rotate about spin axis to avoid bias in measurements along direction of primary components.

GGIs configured as shown in cartoon within unit, i.e. 120° apart and 35° above the horizontal;

System also rotates to avoid bias in measurements.