Damietta University
Faculty of Science
Geology Department

Magnetic Exploration Course

For

First Year Geophysics Program

Code: 102 Geoph

Lecture 8: Magnetic Data Processing and Interpretation

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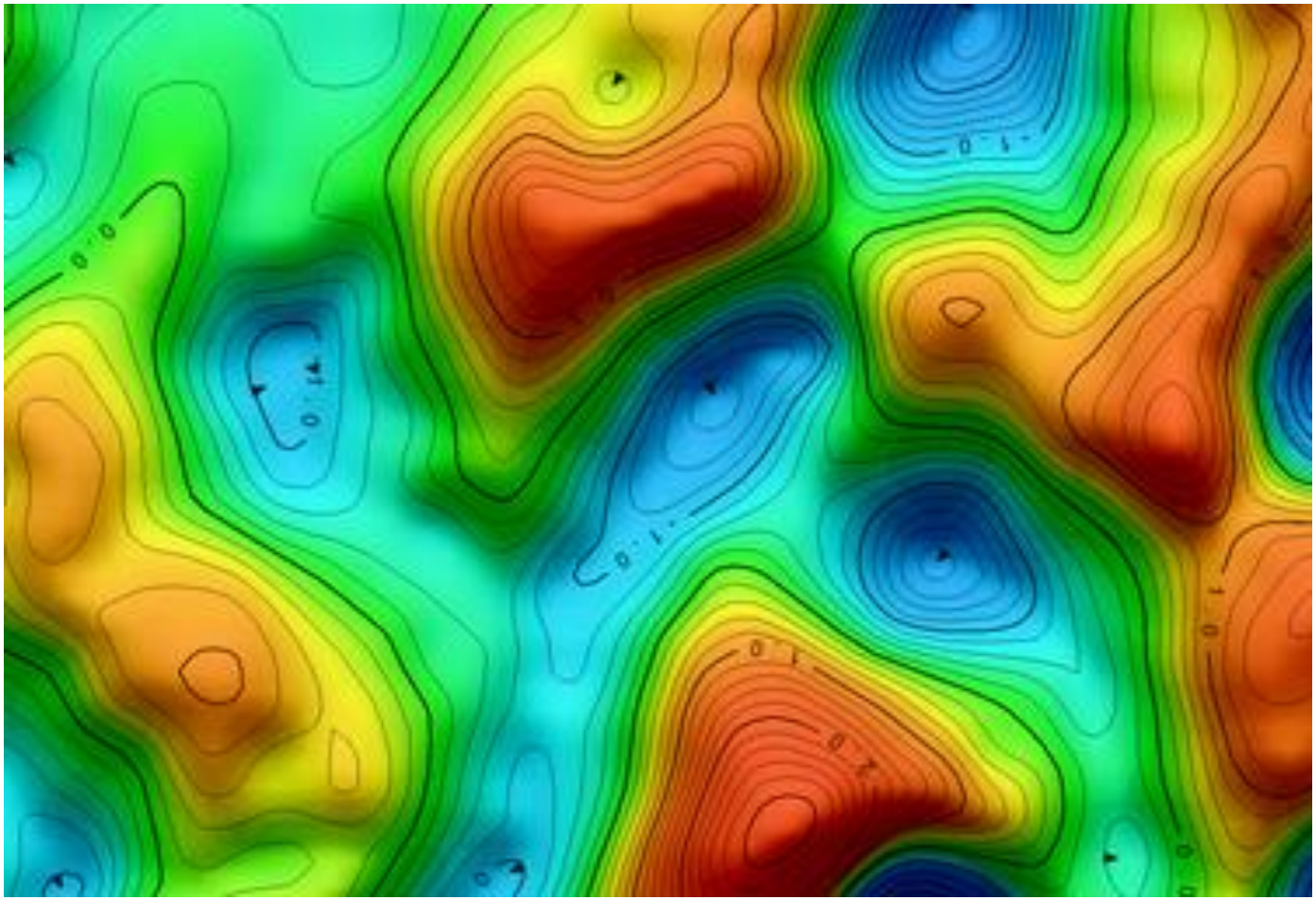
2020

Magnetic Data Processing

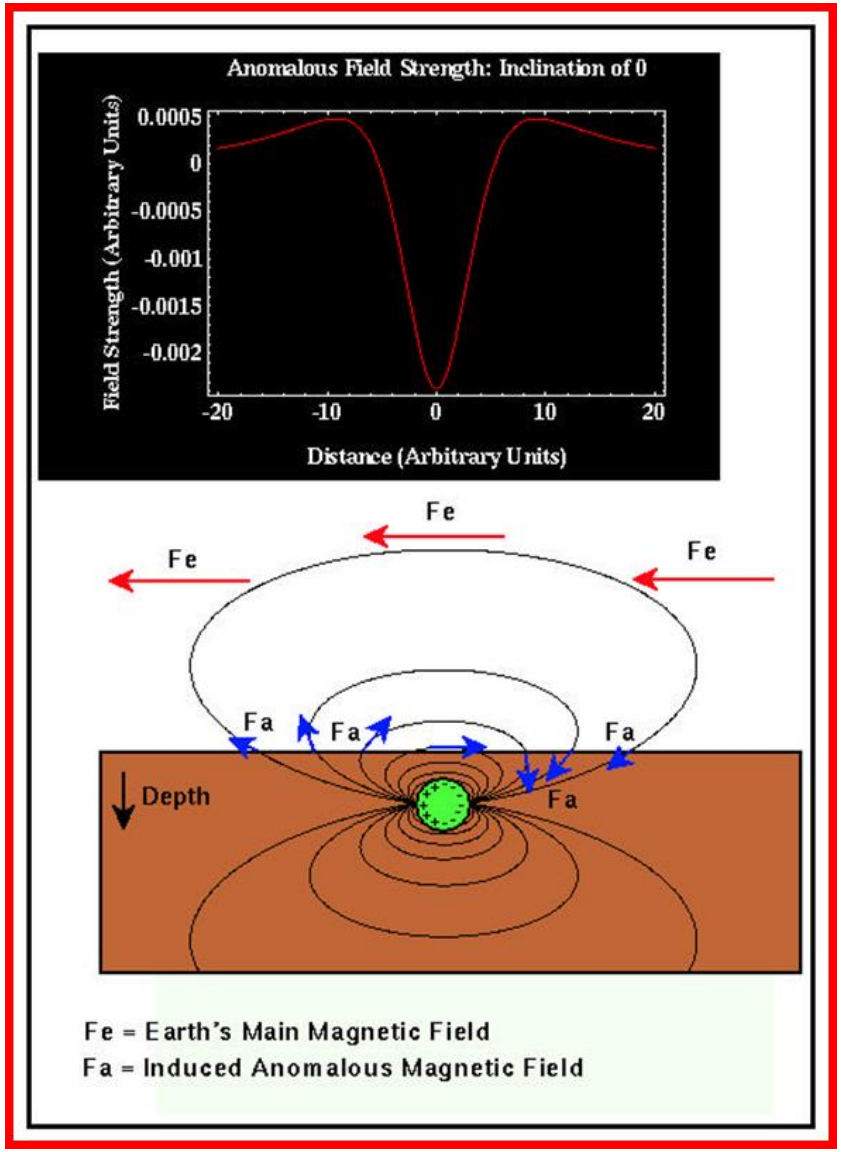


Magnetic Data Processing

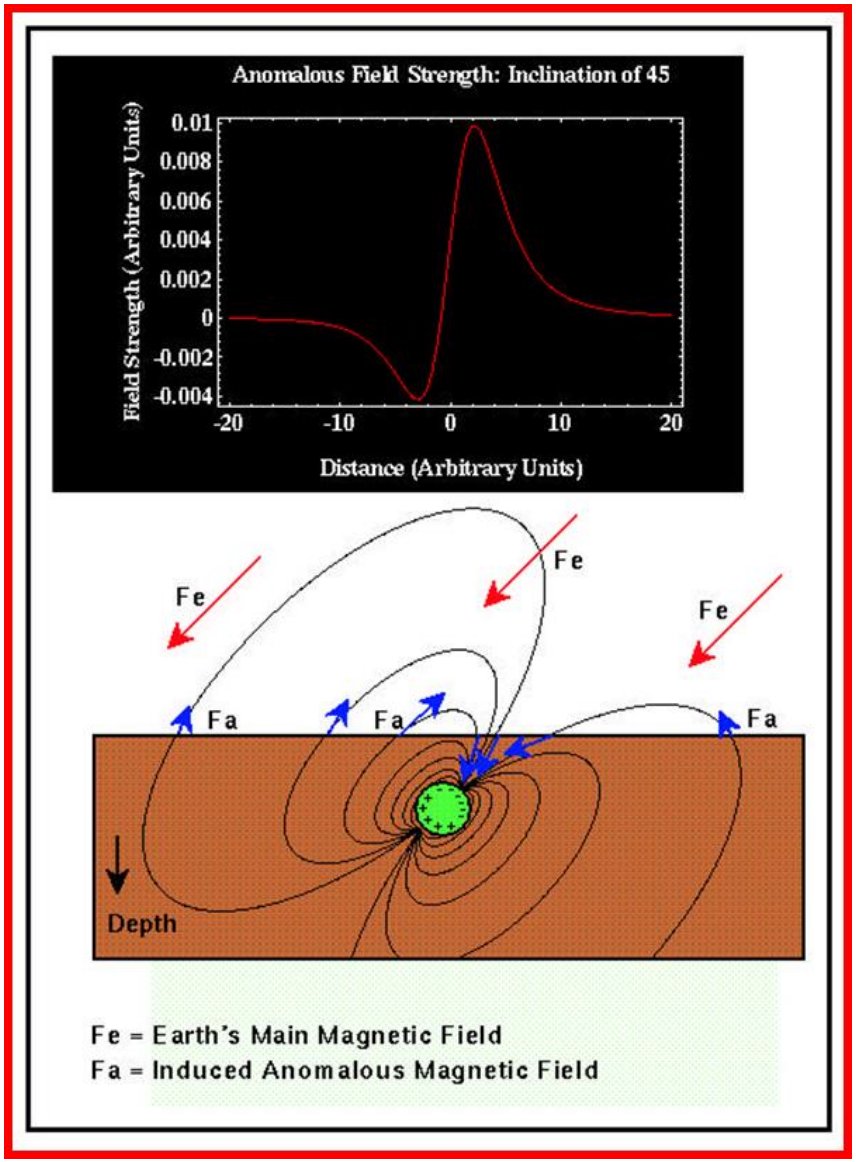
Spatial variations of the Earth's main magnetic field

- Magnetized Sphere at the Equator.
- Magnetized Sphere in the Northern Hemisphere.
- Magnetized Sphere at the Equator.

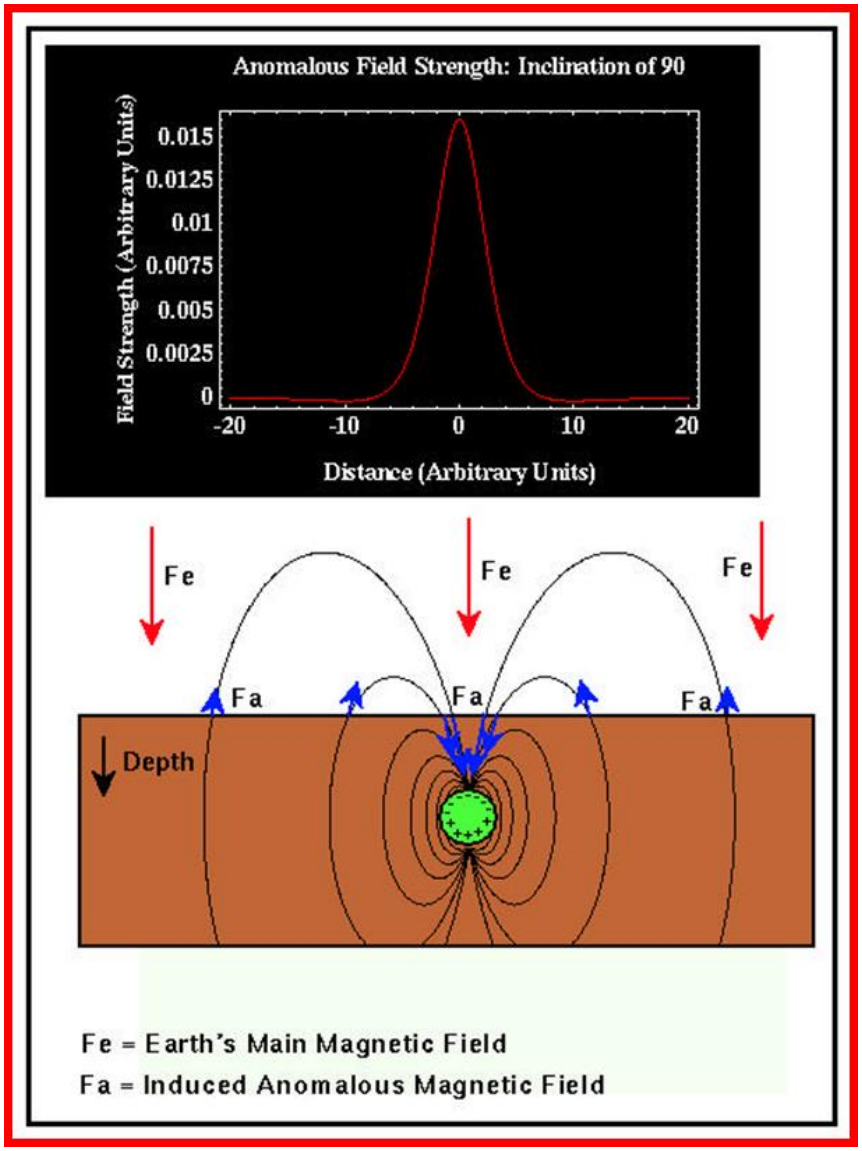
Magnetized Sphere at the Equator



Magnetized Sphere in the Northern Hemisphere

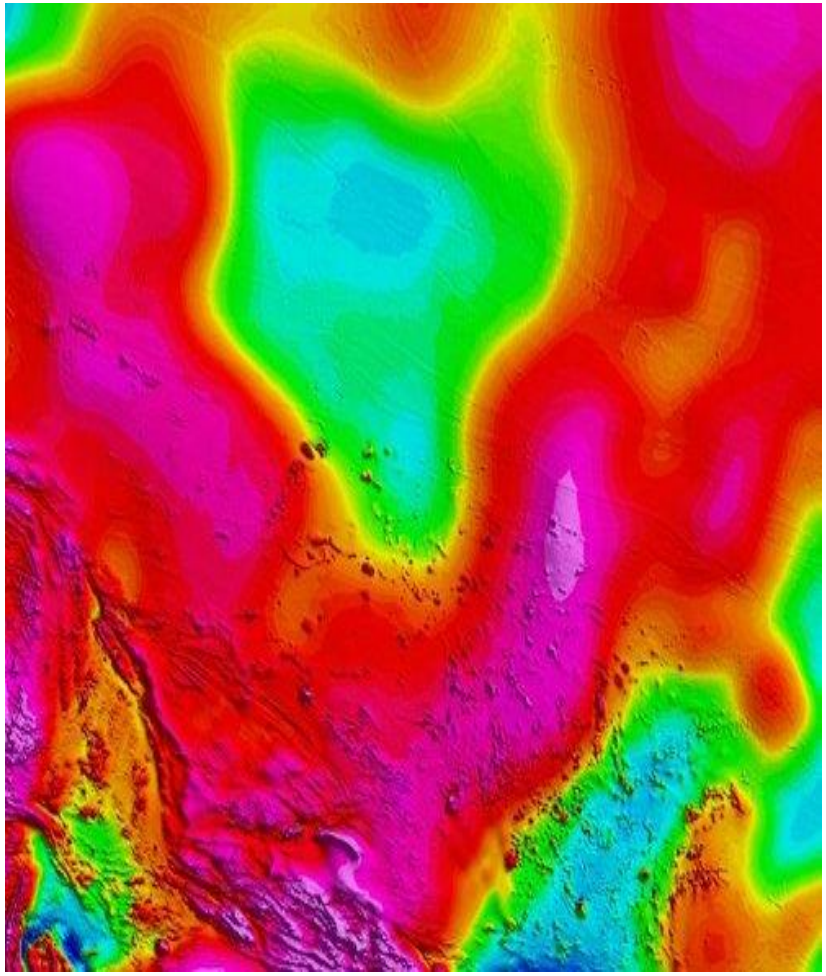


Magnetized Sphere at the North Pole



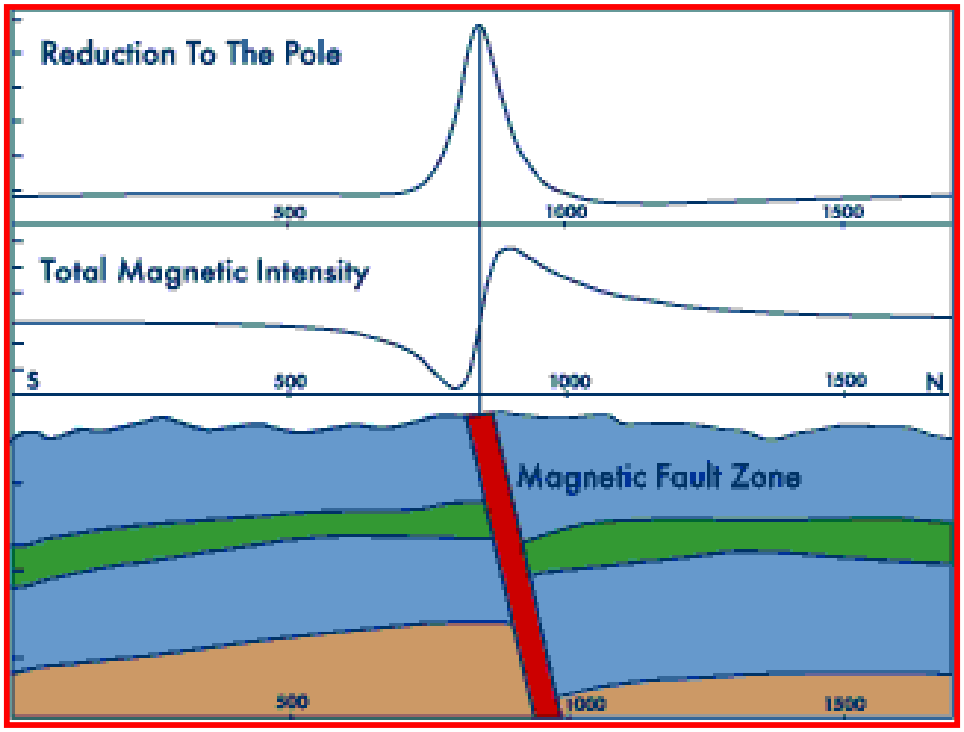
Reduction to the magnetic pole (RTP)

- Recalculates total magnetic intensity data as if the inducing magnetic field had a 90º inclination.
- Transforms dipolar magnetic anomalies to monopolar anomalies centered over their causative bodies
- Simplify the interpretation of the data.
- Usually applied to gridded data.

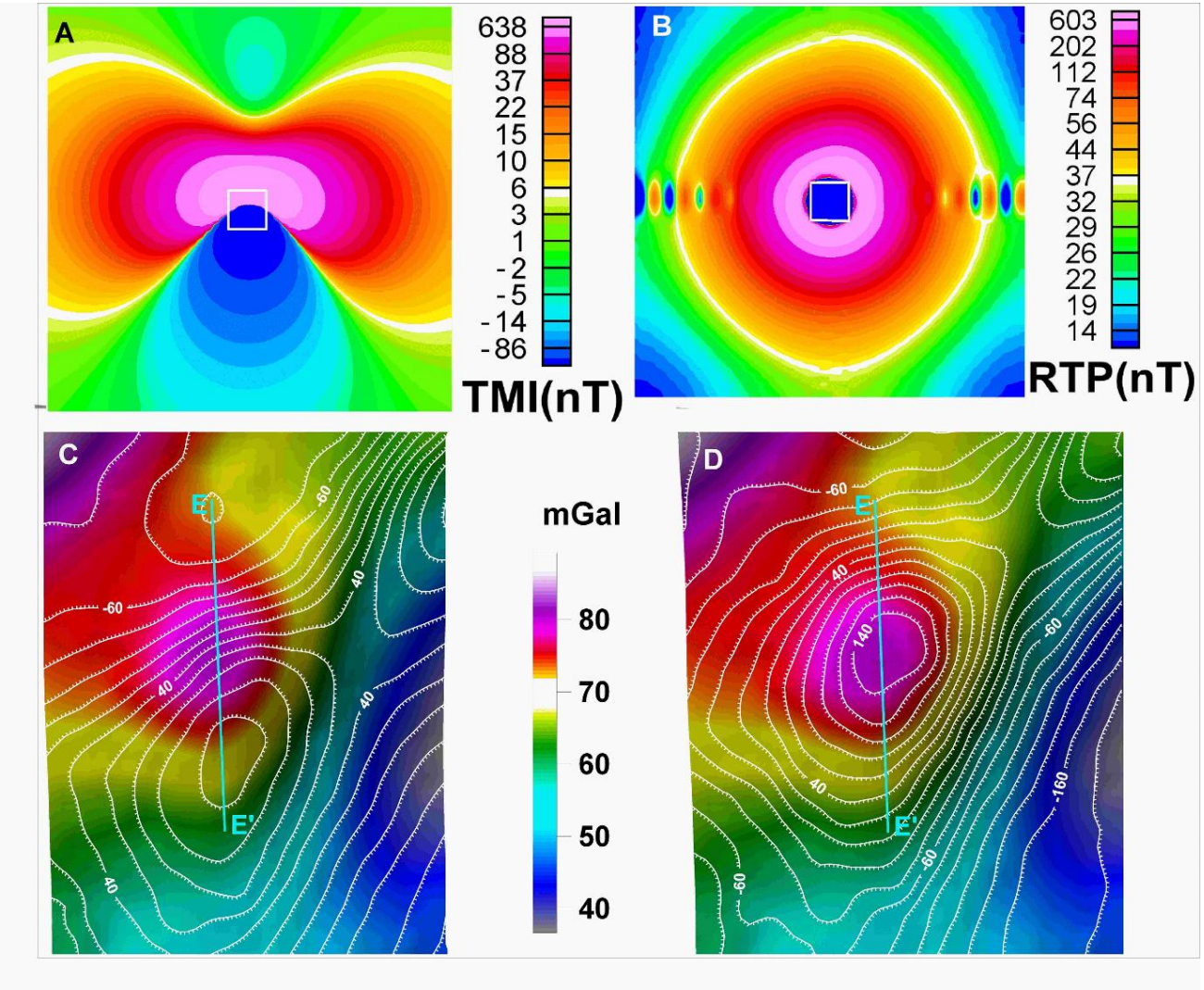


http://www.frogtech.com.au/potential-field-enhancements

Reduction to the magnetic pole (RTP)



Reduction to the magnetic pole (RTP)



http://club.berkovich-zametki.com/?p=7343

Separation of magnetic anomalies

Definition

Is a filtering process in which only the spatial wavelengths of interest are passed and the remainder are eliminated or at least highly attenuated.

Separation of magnetic anomalies

The measured magnetic fields consist of the superposition of anomalies from a variety of sources. They include:

(1) Residual anomalies, which are the anomalies of particular interest in a study,

(2) The longer-wavelength regional components derived largely from deep, large-volume geologic sources, and

(3) The shorter-wavelength noise due to observational and data reduction errors and small, shallow sources.

Isolation and enhancement methods

1- Spatial filtering methods

Graphical methods.

- From Profile
- From map

Analytical methods.

- Griffin method

2- Spectral filtering methods

Wavelength filters.

- Band pass filters
- High pass filters
- Low pass filters

Derivative filters.

- Vertical derivative
- Horizontal derivative

Continuation filters.

- Upward continuation
- Downward continuation

Isolation and enhancement methods

Spectral filtering methods

- Predominant method of isolating and enhancing magnetic anomalies.
- The input data set is Fourier-transformed into the gridded frequency or wavenumber domain by the direct transform.
- Then transformed back into the space domain by the inverse Fourier transform.

Method of separation of anomaly:

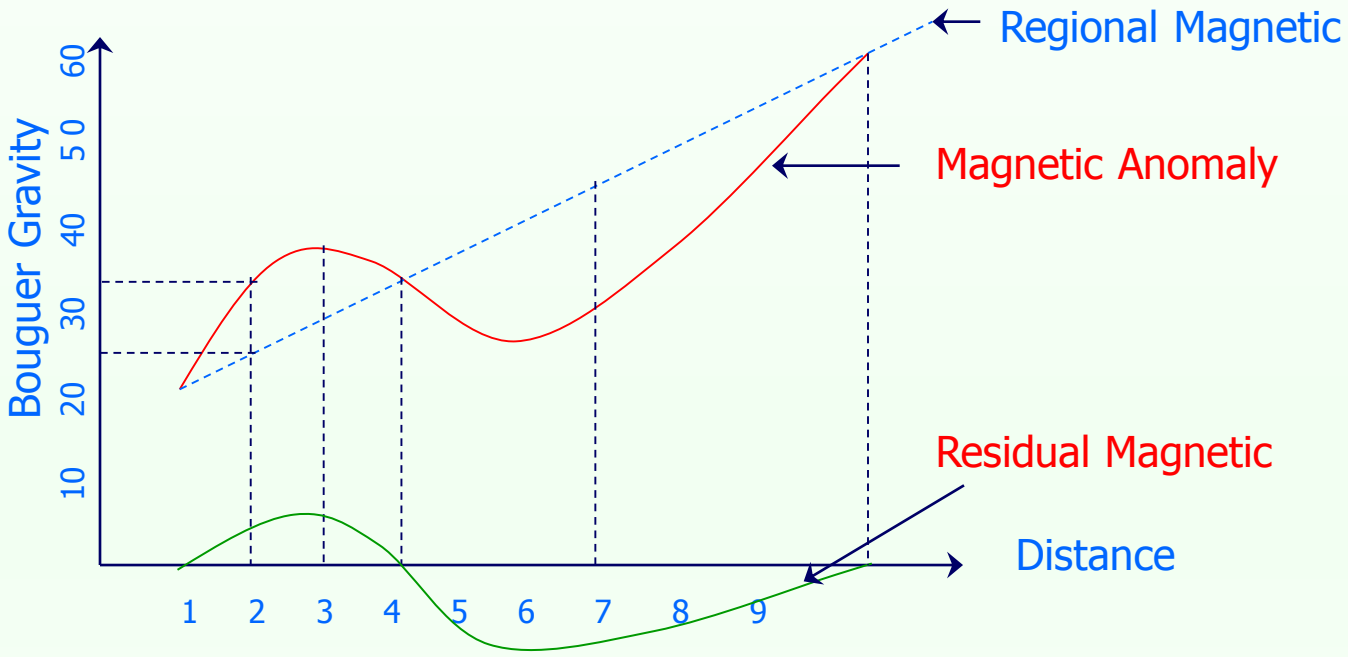
1- Graphical method

a- From profile: characterized by:

1- Separation is easy, especially when there are large and small scale structures.

2- Calculated from profile of the total Bouguer anomaly.

3- Not very accurate.



Station	Magnetic	Regional	Residual
1	21	21	0
2	35	26	9
3	40	30	10
4	36	36	0

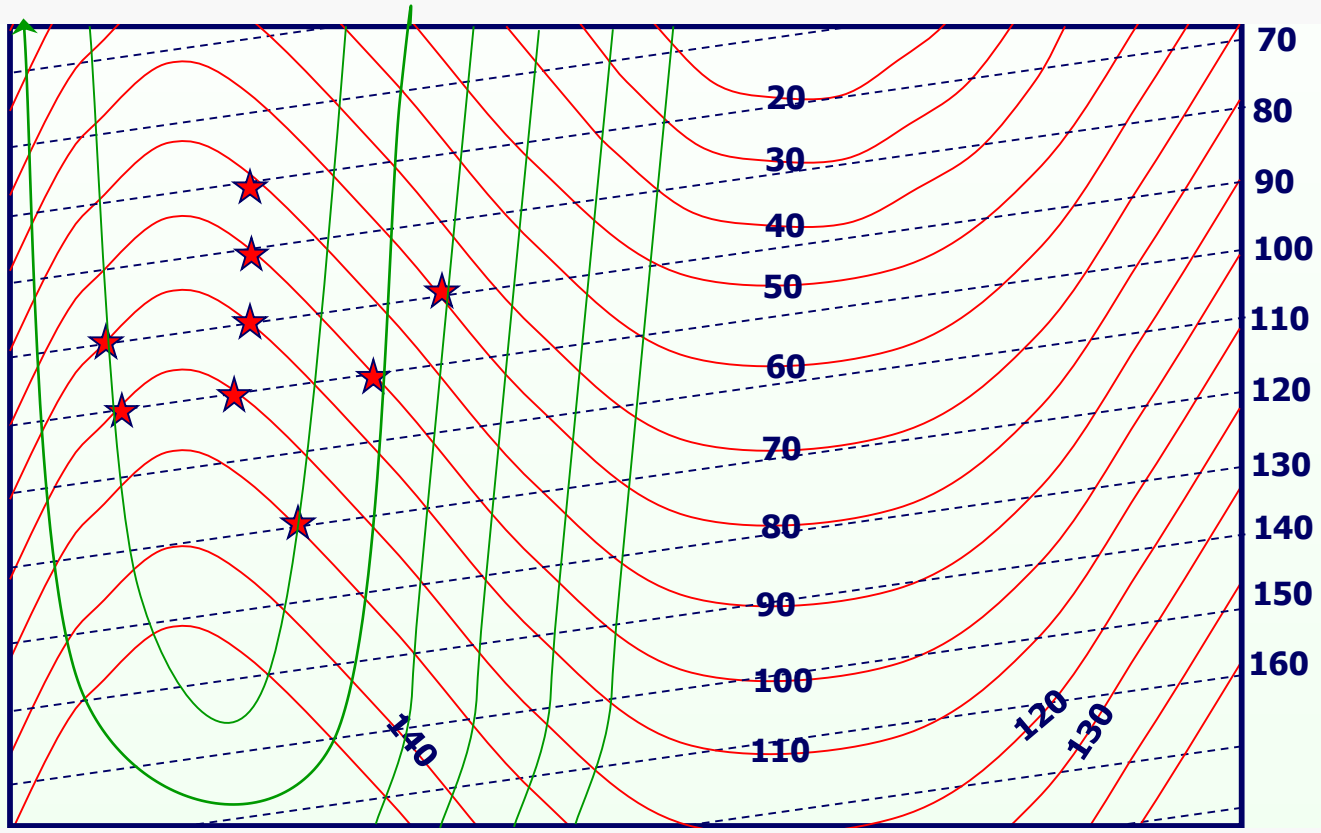
a- From Magnetic Map: characterized by:

1- It is simple process, become difficult when there are two structures of the same size.

2- Calculated from total magnetic map.

3- Moderately it is accurate.

Magnetic Map



Total Magnetic

Regional

Residual

Analytical methods :

Griffin method (circle and centre point).

A- Griffin method:

The following steps have to be followed:

1- Select a suitable circle of radius 1 cm, $\sqrt{2}$ cm, $\sqrt{5}$ cm

2- Draw the circle on the transparent paper.

3- The centre of the circle placed on a certain station, so that:

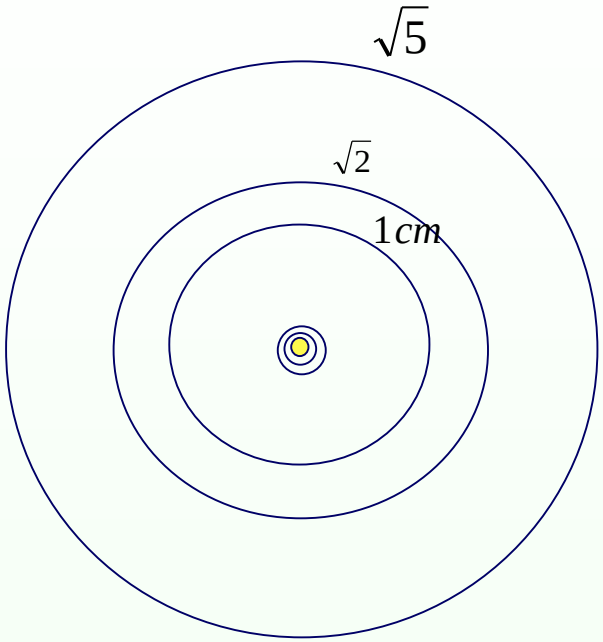
a- Four stations are located on the perimeter محيط .

b- Eight stations are located on the perimeter .

4- Regional magnetic is calculated by:

$$g_{\text{Regional}} = \frac{g_1 + g_2 + g_3 + g_4}{4} \quad for \;\; 1cm \;\; and \;\; \sqrt{2} \;\; cm$$

$$g_{\text{Regional}} = \frac{g_1 + g_2 + \ldots + g_8}{8} \quad for \quad \sqrt{5} \;\; cm$$



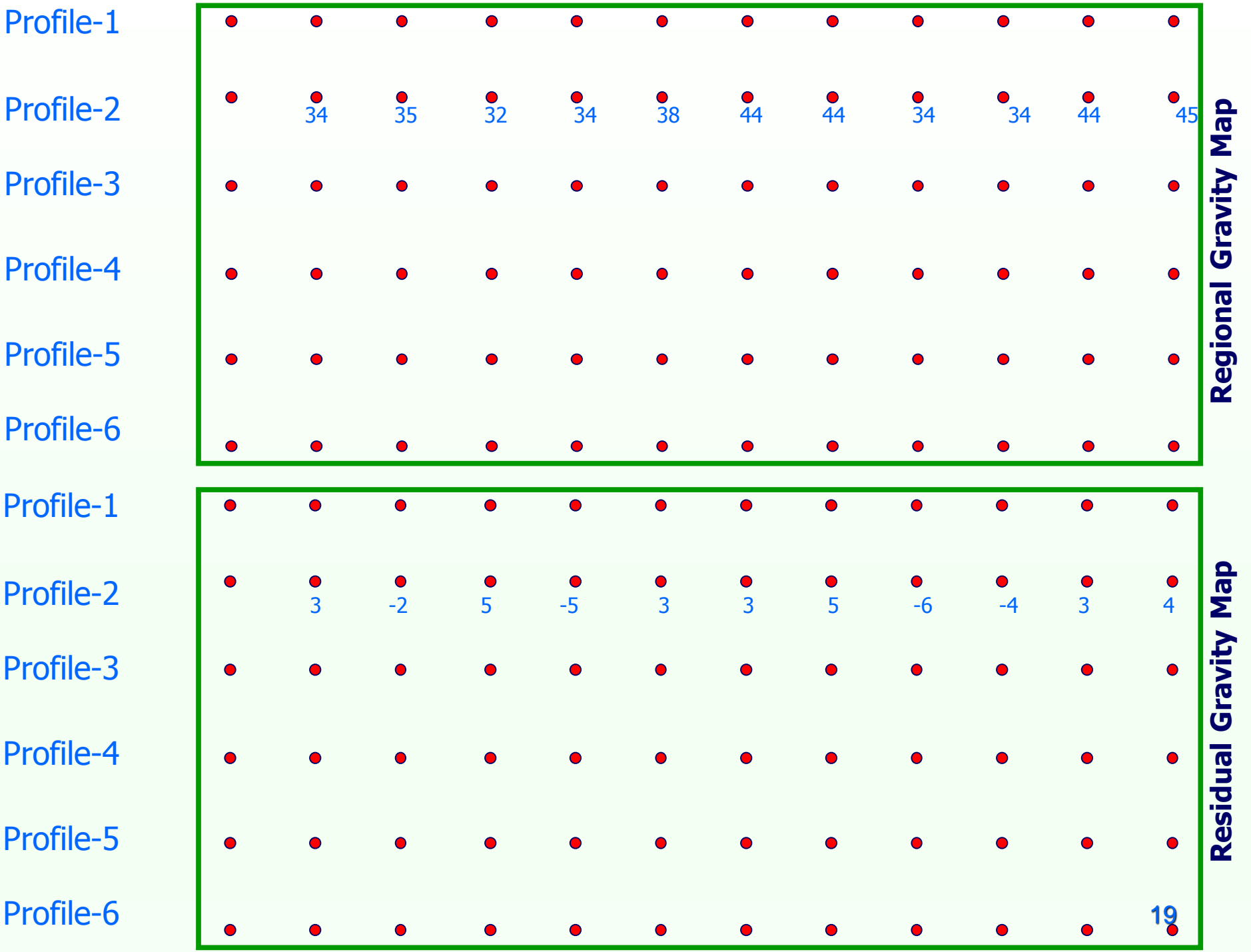
5- Repeat this process for all station.

6- Determine Residual by:

$$g_{\text{Residual}} = g_{station} - g_{\text{Regional}}$$

Profile-1	34	36	33	33	24	44	44	34	34	44	45	46
Profile-2	36	37	33	37	29	41	41	34	34	43	43	46
Profile-3	38	31	33	33	34	38	44	39	37	45	49	48
Profile-4	34	35	30	33	24	44	44	34	34	44	45	46
Profile-5	34	35	30	33	24	44	44	34	34	44	45	46
Profile-6												

Bouguer Gravity Map


Profile-1
Profile-2
Profile-3
Profile-4
Profile-5
Profile-6
34
35
32
34
38
44
44
34
34
44
45
Regional Gravity Map
Profile-1
Profile-2
Profile-3
Profile-4
Profile-5
Profile-6
3
-2
5
-5
3
3
5
-6
-4
3
4
19
Residual Gravity Map

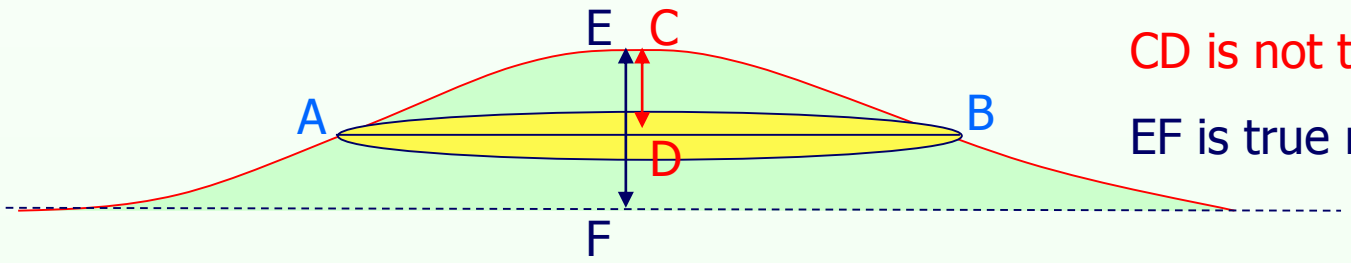
Selecting Suitable circle:

The most suitable separation process depend on best selection of the circle radius.

There are the following cases:

1- If the diameter of the circle is too small than the maximum dimension of an anomaly.

A part of residual is separated, other part mixed with the regional.

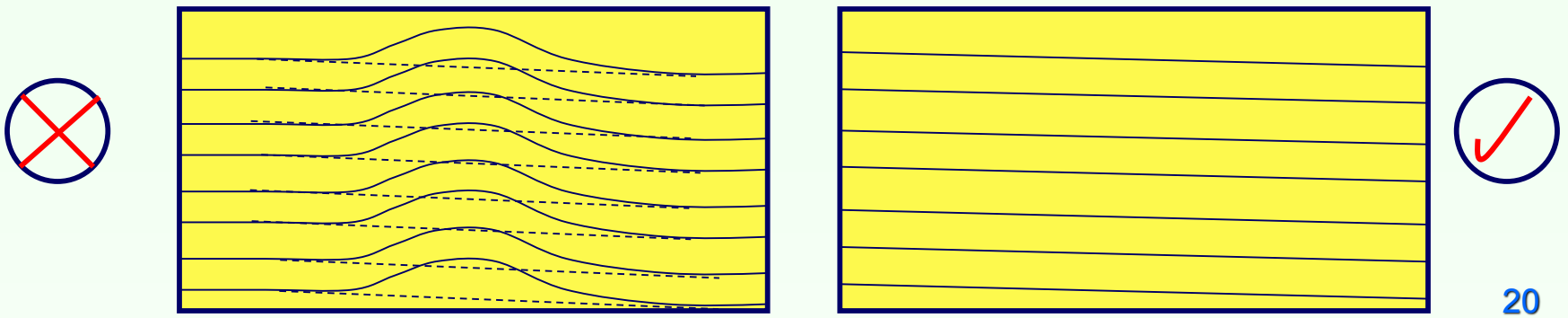


AB is not suitable circle

CD is not true residual

EF is true residual

Separation process is not successful and we can know that from the regional map



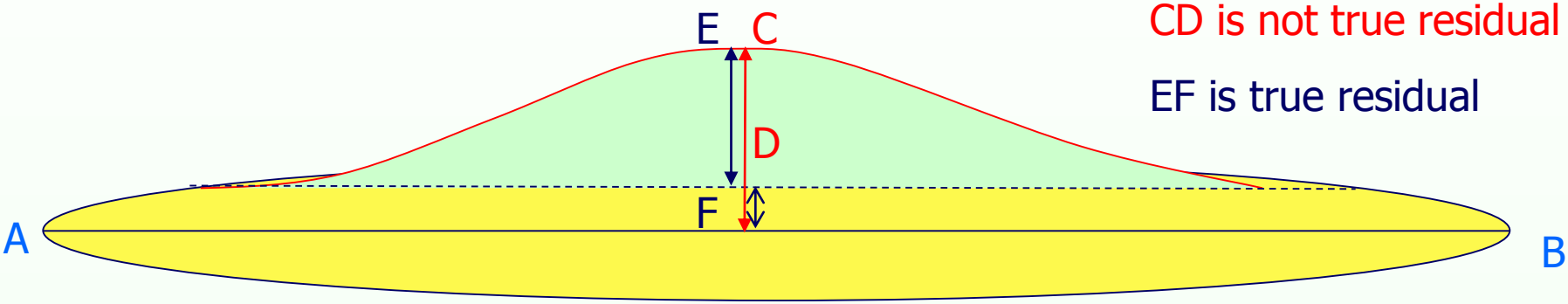
2- If the diameter of the circle is too large than the maximum dimension of an anomaly.

A part of regional is calculated regional.

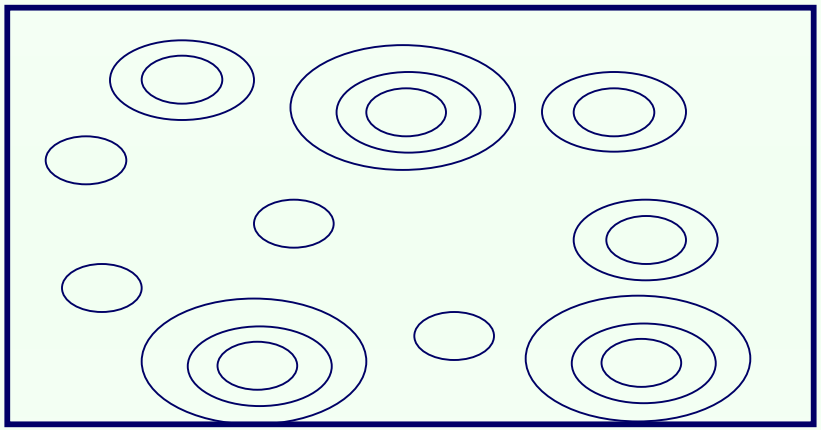
AB is not suitable circle

CD is not true residual

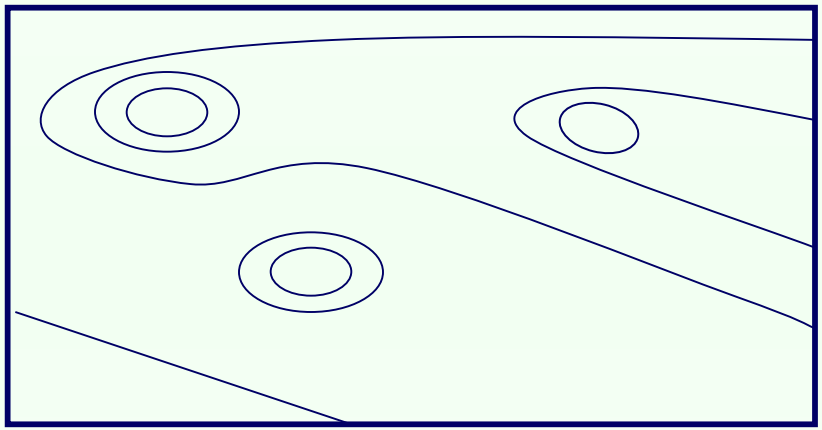
EF is true residual



Separation process is not successful and we can know that from the residual map



Real residual



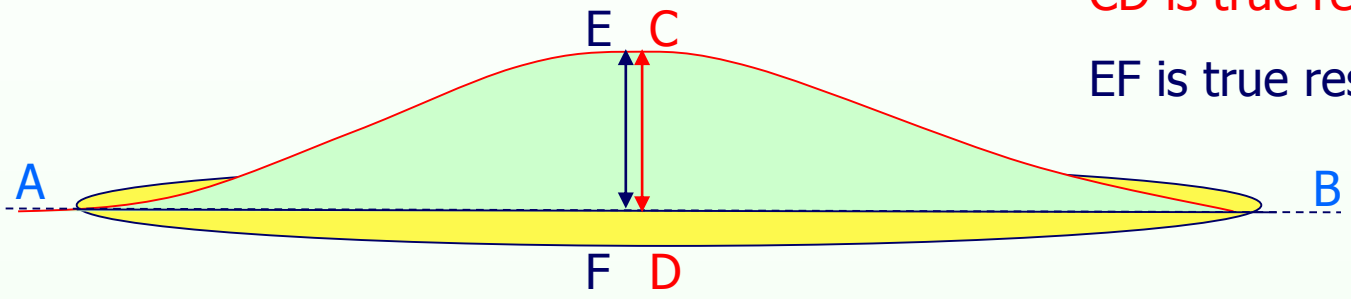
Residual + Part of Regional

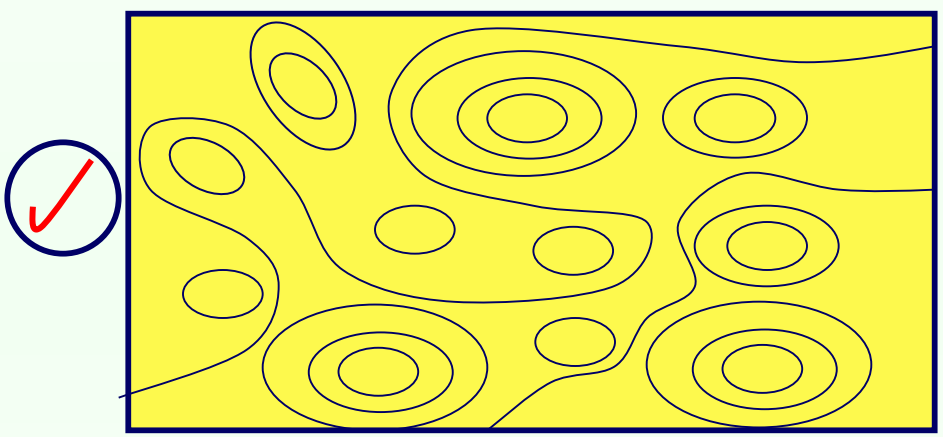
3- If the diameter of the circle is Suitable compare to dimension of an anomaly.
Residual completely separated from the Regional.

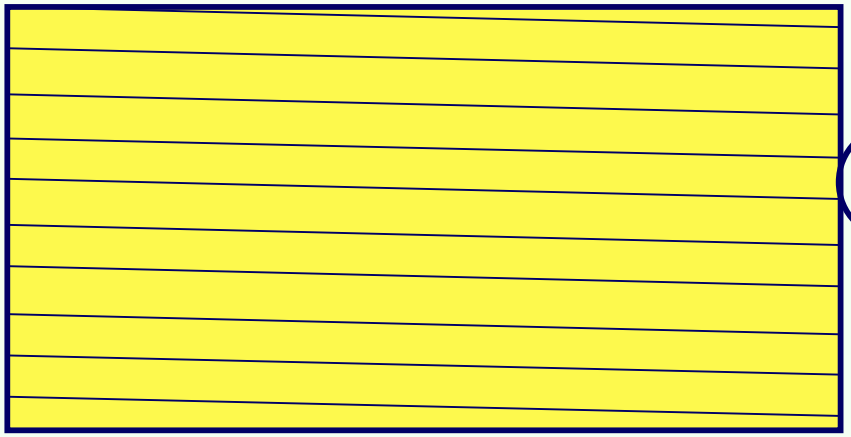
AB is suitable circle

CD is true residual=

EF is true residual







Real residual

Real Regional

First Vertical Derivative (1VD)

- Reduces the effects of regional anomalies and enhances near surface contrasts.
- Enhances anomalies caused by shallow sources and by the top parts of deep bodies or bodies with a large depth-extent.
- Anomaly peaks can be used to locate the centers of sources or the steeper sides of bodies.
- The zero contour lines can be used to locate boundaries of sources.
- Required to closely spaced, high-accuracy observations.
- The first derivative is the gradient of the anomaly in vertical direction, and the second derivative is the gradient of the gradient.

http://www.frogtech.com.au/potential-field-enhancemen

Band-pass Filter (BP)

- Passes frequencies within a certain range.
- Attenuates (reduces) frequencies outside that range.
- Caution is warranted when interpreting the data, because signal may also arise from the aliasing of sources at other depths.

http://www.frogtech.com.au/potential-field-enhancements

High-pass Filter

- Passes high frequencies.
- Attenuates (or reduces) frequencies lower than the cut-off frequency.

http://www.frogtech.com.au/potential-field-enhancements

Low-pass Filter

- A Low-pass (LP) filter passes low.
- Attenuates (or reduces) frequencies higher than the cut-off frequency.
- However, caution is warranted when interpreting the data, because the signals may also arise from aliasing of shallower sources.

http://www.frogtech.com.au/potential-field-enhancements

Analytic Signal (AS)

- Used to evaluate the major potential field variations and structures.
- Calculates the total amplitude of the three directional derivatives (in E-W, N-S and vertical directions).
- In the absence of high-frequency noise in the data, horizontal locations from Analytic Signal are highly accurate.

Upward and Downward continuation

- The process of transforming a data set that it appears that it has been measured at different height is called continuation.
- The process is called upward continuation if the data is being moved further away from source.
- The process is called downward continuation if the data is being moved toward the source.

Upward continuation

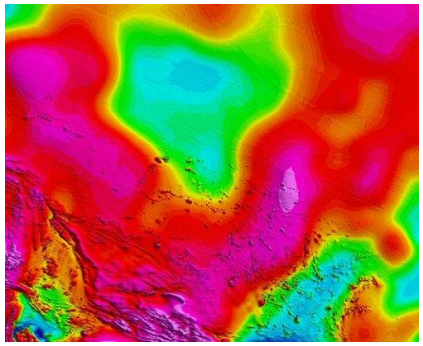
- Upward continuation is used to filter out the effects of near-surface heterogeneities which may not be of primary geological interest.
- It is also used to merge the data from two magnetic surveys, such as a ground-based and an airborne survey, by transferring them to a common altitude datum.

Downward continuation

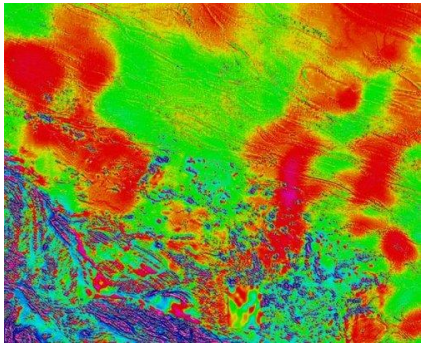
- Downward continuation emphasizes the smaller, shallower anomalies with steep gradients from broader, deeper sources, in other words from the regional anomalies.
- Downward continuation is an enhancement technique.
- The restriction is that the original anomaly field must be free from significant noise because the downward-continuation filter will emphasize all short wavelength components.
- This restriction is sometimes overcome by subjecting the anomaly field to a high-cut noise filter before or after downward continuation of the data.

Magnetic Data Processing

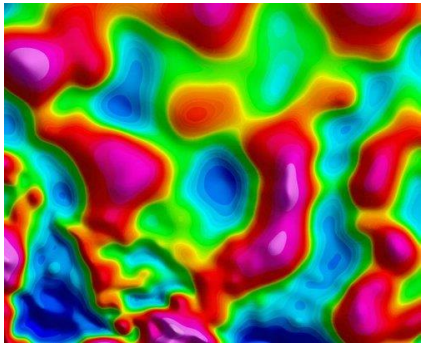
RTP



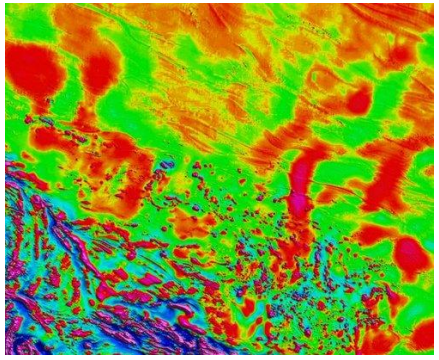
(1VD)



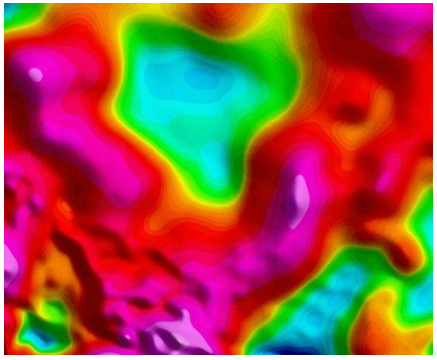
(BP)



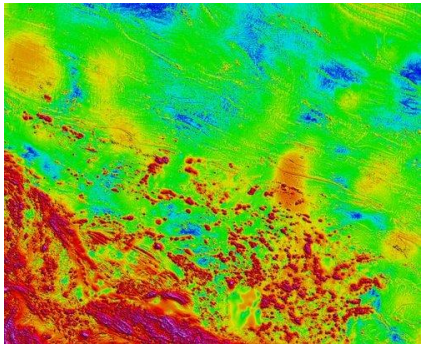
(LP)



(HP)



(AS)



Magnetic Data Interpretation

- End product of magnetometer survey – contoured anomaly map in gamma (or nT).
- Interpretation of magnetic data – similar to gravity data interpretation but more complicated because of:
    a) Dipolar nature of the magnetic field.
    b) The additional unknown parameter introduced by the direction of the magnetization in rocks.
- Two types of interpretation:
    a) Qualitative
    b) Quantitative – forward and reverse modeling and depth estimation

Qualitative interpretation of magnetic data

- Visual inspection of the shape and trend of the magnetic anomalies
- Delineation of the structural trends
- Close examination of the characteristic features of each individual anomaly:
    - The relative locations and amplitudes of the positive and negative parts of the anomaly
    - The elongation and areal extend of the contours
    - The sharpness of the anomaly as seen by the spacing of contours

In many cases meaningful geological information can be obtained directly by looking at the map, without making any calculations.

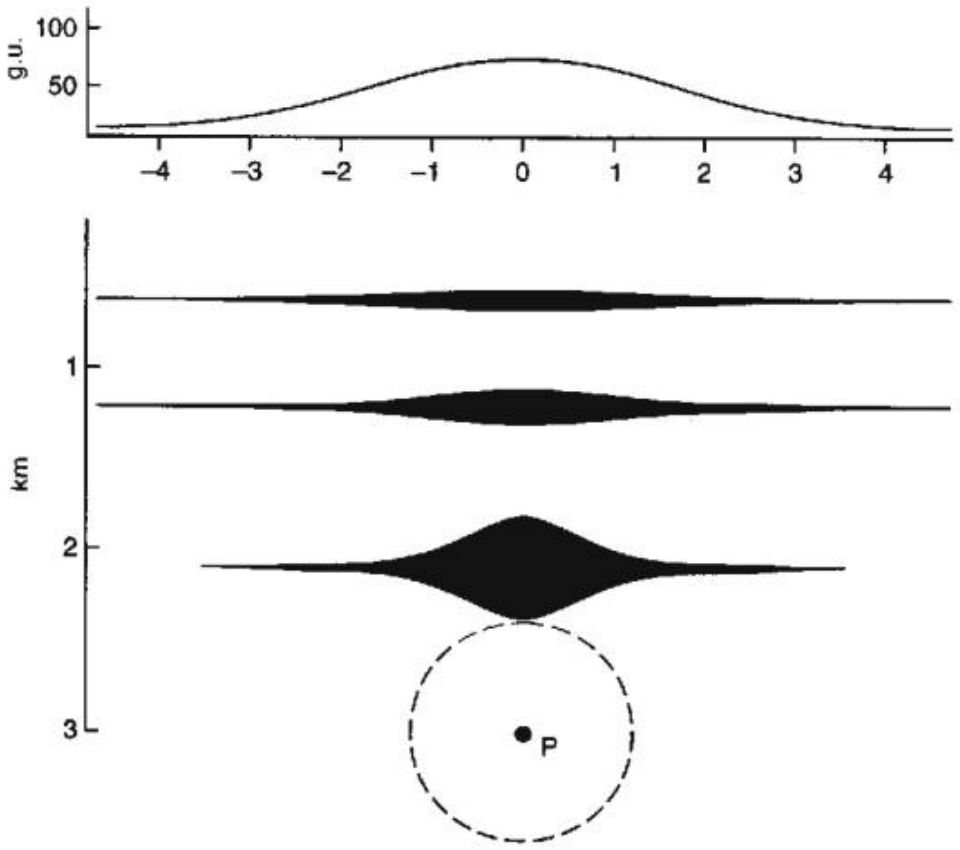
Quantitative interpretation of magnetic data

- From the relative spreads of the maxima and minima of the anomaly the approximate location and horizontal extend of the causative body can be obtained.
- Determine the shape and depth of anomaly from its form.
- The geometrical parameters must be translated into structural terms in the light of known geology.
- From the amplitude of the anomaly, the magnetization contrast can be determined.

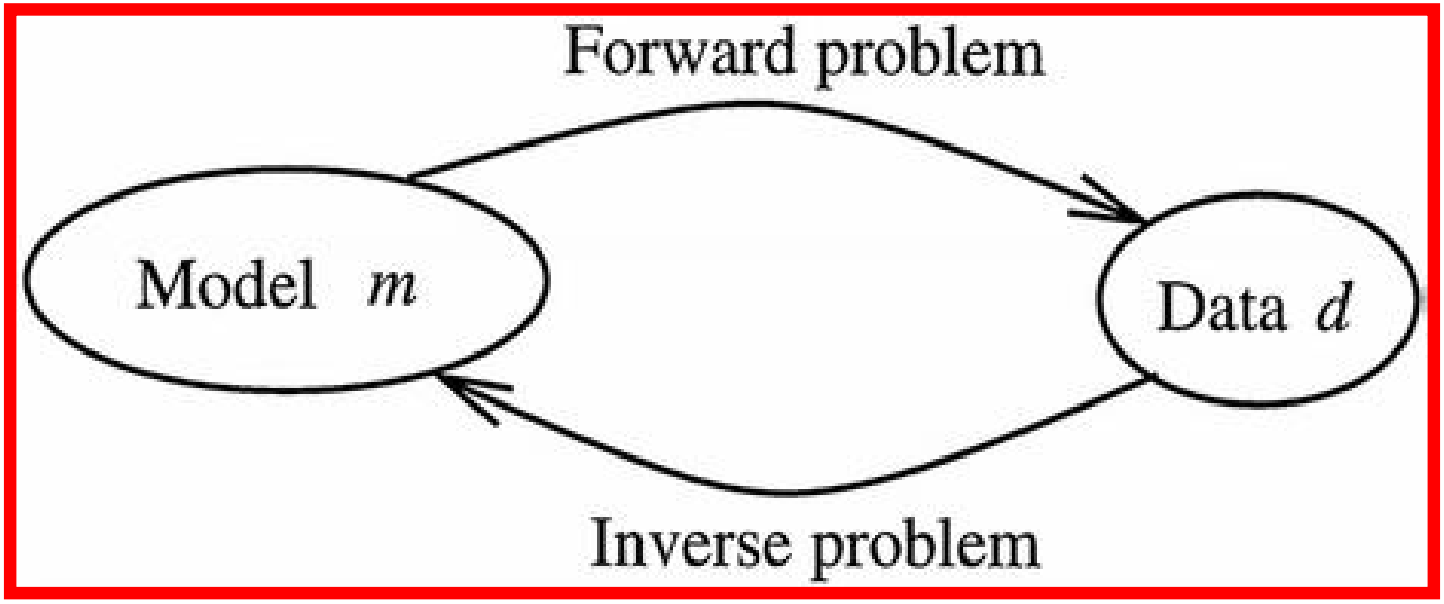
Ambiguity in magnetic interpretation

- A key element in successful magnetic interpretation is the quality and use of available ancillary data and information regarding the subsurface.
- Interpretation is ambiguous even in the case of high-quality data because the observed anomaly can be reproduced by an infinite number of source distributions shallower or possibly deeper than the actual source of the anomaly.

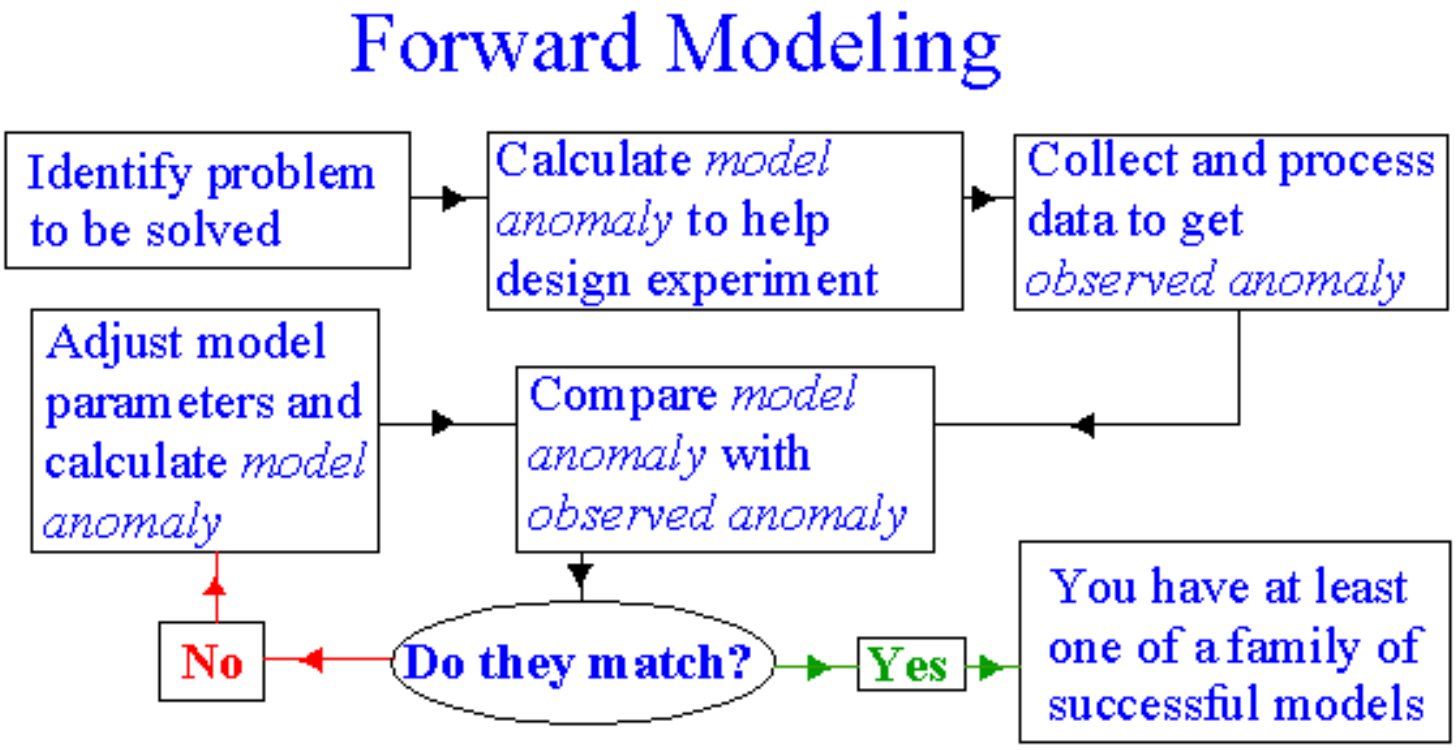
Ambiguity in magnetic interpretation



Forward and inverse modelling

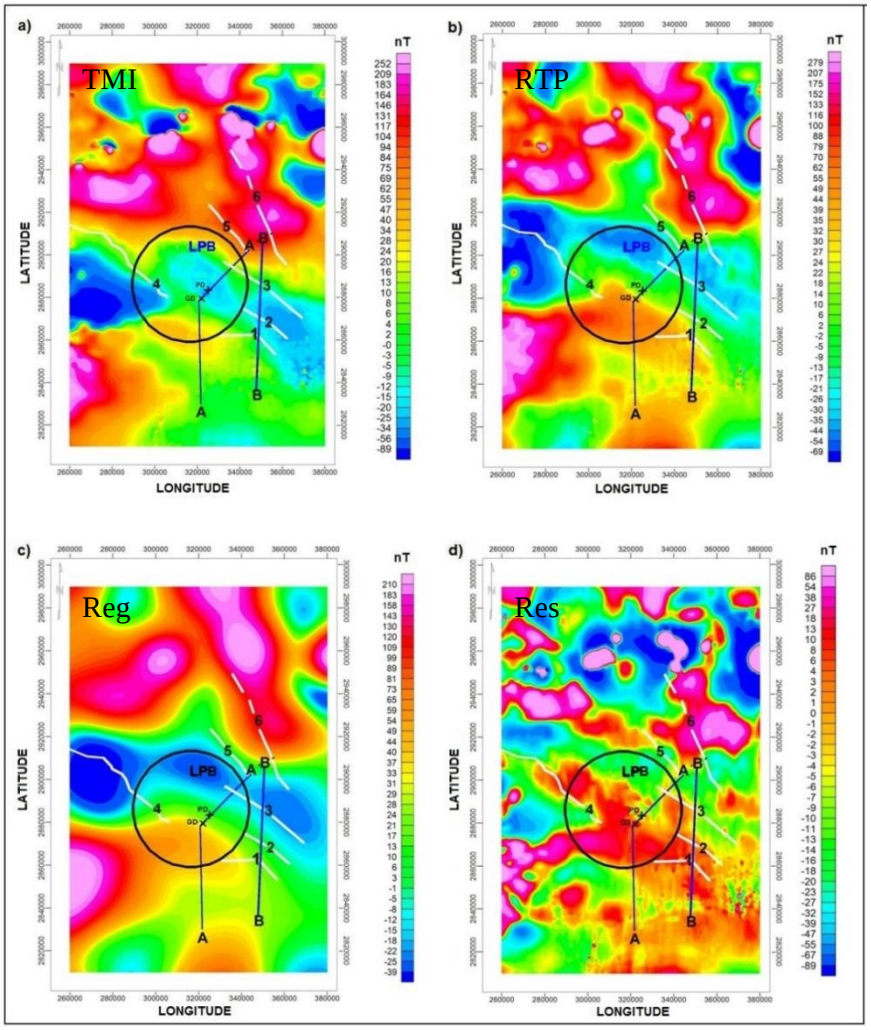


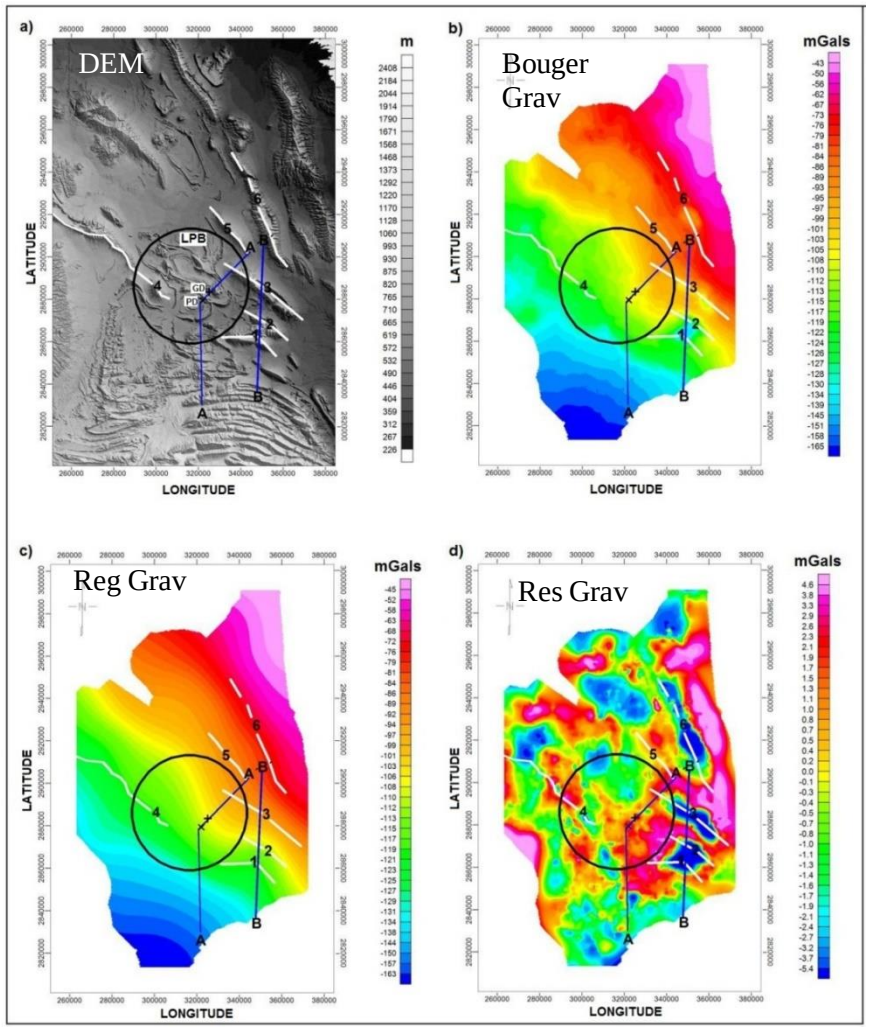
Forward Modelling



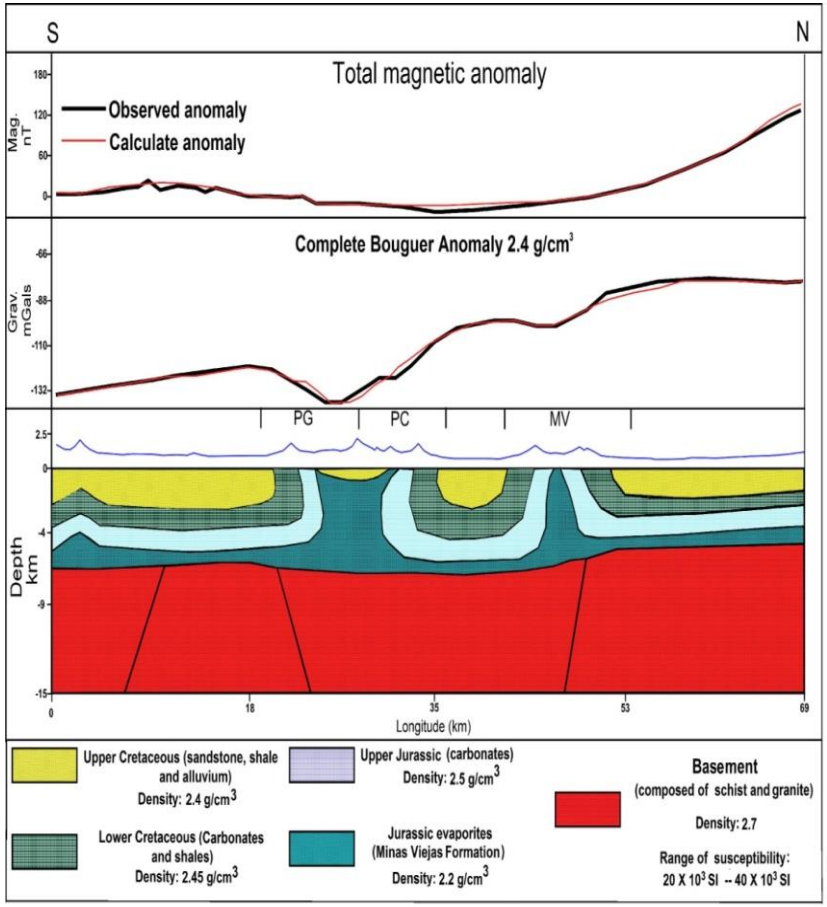
Forward modeling involves creating a hypothetical geologic model and calculating the geophysical response to that earth model.

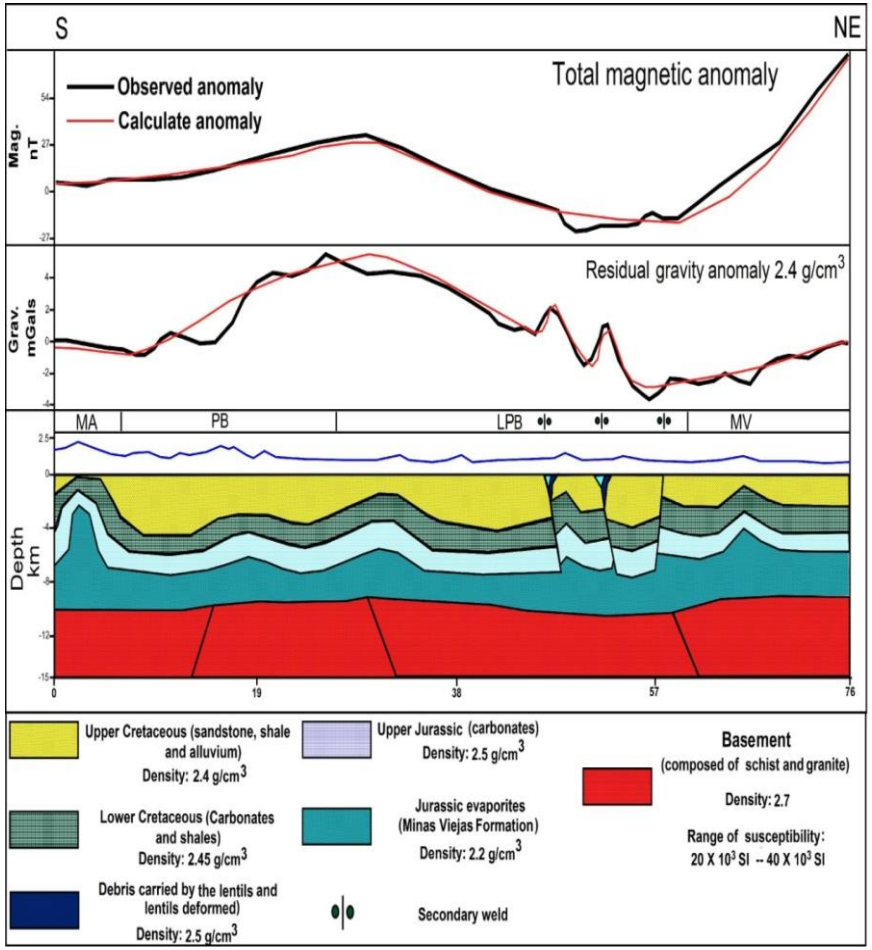
Forward Modelling



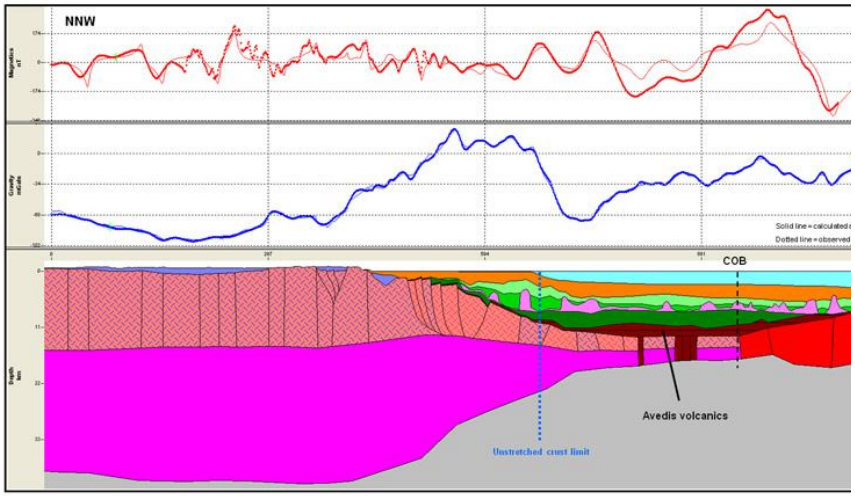


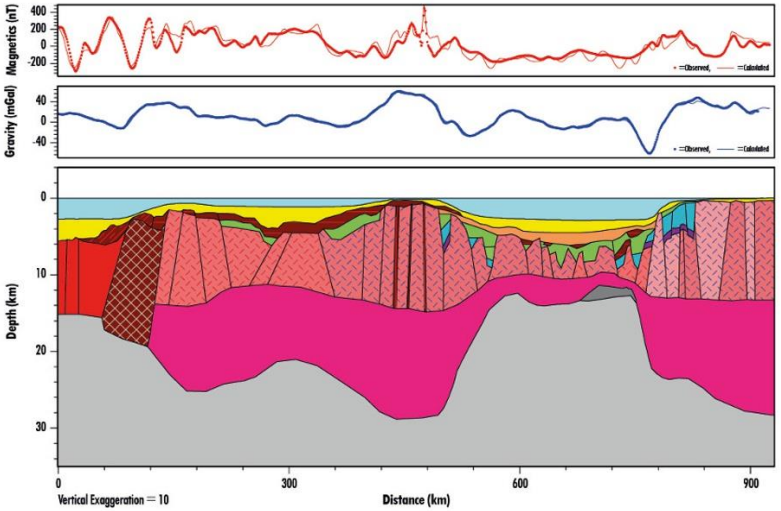
Forward Modelling





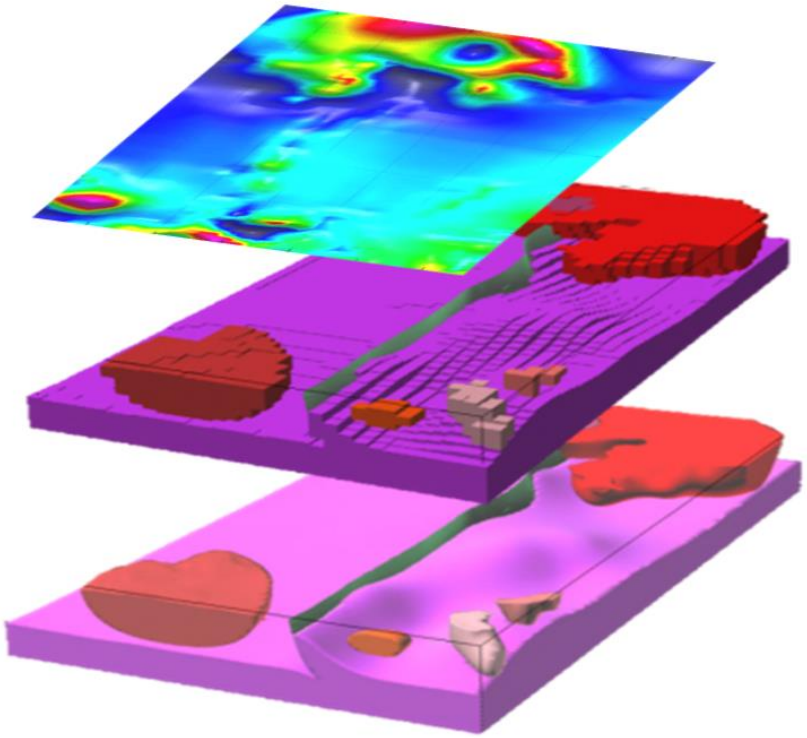
Forward Modelling





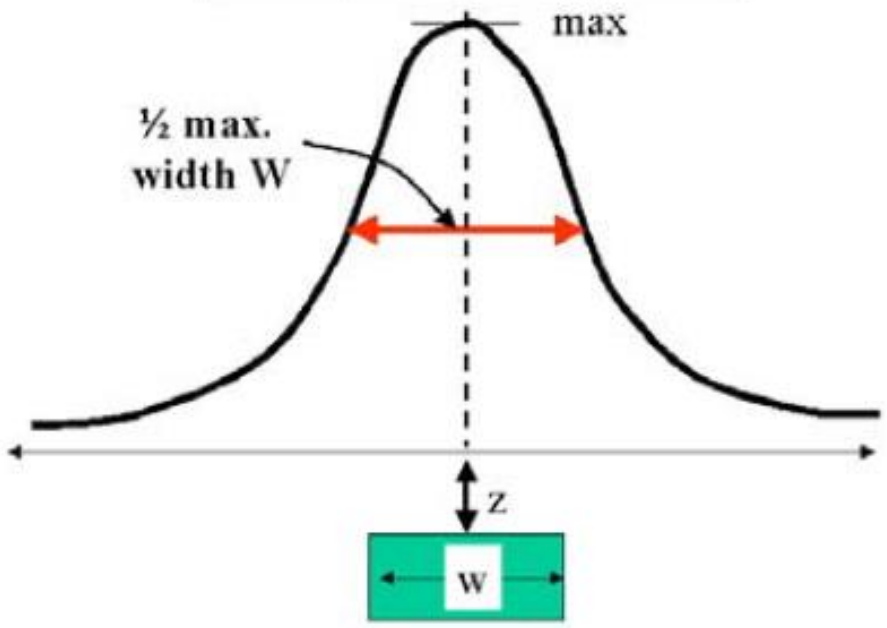
Inverse Modelling

Inverse modeling involves the reverse procedure. Starting with the observed geophysical response, an earth model that will provide the best fit to that data is calculated.



Half Maximum Width

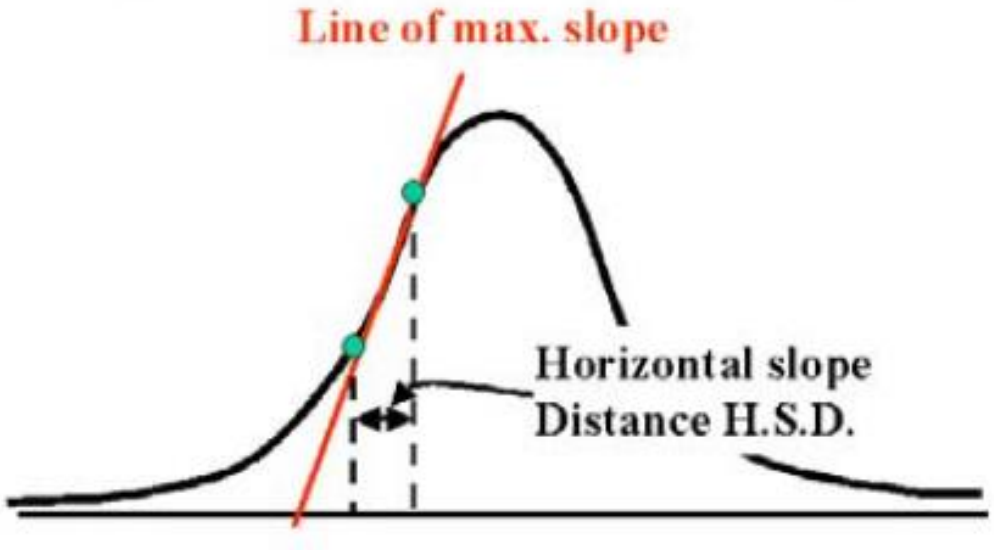
Large Block	Thick Dike	Thin Dike	Pipe
0.67xW W<Z	not Valid	0.5xW	0.66xW



(Henderson & Zietz , 1948)

Horizontal Slope Distance

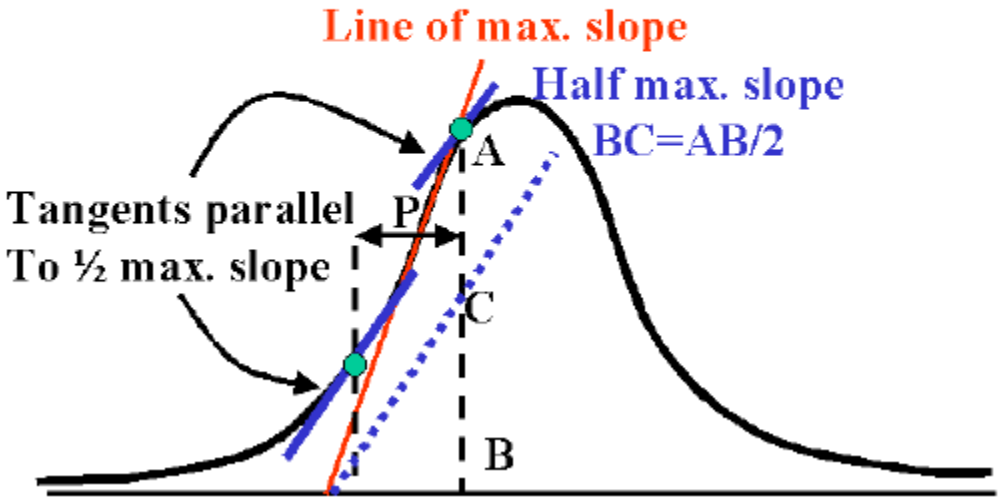
Large Block	Thick Dike	Thin Dike	Pipe
0.8xHSD	1.1xHSD	1.3xHSD	2.2xHSD



(Vacquier, 1951)

Peters Method

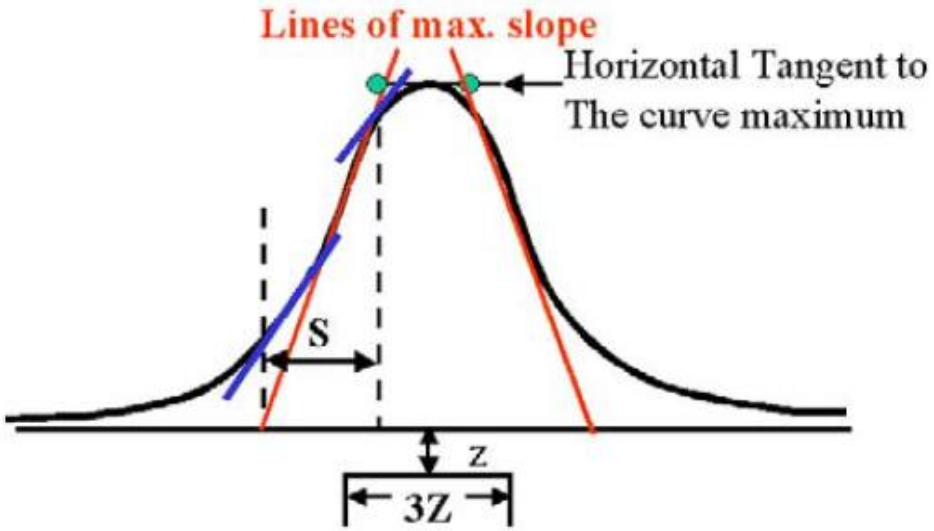
Large Block	Thick Dike	Thin Dike	Pipe
0.45xP	0.53xP	0.7xP	1.2xP



(Peters, 1949)

Sokolov Method

	Large Block	Thick Dike	Thin Dike	Pipe
Z =	0.3xS	0.35xS	0.6xS	0.8xS



(Sokolov, 1956)

Similarities Between Gravity And Magnetic

- The gravity and magnetic methods are often referred to as *potential methods*, and the gravitational and magnetic fields that we measure are referred to as *potential fields*.
- The *acquisition*, *reduction*, and *interpretation* of gravity and magnetic observations are very similar.

Similarities Between Gravity And Magnetic

- Small anomalies in large total field.
- Vary in *time* and *space*.
- Used as reconnaissance tools in exploration.

Differences Between Gravity And Magnetic

- The fundamental parameter that controls gravity variations is *rock density*.
- The densities of rocks and soils vary little from place to place near the surface of the earth.
- The highest densities we typically observe are about 3.0 gm/cm^3 , and the lowest densities are about 1.0 gm/cm^3.

Differences Between Gravity And Magnetic

- The fundamental parameter controlling the magnetic field variations of interest to us, *magnetic susceptibility*.
- On the other hand, can vary as much as four to five orders of magnitude.
- This variation is not only present amongst *different rock types*, but wide variations in susceptibility also occur within a given *rock type*.

Differences Between Gravity And Magnetic

- The gravitational force, which is always *attractive*.
- The magnetic force can be either *attractive* or *repulsive*.

Differences Between Gravity And Magnetic

- A reduced magnetic field, can have as its origin at least *two possible sources*. It can be produced via an *induced* or *remnant magnetization*.
- The gravitational field does not change significantly with time, the magnetic field is highly time dependent.