**Depth to the Bottom of magnetic sources (DBMS)**

* **There are Several spectrum methods for computing the DBMS**

**Spectral Peak method** (Spector and Grant, 1970; Shuey et al., 1977; Connard et al., 1983; Blakely, 1988)

The spectral peaks in the azimuthally averaged spectra are observed only when sources are randomly magnetised; with uniform magnetisation layers, the spectra have power-law form and no spectral peaks are observed

First, Spector and Grant (1970) used a statistical ensemble of sources to estimate the top depth and bottom depth of the magnetic sources by observing the peak in the radially averaged power spectrum.

The observed spectral peak position (kpeak) is a function of Zt and Zb and is given by the following transcendental equation (Connard et al., 1983; Blakely, 1995) from which Zb can be obtained by trial and error:

**Limitation:** the spectral peak is not always observed (e.g. spectra of uniformly magnetised layers keep rising at low wavenumbers with a power law form)

**Forward modelling of the Spectral Peak (**Ravat, 2004; Finn and Ravat, 2004; Ross et al., 2004**)**

**Centroid method** (Bhattacharyya and Leu, 1977; Okubo et al., 1985; Tanaka et al., 1999)

In this method, the depth estimate to the centroid Z0 is obtained from the slope of an azimuthally averaged, **frequency-scaled Fourier spectrum** in the **low wavenumber region**. The estimate of the depth of the top sources is obtained from the slope of the azimuthally averaged Fourier spectrum. The depth to the magnetic bottom is obtained from the equation.

Okubo et al. (1985) expanded on the use of the Bhattacharyya & Leu (1977) method and proposed that centroid estimates could be derived from high-pass filtered (as low as 40-50 km high-pass) magnetic data. However, this approach may result in the loss of important spectral information related to the depths of the deepest layers of interest.

In obtaining the depth to the top of the source using this method, Tanaka *et al.* (1999) advocated fitting the slope to a higher wavenumber part of the spectrum than the lowest wavenumber straight slope segment, arguing that the linearized equation for the depth to the top is valid for wavelengths greater than the thickness of the layer. This leads to deeper magnetic bottom estimates that, at times, appear to be desirable. However, in applications with real data, different slopes of the Fourier spectra imply the existence of multiple layered magnetic structures. Therefore, the major practical limitation in this usage is that the slope from the high-wavenumber part of the spectrum can give the depth to the top of a shallower layer—not the same layer as in the determination of the centroid— and, consequently, give a deeper estimate of the bottom of the deeper layer incorrectly.

**Power- law Corrections**

Power Spectrum analysis of Aeromagnetic data

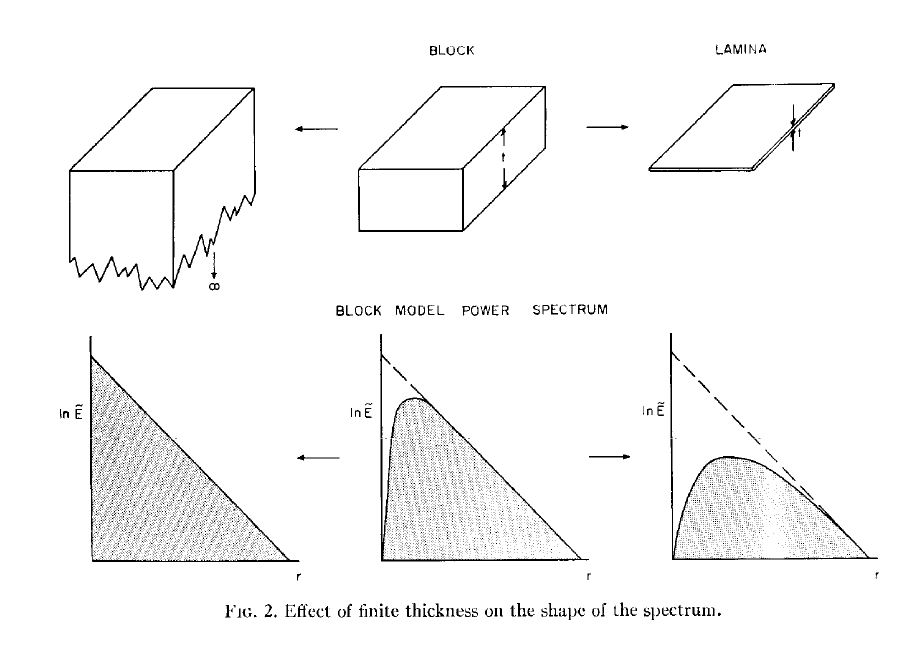
|  |  |  |
| --- | --- | --- |
| Research Article | Author | Conclusions |
| STATISTICAL MODELS FOR INTERPRETING AEROMAGNETIC DATA | Spector and Grant, 1970 |  |
| Analysis of Magnetic Anomalies Over Yellowstone National Park: Mapping  of Curie Point Isothermal Surface for Geothermal Reconnaissance | Bhattacharya and Leu, 1975 | The bottom of the magnetised crust determined from the spectral analysis of residual magnetic anomalies is generally interpreted as the level of the Curie point isotherm. |
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|  |  |  |

**Spector and Grant (1970)**

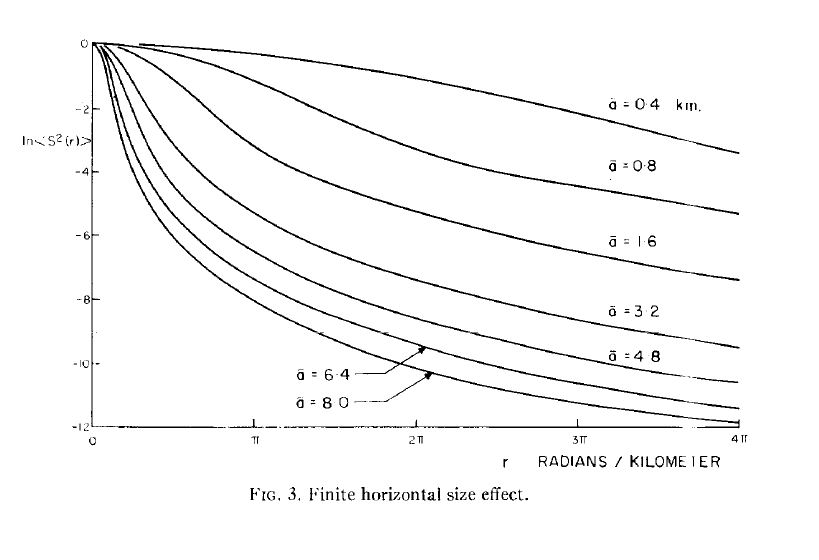
* This method assumes a uniform distribution of parameters for an ensemble of magnetised blocks, leading to a depth-dependent exponential rate of decay.
* This model is a power law rate of decay that is independent of depth.
* All ensemble parameters were uniformly and independently distributed.

**Effect of depth:** the e-*2hr* term is a dominating factor in the power spectrum. Map spectra are usually declining functions of *r,* whose rate of decay is largely determined by the mean depth of the bodies

**Effect of depth extent**: the thickness plays an interesting role in shaping the power spectrum. When combined with the depth factor the effect is to introduce a peak into the spectrum whose position shifts toward smaller wavenumbers with increasing values of thickness. If the majority of the bodies in the area extend to such depths that their bottoms cannot be discerned clearly through the map window, thickness becomes so large that the spectrum peak cannot be seen at all. In that case, we get the spectrum for an ensemble of bottomless prisms, a spectrum which has its maximum value at *r =0*. Whether the sources appear to be depth-limited or not will depend very much upon the size of the map.



**Effect of Size:**

****

**Double ensemble case:** The power spectrum of the double ensemble consists of two parts. The first, which relates to the deeper sources, is relatively strong at the small wavenumbers and decays away rapidly. The second, which arises from the shallower ensemble of sources, dominates the short wavelength end of the spectrum.

**Bhattacharya and Leu (1975)**

* The observed magnetic field at a point is the vectorial combination of fields produced by various sources.
* Residual anomalies, i.e. after subtraction of the regional field, contain a large number of small-wavelength, high-intensity anomalies created by magnetized sources at the surface or at shallow depth. These anomalies distort and sometimes completely mask the effects of deep-seated bodies.

**Gragotsil et al., 1991**

**The occurrence of similar magnetic anomaly patterns and coherent units of susceptibility over a range of spatial scales suggest a self-similar or fractal description of magnetic susceptibility.**

**Pilkington and Todoeschuck (1993)**

* If the power spectrum of the susceptibility or magnetization of the crust is known, then the power spectrum of the magnetic field at the surface can be calculated.
* If the scaling exponent is positive, values are aanti-correlated successive points are likely to have opposite signs. When = 0, we have the familiar white power spectrum. Successive points are completely uncorrelated. When alpha is negative, the series becomes more correlated, and alpha becomes more negative.

**Blakely,1996**

* **Magnetization and density are not completely uncorrelated but rather have a degree of self-similarity. Magnetisation and density can be described as a form of fractal geometry, called scaling noise.**

**Fedi et al., 1997**

* For most cases, except for extreme depths and small block sizes, the observed power spectrum should be corrected for a power law decay rate of ~3.
* If the depth distribution of the magnetic blocks is Gaussian, then the observed power spectrum should be corrected for both a depth-independent power law and exponential decay.
* This power law decay is very similar to the scaling behavior, supposed as a fractal character, of observed magnetic field.
* Magnetic power spectra should be corrected for a power law decay before applying the Spector and Grant method for depth determination.
* Significant insights into the internal earth structure have been obtained from its gravity and magnetic fields, which reflect the way in which density and magnetisation are distributed. Since such fields arise from the superposition of many sources of variable size, they can appear similar over many spatial scales.
* The scaling properties of the source distribution are related to the scaling properties of the fields (Maus and Dimri, 1994).
* The rate of decay of the spectrum is determined by two parameters, the exponent of the power law(-bita) and the depth.

**Ravat et at., 2007**

* Using windows with sufficient width to ascertain that the response of the deepest magnetic layer is captured and by verifying the spectra and computing the depth estimates with the largest possible windows (>300-500 km)
* Avoiding filtering to remove arbitrary regional fields, accomplished by compiling magnetic anomalies derived from modern spherical harmonic degree 13 Earth’s main field models
* Ascertaining the near circularity of the autocorrelation function to avoid analysing biased spectra containing strong anomaly trends.
* Avoid determining the slopes from the exponential, low wavenumber part of the spectra in the cases of layered magnetization.

**Introduction**

Deriving the depths to the bottom of the magnetic sources is important for constraining temperatures in the crust and, thus, the rheological nature of the Earth's lithosphere.

**The background of the methods, the rationale, and the key observations**

Two types of methods have been commonly used in the spectral estimation of the depth to the bottom of the magnetic layer: the spectral peak methods originally given in a landmark paper by Spectra & Grant (1970) and used by Shuey et al., (1977), Connard et al., (1983) and Blakely (1988) among others, and the centroid method originally presented by Bhattacharyya & Leu (1977) and used with certain caveats and variations by Okubo et al.., (1985) and Tanaka et al., (1999). Both methods need a priori estimation of the depth to the top of the same layer. Spectral peaks in the azimuthally averaged spectra are observed only when sources are randomly magnetized as prescribed by Spector & Grant (1970); with uniform magnetization layers, the spectra have power law form and no spectral peaks are observed.

Spectra & Grant (1970) showed that the logarithms of azimuthally averaged Fourier spectra of magnetic anomalies from ensembles of simple sources are related to the depth to the top of the ensemble, and also, spectra have peak positions on the wavenumber axis that are related to the thickness of the magnetic sources.

**The centroid method**

In this method, the estimate of the depth to the centroid is obtained from the slope of an azimuthally averaged frequency-scaled Fourier spectra in the low wavenumber region.

Okubo et al. (1985), elaborating on the application of the Bhattacharyya & Leu (1977) method, suggested that one could obtain centroid estimates from the high-pass filtered magnetic data; however, this leads to the elimination of meaningful part of the spectra-related to the depths to the deepest layers of interest

In obtaining the depth to the top of the source using this method, Tanaka et al. (1999) advocated the slope to a higher wavenumber part of the spectrum than the lowest wavenumber straight slope segment, arguing that the linearized equation for the depth to the top is valid for wavelengths greater than the thickness of the layer. This leads to deeper magnetic bottom estimates that, at times, appear to be desirable. However, in applications with real data, different slopes of the Fourier spectra imply the existence of multiple layered magnetic structures. Therefore, the major practical limitation in this usage is that the slope from the high–wavenumber part of the spectrum can give the depth to the top of a shallower layer – not the same layer as in the determination of the centroid and, consequently, give a deeper estimate of the bottom of the deeper layer incorrectly.

**Power law corrections**

Fedi *et al.* (1997) noted that when the random source variation is large, the Spector & Grant (1970) equation has an inherent power-law form,

* In the spectral peak method, spectral peaks are observed only when the sources are randomly magnetised (Spector and Grant, 1970); with uniform magnetisation layers, the spectra have power-law form and no spectral peaks are observed.
* Spector and Grant (1970) showed that the slopes of logarithms of azimuthally averaged Fourier spectra of magnetic anomalies from an ensemble of simple sources are related to the depth to the top of the ensemble. Also, the spectra have peak positions on the frequency or wavenumber axis that are related to the thickness of the magnetic source layers.
* Deriving the depths to the bottom of magnetic sources is crucial for determining crustal temperatures and the rheological nature of the Earth's lithosphere (Ravat et al., 2007).

The factors for converting the spectral slopes to depths using the relationship slope = factor\*Z (Ravat et al., 2007)

|  |  |  |
| --- | --- | --- |
| The ordinate of the spectral plot | The factor for amplitude spectrum | The factor for the power spectrum |
| Frequency (f) (1km-1) | 2π | 4π |
| Wavenumber (k) (1km-1) | 2π | 4π |
| Wavenumber (k) (2π km-1) | 1 | 2 |

**Bansal et al., 2011**

The power spectrum *P* for the 2D assemblage of bodies can be written as (Spector and Grant, 1970; Blakely, 1995)

**, (1)**

Where and are the wavenumbers in the x and y directions; is a constant of proportionality; is the power spectrum of the magnetization; and are the directional factors related to the magnetization and geomagnetic filed, respectively; and are the top and bottom depth of the magnetic sources. After annular averaging, equation 1 can be written as

**(2)**

Where is a constant, equation (2) can be further simplified to compute the centroid depth of magnetic sources from the slop of the radially averaged frequency scaled power spectrum in the low wavenumber part (Bhattacharyya and Leu,1975,1977; Okubo at al., 1985).

(3)

Where ln is the natural logarithm and is a constant. Equation 2 is also simplified to compute the top of magnetic sources by assuming that the signals from the source tops dominate the power spectrum (Spector and Grant, 1970; Bhattacharyya and Leu,1975,1977; Okubo at al., 1985)

(4)

The estimates of DBMS are performed in two steps: (1) calculate the centroid depth of the deepest magnetic sources using tquation 3, and (2) calculate the top depth of the deepest magnetic sources using equation 4. This approach is known as the centroid depth method.

DBMS can be calculated as

(5)

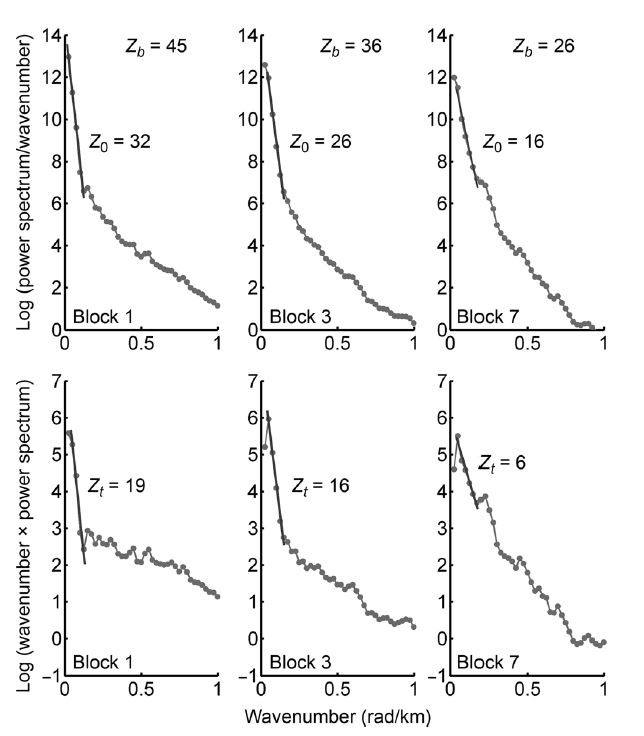


Figure 6. Power spectra versus wavenumbers for calculating the centroid and top depths of the deepest magnetic sources for blocks 1, 3, and 7. (top row) Wavenumber scaled power spectrum for computing centroid depth. (bottom row) Power spectrum for calculating top depth. The x-axis is shown only up to 1.0 rad=km, whereas the Nyquist wavenumber is 2p rad=km. The centroid and top depths are shown after applying the correction for the reference altitude of the magnetic anomaly data of 1 km above sea level. Therefore, given depths refer to mean sea level.

**Kumar et al., 2020**

Blakely (1995) presented a relation between the power spectra of the magnetic field and magnetization in terms of depth to the top and bottom of an anomalous body while assuming a constant vertical magnetization for the uncorrelated source distribution (Spector and Grant, 1970). The power spectra of the total magnetic anomaly can be written as:

**(1)**

Where and are the wavenumbers in the x and y directions and their Euclidean norm, ; is a constant of proportionality; is the power spectrum of the magnetization; and are the directional factors related to the magnetization and geomagnetic filed, respectively; and are the top and bottom depth of the magnetic sources. In the case of the one-dimensional radial average power spectrum, the terms and become constant. The magnetization term, , becomes constant for a random and uncorrelated distribution of sources.

From several bore-hole studies, it is found that magnetic sources are correlated in space and have a coloured amplitude spectrum in the frequency domain (Pilkington and Todoeschuck, 1993; Maus and Dimri, 1994; Fedi et al., 1997). In the case of the fractal/scaling nature of the source distribution, eq. 1 can be written in terms of the 1D radial average power spectrum (Bansal et al., 2011; Li et al., 2017).

**(2)**

Where is aconstant and is the scaling exponent related to lithology and heterogeneity of the subsurface (Bansal et al., 2010, 2011).

**Centroid method**

The centroid method was originally proposed by Bhattacharyya and Leu (1975, 1977). The method involves the estimation of the top and centroid depth of the horizontally seated magnetic slab of uniform magnetization from the radially ageraged power spectrum of the magnetic data. Later, the method was modified foe ensembles of sources with random magnetization (Okubo et al., 1985; Tanaka et al., 1999).

Moreover, for scaling source distribution, eq. (2) can be simplified in terms of centroid depth

**(3, check this equation it will be amplitude spectra)**

**Eq. (3) can be simplified in terms of the centroid depth at low wavenumbers of the radially averaged power spectra (Bansal et al., 2011),**

**(4)**

**The method is called a modified centroid method**

**Considering random and uncorrelated source distribution , eq. (4) can be converted to centroid method (Tanaka et al., 1999)**

**(5)**

For medium to high wavenumbers, eq. (2) can be written as (Bansal et al., 2011; Fedi et al., 1997; Maus and Dimri, 1995)

**(6)**

Where  **is constant. For random and uncorrelated course distribution (Spectra and Grant, 1970), eq. (6) can be simplified as**

**Synthetic Data**

Two‐dimensional synthetic magnetic fields are generated using the Pilkington and Todoeschuck (1993) approach, which is widely used in recent publications (e.g., Bouligand et al., 2009; Chen et al., 2016; Li et al., 2013).

**Demarco et al., 2021**

From the analysis of the crustal magnetization of the field, it is possible to calculate the depth below which no magnetisation could exist i.e. depth to the bottom of the magnetic source (DBMS). And the DBMS can be related to the depth at which rocks lose their magnetic properties due to the interior temperature i.e. when rocks mineral reaches its curie temperature. As a result, DBMS is often considered with the Curie isotherm depth also curie point depth.

Rocks magnetization depends on composition (amount of magnetic minerals) and temperature. In fact, thickness estimates of the magnetized earth’s crust suggest that there can be two limits corresponding to vertical changes in composition and/or temperatures at which rocks lose their ferromagnetic properties. In this regard, DBMS can sometimes represent a petrological limit (Langel & Hinze 1998; Rajaram et al., 2009; Blakely 1998). At depth, the composition of the crust can change, so that rocks become poor in magnetic minerals.

**Note:** In regions of very low thermal flux (e.g. shield areas) the curie isotherm can be found below the Moho, but the mantle rocks are often believed to be non-magnetic DBMS in those regions may correspond to the Moho instead of the curie isotherm. However, some studies have concluded that the upper mantle can also contribute to the geomagnetic field in some tectonic environments. For example, in regions with low thermal flux or alternatively in regions with thin crust as in oceanic regions. Curie isothermal depth is most likely reached in the upper mantle rather than in crust. When DBMS correlates with a velocity or density limit, it most likely reflects a compositional change. However, when it does not coincide with such kinds of limits, it more likely reflects the depth to Curie isotherm (Beardsmore & Cull 2001). The DBMS allows us to estimate the depth at which Curie temperature is reached and, therefore, the geothermal gradient in the studied region.  **Magnetite is considered as the magnetic mineral. The curie temperature of the magnetite is 580 C when it is pure, but it can drop down to 300 C for titanium magnetite or rise to up to 620 or 1100 C for Fe-Co-Ni alloys. The generalization of 580 C as the temperature of curie isotherm is a reasonable approximation for the continental crust (Ross et al., 2006), but it should be considered with appropriate caution.**

**(1)**

**(2)**

**Where A is constant. applying to both sides of the equation yield:**

**(3)**

**For medium to high values *k*, the exponential terms go to zero, and the logarithm also approaches zero. Hence, eq. (3) corresponds to a line with a slope equal to 2**

**(4)**

**Dividing (4) by 2 gives:**

**(5)**

**Therefore, we can calculate the power spectrum of our magnetic data, then the radial average of the power spectrum and finally determine the slope for long wavelength and thus obtain the depth to the top of the magnetic layer using equation (5)**

**On the other hand, rearranging terms and multiplying by , eq. (2) can be written as:**

**(7)**

**Substituting the last exponential terms of eq. (7) by the first terms of their Taylor series approximation, for ~0, yields:**

**(8)**

**(9)**

**Considerations about the centroid method**

* There are several applications that calculate and in the same wavenumber ranges (Ates et al., 2005; Bansal et al., 2011; Zaher et al., 2018; Quintero et al., 2019)
* Or different ranges but using the same curve (Bello et al., 2017; Aliu et al., 2018)

**Unit systems**

* Wavenumber units are another source of confusion, as was noted by Ravat et al., (2007).
* Wavenumbers can be expressed in radians km-1 (noted as 2π km-1) or cycles km-1 (1 km-1)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Wavenumber (1 km-1) | | Wavenumber (2π km-1) | |
| Amplitude Spectrum | Power  Spectrum | Amplitude Spectrum | Power  Spectrum |
| Depth | Slope/2π | Slope/4π | slope | Slope/2 |

**Wavenumber ranges**

* **Other complexities of the method lie in defining the wavenumber ranges in which cap Zt and cap Z0 should** be calculated.
* Most of the authors do not specify the wavenumber ranges and usually select them by hand according to the patterns observed in each spectrum.
* In some cases, the centroid depth is calculated in narrow ranges (0~0.05 rad/km), while in others, it is calculated in extremely wide ranges (0~0.4 rad/km).
* **Zt can be calculated in almost all ranges of k>0.05 rad/km (Demarco et al., 2020) on the basis of the slope difference between linear approximation and the theoretical curve.**
* **The range of wavenumber between 0 and 0.05 rad/km appears to be the most confident region to calculate Z0**

**Speaker Notes:**

* "To calculate ZtZ\_tZt​, we can use data for wavenumbers greater than 0.05 radians per kilometer."
* "This approach is based on the method described by Demarco et al. in 2020."
* "The key to this calculation is the slope difference between the linear approximation of our data and the theoretical curve."

**Slide: Reliable Region for Z0Z\_0Z0​ Calculation**

**Speaker Notes:**

* "For Z0Z\_0Z0​, the most reliable calculations come from the wavenumber range between 0 and 0.05 radians per kilometer."
* "This range has proven to be the most dependable for accurate Z0Z\_0Z0​ estimations."

**Pappa et al., 2019**

**Gravity suffer from nonantiques and thus suffer for addition constraint. In relation to crustal thickness, thic can be a certain density contrast at the Moho, in combination with a reference**

**Labani Ray (2021)**

**Prasad et al., 2023**

**Effect of window size and scaling exponent on DBMS estimation**

* Choosing these two parameters depends on the amplitude of the magnetic field and the tectonic settings of the region.
* To fix the window size and scaling exponent value, we performed synthetic data analysis.
* On what basis Magnetisation 1.50 A/m and standard deviation 0.20A/m was decided?
* How do you generate the magnetic anomaly?
* How to get the maximum wavenumber 1.5 km-1?

**Surface heat flow analysis**

Assuming that conduction is the main mechanism for the heat transfer, the surface heat flow is computed from the DBMS values using Fourier’s law as:

(1) (negative indicates the heat flow in the direction of the decreasing temperature)

Eq. (1) is a simple 1D equation assuming heat flow in a vertical direction, steady-state heat conduction, and constant thermal conductivity in the medium. The solution to eq. (1) can be achieved if the surface heat flow is related to the DBMS (Turcotte and Schubert, 2014) and is given by

(2)

where λ is the coefficient of thermal conductivity, θc is Curie temperature, which equals 580 ◦C (magnetite), Ts is the surface temperature (15◦C), Zb is the DBMS, Ao is the radiogenic heat production and hr is the length scaling (considered as 9 km) for Ao and decreases with depth (Martos et al., 2017).

* The derived proxy surface heat flow varies between 40 and 125 mW/m2.
* High heat flow values are observed towards the north of the Singhbhum nucleus and the south-eastern part of the CGC (90-125mW/m2).
* Moderate heat flow values are observed over the western part of the Singhbhum Craton, Singhbhum Mobile Belt and southwestern part of the CGC (~70mW/m2).
* The Eastern Ghats Mobile Belt and Bengal basin have low heat flow values (40-70mW/m2).

Presentation mode

To fix the window size and scaling exponent, we performed the synthetic data analysis. A 3D magnetization volume is produced using the Pilkington and Todoeschuck (1993) approach and generates a three-dimensional magnetization model of dimension N x N x n. The cubic cells 1x1x1 km3 are assigned with a mean magnetization of 1.5 A/m and standard deviation of .20 A/, where N and n are the numbers of cells in the horizontal and vertical dimensions.

* Chatgpt(Let's start with the high heat flow regions. These are primarily located towards the north of the Singhbhum nucleus and the southeastern part of the Chhattisgarh Craton, or CGC. In these areas, the heat flow values range from 90 to 125 mW/m², indicating a high level of geothermal activity.

Next, we have the regions with moderate heat flow values. These areas include the western part of the Singhbhum Craton, the Singhbhum Mobile Belt, and the southwestern part of the CGC. Here, the heat flow values are around 70 mW/m², showing a moderate level of geothermal activity.

Lastly, the regions with low heat flow values are the Eastern Ghats Mobile Belt and the Bengal Basin. In these areas, the heat flow values range from 40 to 70 mW/m², indicating relatively lower geothermal activity.

In summary, the variation in surface heat flow across these regions highlights different geothermal characteristics, with higher values suggesting more geothermal activity or possibly a thinner crust, and lower values indicating less geothermal activity or a thicker crust).

**Turcptte**

* The average heat flux at the Earth’s surface provides important information on the amount of heat being produced in the Earth and the temperature distribution in its interior.
* Temperature measurements in caves and mines give approximate values for the near-surface thermal gradient; accurate measurements of the thermal gradient in continental areas require deep drill holes.
* Since the thermal conductivities of near-surface rocks are usually in the range 2 to 3Wm−1 K−1, the heat flow to the surface of the Earth implied by these temperature gradients is 40 to 90 mWm−2.
* Dep measurements are necessary because climatic variations in the Earth’s surface temperature, particularly those due to ice ages, influence the temperatures on the near-surface.
* In order to reach the steady state thermal structure, holes must be drilled deeper than about 300m.
* The mean heat flow of all continents is about 65 mW/m2.
* Approximately one-half of the heat flow in the continents can be attributed to the heat production from the radioactive isotopes of uranium, thorium, and potassium in the continental crust.
* Surface heat flow systematically decreases with the age of the surface rocks in stable continental areas.
* Similarly, the concentration of the radioactive isotopes in the surface rocks also decreases with the age of the rocks.
* The conclusion is that the decrease in the surface heat flow with age in stable continental areas can be primarily attributed to the decrease in the crustal concentrations of heat-producing isotopes.
* The mean measured heat flow for all the oceans is 101 mW/m2.
* The contribution of heat production by the radioactive isotopes in the oceanic crust to the surface heat flow is negligible (~2%).
* Mean surface heat flow is about 87 mW/m2

**Question and Answer**

* What are the statistics?
* Numbers that have been collected in order to provide information about something.
* What is the statistical model?
* An ensemble of blocks of varying depth, width, thickness and magnetisation is considered a statistical model.
* What is the Statistical analysis?
* Statistical analysis is the process of collecting and analysing data in order to discern patterns and trends.
* What do mean by fractal?
* Fractals means a self-similarity across different scales
* an irregular shape that looks the same at any scale on which it is examined.
* A fractal is an infinite pattern that appears similar no matter how closely we look it.
* **The occurrence of similar magnetic anomaly patterns over a range of spatial scales suggests a self-similar or fractal description of the magnetic source (Susceptibility).**
* What do mean by Stochastic?
* Stochastic means random or probabilistic. This acknowledges that there's an inherent level of randomness or uncertainty in the magnetic data.
* What do you mean by Gaussian Distribution?
* This is a symmetrical, bell-shaped probability distribution. It implies that most magnetic blocks will have depths close to a certain average depth (the mean), with progressively fewer blocks at shallower or deeper positions. The standard deviation quantifies the spread around the mean.
* There are a couple of reasons why a Gaussian distribution might be used to described the depth distribution of magnetic blocks:

1. **Geological Processes:** Many natural processes, including the formation of geological structures, can be modelled by random variations around an average value. A Gaussian distribution reflects this randomness, suggesting that clustering of blocks around a certain average depth is more likely than finding them at extreme depths.

* Average depth?
* **Average depth provides a general understanding of where sources are concentrated within the Earth**.
* What is the Isotherm?
* A line of the same temperature on the map.
* What is the heat and temperature?
* Temperature is the degree of hotness or coldness of a substance or Temperature is the measure of hotness and coldness. Heat is a form of energy associated with the motion of atoms or molecules.
* What is the Geothermics
* Geothermics is a branch of geophysics that deals with the thermal state of the earth, the heat budget of the earth, and temperature variations inside the earth.
* What is the Fourier transform?
* The Fourier transform is a mathematical tool used to analyze signals. It provides the frequency information of a signal. FT is complex and contains information on amplitude and phase relationships about all the frequencies.
* What is the basic goal of your research?
* Why do we choose logarithmic spectra?
* What about RTP?
* What are the properties of the power spectrum?
* What is the heat flow?
* What is the thermal conductivity?
* The thermal conductivity of a material is **a measure of its ability to conduct heat**.
* What are the factors that control the Geothermal heat flux?
* Geothermal heat flux depends on several geological factors including heat flow from the mantle, heat production in the crust by radioactive decay, and tectonic history
* What is the conduction, convection and radiation?
* They are the mechanisms for the transfer of heat. In conduction, heat energy is passed from one molecule to another through direct contact. Convention is the transfer of heat by the physical movement of a fluid (which can be a liquid or a gas). It is associated with the motion of a medium. Radiation is the transfer of heat through electromagnetic waves. In the Earth, radiative heat transfer is only important on a small scale, and its influence can be absorbed into the definition of thermal conductivity.
* What is the thermal conductivity?
* What is the heat production?
* What is the rheology?
* The study of the deformation and flow behaviour of the matter.
* The way in which a solid reacts to stress depends on how large the stress is and the length of time for which it is applied. The time-dependent deformation is called plastic flow, and the capacity of the solid to flow is called its ductility.
* What is the power law form?
* What is the fast Fourier transform (FFT)?
* FFT is an algorithm to compute the Discrete Fourier Transform (DFT) and its inverse. It converts the time domain signal into the frequency domain.
* How you define the uncertainty in DBMS?
* The uncertainties in the DBMS are based on the uncertainties in fitting the data when deriving top depth and centroid depth and calculated as follow
* What do you mean by first order trend?
* This refer to a linear trend. A first order trend can obscure the true frequency components of the signal.
* How to choose the wavenumber range for estimating the top and centroid depth?
* has the elevation been removed from the DBMS to show the DBMS from the mean sea level?

**Isostasy**

* the compensation of a topographic load by a less-dense subsurface structure as isostasy.
* The concept of isostasy is essential to the understanding of the geodynamics of topography. Isostasy provides a simple explanation for the formation of mountains and sedimentary basins. Under compressional forces the continental crust thickens, forming mountains and their crustal roots. Under tensional forces the continental crust thins, leading to surface subsidence and sedimentary basins.
* What is the isostatic anomaly?
* Isostatic anomaly is a measure of the degree of compensation.
* The isostatic gravity anomaly is defined as the difference between the Bouguer gravity anomaly and the computed anomaly of the root-zone
* What is the cause of the isostasy anomaly?
* Isostatic anomaly is mainly caused by intra-crustal masses.

**Inversion**

* **The basic statement of an inverse problem is that the model parameters and the data are in some way related. his relationship is called the model.**

**Forward Problem:**

**Model {model parameters m, sources s}**

* Correlated and uncorrelated distribution of the magnetic sources

**Correlated Random Distribution:**

* **Meaning:** Here, the magnetic fields from multiple **randomly located** sources are not entirely independent. They **influence each other** in some way. This can lead to two main effects:
  + **Reinforcement:** If the sources are oriented in a way that their fields point in the same direction, they can **amplify** each other, creating a stronger overall field in specific areas.
  + **Cancellation:** Conversely, if the sources are oriented oppositely, their fields can partially or completely **cancel each other out** in specific regions, resulting in a weaker or even zero net field.

**Imagine:** You have multiple bar magnets scattered randomly on a table. Some magnets might be standing upright, while others are lying flat.

* **Correlated:** In this case, if all the standing magnets have their north poles pointing upwards, their fields would reinforce each other, creating a strong magnetic field region above the table.
* **Uncorrelated:** If the magnets have random orientations (north and south poles pointing in various directions), their individual fields might partially cancel each other out, resulting in a weaker and more complex overall magnetic field.

**Examples:**

* **Carefully designed electromagnets:** Engineers can arrange coils in a way that their magnetic fields add up, creating a stronger and more uniform field within the electromagnet.
* **Superconductors:** The currents flowing through a superconductor create correlated magnetic fields that work together to expel any external magnetic field (perfect diamagnetism).

**Uncorrelated Random Distribution:**

* **Meaning:** Here, the magnetic fields from multiple **randomly located** sources are **independent** and don't significantly influence each other. This typically happens when:
  + **Sources are far apart:** The strength of a magnetic field weakens with distance. Distant sources, even with random orientations, will have minimal influence on each other's fields.
  + **Sources are weak:** Weak magnetic fields generally have a smaller area of influence, making their interaction negligible when spread out randomly.

**Imagine:** You have tiny iron filings scattered randomly on a table. Each iron filing acts like a weak magnet.

* **Uncorrelated:** If these filings are spaced out, their individual weak magnetic fields wouldn't significantly interact. The overall magnetic field distribution would be weak and complex, with no clear areas of reinforcement or cancellation.

**Examples:**

* **Natural magnetic fields of individual atoms:** In a paramagnetic material (weakly attracted to magnets) at room temperature, the random orientations of individual atoms' magnetic fields lead to a net magnetic field of zero for the entire material.

**Important Note:**

Real-world scenarios often involve a mix of both correlated and uncorrelated aspects. Even seemingly "independent" sources may have some underlying correlation due to factors like the Earth's magnetic field or a shared source material.

Understanding how magnetic source distributions are correlated or uncorrelated is crucial for fields like:

* **Electromagnetics:** Designing efficient electromagnets and transformers
* **Geophysics:** Studying the Earth's magnetic field and its variations
* **Material Science:** Developing new materials with specific magnetic properties

By analyzing and manipulating magnetic source distributions, scientists and engineers can achieve the desired effects in various technologies and scientific applications.

* what is the meaning of the randomaly magnetized and uniform magnetization? show with example

**Randomly Magnetized Sources**

**Random Magnetization** refers to magnetic sources where the direction and intensity of magnetization vary in an irregular or unpredictable manner. This randomness can be due to various geological processes that affect the magnetic properties of rocks over time.

**Example:**

Imagine a region of the Earth's crust where volcanic activity has resulted in the formation of igneous rocks with different cooling rates, mineral compositions, and subsequent geological alterations. These factors can cause the magnetic minerals within the rocks to acquire magnetization in various directions and strengths. As a result, the magnetic anomalies observed over this region would be complex and varied.

**Visualization:**

1. **Magnetization Directions**: Arrows pointing in different directions and of different lengths represent the varying magnetization vectors.
2. **Power Spectrum**: The azimuthally averaged power spectrum would show distinct peaks corresponding to different depths of the randomly magnetized sources.

**Power Spectrum (Randomly Magnetized):**

* **Spectral Peaks**: Clear peaks at specific wavelengths indicating distinct depth levels.

**Uniformly Magnetized Sources**

**Uniform Magnetization** refers to magnetic sources where the direction and intensity of magnetization are consistent throughout the layer. This uniformity often results from geological processes that have a homogenizing effect on the magnetic properties of the rocks.

**Example:**

Consider a large sedimentary basin where layers of sediment have been deposited over long periods. These layers might become uniformly magnetized if the conditions during deposition and post-depositional alterations were consistent. This consistency could be due to factors like uniform deposition rates and homogeneous mineral content.

**Visualization:**

1. **Magnetization Directions**: Arrows of equal length pointing in the same direction represent the uniform magnetization vectors.
2. **Power Spectrum**: The azimuthally averaged power spectrum would follow a power-law decay without distinct peaks.

**Power Spectrum (Uniformly Magnetized):**

* **Power-Law Form**: A smooth, continuous decay in power without any distinct peaks.

**Summary**

* **Random Magnetization**: Varies in direction and intensity; leads to complex magnetic anomalies and spectral peaks.
* **Uniform Magnetization**: Consistent in direction and intensity; results in simpler magnetic anomalies and a power-law spectrum.

These differences are crucial for interpreting magnetic data and understanding the geological history of the area under study.

4o

### Magnetic Susceptibility (χ)

1. **Definition**:
   * Magnetic susceptibility (χ\chiχ) is a dimensionless quantity that indicates how much a material will become magnetized in an applied magnetic field. It measures the degree of magnetization of a material in response to an external magnetic field.
2. **Formula**:
   * χ=MH\chi = \frac{M}{H}χ=HM​
     + MMM is the magnetization of the material (magnetic moment per unit volume),
     + HHH is the applied magnetic field strength.
3. **Types**:
   * **Positive Susceptibility**: Materials with positive susceptibility (e.g., paramagnetic and ferromagnetic materials) are attracted to magnetic fields.
   * **Negative Susceptibility**: Materials with negative susceptibility (e.g., diamagnetic materials) are repelled by magnetic fields.
4. **Behavior**:
   * **Paramagnetic Materials**: Have a small positive susceptibility.
   * **Ferromagnetic Materials**: Have a large positive susceptibility and can retain magnetization.
   * **Diamagnetic Materials**: Have a small negative susceptibility.

### Magnetic Permeability (μ)

1. **Definition**:
   * Magnetic permeability (μ\muμ) is a measure of how easily a material can support the formation of a magnetic field within itself. It indicates the ability of a material to conduct magnetic lines of force.
2. **Formula**:
   * μ=BH\mu = \frac{B}{H}μ=HB​
     + BBB is the magnetic flux density,
     + HHH is the magnetic field strength.
3. **Relationship with Susceptibility**:
   * Magnetic permeability is related to magnetic susceptibility by the formula:
     + μ=μ0(1+χ)\mu = \mu\_0 (1 + \chi)μ=μ0​(1+χ)
       - μ0\mu\_0μ0​ is the permeability of free space (vacuum permeability), approximately 4π×10−7 H/m4\pi \times 10^{-7} \, \text{H/m}4π×10−7H/m (henries per meter).
4. **Types**:
   * **Relative Permeability (μr\mu\_rμr​)**: The ratio of the permeability of a material to the permeability of free space:
     + μr=μμ0\mu\_r = \frac{\mu}{\mu\_0}μr​=μ0​μ​.

### Key Differences

1. **Nature**:
   * **Magnetic Susceptibility**: Measures the extent to which a material can be magnetized by an external magnetic field.
   * **Magnetic Permeability**: Measures the extent to which a material can support the formation of a magnetic field within itself.
2. **Dimension**:
   * **Magnetic Susceptibility**: Dimensionless.
   * **Magnetic Permeability**: Has dimensions (in SI units, measured in henries per meter, H/m).
3. **Role in Equations**:
   * **Magnetic Susceptibility**: Used to describe how materials respond to an applied magnetic field in terms of magnetization.
   * **Magnetic Permeability**: Used to describe the relationship between magnetic field strength and magnetic flux density.
4. **Behavior in Materials**:
   * **Magnetic Susceptibility**: Indicates if the material is paramagnetic, diamagnetic, or ferromagnetic.
   * **Magnetic Permeability**: Describes how effectively the material can conduct magnetic lines of force.

Understanding these properties is crucial in fields like material science, electrical engineering, and physics, where magnetic behavior plays a significant role in the design and application of various devices and systems.

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### Uncorrelated Random Distribution

In an uncorrelated random distribution, the magnetic sources (such as rocks containing magnetic minerals) are distributed randomly and independently from each other. This means that the location and intensity of one magnetic source do not influence the location and intensity of another. When analyzing aeromagnetic data, this assumption simplifies the mathematical models because the magnetic anomalies are considered to result from isolated, individual sources without any underlying pattern or structure.

### Correlated Random Distribution

In a correlated random distribution, the magnetic sources are still random, but they exhibit some degree of correlation with each other. This means that the presence and characteristics of one magnetic source can influence or are related to the presence and characteristics of another. In nature, magnetic sources often display some spatial correlation due to geological processes that create patterns or clusters of magnetic anomalies. This correlation needs to be accounted for in the mathematical models used to estimate the DBMS.

### Key Differences

1. **Assumption of Independence**:
   * **Uncorrelated Random**: Assumes independence between sources.
   * **Correlated Random**: Assumes some degree of dependence or relationship between sources.
2. **Model Complexity**:
   * **Uncorrelated Random**: Simpler models, as interactions between sources are not considered.
   * **Correlated Random**: More complex models that account for interactions and patterns between sources.
3. **Real-world Application**:
   * **Uncorrelated Random**: Often used in initial or simplified analyses where the complexity of geological formations is not heavily considered.
   * **Correlated Random**: More accurate for real-world scenarios where geological formations create patterns in the distribution of magnetic sources.

### Examples in Literature

* **Uncorrelated Random**: Methods and studies by Spector & Grant (1970), Bhattacharyya & Leu (1975), Okubo et al. (1985), and Tanaka et al. (1999) typically fall into this category.
* **Correlated Random**: Methods and studies by Pilkington & Todoeschuck (1993), Fedi et al. (1997), Ravat et al. (2007), and Bansal et al. (2011) account for correlations between magnetic sources.

By classifying methods into these two categories, researchers can choose the appropriate model based on the nature of the magnetic source distribution in the study area, leading to more accurate estimations of the DBMS.

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* **Random Variable:** As mentioned earlier, this represents a quantity that can take on different values due to chance.
* **Source Distribution:** This refers to the probability distribution that describes how likely each possible value of the random variable is to occur.
* **Uncorrelated:** Two random variables are considered uncorrelated if the value of one variable doesn't influence the value of the other. There's no inherent relationship between them.
* **Correlated:** Conversely, correlated random variables exhibit a relationship. The value of one variable can provide information about the likely value of the other.

Here's how these concepts might be used in different contexts:

* **Signal Processing:** Imagine receiving a signal with noise. The original signal could be a random variable with a specific distribution. The noise itself could be another random variable with a different distribution. These might be uncorrelated, meaning the strength of the noise doesn't depend on the specific value of the original signal.
* **Finance:** Stock prices of two different companies might be modeled as random variables. If their markets aren't directly related, the price change in one company's stock might not influence the price change in the other. These stock prices could then be considered uncorrelated random variables.
* **Physics:** In some situations, multiple physical properties of a system might be modeled as random variables. If these properties have no inherent link (e.g., temperature and pressure), they might be considered uncorrelated.

Going back to magnetic susceptibility, the focus is on the observed patterns within a single material property, not necessarily on multiple random variables and their correlation.

how we can difeine the above efinition for magnetic sources

Show drafts

Magnetic sources, unlike the random variables discussed earlier, are deterministic (not random) and directly influence the magnetic field. Here's how we can redefine the concepts in the context of magnetic susceptibility:

* **Source Distribution:** In this case, the "source" refers to the way magnetic susceptibility is distributed within the material. This distribution describes how the susceptibility varies across different spatial scales (large and small).
* **Uncorrelated vs. Correlated Susceptibility Distribution:**
  + **Uncorrelated Magnetic Susceptibility Distribution:** This scenario implies that the susceptibility variations at different scales are independent. In other words, the susceptibility value at a large scale doesn't influence the susceptibility value at a smaller scale (and vice versa). This is a less likely scenario.
  + **Correlated Magnetic Susceptibility Distribution (Self-Similar/Fractal):** This is the more likely scenario suggested by the sentence. It implies a hierarchical structure where the susceptibility variations at different scales are related. Imagine a nested pattern – high susceptibility regions might contain smaller regions with a similar pattern, and so on, at progressively smaller scales. This self-similar or fractal distribution of susceptibility would then influence the overall magnetic behavior of the material.

Here's an analogy:

* Imagine a mountain range with varying elevations.
  + Uncorrelated distribution: The height of a peak (large scale) wouldn't be related to the hillocks on its slopes (smaller scale).
  + Correlated (fractal) distribution: The mountain range might have a self-similar structure, where smaller ridges mirror the overall shape of the larger range.

By analyzing the magnetic susceptibility distribution across different scales, scientists can gain insights into the underlying structure of the material and how it interacts with magnetic fields.

cant not understand

Show drafts

I apologize if the previous explanation was too complex. Let's try a simpler approach:

Imagine a rock with magnetic properties. This rock might not be uniformly magnetic throughout. Instead, there could be areas with high magnetism (like iron deposits) and areas with low magnetism.

* **Random, Uncorrelated Distribution:** This means the magnetic strength at different scales (large and small) doesn't have a pattern. It's like a random sprinkle of magnetic "pepper" throughout the rock.
* **Correlated, Fractal Distribution:** This is where things get interesting. Here, the magnetic strength might show a repeating pattern across scales. Imagine the rock has large, high-magnetism regions. Within those regions, there might be smaller patches of high magnetism, and so on, at progressively smaller scales. This repeating pattern is similar to a fractal, where a complex shape keeps replicating itself in miniature versions.

The sentence suggests that the observed magnetic patterns in the rock are more likely due to a **correlated, fractal distribution** of magnetic susceptibility. This tells us something about the rock's internal structure and how it interacts with magnetic fields.

Presentation

**Thesis title**

Good afternoon, everyone; my name is Vikash Chand Patel, and today I am going to give my DAC-III presentation. The title of my PhD thesis is Crustal Structure of the Eastern Indian Shield Based on Gravity and Magnetic Methods

**Outline**

**These are the outlines of my presentation**

First, I will address the comments from DAC-II. Then, I will discuss the geology and tectonics of my study area.

Comments of DAC-II

These are the comments from DAC-II, i.e.

* Change the thesis title
* What is the gap in this area i.e. EIS from the geological aspect?
* What is the assumption when computing the isostatic anomaly?
* What is the assumption in inverting the gravity?
* When you say inverted Moho is greater than isostatic Moho, does it have any implications? What does it mean to overcompensation? If it is overcompensation, then what?
* How do you reconcile the difference between Seismological Moho and Gravity Moho? Why is there a difference between seismological Moho and gravity Moho?

The comments from DAC-II are as follows:

1. The first comment was to change the thesis title. The initial title was "Crustal Structure of the Eastern Indian Shield: An Integrated Geopotential Approach." It has now been modified to "Crustal Structure of the Eastern Indian Shield Based on Gravity and Magnetic Methods." Because earlier integrated geopotential approach involved which also include electrical method, here I am only focusing on gravity and magnetic methods, the title modified accordingly.
2. What is the gap in this area i.e. EIS from the geological aspect?
3. The Eastern Indian Shield has been a focal point for geological research, particularly to understand its tectonic evolution. Despite extensive studies, there are still several research gaps in our understanding. Some of these research gaps include.
4. There is no geological evidence for the existence of SSZ and SPSZ towards the western part of the SMB.
5. The tectonic regime of the Dalma volcanism has been interpreted based on insufficient geochemical data (Bose, 2009).
6. The Magmatism, sedimentation, and metamorphism deformation of SC, SMB and CGC remain subjects of ongoing research.

It is uncertain whether the subduction of SC below CGC is a single or double stage process. Additionally, the direction of subduction is also unclear.

**The next question is: What assumptions are made when computing the isostatic anomaly?**

**When computing the isostatic anomaly, it is assumed that the Earth is a spheroid with homogeneous concentric layers. It is also assumed that the reference Earth is in hydrostatic equilibrium.**

**The isostatic anomaly is defended as the difference between the Bouguer anomaly and the response of the root zone. So, for computing the root, it is assumed the density of the crust and mantle are constant, and the three parameters required are topographic density, mean sea level, crustal thickness, and density contrast across the bottom of the root.**

The next one is **What is the assumption in inverting the gravity anomaly?**

For that first lets understand what inversion is the main purpose of the inversion is to estimate the model parameters form the data

In case of forward problem, data is estimated from the model

In case of inverse problem, the model parameter is estimated from the data

In some geophysical inverse problems, the source is estimated from the data, with the assumption that the model parameters are known. Therefore, the basic assumption for inverting the gravity anomaly is that the model parameters, such as reference depth and density contrast, are known."

The next one is **When you say inverted Moho is greater than isostatic Moho, does it have any implications? What does it mean to overcompensation? If it is overcompensation, then what?**

* When we say the inverted Moho is greater than the isostatic Moho, it indicates a case of overcompensation. Overcompensation means the root is too large compared to the topography it supports. In other words, **Overcompensation occurs when the Moho boundary is deeper than expected for isostatic equilibrium. If the eroded mountains are no longer enough to justify their deep root zone, the topography is isostatically overcompensated. Overcompensation may also indicate that the topography may be regionally compensated. For example, foreland Ganga basin shows overcompensation due to the regional compensation of Indian plate colliding with the Eurasian Plate.**

**How do you reconcile the difference between Seismological Moho and Gravity Moho? Why is there a difference between seismological Moho and gravity Moho?**

**The difference between seismological moho and gravity moho arises due to structural heterogeneity.** If the Earth's layer structure were homogeneous, the Seismological Moho and the Gravity Moho would coincide. **The second one is due to a range of density is possible for rock of each seismic velocity(refernce). As shown in figure for a particular velocity there is a range of the density so these are factors that responsible for the difference between seismological Moho and Gravity Moho**

**In our case, for estimating the moho depth, a content density contrast was taken, which is based on the global average density.**

**Geology and tectonics**

**Now, I will come to my study area, which is the Eastern Indian Shield (EIS). This figure shows the geology and tectonics EIS.**

**In the second DAC, I already discussed the geology and tectonics of the eastern Indian Shield; here, I will briefly introduce the same.**

**The Eastern Indian Shield includes the Singhbhum Mobile Belt with the Chhotanagpur Gneiss complex to its north and the Singhbhum Craton and Eastern Ghats Mobile Belt to its south.**

**The SC forms the nucleus of the Eastern Indian Shield, whereas the Chhotanagpur Gneiss complex covers most of the area in the north.**

**The SInghbhum Craton, Singhbhum mobile belt and Chhotanagpur Gneiss complex are bounded by the Mahanadi basin in the west, Eastern Ghats mobile belt and coastal alluvium in the south, Ganga basin in the north and Bengal basin in the East.**

**The Singhbhum Craton preserves some of the oldest rocks which include older metamorphic group, older metamorphic tonalite gneiss, Singhbhum granite and iron ore group. The singhbhum craton also include several volcanic rocks**

**Singhbhum mobile belt comprises metasedimentary and metavolcanic rocks and separate the Singhbhum craton from the Chhotanagpur gneiss complex**

**Objective**

**These are the objectives of my research**

**The first objective i.e, 3D crustal structure and the isostatic state of EIS have been discussed in DAC II**

**The second one i.e. new insight into the cristal magnetisation of the Eastern Indian shield I will discuss here**

**And last two I will discuss in DAC 4**

Aeromagnetic anomaly map

This figure illustrates the aeromagnetic anomaly map of the eastern Indian shield. The data were collected at different epochs using NS-oriented flight lines spaced by 4000m and the perpendicular control line spaced by 8000 m. The average flight altitude was 120m above the topography.

The data was corrected for the main field using the IGRF and brought a common elevation of 1.5 km.

The total aeromagnetic anomaly map shows considerable variations ranging between -300 and 300 nT. The main magnetic sources are associated with both exposed and subsurface carnotite/chondrite, iron ore bodies, mafic and ultramafic, as well as intrusive trap flow and supracrustal rocks. The high magnetic anomalies are observed in various regions, including the northwestren of the Eastern Ghats Mobile belt at Balngir, all along the western margin of the Sikinda fault, the western end of the Singhbhum Craton, southwest and northwest of the Chhotanagpur Gneiss complex. At Balangir the high magnetic is due to the presence of the Anorthosite. Along the Sukinda fault and the region between the Mahanadi Shear Zone and the Sukinda fault shows high magnetic anomaly due to the presence of the Charnochite and chromite deposits. The eastern, western and southern parts of the SC show a bipolar anomaly due to the presence of the Iron Ore Body. Decaan trap and Mahakosal belt of supraorbital rock are the reason for the high magnetic anomaly in the western part of the Chhotanagpur Gneiss Complex. The eastern part of the Singhbhum Mobile belt shows high magnetic anomaly, which may be linked to the subsurface structure as it has no surface appearance.

**DBMS**

From the analysis of the crustal magnetisation, it is possible to estimate the depth below which no magnetisation could exist. Depth to the bottom of the magnetic source, that is, DBMS, can be defined as the depth at which rocks lose their magnetic properties due to the increase of the temperature in the crust above the curie temperature. DBMS allows us to estimate the depth at which Curie temperature is reached and, therefore, the geothermal gradient in the studied region. The Rocks magnetisation depends on composition and curie temperature. The main mineral that contribute the magnetization of the lower crustal rocks are magnetite and curie temperature of the magnetite is 580 degree sentigrade

The DBMS can sometimes represent a petrological limit; at depth, the composition of the crust can change so that rocks become poor in magnetic minerals

**Methodology**

The usual methodology to calculate the depth of the magnetic sources from the magnetic anomaly involves calculating the power spectrum of the magnetic data, then calculating the radially average power spectrum, and finally fitting the experimental curve, which directly depends on the depth of the magnetic sources

**Effect of window size and scaling exponent on DBMS estimation**

The other problem in spectral analysis is selecting the window size and scaling exponent. Most of the studies use window size and scaling exponent based on the previous studies or arbitrarily.

In order to address this issue, we conducted synthetic data analysis. We created the three-dimensional magnetization model using the Pilkington and Todoeschuck (1993) approach. Then, we generated synthetic magnetic anomalies for four models. These models maintained a constant depth of 3 km to the top, while the depth to the bottom varies at 10, 20, 30 and 40 km. Fig.3a shows the 3D magnetization model with a top depth of 3km and a bottom depth of 40km and the 4 synthetic magnetic anomalies presented in figs b, c, d, and e. This analysis involves four different window sizes namely, 100 by 100, 150 by 150, 200 by 200 and 250 by 250 km square. These four models are used to test the depth estimate using the modified centroid method with a scaling exponent varying between 0 to 3 with a 0.5 step factor.

The results for the four models with varying scaling exponent at four window sizes are summarized in the table below.

This table shows that as the scaling exponent increases, the top depth and bottom depth decrease for all window sizes. Additionally, as the window size increases from 100 to 200 km2, the top depth and bottom depth also increase, but for a window size of 250 km2, this decrease. Furthermore, with an increase in the thickness of the magnetized body, the top depth and bottom depth also increase.

We estimate the top depth and bottom depth for each window with varying scaling exponent.

**Relationship between window size and scaling exponent**

This figure shows the relationship between window size and scaling exponent. **For window size 100 by 100 km** square the top depth decrease gradually with an increase of the scaling exponent from 0 to 3. For model 1, the top depth is under estimated. For model 2 top depth is close to true depth at beta equal to 3. For model 3 and 4 the top depth is more 50% at beta equal 0, reached to the true value at beta equal to 2.

For bottom depth as shown in figure b, for model 1 the bottom depth is overestimated and for model 2, 3, and 4 the results are underestimated.

**For window size 150 by 150** km square the estimated top depth is close to true depth at beta 1 and 1.5 for model 1 at beta equal to 0 the top depth is 50% more than the true depth and at beta 2.5 or mode it is 50% less than true depth. For model 2 the top depth is overestimated when beta equal 0 to 2 and reliable at beta equal 2.5 and 3. For model 3 and 4 the top depth is overestimated when beta is equal to 0 to 2.5 and reliable at beta 3. In the case of the estimated bottom depth as shown in fig d for model 1 it is close to true depth at beta equal to 2.5 for model 2 it is at 1.5, for model 3 it is at 0.5 and 1 and for model4 it as at 0

**For window size 200 by 200** km square the estimated top depth is close to true depth at beta equal 1 and 1.5 for model 1. The estimated top depth for model 2 is close to the true depth at beta equal 3. And for model 3 and 4 the estimated top depth is overestimated. If we talk about estimated bottom depth for model 1 it is close to true depth at beta equal to 3. For model 2 it is close at 2 for model 3 it is close at 0,05, 1.

For window size 250 by 250 km square the estimated top depth is clos to true depth at beta equal to 0.5 and 1 for model 2 it is close at 2 and for model 3 and 4 this overestimated. In case of estimated bottom depth for model 1 this clos to the true depth at beta equal to 3 for model it is clos at 2.5 for model 3 it is close at 1.5 and 1 for model 4.

Based on this synthetic analysis, we conclude that model 3 and 4 have the estimated bottom depth with less than 20 % error at scaling exponent value in the range of 0.5 and 1.5.

On basis of this analysis and previous, we selected window size as 150 by 150 km square and scaling exponent as 1 for this study.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Window size (100x100) | | | Window size (150x150) | | | Window size (200x200) | | | Window size (250x250) | | |
| model | Top depth (decrease in %) | Bottom depth (decrease in %) | model | Top depth (decrease in %) | Bottom depth (decrease in %) | model | Top depth (decrease in %) | Bottom depth (decrease in %) | model | Top depth (decrease in %) | Bottom depth (decrease in %) |
| 1 | 93-47 | 174-79 |  |  |  |  |  |  |  |  |  |
| 2 | 157-110 | 94-46 |  |  |  |  |  |  |  |  |  |
| 3 | 160-80 | 96-48 |  |  |  |  |  |  |  |  |  |
| 4 | 153-73 | 78-42 |  |  |  |  |  |  |  |  |  |

**Radially Averaged Power Spectrum**

This figure shows the radially averaged power computed for three blocks. Here first I will define the what is the power spectrum. Power spectrum is a representation of the distribution of the power a signal into its frequency component and averaging the power over all direction at each radially frequency, is called radially averaged power spectrum.

Age of the Singhbhum Craton

|  |  |
| --- | --- |
| Age (GA) | Referance |
| 3.6 | Mishra et al.,1999 |
|  |  |
|  |  |
|  |  |

Profile 1

Good afternoon everyone my name is Vikash chand patel and I am reseach scholr at CSIR NGRI Hyderabad. Today I will present my research work on structural mapping of the eastern Indian shield insights from aeromagnetic data.

These are the outline of my presentation

First I will introduce the geology and tectonics of the study region

Then I will go for objective, aeromagnetic anomaly, reduction to pole, methodology results and conclusions.

This figure shows the geology and tectonics maps of the eastern Indian shield. The easten indian shield include singhbhum craton singbbhum mobile belt and chhotanagpur gneiss complex and these are bounded by the Mahanadi basin in west eastern ghats mobile belt and coastal alluvim in south ganga basin in the north and Bengal basin in east. Structurally this region defined by major fault and shear zone system such as son Narmada north fault son Narmada south fault, north purulia shear zone south purulia shear zone singhbhum shear zone kerazang fault and mahandai shear zone. This fault and shear zone have played a significant role in shaping the tectonic framework of the eastern Indian shield.

This study aims to identify and characterised these major tectonic features and lithological contact through the aeromagnetic data and perform 2D modelling of the subsurface to enhance our understanding of the structural framework of the EIS.

To achieve this objective, we carried out aeromagnetic data. This figure shows the aeromagnetic anoma ly map of the eastern Indian shield. The aeromagnetic data cover most of the study area and gap area was filled by the EMAG2 data. The total magnetc anomaly varies betwee -599 and 638 nT. The primary magnetic sources are associated with charnckite/khondalite, iron ore body, trap flow, supracrustal rock and mafic and ultramafic intrusion.

The interpretation of the magnetic anomaly is complex due the bipolar nature and inclination and declination of the earth’s magnetic field which lead to magnetic anomaly distortion. To address this issue reduction to pole method is utilised which convert the magnetic field into an equivalent vertical field and remove the asymmetry arise due the earth’s magnetic field inclination. Here we used the inclination of 32 degree and declination of -.5 degree to estimate the reduction to pole of magnetic anomaly. In reduction to pole method at low latitude is that a north south features are highlighted which we can in this figure. And to remove this an additional amplitude corrected inclination 90 was applied ~~to remove this north south feature~~ as we can see in this figure.

For mapping the geological structural a systemic methodlogy was applied, which include Horizontal gradient, analytical signal, tilt angle, euler deconvolution and CET grid analysis.

The horizontal gradient defined as the square root of the sum of the square of the derivative of the field with respect to x and y

Analytical signal defined as the square root of the sum of the square of the derivative of the field with respect to x y and Z.

The tilt angle defined as the arctangent of the ratio between vertical gradient and horizontal

gradient.

Euler deconvolution is used to estimate the position and depth of the causative source body. This method uses the euler homgenity equation to estimate the source position and depth by least square inversion method

CET grid analysis technique is used to identify the lineament. Texture analysis phase symmetry amplitude thresholding these are process involve in CET grid analysis to estimate the lineaments.

The 2d forward modelling involves crating a hypothetical geological model and calculating the geophysical response of that model and this is performed using GMSYS which allow interactive manipulation of the geological model and real time calculation of the gravity and magnetic response.

Result

The maxima of the HG AS and zeros of the TA together provide a powerful tool for mapping the boundary of the different lithological units, faults, and contacts between magnetic and non- magnetic sources. The boundary of baster craton, EGMB, rengali province and different faults and shear zone in this study area are identified by HG AS and TA as shown in figure.

Depth estimate obtained from euler decon varies from less than 1 km to over 11 km. this depth range suggest a variety of subsurface structure from shallow to deeper feature.

The CET results show that the lineaments are oreianted in E-W, ENE to WSW, NE-SW, and N-S direction which is shown by the rose digram

We also conducted 2D modelling along the 2 profile the profile AB which in SW to NE direction, crosses eastern Ghats mobile belt, rengali province and singhbhum craton. This modelling provides the insights into the internal structure of these geological units. the kerajang fault which separate the eastern ghats and rengali province is characterized by a sharp magnetic anomaly gradient, highlighting its significance as a major tectonic boundary.

Profile 2

The profile CD which is in SN direction traverse singhbhum craton singbhum mobile belt and chhotanagpur gneiss complex provides detailed insights into their subsurface structure.

Conclusions

We conclude that The combined analysis of the aeromagnetic anomaly map, reduction to pole, its horizontal gradient, analytical signal, tilt angle, emphasize the main structural features and magnetic sources in the study region. CET grid analysis identify the lineament Euler deconvolution estimate the depth which is vary from less than1 to over 11 km 2d modelling highlight the deep and shallow features which is responsible for the magnetic anomalies.

* The Proterozoic period is well known for extensive orozonic activity along the cratonic block.
* These orozonic belts record polyphaser magmatic metamorphic and sedimetation history and form a key element to understand supercontinents reconstruction.
* **There are Several Spectrum methods for computing the depth to the bottom of magnetic sources (DBMS) from the Aeromagnetic Data (e.g. power spectrum peak, centroid method, forward modelling of the spectral peak method, de-fractal method, modified centroid method)**
* **The different methods for estimation of the DBMS from aeromagnetic data can be classified into two classes:**
* **(1) those based on uncorrelated random (Spector & Grant, 1970; Bhattacharyya & Leu, 1975; Okubo et al., 1985; Tanaka et al., 1999)**
* **(2) Those based on correlated random distribution of the magnetic sources (Pilkington & Todoeschuck, 1993; Fedi et al., 1997; Ravat et al., 2007; Bansal et al., 2011)**