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# Geomagnetic Study at Prut Falls, Sohra, Meghalaya

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## 1. Introduction:

Geomagnetism is the study of the Earth's magnetic field. It involves the investigation and analysis of earth's magnetic field in a particular location. This can be observed in magnetic observatories, magnetic satellites and there are also other methods to measure this magnetic field. The parameters that characterized the Earth's magnetic field are called the magnetic elements of the earth and these are magnetic declination, magnetic inclination or dip angle and horizontal component of earth's magnetic field [1]. Geomagnetic studies conducted at different places hold significant importance for various fields and applications ranging from geology, environmental sciences to the setup of geomagnetic observatory and so on. Magnetic declination is the angle between the magnetic meridian and geographic meridian of the earth. It changes with location as well as with time. Declination is positive or negative if the magnetic north is east or west of the geographic north respectively. Magnetic inclination or dip at a place is the angle between the direction of the total magnetic field intensity of the earth and the horizontal line in the magnetic meridian. The angle of dip changes with location and it varies from $0^0$to $90^0$as we move from the equator to the poles. The horizontal component of earth's magnetic field is the component of the total magnetic field intensity of the earth in the horizontal direction of the magnetic meridian. It changes with time and location on the surface of the earth and is maximum at the equator.

Several studies have been conducted to measure and study the magnetic field of the earth at different places using different techniques. A more pertinent and recent study was conducted by a group of high school students from Portugal where they measured the magnetic field of the earth using a magnetometer, onboard the International Space Station (ISS) [2]. Another study was conducted by undergraduate students from the Beijing Institute of Technology to measure the local geomagnetic field in the Laboratory by using a modified Helmholtz coil [3]. A geomagnetic Study of the Hot Spring Area in Rokan Hulu, Riau – Indonesia was conducted by Nur Islami et.al. They observed low magnetic fields in these hot springs which they attributed to the high temperature of the rocks in those regions [4].SameerArabasi et. al. measured the angle of dip using a smart phone aided set up [5]. The purpose of their study is to familiarized students about the vector nature of earth's magnetic field.To the best of our knowledge, a similar kind of study has not been done before in and around Prut Falls, Sohra.

In this paper we proposed to study the magnetic field near the vicinity of the Prut Falls located at Sohra, Meghalaya. Firstly, the aim of this study is to enable students to apply experimental techniques done in the laboratory to the field and secondly, to instill a scientific temperament amongst the students.

## 2. Materials and Methods

### 2.1 Study Area:

Prut Falls is located approximately 50km away from Shillong at a latitude of $25^0$18'46" N and longitude of $91^0$41'35" E. It is located inthe picturesque location of Sohra which is the second wettest place on Earth and is home to many beautiful waterfalls like the Nohkalikai Falls, the Nohsngithiang Falls, the Wakaba Falls to name a few. Prut Falls is located in a small village in Sohra called Laitlyndop. It is one of the few waterfalls located in the region, approximately one kilometer away from the beautiful Lyngksiar Falls.

### 2.2 Experimental Methods

#### 2.2.1 Magnetic Declination

The magnetic declination was determined using an online Geomagnetism calculator available at the National Centers for Environmental Information which is maintained by the National Oceanic and Atmospheric Administration which is under the purview of the US Department of Commerce [6].

#### 2.2.2 Magnetic Inclination or Dip

The Magnetic Inclination or Dip was determined with the help of a Dip Circle [7]. The Dip Circle (Fig 1) was first leveled and the vertical plane was aligned in the magnetic meridian. The needle was then marked and the Dip Circle was directed towards east. The readings of the needle from the vertical scale were then noted ($\theta_1 and\ \theta_2$). The needle was then reversed in its bearings and the readings of the vertical scale were again noted ($\theta_3 and \theta_4$). The mean of the four readings were taken (say $\alpha$). The entire operation was repeated after turning the vertical plane of the Dip circle by $180^0$ and another set of four readings were obtained ($\varphi_1, \varphi_2, \varphi_3, \varphi_4$) and their mean value was determined (say $\beta$). The angle of Dip is then the average of $\alpha\ and\ \beta$.

***Fig 1: Dip Circle***

### 2.2.3 Horizontal Component of Earth's Magnetic Field

The Horizontal Component of Earth's Magnetic Field was determined with the aid of a deflection (Fig 2) and vibration magnetometer (Fig 3) [8].Deflection magnetometer is based on tangent law of Magnetism: "when a compass needle is suspended between two perpendicular magnetic fields, then it will come to rest in a particular position" such that

***Fig 2: Deflection magnetometer***

$B = H \tan\theta$----- (1)

where 'B' is the magnetic field due to a bar magnet, 'H' is the horizontal component of earth's magnetic field and $'\theta'$ is the deflection of the needle from the magnetic meridian.

If the compass needle is placed on the $\tan A$ position or axial line of a bar magnet at a distance 'r' from its centre, then, we have,

$$B = \frac{2rM}{(r^2 - l^2)^2} \text{----- (2)}$$

where 'M' is the magnetic moment of the bar magnet and '$l$' the magnetic length.

From (1) and (2):

$$\frac{M}{H} = \frac{(r^2 - l^2)^2}{2r} \tan\theta \text{----- (3)}$$

If a bar magnet placed in a vibration magnetometer is suspended freely in the earth's magnetic field, then the time period of oscillation 'T' is given by

$$T = 2\pi\sqrt{\frac{I}{MH}} \text{----- (4)}$$

where 'I' is the moment of inertia of the barmagnet

***Fig 3: Vibration magnetometer***

From (4):

$$T^2 = 4\pi^2 \frac{I}{MH}$$

$$MH = \frac{4\pi^2 I}{T^2} \text{----- (5)}$$

The Horizontal Component of Earth’s Magnetic field is then given by

$$H = \sqrt{MH \div \frac{M}{H}} \text{ ----- (6)}$$

In order to determine the Horizontal Component of Earth’s Magnetic field, the following parameters are to be determined r, $l$, $\theta$,I and T. The parameters ‘r’ and $'\theta'$ were determined from the deflection magnetometer and ‘T’ was determined from the vibration magnetometer.

The moment of inertia of the bar magnet is calculated using the formula

$$I = \frac{m}{12}(L^2 + b^2) \text{ ----- (7)}$$

where ‘m’ is the mass, ‘L’ is the length and ‘b’ is the breadth of the bar magnet

Magnetic length ‘$l$’ is determined using the formula

$l$ = 0.84 × L ----- (8)

3. **Results and Discussion**

In this section, we present the experimental results of dip angle and horizontal component of Earth’s magnetic field.The dip angle at the site of interest is found to be 41°.

**Table 1:** Location of the Magnetic Meridian

| No. of obs | Needle reading | Needle reading | Total reading | Mean | Magnetic Meridian |
|---|---|---|---|---|---|
| 1 | Front | Upper 90°<br>Lower 90◦ | 39.05<br>42.04 | $\theta$1= 43.80 | 133.30 |
| 2 | Reverse | Upper 90°<br>Lower 90 | 45.05<br>49.04 | | |
| After rotation by $180^0$ | | | | | |
| 3 | Front | Upper 90°<br>Lower 90 | 227.04<br>224.04 | $\theta$2= 222.80 | |
| 4 | Reverse | Upper 90°<br>Lower 90 | 221.05<br>219.04 | | |

**Table 2:** Measurement of Angle of Dip

| No. of obs | Needle reading | Upper end (degrees) | Lower end (degrees) | Mean of the two readings (degrees) | Mean (degrees) | Angle of Dip (degrees) |
|---|---|---|---|---|---|---|
| 1. | Front | 41 | 42 | 41.5 | 41.5 | 41 |
| 2. | Reverse | 41 | 42 | 41.5 | | |
| After rotation by $180^0$ | | | | | | |
| 3. | Front | 40 | 41 | 40.5 | 40.5 | |
| 4. | Reverse | 40 | 41 | 40.5 | | |

The moment of inertia of the magnet of length $7.51\ cm$, used in this study, is 224.68 $gm - cm^2$, its period of oscillation is 2.53 $sec$ and hence the $MH$ resulted at 1,383.88 $dyne\ cm$. Two observations of $\frac{M}{H}$ have been done and the mean from the two readings is $9{,}008.4\ dyne\ cm$ as shown in Table 3 below. Then, finally the horizontal component of Earth's magnetic field is calculated using the formula given in equation (6) and is found to be 0.392 $oersted$ or $3.92 \times 10^{-5}\ Tesla$.

**Table 3:** Measurement of the deflection of the magnetometer

| No. of observations | Position of the bar magnet, $r$ (cm) | Deflection of the needle(°) | M/H ($dyne\ cm$) | M/H ($dyne\ cm$) |
|---|---|---|---|---|
| 1 | 13.75 | 84.37 | 8006.97 | 9008.04 |
| 2 | 17.75 | 82.31 | 10009.11 | |

As mentioned in Section 2.2.1, the magnetic declination was determined from Geomagnetism Calculator [6, accessed on 8/07/2023] and the value reported is $0.53°\ West \pm 0.30°$.We have also retrieved the values of angle of dip and the horizontal component of the Earth's magnetic field from the same source of information and the values reported are $39.87° \pm 0.21°$ and $(3.69 \pm 0.01) \times 10^{-5}\ Tesla$, respectively.

A comparison between the results of dip angle and the horizontal component of Earth's magnetic field from the present study and the data from Geomagnetism calculator: National Centers for Environmental Information [6] shows that the two are in acceptable agreement with each other. The uncertainties in the dip angle and horizontal component of Earth's magnetic field are $2.84\ \%$ and $6.23\ \%$, respectively.The variation of the experimental results from the one reported online may be due to the friction of the needle, oscillation of the vibration magnetometer or it may be due to the unseen magnets or magnetic materials presents near the magnetometer during the time when experiment was conducted.

It is a well known fact that the magnetic field of the earth varies with time and location, so these magnetic elements of the earth at a particular location changes with time. According to the data retrieved from Geomagnetism calculator: National Centers for Environmental Information, the magnetic changes at Prut falls are: magnetic declination changing by $0.04°\ West$ per year, the dip angle changing by $0.11°$per year and the horizontal component of Earth's magnetic field by $(5.7 \times 10^{-9})\ Tesla$ per year.

***Fig 4: Students performing experiment***

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