

ABSTRACT

The application of magnetics has been instrumental either partially or wholly since 1915, when the various geophysical methods were first applied in oil and gas exploration. In this essay, the following topics were discussed: magnetic instruments (e.g., proton–precession magnetometer), magnetic susceptibility, airborne magnetics, and data interpretation with emphasis on depth–estimation method.

Key words: airborne magnetics; magnetometers; Euler method.

INTRODUCTION

Understanding the magnetic effects associated with Earth materials require the knowledge of the principles of magnetism (Dobrin and Savit, 1988). These basic principles are fundamental to the applications of magnetics for oil and gas exploration.

Magnetics was initially used for oil and gas exploration in areas where the structure in oil-bearing sedimentary layers appears to be controlled by topographic features, such as ridges or faults. Magnetics can also be used for direct detection of oil and gas.

Rocks vary in their magnetic properties, so changes in the rock types below the Earth's surface can cause small magnetic variation in the magnetic field of the rocks measured at the surface (Montgomery, 2000). Some oil and gas deposits are detected in this way.

MAGNETIC SUSCEPTIBILITY

The inherent magnetism of rocks called magnetic susceptibility is caused by changes in the subsurface geologic structures.

Magnetic susceptibility is the ratio of magnetization I (i.e., magnetic moment per unit volume) in a substance to the corresponding magnetic force H . It is mathematically expressed as,

$$I = KH \quad (1)$$

The factor K , is the magnetic susceptibility. In SI Units, K is “dimensionless,” since I and H have the same unit (A/m) (Ugwu and Umahi, 1999).

Magnetic susceptibility of rocks is the fundamental parameter in the applications of magnetics for oil and gas exploration. In every case, the susceptibility of rocks depends on the amount of magnetite (Fe_3O_4). TABLE I shows the typical magnetic susceptibility of earth materials (Urquhart, 2004). FIGURE I is a bar chart of typical susceptibilities sketched from TABLE I.

INSTRUMENTATION

As time went by, development in magnetic instruments occurred, starting from the simplest ones to the more complex magnetometers. A magnetometer is a magnetic instrument, which measures the Earth’s magnetic field strength in gamma units.

Magnetometer surveys can be ground, airborne or ship borne with different suitable instruments of different sensitivities measuring vertical, horizontal or total field. Typical sensitivity required in a ground magnetic instrument is between 1 and 10 nT in a total field rarely larger than 50,000 nT, but airborne application has led to the development of magnetometers with 0.001 nT measuring absolute field (Telford et al. 1976).

Common types of magnetic instruments in use today

Some of these instruments include fluxgate, proton–precession, Schmidt (occasionally used), optical-pumping, metastable, Overhauser, and Squid

magnetometers, gradiometer, variometer etc. The future use of these instruments is destined to increase with airborne capabilities.

Proton–precession magnetometer

This was developed in the mid -1950s. It is reliable, economical, simple and very good in airborne magnetic survey for reconnaissance and large data acquisition. As the name implies, it utilizes the magnetic and gyroscopic properties of protons in fluids such as gasoline, water, and alcohol etc.

Fluxgate, too, are slowly being replaced by the proton–precession magnetometers, which have greater sensitivity (≈ 1 nT or better), absolute accuracy, no moving parts and measures total field intensity with freedom from orientation errors (Breiner, 1973).

MAGNETIC SURVEY FOR OIL AND GAS EXPLORATION

The main objective is to determine the depth to the basement rather than the boundaries between different basement rock types (Reford, 1980)

Another objective has been to make use of weak anomalies, which may reflect local relief on the basement surface, and to analyze these quantitatively. Magnetic survey methods can be airborne, ground or ship borne.

Airborne magnetic survey procedure

It should be noted that in mounting proton–precession magnetometer as a survey instrument, the sensor is housed in a streamlined cylindrical container

called “a bird “(FIGURE II), the same as “a fish” in ship borne magnetics. A cable of 30 – 150 m long connects the sensor. Aligning along the total field axis to give normal signal amplitude must stabilize the magnetometer.

During exploration, the aircraft flies in parallel lines spaced 100 m to several Kilometers apart at an elevation of 500 m. The elevation must be maintained to avoid herringbone pattern that would alter the interpretation based on anomaly shape measurement. These precautions ensure that the noise due laterite rubble near the surface is reduced, because its effects decrease with inverse cube of distance.

Ground magnetics, is used to locate airborne anomalies for detailed survey. The position of the aircraft can as well be located using cameras and photography.

DATA PROCESSING AND CORRECTION

Processing the collected airborne magnetic data removes the Earth’s natural magnetic field and any diurnal variation. A part from the great development in magnetic instruments processing has also been advanced digital recording (S. A. Ugwu, personal communication, 2005). The difficulty in detecting errors is the negative side effect of digital processing.

Data Correction

Diurnal correction. - This correction is made by flying the survey on a pattern of “ flight lines” with a pair of ” tie lines” crossing them at surface interval

(FIGURE III)

Normal - field correction. - In this case, normal variation of the geomagnetic field intensity is considered and referenced to world contour maps. Alternatively, the table of the International Geomagnetic Reference Field (IGRF) can be used. In airborne magnetic survey, terrain correction can be made; sometimes-magnetic storms are allowed to stop before survey is continued.

INTERPRETATION FOR OIL AND GAS EXPLORATION

The end product of an airborne magnetic survey is a contoured anomaly map in gammas or nanoteslas (FIGURE IV) without a magnetic anomaly, there cannot be a depth estimate.

As a first step, it is useful to estimate the magnitude and form of the magnetic anomalies over bodies of simple shapes; this helps in making quantitative and qualitative interpretation. The next step is to translate the magnetic data into subsurface geology.

Magnetic data interpretation methods

In general, there are (at least) four main ways to interpret magnetic data:

1. Forward modeling.
2. Direct detection of structural trends.
3. Estimation of depth to magnetic basement.
4. Inverse modeling.

Estimation of depth to magnetic basement

The wavelength of magnetic anomalies is a fundamental effect of the depth of burial. Attenuation caused by thickness of the sedimentary section is of obvious importance in oil and gas exploration. This effect for the case of dike is illustrated in FIGURE V.

Euler method. - This is a profile-based depth estimation method based on the concept that the magnetic fields of localized structure's are homogenous functions of the coordinates and therefore satisfies Euler's equation, which according to Thompson (1982) could be written in form,

$$(x - x_0) \partial T / \partial x + (y - y_0) \partial T / \partial y + (z - z_0) \partial T / \partial z = N (B - T), \quad (2)$$

Where (x_0, y_0, z_0) is the position of a magnetic source whose total field T is detected at (x, y, z) . The total field has a regional value of B . N is the structural index. Also, McGrath and Hood (1973) summarized a computer method for magnetic interpretation (FIGURE VI).

CONCLUSIONS

Effective application of the improved methods of data acquisition, processing, Interpretation and modeling by skilled geophysicists aids in accurate oil and gas exploration using magnetics.

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REFERENCES

- Breiner, S., 1973, Applications manual for portable magnetometers: Geometrics , Inc., [online], June 16, 2005. http://www.georentals.co.uk / ampm_opt.pdf.
- Dobrin, M. B., and C. H. Savit, 1988, Introduction to geophysical prospecting: McGraw – Hill Companies, Inc.
- McGrath, P. H., and P. J. Hood, 1973, An automatic least squares multimodel method for magnetic interpretation: Geophysics, **38**, 349 – 358.
- Montgomery, C. W., 2000, Environmental geology: McGraw – Hill Companies, Inc.
- Reford, M. S., 1980, Magnetic method: Geophysics, **45**, 1640 – 1658
- Telford, W. M., Geldart L. P., Sheriff R. E., and D. A. Keys, 1976, Applied geophysics: Cambridge University Press.
- Thompson, D. T., 1982, EULDPH – a new technique for computer – assisted depth estimates from magnetic data: Geophysics, **47**, 31 – 37.
- Ugwu, G. Z., and A. E. Umahi, 1999, Modern physics: Rojoint Communication Services.
- Urquhart, W. E S., 2004, Airborne magnetic data compilation and interpretation: GeoExplo Ltda., [online], June 16, 2005. http://www.geoexplo.com/ airborne_magnetics_compilation_and_interp.html.

FIGURE CAPTIONS

FIGURE I: A simple bar chart, which shows that magnetite, has the highest susceptibility. It also indicates that small amount of magnetite can be found in sedimentary rocks, thus; low magnetic readings (weak anomalies) – oil traps may be detected, while the igneous rocks have the highest magnetic susceptibility of the rock types.

FIGURE II: The arrangement of proton – precession magnetometer during airborne magnetic survey.

FIGURE III: A pattern of “flight lines” with a pair of “tie lines” crossing them at surface intervals.

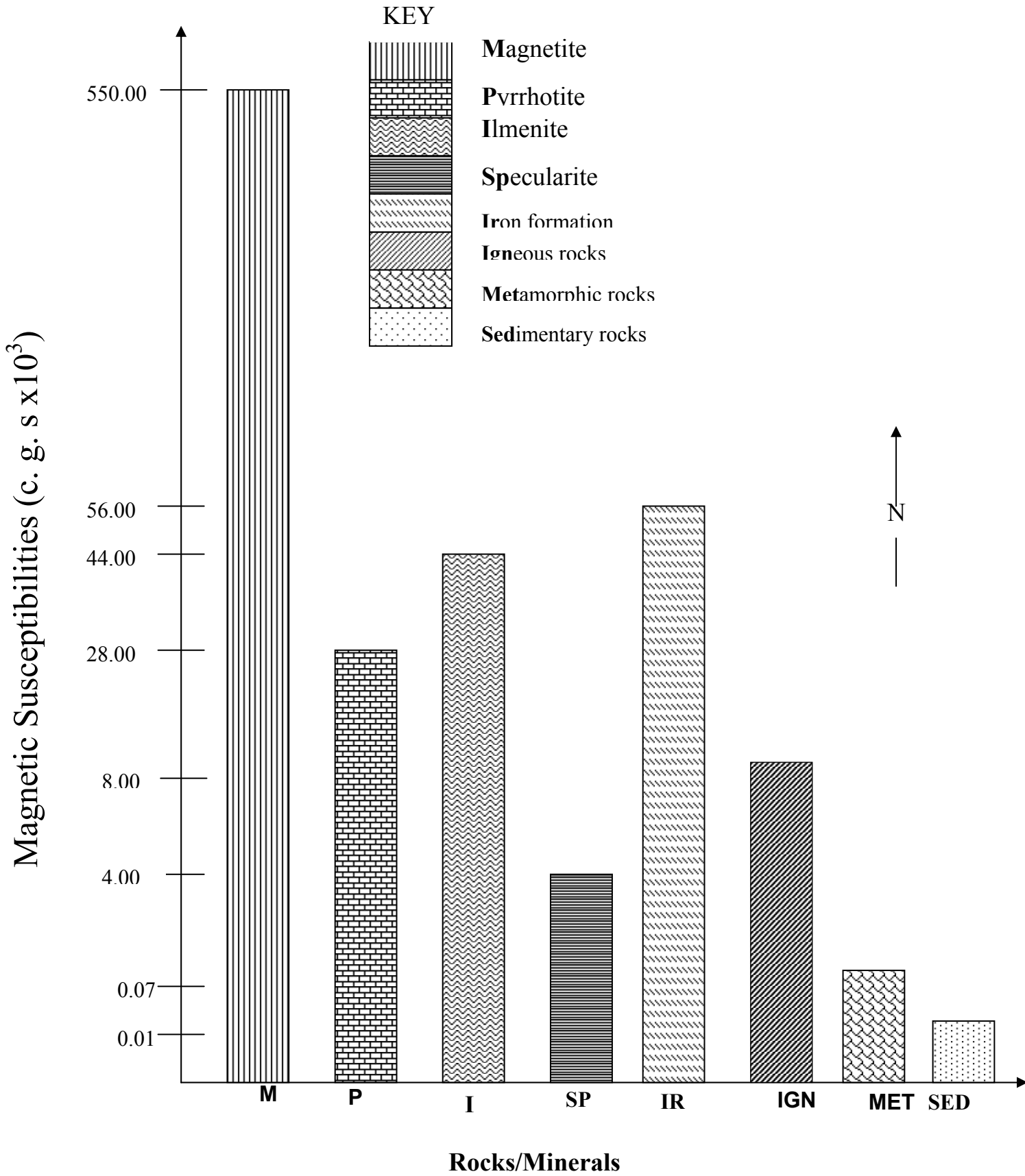
FIGURE IV: An example of contoured map of the total magnetic intensity. In this map, a number of lineations, which show evidence of dikes, are clearly evident in the data. In addition, some lineations show evidence of lateral offset, which may be related to faulting. The color scheme in the figure indicates magnetic lows as blue and highs as red.

FIGURE V: An illustration of the effect of the depth of burial to the magnetic basement.

FIGURE VI: A summarized multimodel method for magnetic interpretation. It is a computer modeling procedure.

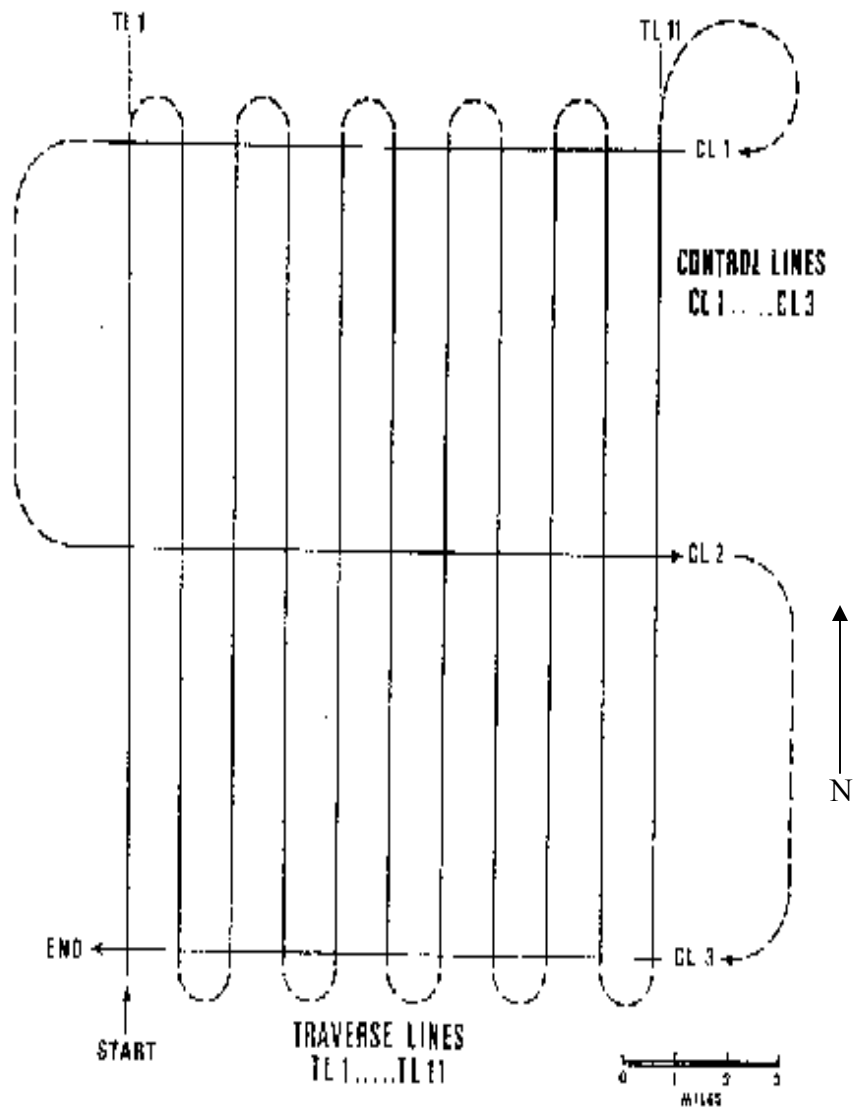
**TABLE I: Typical Magnetic Susceptibilities of Earth
Materials.**

Rock (Mineral)	Type Susceptibility (c.g.s.)
Magnetite	0.3 to 0.8
Pyrrhotite	0.028
Ilmenite	0.044
Specularite	0.004
Iron Formation	0.056
Basalt	0.00295
Diabase	0.00259
Rhyolite	0.00112
Gabbro	0.00099
Granite	0.00047
Other Acid Intrusives	0.00035
Ely Greenstone	0.00009
Slates	0.00005
Sedimentary Rocks	0.00001 to 0.001

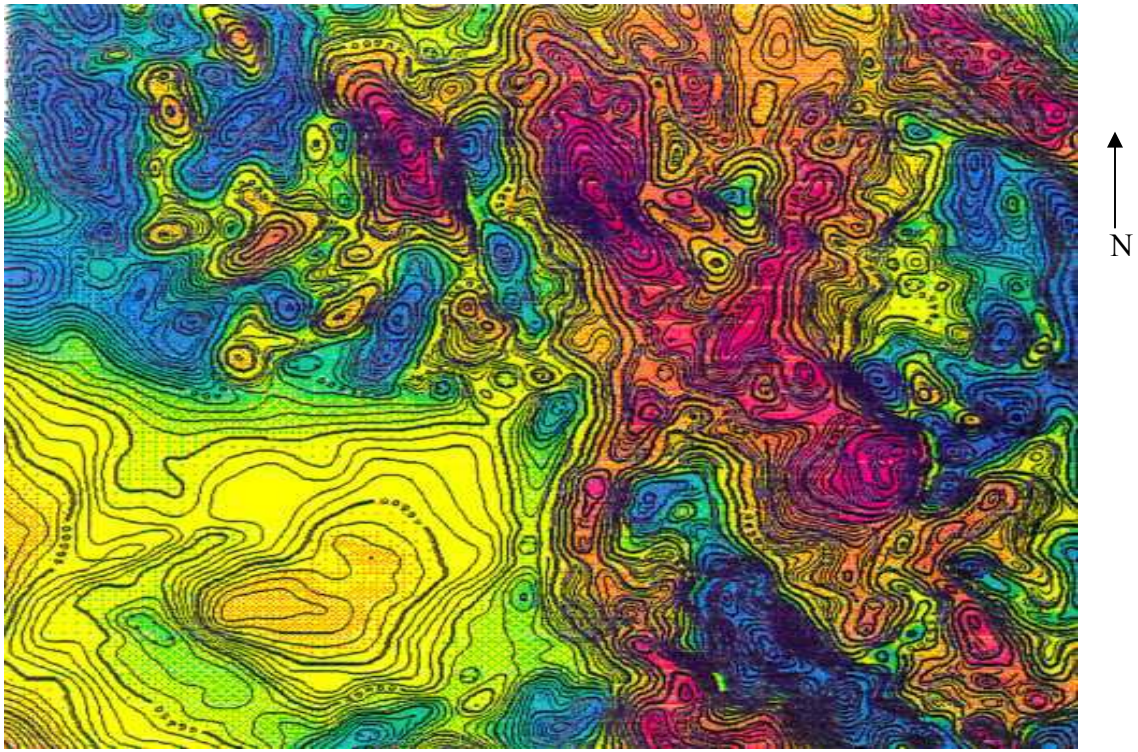




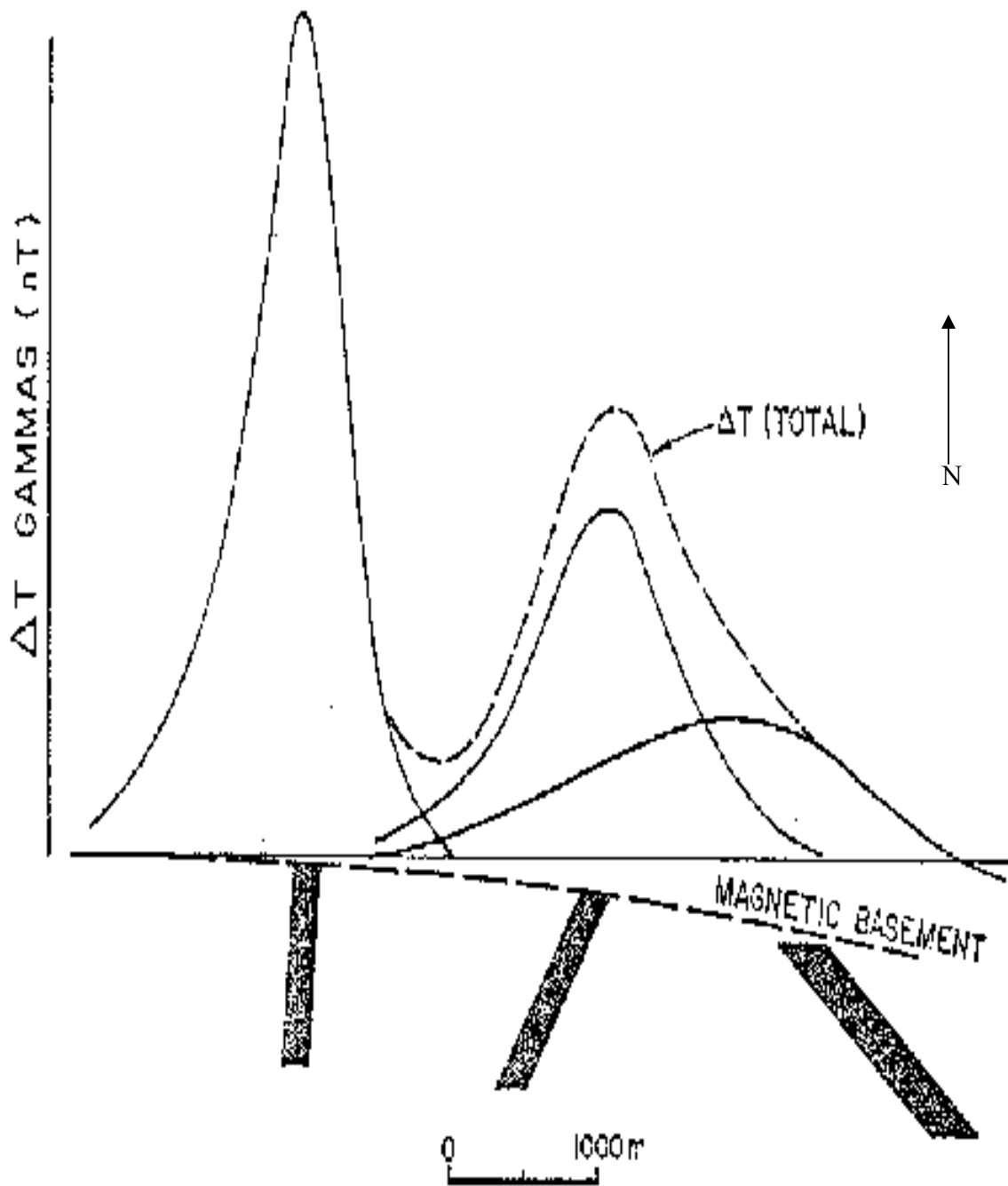
UTOM / FIGURE II



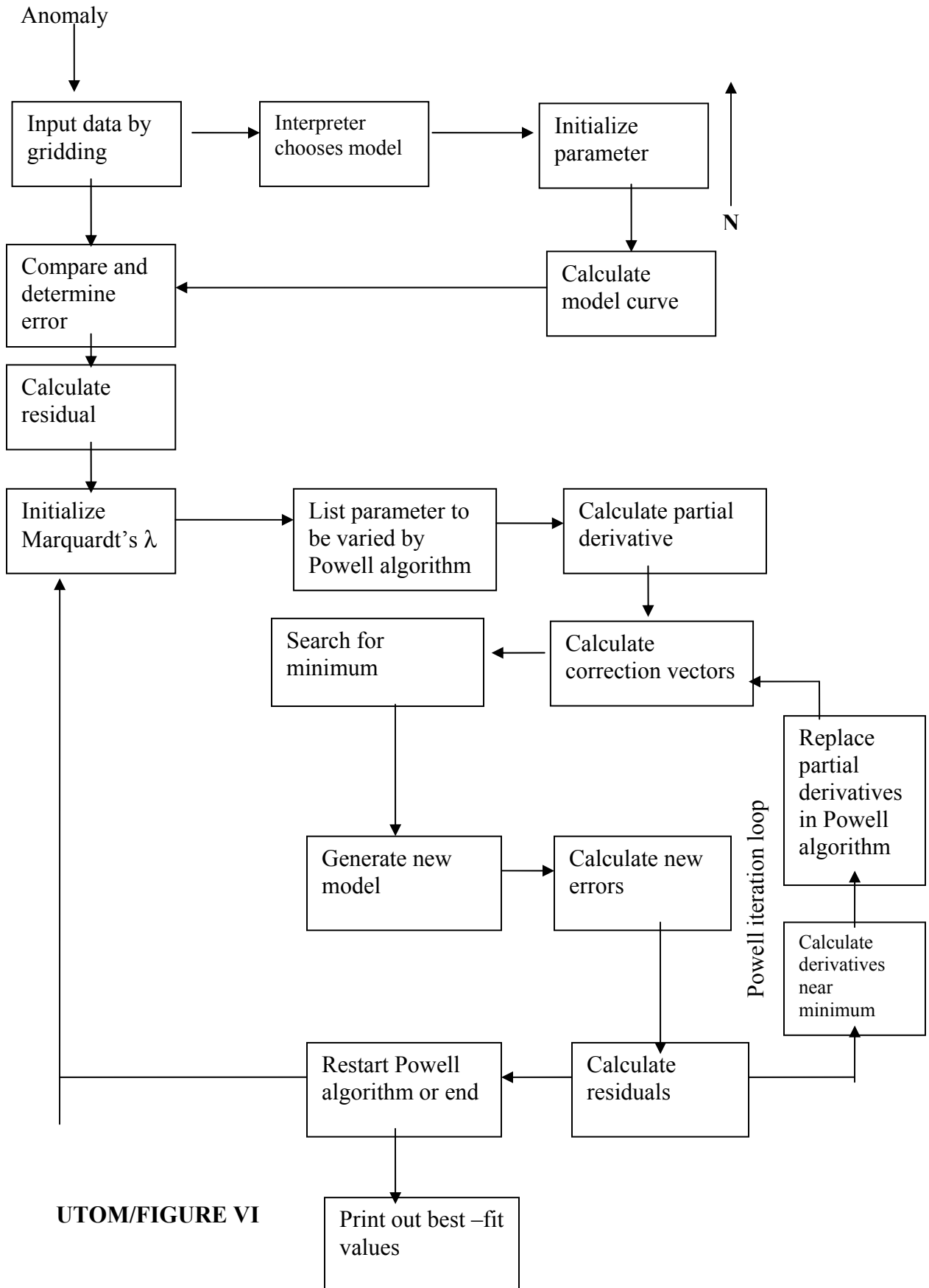
UTOM/ FIGURE III



UTOM / FIGURE IV



UTOM / FIGURE V



UTOM/FIGURE VI

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