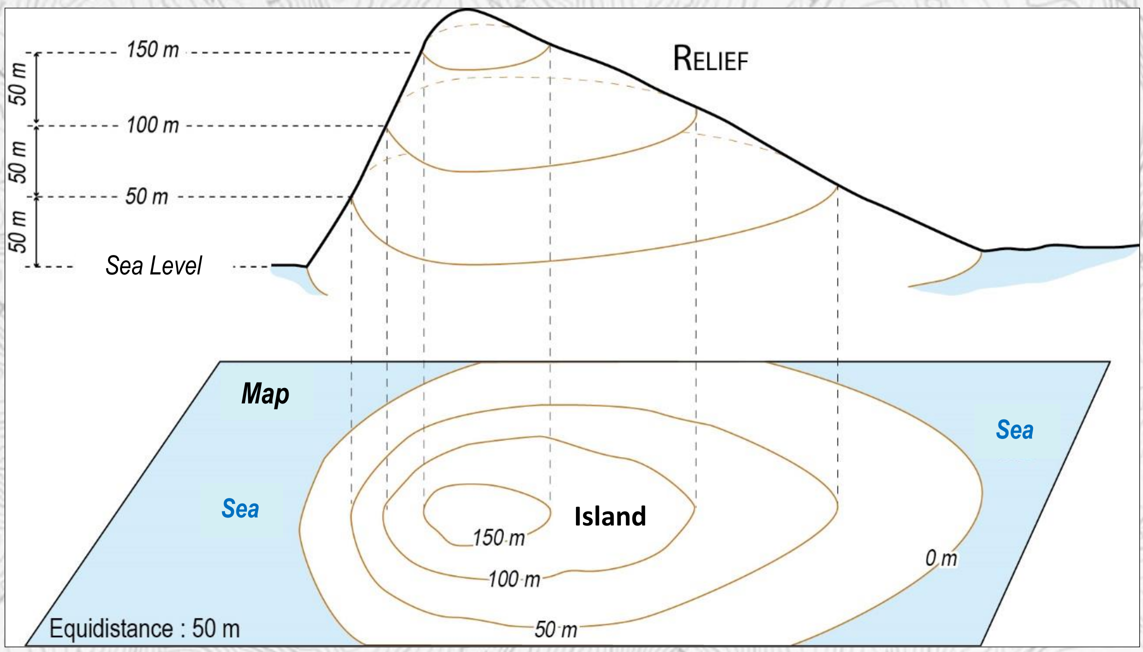
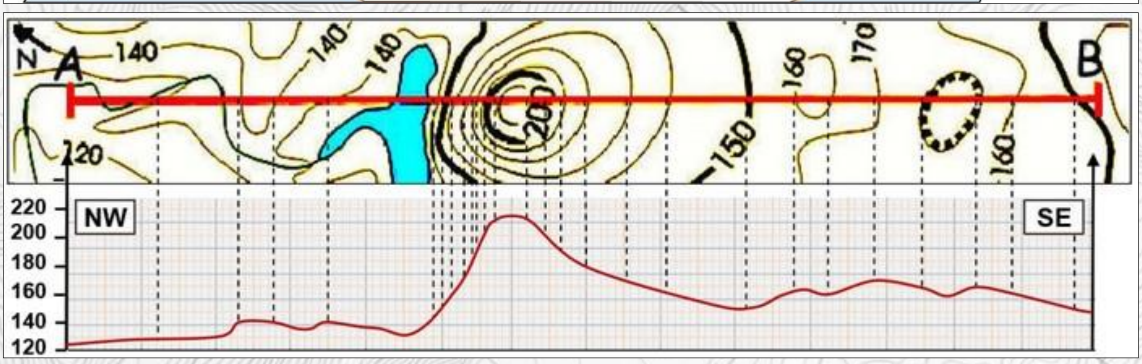
University Ferhat Abbas Setif-1
Faculty of Natural and Life Sciences
Department of Basic Studies





Directed Works in Geology

Intended for First-Year Bachelor's Students
in Natural and Life Sciences

Presented by:
Dr. BOUCHAGOURA Louiza

Academic Year: 2024/2025

Preface

Since the dawn of humanity, people have had a fundamental need to find their bearings, to understand their place in the world and to give meaning to their environment. This desire to master space, extend their knowledge and mark their presence in the landscape has forged the art of cartography over time. Far from being mere tools, maps embody the human ability to capture and translate the complexity of the world into a comprehensible vision, while reflecting the thinking and imagination of their time. Each map is a mirror of human perception, a visual interpretation that captures the subtle interaction between mind and space, making the link between thought and image palpable.

This document, intended for first-year students in Natural and Life Sciences, presents a comprehensive overview of the essential concepts for a thorough understanding of topographic maps and their effective application in geology and data access. It covers the fundamentals that students need to grasp in cartography.

The main objectives of this workbook are as follows:

- Highlight the importance and benefits of using cartography.
- Explain in detail the advantages of topographic maps and the various possible applications.
- Develop a complete mastery of cartographic language.
- Teach the precise representation of reliefs in depth.
- Ensure an understanding of the fundamental principles of topography, enabling students to expertly read and interpret topographic maps in a geographical context.

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Chapter I

General Presentation of the Topographic Map

Chapter I: General Presentation of the Topographic Map

1. Cartography and Map

1.1. Cartography

Cartography is the science and art of graphically representing the Earth's surface or other celestial bodies in the form of maps. It is based on the collection, processing, and interpretation of geographic data to create representations at various scales. Historically, cartography has evolved from the first rudimentary maps to complex geographic systems, thanks to technological advances such as Geographic Information Systems (GIS) and remote sensing.

The objectives of cartography include:

- The visual representation of geographic information to facilitate analysis and interpretation.
- The communication of geospatial information, such as the distribution of reliefs, infrastructures, borders, etc.
- Assistance in navigation and travel planning (land, sea, and air).

1.2. Map

A map is a graphic representation, usually flat, of the Earth's surface or a part of it. It is created at a specific scale and uses various conventional symbols to represent natural or artificial objects. A map simplifies reality according to the user’s purpose and the scale used.

2. Topography and Topographic Map

2.1. Topography

Topography is a branch of geography that studies and describes the configuration of places, particularly the forms of terrestrial relief. It involves measuring and representing natural and artificial features of the Earth's surface through field survey techniques. Topography considers variations in altitude, slopes, rivers, mountains, and other landforms. Modern tools such as GPS, drones, and total stations facilitate precise topographic surveys.

Objectives of topography:

- To represent relief and landforms on a map or plan.
- To support land planning, construction, agriculture, and other fields requiring thorough knowledge of the terrain.

2.2. Topographic Map

A topographic map is a detailed and precise representation of the relief forms and features of a territory at a defined scale. Unlike other types of maps (road maps, political maps), a topographic map emphasizes relief and altitudes, shown by contour lines, along with other elements such as rivers, forests, roads, buildings, etc.

Distinctive elements of a topographic map:

- **Contour lines:** These are lines connecting points of equal altitude on a map, allowing visualization of slopes and the general shape of the relief.
- **Frequent scales:** Topographic maps are often produced at scales of 1/25000, 1/50000, or 1/100000. These scales enable precise representation of relief and geographic details, facilitating activities such as hiking, urban planning, and environmental studies.

2.3. Presentation of the Topographic Map

2.3.1. Maps at 1/25000 Scale

These maps are highly detailed and depict the geographic features of a small area with high precision. One centimeter on the map corresponds to 250 meters on the ground. They are often used for activities requiring high accuracy, such as hiking, surveying, or land use planning.

2.3.2. Maps at 1/50000 Scale

Maps at this scale provide a broader view than 1/25000, though with slightly less precision. One centimeter on the map represents 500 meters on the ground. They are often used for road navigation, urban planning, and certain environmental studies.

2.3.3. Maps at 1/100000 Scale

This scale allows coverage of large geographic areas with fewer details but is useful for activities requiring an overview of a wide territory. One centimeter on the map represents 1 kilometer on the ground. These maps are primarily used for regional planning, large-scale studies, and military missions.

2.4. Elements Represented on the Topographic Map

2.4.1. Information Found on the Topographic Map

A topographic map contains various types of information that help understand the layout of the terrain:

- **Relief**: Represented by contour lines, the relief allows for visualization of elevations and depressions.
- **Hydrography**: Represents water features such as rivers, lakes, and other water-related elements.
- **Vegetation**: Indicates the presence of forests, grasslands, natural parks, etc.

- **Transportation**: Represents infrastructure such as roads, railways, trails, paths, and other means of communication.
- **Artificial Entities**: Includes buildings, industrial areas, towns, villages, bridges, etc.
- **Borders and Boundaries**: Shows administrative boundaries, such as national, regional, or local borders.
- **Toponymy**: Geographic names or toponyms are labeled on the map to designate towns, villages, rivers, mountains, and other notable features.

2.4.2. Colors Used

Topographic maps use a standardized color code to make reading more intuitive:

- **Brown** for contour lines and relief. Cliffs are drawn in black.
- **Blue** for hydrographic elements such as rivers, the sea, ponds, canals, and glaciers (contours drawn with blue lines), marshes, flood zones, etc. The names of hydrographic features are printed in blue.
- **Green** for vegetation: different graphic treatments indicate the type of vegetation cover, such as deciduous trees, conifers, vineyards, bushes, except for cultivated areas, which are left white. The boundaries of state forests and natural parks are shown by thick green lines.
- **Black** is used for most labels or numeric indicators: Toponymy includes place names, villages, hamlets, ruins, altitudes, population figures, road numbers, etc. Railways, paths, trails, administrative boundaries, etc., are also indicated in black.
- **Red** for main and secondary roads.
- **Yellow** or **Orange** for unclassified roads.

2.5. Fundamental Elements of the Map

To effectively use a topographic map, it is essential to understand its key elements:

- **Frame**: Defines the area covered by the map. In addition to the represented surface, the frame contains information on geographic or rectangular coordinates, such as longitude and latitude scales (indicated in grads for Lambert projection and in degrees for UTM projection), as well as the grid and numbering origins.
- **Title**: Indicates the region or location represented. It is a central element of a map, signifying the map's subject and inviting the observer to examine it more closely. The title is usually located at the top left of the map.

- **Scale**: Shows the reduction ratio of reality. This is an essential formatting element of a map and must always be present, regardless of the type of map produced. It establishes a direct link between real space and its graphical representation. In other words, the scale of a map (E) is the ratio between the length measured on the map (Lc) in a given unit and the corresponding horizontal distance on the ground (Lt), expressed in the same unit: E = Lc/Lt.
- **Legend**: Explains the meaning of symbols and colors used to represent the elements present on the map. These elements are organized by theme (road network, vegetation, etc.). The legend must be complete: every symbol or graphic representation appearing on the map must be mentioned and explained in the legend.
- **Orientation**: Indicates the direction of north (often true north).
- **Geographic Coordinates**: A system that allows for precise location of a point on the map. Geographic coordinates (also called "geographic markers") of a point on Earth refer to a system of three coordinates, usually composed of latitude, longitude, and altitude (or elevation). Altitude can be measured relative to mean sea level (orthometric elevation) or relative to a reference surface, often an ellipsoid (ellipsoidal elevation).
- **Conventional Symbols**: These are symbols and colors used to represent elements on the map, such as bridges, marshes, roads, buildings, soil type, and colors like blue and green.

3. The Scale

The scale represents the reduction ratio between a distance measured on the map and the actual distance observed on the ground.

$$\textit{Scale} = \frac{\textbf{1}}{\textbf{50000}} \quad \begin{matrix} \rightarrow \textit{Measured on the map} \\ \rightarrow \textit{Measured on the ground} \end{matrix}$$

3.1. Numerical Scale

It is expressed as a ratio, for example, 1/50,000, which means one unit on the map corresponds to 50000 units in reality.

<u>*Example:*</u> If two points are 5 km apart on the ground and 10 cm apart on the map, the scale is calculated as:

$$S = \frac{10}{500000} = \frac{1}{50000}$$

Thus, the scale of the map is: $S = \frac{1}{50000}$

meaning 1 cm on the map represents 50,000 cm or 500 m on the ground.

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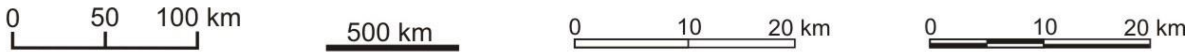
3.2. Graphical Scale

The graphical scale is represented as a horizontal line divided into equal segments, each marked by a vertical stroke called a tick mark. Numbers, ideally rounded values, are placed above these tick marks. This scale is easier to read and remember, offering quick conversion of measured lengths. It also remains accurate even if the map is enlarged or reduced.



<u>Note</u>: Be careful with the terminology "small scale" and "large scale." Scale is a ratio: the larger the denominator (and thus the smaller the ratio), the smaller the scale.

Maps are distinguished by their scale, which determines their level of detail.

- Large-scale maps focus on a small area but offer very detailed representations of the territory.
- Small-scale maps cover a larger area but must simplify their representation.

This fundamental difference means that large-scale maps can depict features with accuracy and detail, while small-scale maps require simplification of the base map and its information through a process called cartographic generalization.

<u>Example 1</u>:

Measured distance AB on the map = 16 cm

Real horizontal distance AB = 4 km

- Determine the scale of this map.

Solution:

E = AB on the map / AB on the ground = 16 cm / 400,000 cm = 1/25000.

<u>Example 2</u>:

On a map with a scale of 1/25000, two points separated by 7 cm on the map are:

7 cm × 25000 = 175000 cm or 1750 m apart on the ground.

3.3. Activity 1: Scale Applications

<u>Exercise 1</u>

What are the scales of the maps with the following characteristics?

- ✓ 5 km on the ground corresponds to 10 cm on the map.
- ✓ 20 cm on the map corresponds to 5 km on the ground.
- ✓ 1 km on the ground corresponds to 1 cm on the map.

Exercise 2

Use the scale to determine the real distance based on the distance measured on the map.

Map	Map Distance	Scale	Actual Distance (cm)	Actual Distance (km)
01	10 cm	1/200 000	………………….	………………….
02	4,5 cm	1/100 000	………………….	………………….
03	13,2 cm	1/50 000	………………….	………………….
04	7,8 cm	1/25 000	………………….	………………….
05	9 mm	1/5 000	………………….	………………….

Exercise 3

Use the scale to determine the actual distance based on the distance on the map.

Map	Actual Distance	Scale	Map Distance (cm)
01	25 km	1/200 000	……………………….
02	31 km	1/100 000	……………………….
03	4,5 km	1/50 000	……………………….
04	150 km	1/25 000	……………………….
05	600 m	1/5 000	……………………….

Exercise 4

On the road map, the distance between two cities is represented by a segment of 8 cm. The map scale is 1/1000000. Calculate the actual straight-line distance between the two cities in kilometers.

Exercise 5

On a map with a scale of 1/50000:

- How many kilometers are represented by 10 cm?
- How many centimeters are represented by 2 km?

Chapter II

Geographic and Cartographic Coordinate Systems

Chapter II: Geographic and Cartographic Coordinate Systems

1. Coordinates

Geographical objects are located in space using two types of referencing. The first uses precise coordinates, which can be planar or spherical, in two or three dimensions, defined within a geographic reference system. The second describes their position relative to other elements, indicating whether they are contained within other objects or overlap with them.

These reference systems (whether geographic, UTM, or Lambert) appear on maps and serve as guides for accurately locating all mapped elements.

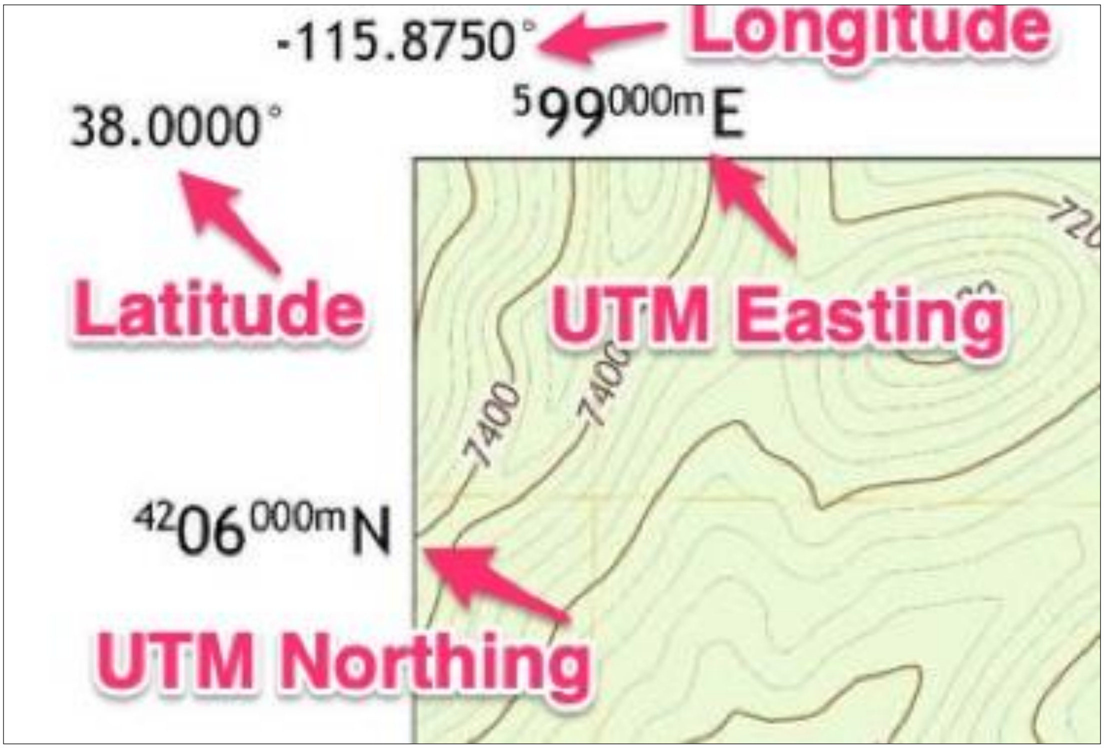


Figure 1. Illustration of Geographic and Cartographic Coordinates ***(Nabed, 2020)***

1.1. Geographic Coordinates

Geographic coordinates are a localization system used to determine the position of a point on the Earth's surface. This system is based on two main angles, latitude and longitude, measured from fixed references such as the equator and the Greenwich meridian.

- **Latitude:** The angular distance of a point from the equator, measured in degrees north or south. Latitude ranges from 0° at the equator to 90° at the poles.
- **Longitude**: The angular distance of a point from the prime meridian (Greenwich meridian), measured in degrees east or west. Longitude ranges from 0° at Greenwich to 180° east or west.

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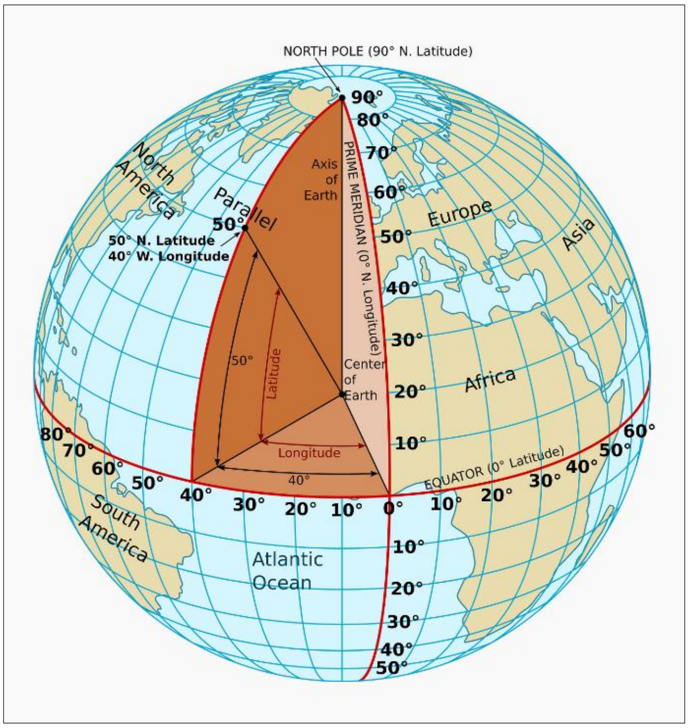

Figure 2. Latitude and Longitude

These coordinates allow precise localization of any point on Earth.

Meridians and parallels form an imaginary grid system used to define geographic positions.

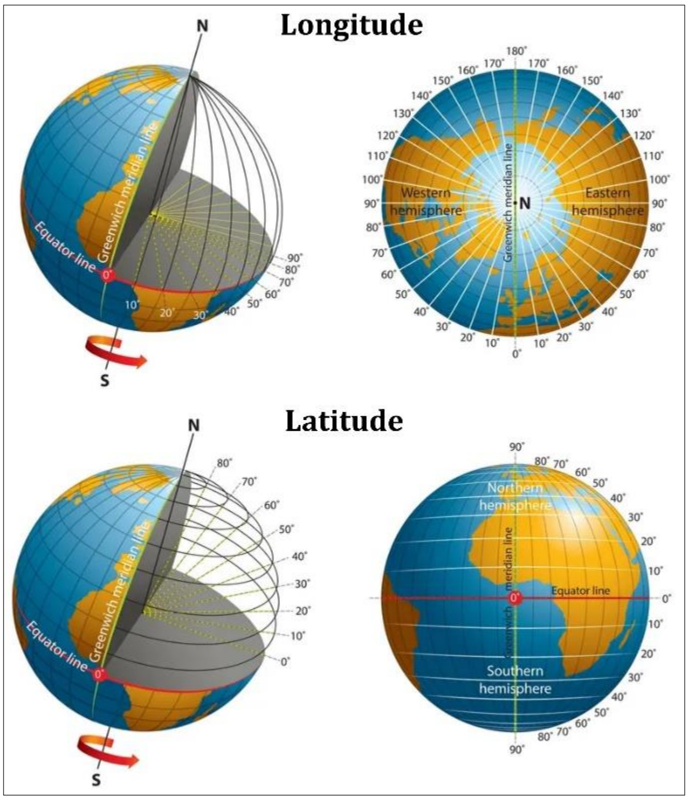

Figure 3. Parallels and Meridians (***Anne, 2004)***

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- **Meridians:** These are semicircles connecting the North and South Poles. The Greenwich Meridian (0° longitude) serves as the international reference for calculating longitudes.
- **Parallels:** These are circles parallel to the equator. They define the latitude of a point. The equator is the reference parallel (0°), and the other parallels extend toward the poles.

The Earth is divided into 360 meridians: 180 meridians are located east of Greenwich, while the remaining 180 are west of Greenwich. If longitude is measured to the right of Greenwich, i.e., westward, it is referred to as west longitude. If measured to the left of Greenwich, it is called east longitude.

The equator naturally serves as the zero point for latitudes. However, there is no natural reference for longitudes. The Greenwich Meridian was chosen (somewhat arbitrarily) as the reference point for maps.

The Greenwich Meridian is a meridian where longitude is defined as 0°. It passes through the Royal Observatory in Greenwich (a suburb of London), United Kingdom.

In Algeria (over 1555 km); The prime meridian passes through the locality of Stidia, a coastal commune in the wilaya of Mostaganem (marked along the RN11 national road), then through Hacine, a commune in the wilaya of Mascara, west of Mascara city. It continues to Aïn Fekan, a commune located on the RN7 national road between Mascara and Sidi-Bel-Abbès, and between Youb and Saïda. Further east of Adrar, it crosses the Guentour oasis, west of Reggane. Finally, the meridian passes through Algeria's desert region, west of Bordj Badji Mokhtar (Fig. 4).

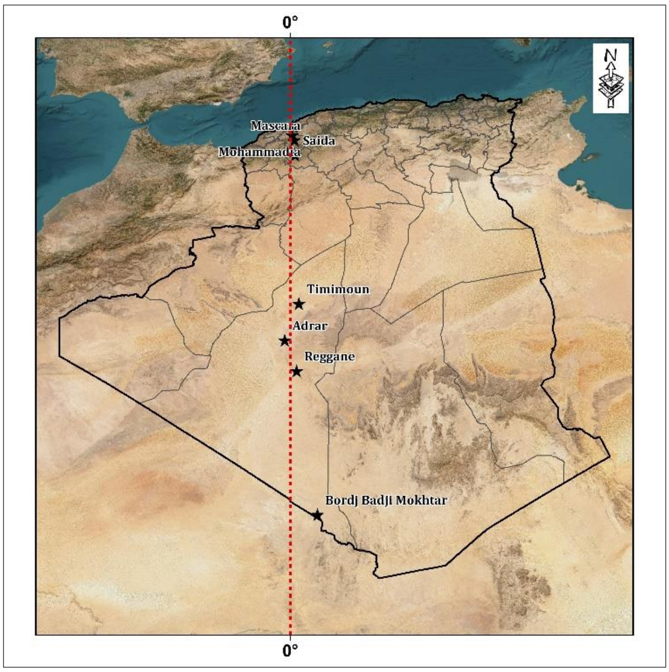


Figure 4. Localities Crossed by the Reference Meridian: Greenwich in Algeria

1.2. Cartographic Coordinates

Unlike geographic coordinates, cartographic coordinates are often expressed in a planar system (such as X and Y coordinates) that represents the Earth's curved surface on a flat plane. This system is commonly used for topographic maps, where projecting the Earth's surface is necessary to make the maps readable and practical for various applications. One of the most widely used cartographic coordinate systems is the UTM (Universal Transverse Mercator) system.

- **X Coordinates (abscissa):** Represent the horizontal distance from a reference meridian.
- **Y Coordinates (ordinate):** Represent the vertical distance from a reference parallel.

These coordinate systems are essential for topographic surveys, navigation, and geographical studies.

1.3. Reminder on Angle Measurements

Angles are a critical part of coordinate systems as they allow the measurement of distances and positions in a spherical system, such as that of the Earth. Several units of angle measurement are used in geography and cartography:

1.3.1. Degrees

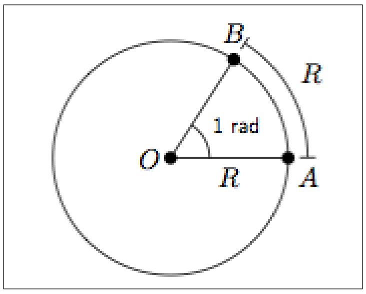
Degrees are the most commonly used unit for measuring angles. A complete circle is divided into 360 degrees (°). Each degree is subdivided into 60 minutes ('), and each minute into 60 seconds (").

1.3.2. Grads

The grad is another unit of angle measurement, mainly used in navigation systems and certain scientific calculations. A circle is divided into 400 grads, and one grad is equivalent to 0.9 degrees.

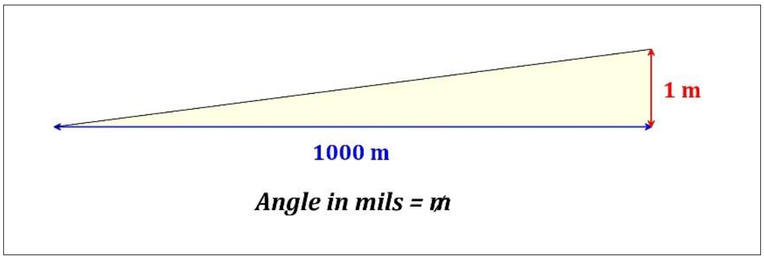
1.3.3. Radians

The radian is the unit of angle measurement used in mathematics and physics. One radian corresponds to the angle subtended at the center of a circle by an arc equal in length to the circle's radius. A complete circle measures 2π radians, or approximately 6.28 radians.



1.3.4. The Mil

The mil is primarily used in artillery and military topography. A circle is divided into 6400 mils, making it a highly precise unit for measuring angles. The mil is slightly different from 1/1000 of a radian and can be considered as the angle under which 1 meter is observed at a distance of 1000 meters.

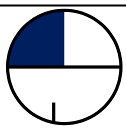
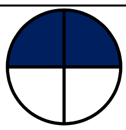
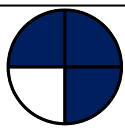
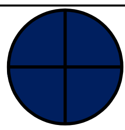
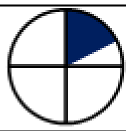
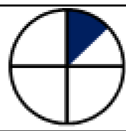


The notation for the mil is: m̸ radian

1.4. Equivalences

In geographical studies, it is often necessary to convert angle or time units into other units. Therefore, several practical equivalences exist to facilitate these conversions.

Table 03. Conversion Table

Unit						
Degree (°)	90	180	270	360	60	45
Grad (G)	100	200	300	400	66,66	50
Radian (rd)	π/2=1,57	π=3,14	π3/2=4,71	2π=6,28	π/3=1,05	π/4=0,79
Mil (m̸)	1600	3200	4800	6400	1066,66	800

1.4.1. Equivalence Between Distances and Angles

This relationship is particularly important in topographic surveys, where it is necessary to convert measured angles into actual distances on the ground, depending on the map's scale.

Given that the Earth's circumference is approximately 40000 km,

400 Gr ⇔ 40,000 km, and 100 Gr ⇔ 10,000 km, therefore **1 Gr = 100 km**

Similarly, 360° ⇔ 40000 km, and 90° ⇔ 10000 km, therefore **1° = 111 km**

1.4.2. Equivalence Between Time and Angles

Time can be related to angles, particularly in celestial navigation. For instance, a one-hour time difference corresponds to 15 degrees of longitude. This equivalence is based on the Earth's rotation.

The Earth rotates around its polar axis from west to east with a period of 24 hours.

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360° ⇔ 24 h, and 90° ⇔ 6 h, therefore **15° = 1 h**

Similarly, 400 Gr ⇔ 24 h, and 100 Gr ⇔ 6 h, therefore **16.667 Gr = 1 h**

1.4.3. Equivalence Between Distances and Time (or Angles)

This equivalence allows determining a distance based on the elapsed time and speed of travel, or the angle covered based on the time elapsed.

As mentioned earlier, the Earth's rotation completes a quarter turn in 6 hours. At the equator, the Earth's circumference is approximately 40,000 km, so to cover 10000 km (a quarter of the circumference), it takes 6 hours (24 h ÷ 4).

Thus, in 1 hour, the Earth covers 1667 km. At the equator, our relative speed with respect to the Earth's center is therefore 1667 km/hour.

1.5. Activity 2: Applications on Conversions

Exercise 1: Convert 2° 20' 14" into grades (This is the angle between the Greenwich Meridian and the Paris Meridian).

Solution:

- ✓ Convert the sexagesimal seconds into sexagesimal minutes:

14''/60 = 0.233', so 20'+ 0,233' = **20,233'**

- ✓ Convert the sexagesimal minutes into sexagesimal degrees:

20.223'/60 = 0,337°, thus: 2° + 0.337° = **2.337°**

- ✓ Convert the sexagesimal degrees into grades:

2.337° x 10/9 = **2.5966 Gr**

- ✓ Convert the decimal part of the grades into centesimal minutes and seconds:
  - Decimal part of the grades: 0.5966 x 100 = 59.66′ (centesimal minutes)
  - Decimal part of the centesimal minutes: 0, 66 x 100 = 66'' (secondes centésimales).

Final result: 2°20'14'' = 2^{Gr} 59' 66''

Exercise 2: Convert 22° 32' 45" into grades.

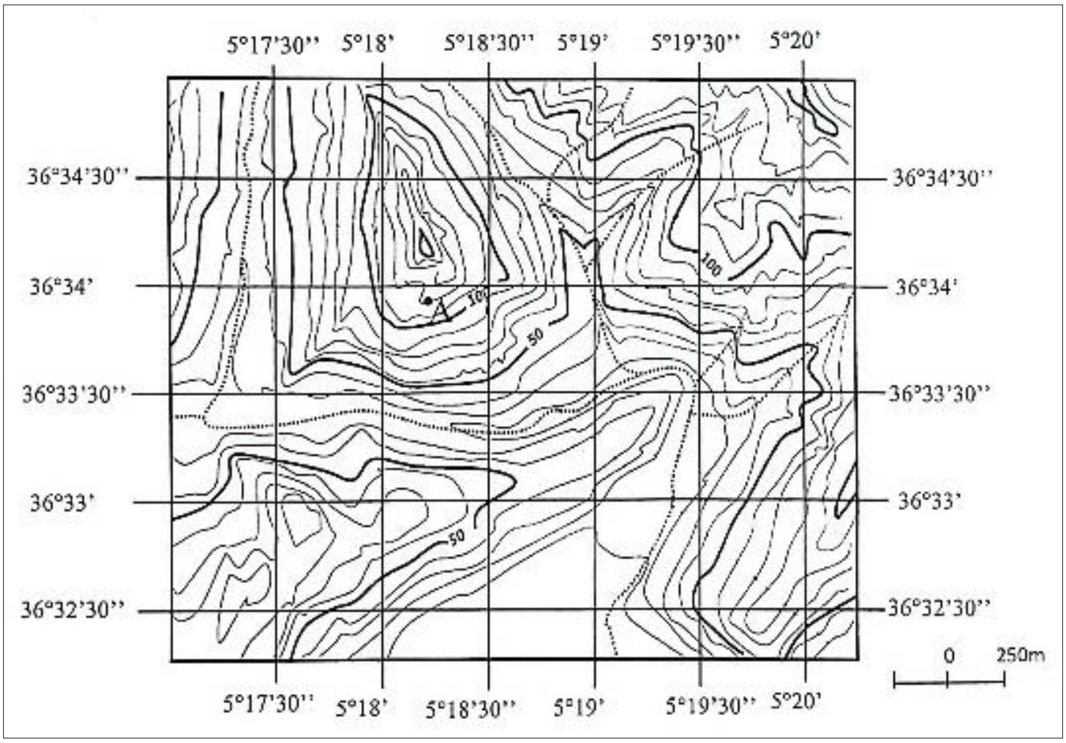
Exercise 3: Convert 48 ^{Gr} 52' 84" into degrees.

1.6. Activity 3: Calculating the Geographical Coordinates of a Point

The calculation of geographical coordinates is essential to determine the exact position of a point on the Earth's surface. This can be done using systems like GPS or traditional methods based on astronomical observations.

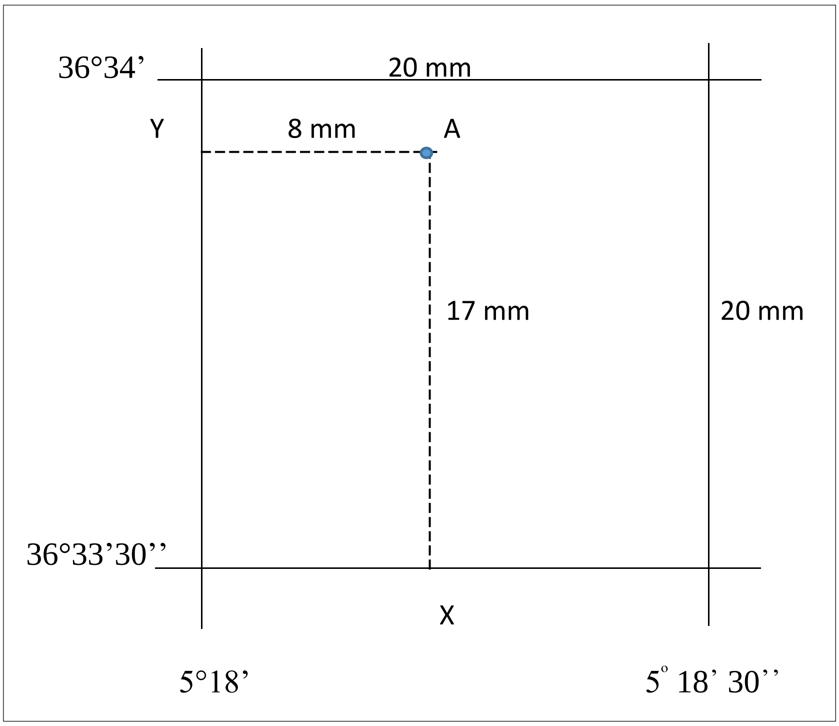
Exercise 1:

Determine the geographical coordinates of point A, located on the topographic map in the figure below. Convert these coordinates into grades, considering the origin of the meridians.



<u>Solution :</u>

Point A is located between the geographical meridians 5°18' and 5°18'30" and between the geographical parallels 36°33'30" and 36°34'.



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a- Determination of Longitude:

- *Step 1*: Determine the difference in longitude between the two meridians closest to point A: 5°18'30" - 5°18' = 5°18'30" - 5°17'60" = 30"
- *Step 2*: Measure the distance in millimeters between the two closest meridians to point A, which is 20 mm. Draw a line from point A to the 5°18' meridian parallel to the geographical parallels on the map, and measure its length as 8 mm.
- *Step 3*: Calculate the longitude corresponding to this 8 mm distance using the rule of three:

$$\left.\begin{array}{lll} 20\text{ mm} & \rightarrow & 30'' \\ 8\text{ mm} & \rightarrow & X \end{array}\right\} \rightarrow \quad X = 8\text{mm} \times 30''/20\text{mm} = 12''$$

- Step 4: Add this value to the longitude of the preceding meridian:

  5°18' + 12" = **5°18' 12"**

b- Determination of Latitude:

- *Step 1*: Determine the difference in latitude between the two parallels closest to point A: 36°34'- 36°33'30"= 36°33'60"- 36°33'30"= 0° 0' 30" = **30"**
- *Step 2*: Measure the distance in millimeters between the two closest parallels to point A, which is 20 mm. Draw a line from point A to the 36°33'30" parallel parallel to the geographical meridians on the map, and measure its length as 17 mm.
- *Step 3*: Calculate the latitude corresponding to this 17 mm distance using the rule of three:

$$\left.\begin{array}{lll} 20\text{ mm} & \rightarrow & 30'' \\ 17\text{ mm} & \rightarrow & Y \end{array}\right\} \rightarrow \quad Y = 17\text{mm} \times 30''/20\text{mm} = 25.5''$$

- Step 4: Add this value to the latitude of the preceding parallel:

  36°33'30"+ 25.5" = **36°33'55.5"**

Geographical Coordinates of Point A:

X = 5°18' 12"	**Y = 36°33'55,5"**	**Z = 120m**

Conversion of Geographical Coordinates into Gradians

1- Conversion of Longitude: ***5°18' 12"***

- *Step 1*: Convert sexagesimal seconds into minutes:

  12" / 60 = 0.20' so 18' + 0.20' = 18.2'
- *Step 2*: Convert sexagesimal minutes into degrees:

  18.2'/60 = 0.3033° so 5° + 0.3033° = 5.3033°
- *Step 3*: Convert degrees into gradians: 5.3033° X 10/9 = $\mathbf{5.8925^{Gr}}$

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– *Step 4*: Adjust for the meridian origin: **5.8925^{Gr} – 2.5966^{Gr}** = **3.2959^{Gr}**

Longitude in gradians = 3^{Gr} 29' 59''

*2- Conversion of Latitude: **36°33'55.5"***

– *Step 1*: Convert sexagesimal seconds into minutes:

55.5''/60 = 0.925' ⇒ 33'+0.925'= 33.925'

– *Step 2*: Convert sexagesimal minutes into degrees:

33.925'/60 = 0,5654° ⇒ 36° + 0,5654° = 36.5654°

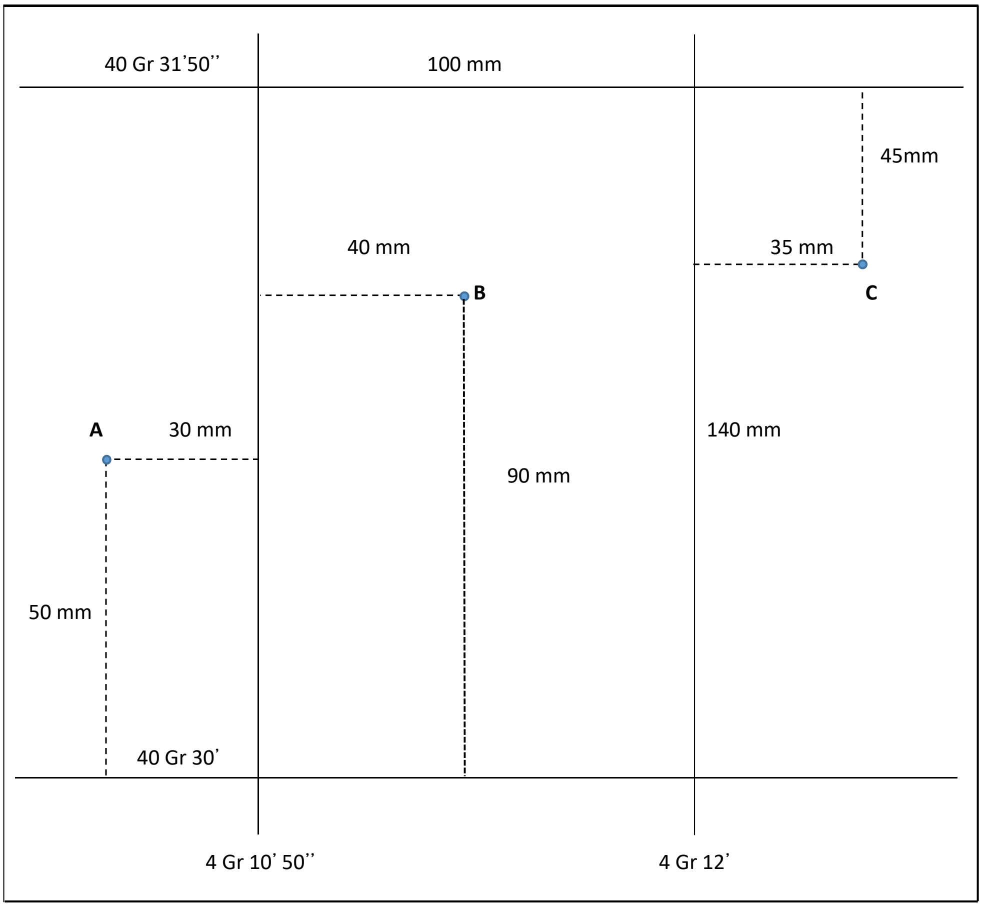
– *Step 3*: Convert degrees into gradians: 36.5654° x 10/9 = **40.6282^{Gr}**

Latitude in gradians = 40^{Gr} 62' 82''

Geographical Coordinates of Point A in Gradians:

X = 3^{Gr} 29' 59'' **Y = 40^{Gr} 62' 82"** **Z = 120m**

Exercise 2: Determine the geographical coordinates of points A, B, and C on the following diagram and convert these coordinates into degrees, taking into account the meridian origin.



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2. Planar Projections

2.1. Introduction

The transition from an elliptical reference frame to a cartographic reference frame is achieved through a mathematical deformation model known as a projection (also called a planar transformation).

The purpose of cartographic projections is to obtain a planar representation of the Earth's ellipsoidal surface. The primary benefit lies in the metric values, which are much easier to use, particularly for measuring distances.

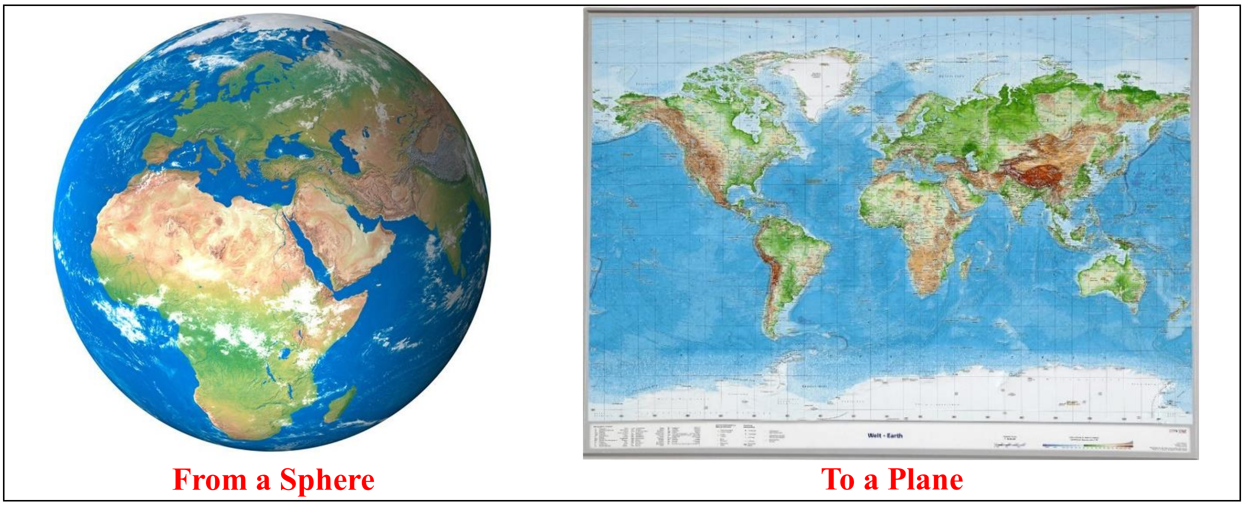

Figure 5. From the Globe to the Earth

Since the Earth is round (a three-dimensional object) and a map is usually presented in two dimensions, it is necessary to convert locations from a curved surface to a flat one. To achieve this, a mathematical formula is required to establish an appropriate correspondence between points on the ellipsoid and those on the plane. This correspondence system is called a projection system or a planar representation system.

For example, point A located within the ellipsoid coordinate system must be transferred to the plane:

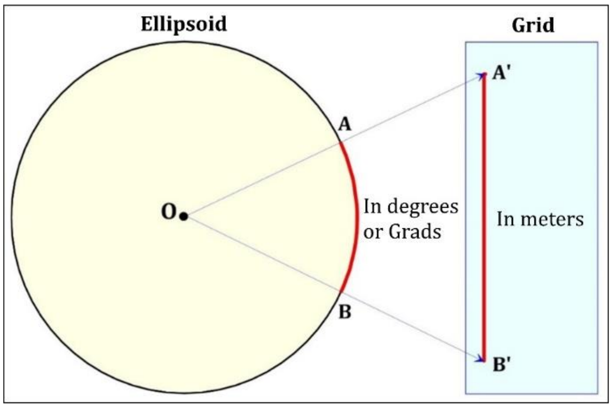

Figure 6. Principle of Cartographic Projection

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However, projections inherently involve distortions. To illustrate this, imagine trying to flatten the skin of an orange! Nonetheless, through calculation, it is possible to define the type and parameters of a projection to minimize specific distortions. Depending on the purpose, one may choose to:

- Preserve areas (equivalent projections).
- Preserve local angles (conformal projections).
- Preserve distances from a specific point (equidistant projections).

2.2. Classification of Map Projections

Map projection is the process of representing a curved surface (the Earth) on a flat surface (a map). Each map projection introduces certain distortions (of altitude, distance, area, or angle), which is why different types of projections exist depending on cartographic needs.

2.2.1. Based on the Nature of Distortions

Projections can be classified according to the type of distortion they correct or minimize. They are grouped into three types:

- **Conformal Projections:** These preserve local angles but distort areas. They are often used for nautical and aeronautical maps.
  - Parallels (latitude lines) are represented by arcs of circles.
  - Meridians (longitude lines) are straight lines, equally spaced.
  - Conformal projections maintain angles (and thus shapes). The angles measured on the ground are identical to those measured on the map. However, area distortion increases as one moves away from the projection center.
  - Example: Mercator Projection (1569).

Figure 7. Conformal Projection

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- **Equivalent Projections:** These preserve areas but distort shapes and angles. They are useful for thematic maps (e.g., demographics, resource distribution).
  - This type of map introduces distortions in shapes and angles. The distortion worsens as one moves away from the point of origin.
  - Example: Albers Projection.

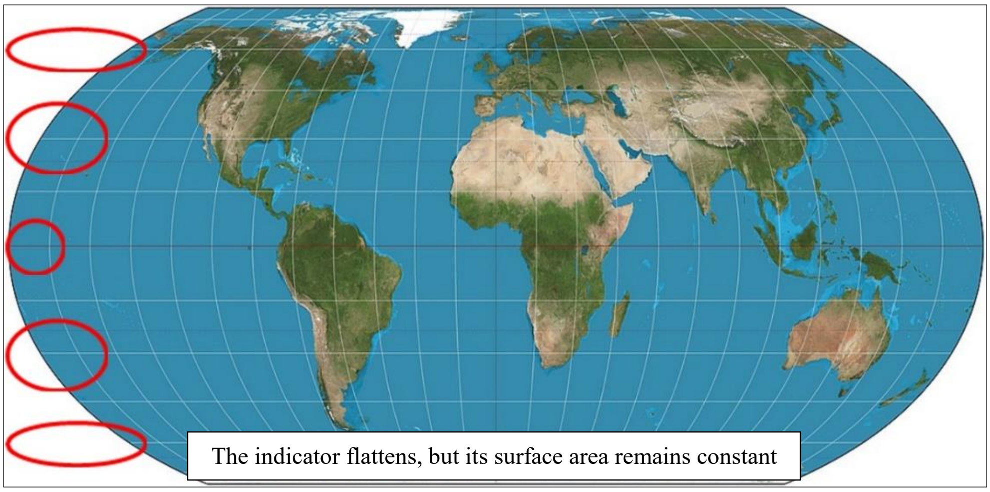

Figure 8. Equivalent Projection

- **Aphylactic (Arbitrary) Projections:** These preserve neither angles nor areas but aim to minimize overall distortions. This term refers to the infinite number of projections that are neither conformal nor equivalent.

  Example: Equidistant Projections, where the spacing of parallels is consistent and at scale everywhere.

2.2.2. Based on the Type of Projection Surface

Projections can also be classified according to the geometric surface used for the projection.

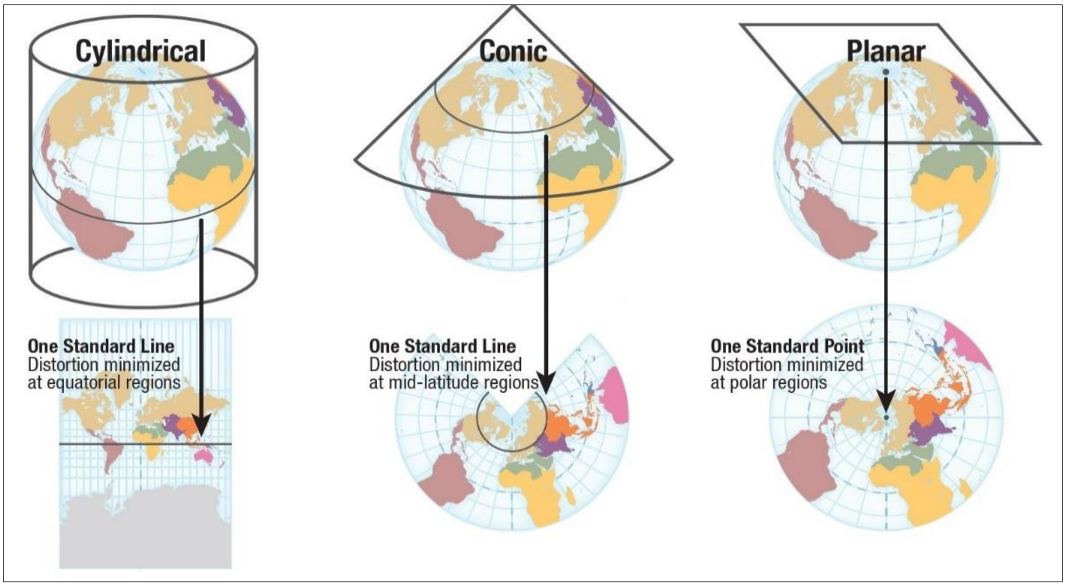

Figure 9. Types of Projections

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- **Conic Projections:** A cone is used to represent the Earth's surface and is often preferred for mid-latitude regions, such as Europe or North America.

  The reference surface is a cone, which can be tangent or secant to the ellipsoid, depending on the number of selected parallels (usually one or two). These parallels define the guiding lines of the projection.

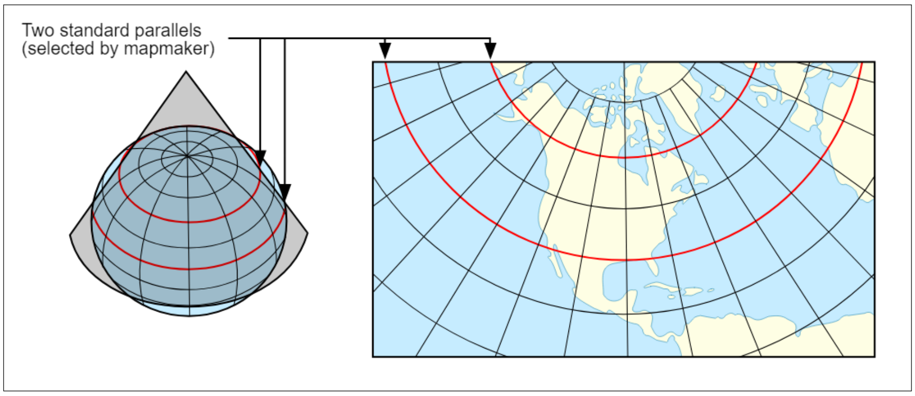

Figure 10. Conic Projection

- **Cylindrical Projections:** The Earth's surface is projected onto a cylinder. The Mercator Projection is the most famous example, widely used for maritime navigation.

  The projection surface may be a tangent or secant cylinder.

  Meridians are represented as straight, parallel, and equidistant lines, while parallels appear as straight lines perpendicular to the meridians.

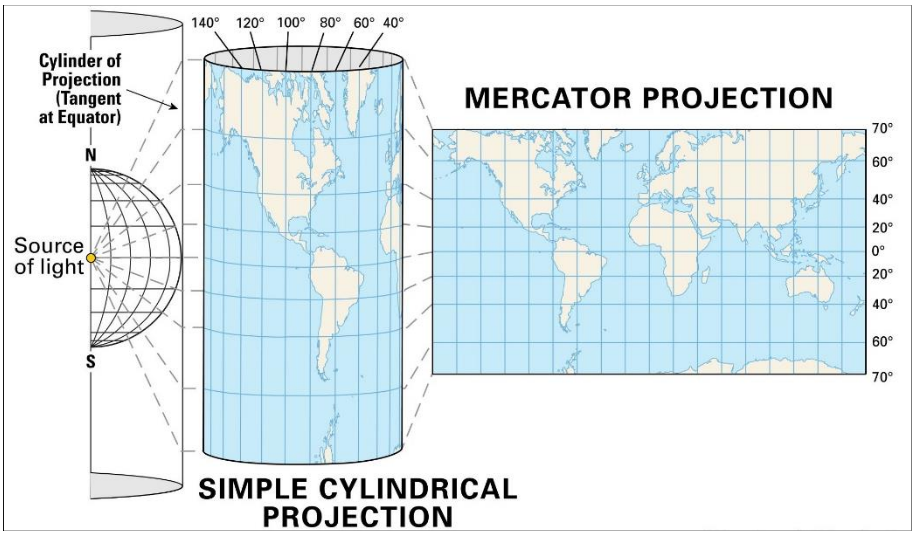

Figure 11. Cylindrical Projection

- **Azimuthal Projections:** These project the Earth's surface onto a plane tangent to a specific point and are often used for polar regions or aerial maps.

  In this type of projection, meridians appear as straight lines converging toward a point representing the pole, while parallels are represented as concentric circles around the same point.

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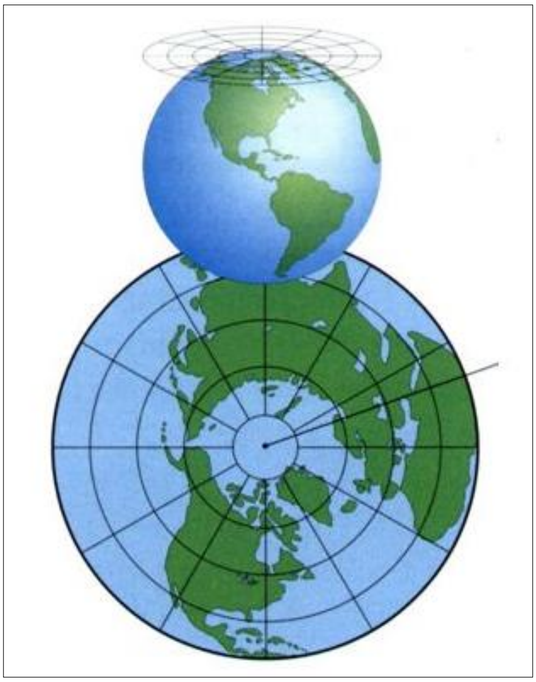

Figure 12. Azimuthal Projection

2.3. Choosing an Appropriate Projection System

The choice of a projection system depends on the specific requirements of the map. For topographic maps, projections that minimize distortions within a limited area are typically preferred. For world maps, projections prioritizing area or angles are often used.

The selection of a suitable projection system for creating a map depends on several variables:

- The purpose of the map or its application: For small-scale maps covering large areas, it is preferable to use an equivalent projection.

  Example: The direct conformal cylindrical projection of Mercator is useful for maritime and aerial navigation.

- The shape of the area to be mapped.
- The position of the area on the ellipsoid.

2.3.1. Map Projections Used in Algeria

Several series of maps by the IGN (Institut Géographique National) cover Algeria at different scales:

- **1 : 25000** : These maps use the Universal Transverse Mercator (UTM) projection on the Clarke 1880 ellipsoid.
- **1 : 50000** : These maps are based on the Clarke 1880 ellipsoid.
  - Initially, they used the Bonne projection until 1942.

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- Subsequently, they adopted the Lambert Conformal Conic projection (Fig. 8), divided into two zones: Lambert North Algeria and Lambert South Algeria.
- In 2009, the INCT (National Institute of Cartography and Remote Sensing) launched a new program to update basic topographic mapping at a scale of 1:50,000, replacing outdated maps and introducing a new geographic division. The Lambert Conic projection was replaced with the UTM system.

- **1 : 100000 :** These maps use the geodetic reference system Voirol 1875, with the associated ellipsoid being Clarke 1880.
  - They are primarily of the 1956 type, except for five sections in the Colomb-Béchar region, which are of the 1922 type.
  - The projections used are either Lambert North Algeria or Lambert South Algeria.
- **1 : 200000** : When labeled as type 1960, these maps are based on the North Sahara 1959 geodetic reference system, which uses the Clarke 1880 ellipsoid (English version).

2.3.2. The Lambert Projection

The Lambert projection is a conformal conic projection used for mapping Algeria at a 1:50,000 scale from 1943 to 1960. It features a red kilometer grid called the "Lambert graticule," marking 1-km² squares for identifying planimetric and altimetric details.

To minimize linear distortions, Algeria was divided into two zones (Fig. 13):

- "*Lambert North*" Projection: Covers northern Algeria.
- "*Lambert South*" Projection: Covers southern Algeria.

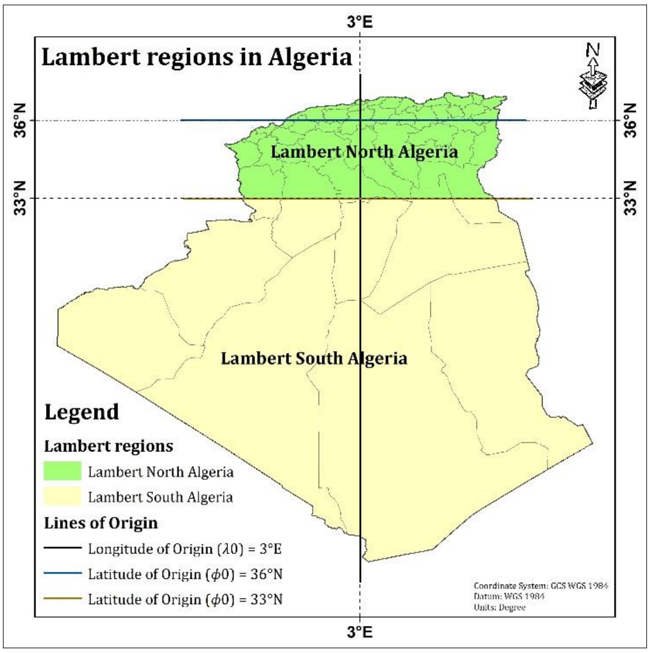

Figure 13. Lambert Projection in Algeria

2.3.3. The Universal Transverse Mercator (UTM) Map Projection

The Mercator projection has the following characteristics:

- It divides the world into 60 zones (numbered 1 to 60), each covering 6° of longitude.
- It is a transverse cylindrical conformal projection, meaning it preserves angles (Darteyre, 2008).
- Rectangular (Cartesian) coordinates are expressed in meters.

In 2003, Algeria adopted the UTM (Universal Transverse Mercator) system as the official flat cartographic representation. Algeria spans four UTM zones, from west to east: zones 29, 30, 31, and 32, ranging from 9° west to 12° east of the prime meridian (Fig. 14). The UTM projection is currently used for Algeria, with each zone covering 6° of longitude (Daouadi, 2015). Algeria occupies the following four UTM zones:

- UTM North Zone 29: Between 8.67°W and 6°W of Greenwich.
- UTM North Zone 30: Between 6°W and 0°E of Greenwich.
- UTM North Zone 31: Between 0°E and 6°E of Greenwich.
- UTM North Zone 32: Between 6°E and 12°E of Greenwich.

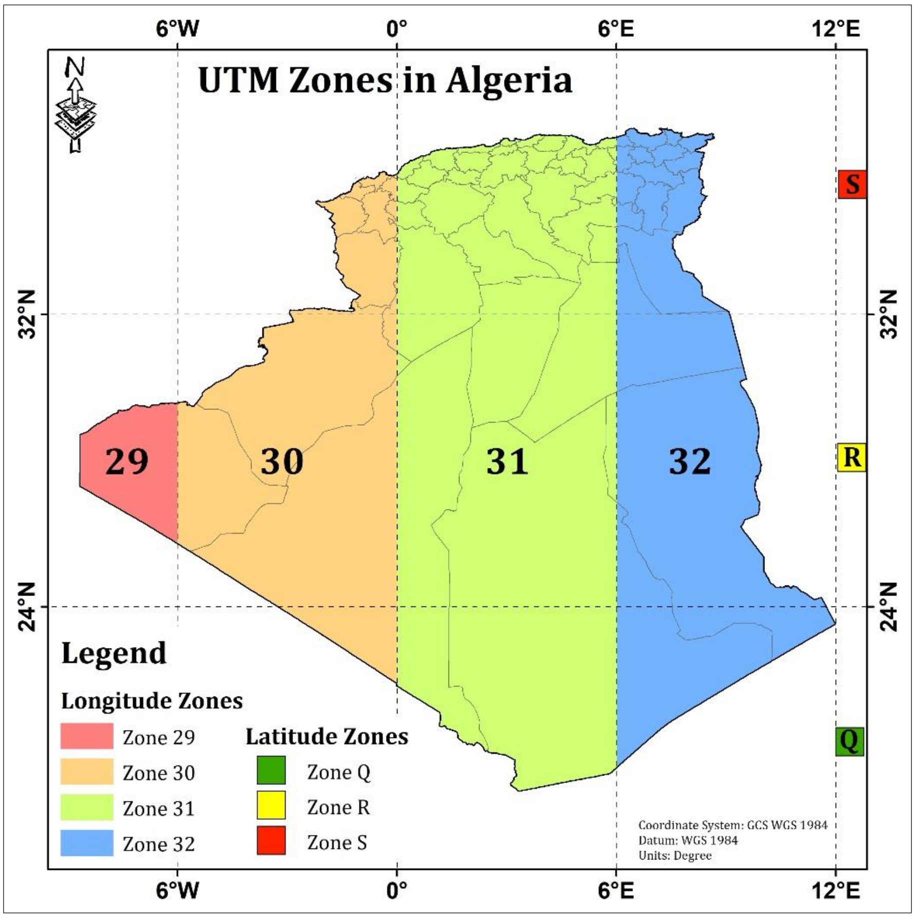

Figure 14. UTM Zones in Algeria

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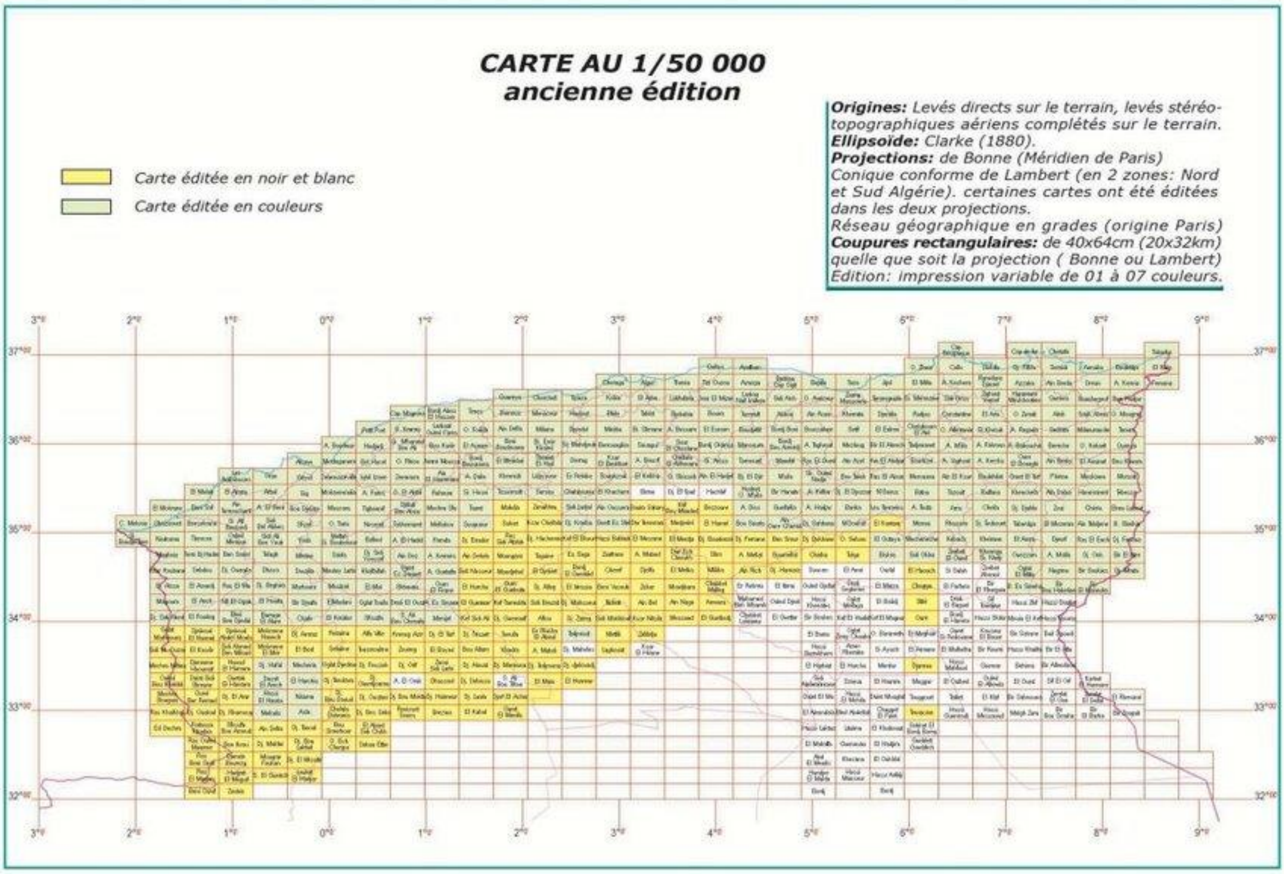
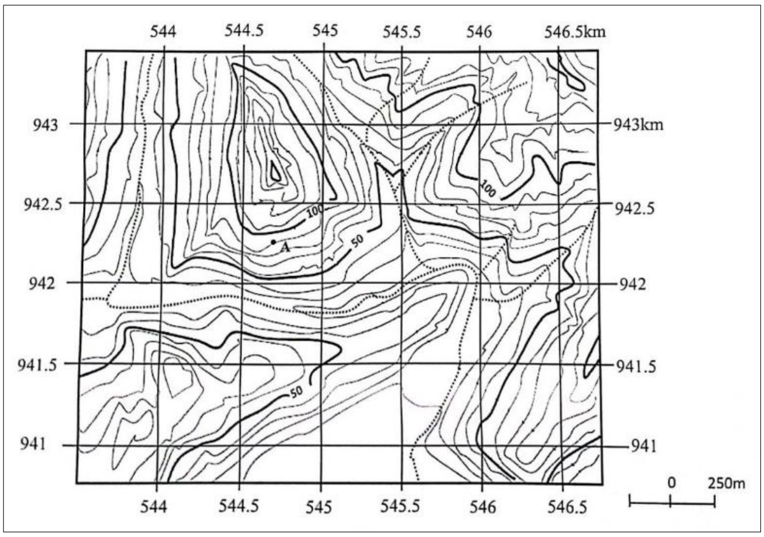


Figure 15. Former Division of Northern Algeria in 1:50,000 Maps Using the Lambert Conformal Conic Projection (INCT).

2.4. Activity 4: Calculating Cartographic Coordinates of a Point

Calculating cartographic coordinates is essential to determine the position of a point on a map using its projection system. This method generally involves complex mathematical formulas tailored to each type of projection. The principle for determining cartographic coordinates of a point on a topographic map is the same for both UTM and Lambert projection systems.



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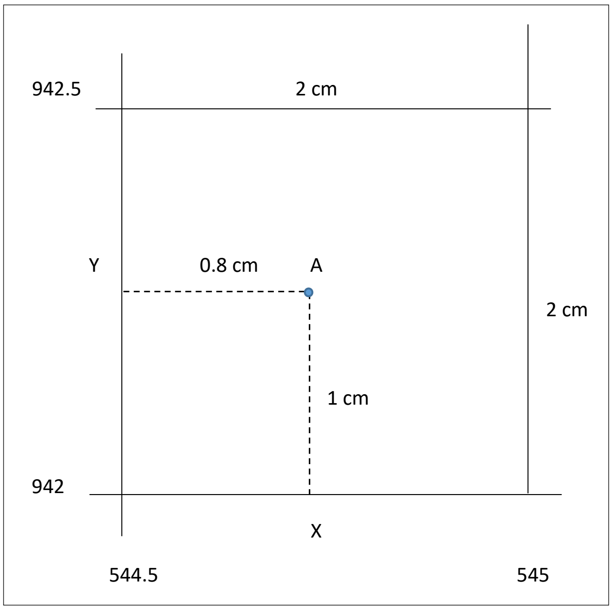
Exercise

Calculate the UTM coordinates of point A located on the topographic map in the following figure:



Solution :

- Point A is located within the square bounded by UTM meridians 544.5 and 545, and UTM parallels 942 and 942.5
- Draw the two meridians and the two parallels.

Coordinates to calculate: **XA = ?** **YA = ?** **ZA = ?**

First Method:

XA = ?

- Measure the orthogonal distance between point A and UTM meridian 544.5: 0.8 cm.
- Determine the value of X corresponding to this distance (8 mm) using the rule of three:

2 cm → 50000 cm
0.8 cm → X } → X = (50000 x 0.8) / 2 = 20000 cm = 200 m

- Add this value to the preceding UTM meridian value: 544.5 km + 200m = **544.5 km + 0.2 km = 544.7 km**

⇒ **XA = 544,7 km**

YA = ?

- Measure the orthogonal distance between point A and UTM parallel 942: 1 cm.
- Determine the value of Y corresponding to this distance (1 cm) using the rule of three:

2 cm → 50000 cm
1 cm → Y } → X = (50000 x 1) / 2 = 25000 cm = 250 m

- Add this value to the preceding UTM parallel value: 942 km + 250m = **942 km+0.25 km = 942.25km**

YA = 942.25 km

XA = 544.7 km **YA = 942.25 km** **ZA = 90 m**

Second Method:

Determine the numerical scale of the map:

From the map's graphical scale:

1cm → 250m i.e. 1 cm → 25000 cm donc **E= 1/25000**

XA = ?

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- Measure the orthogonal distance between point A and UTM meridian 544.5: 0.8 cm.
- The distance is: 0, 8 cm x 25000 cm = 20000 cm = 200 m = 0.2 km
- Add this value to the preceding meridian value:

XA= 544.5 km + 0.2 km = **544.7 km** **so**: **XA = 544.7 km**

YA = ?

- Measure the orthogonal distance between point A and UTM parallel 942: 1 cm.
- The distance is: 1 cm x 25000 cm =25000 cm = 250m = 0.25 km
- Add this value to the preceding parallel value:

YA = 942 km + 0.25 km = **942.25 km** **So**: **YA = 942.25 km**

XA= 544.7 km **YA= 942.25 km** **ZA= 90 m**

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Chapter III

Contour Lines

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Chapter III : Contour Lines

1. Introduction :

A topographic map can initially be obtained through the cylindrical projection of the Earth's surface onto a horizontal plane. This process, known as planimetry, must be complemented by the representation of relief, or orography. Orography (from the Ancient Greek ὄρος, "mountain," and γραφή, "writing") is a field within geomorphology and physical geography focused on describing terrain relief, which enables the representation of the terrain's features.

2. Definition of Contour Lines

Contour lines, or isohypses, are imaginary lines on a topographic map that connect points of equal elevation, usually relative to mean sea level. They allow the representation of terrain relief in two dimensions, helping visualize slopes, valleys, and peaks. The spacing of these lines indicates the slope: closely spaced lines signify steep terrain, while widely spaced lines indicate flatter areas. (Fig. 16).

Contour lines are utilized in many fields, such as geography, urban planning, construction, and archaeology, to understand and analyze terrain shapes.

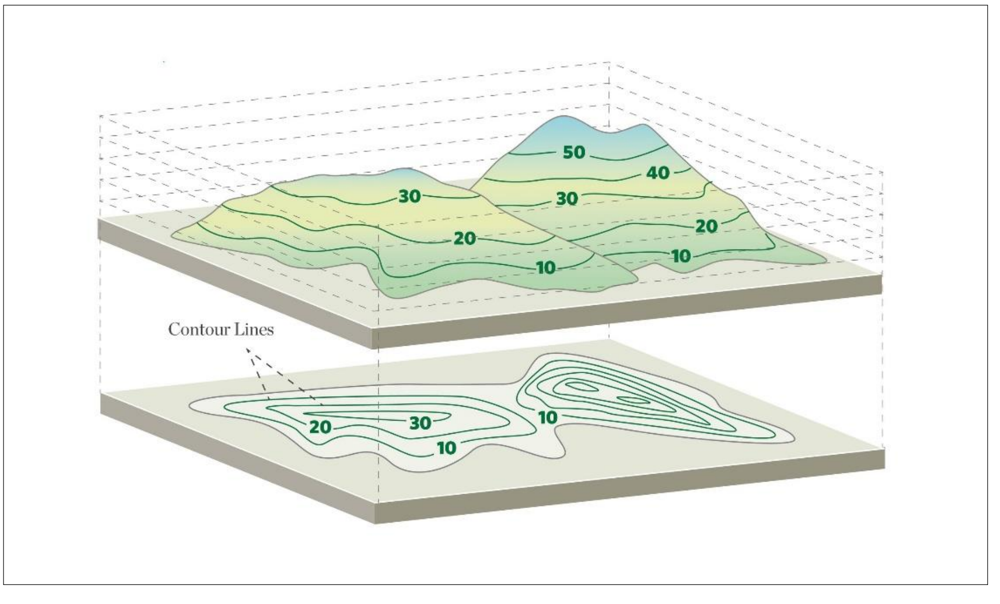

Figure 16. Contour Lines

2.1. Principle of Establishing Contour Lines

To draw contour lines, the terrain is divided into "slices" based on relief, from the lowest to the highest points, and then projected onto a flat surface, similar to the rings of a tree. The thickness of the contour lines (spacing) must remain constant. A primary contour, thicker and often marked with its altitude, appears every five or ten lines as a reference (Fig. 17).

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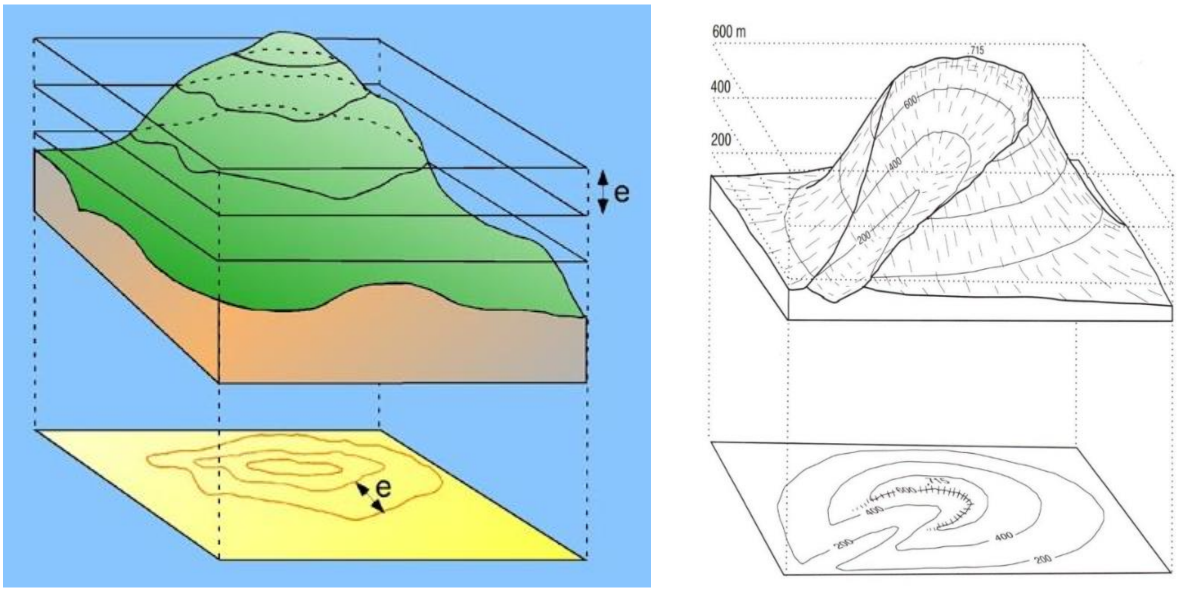


Figure 17. Relief Representation with Contour Lines

2.2. Spacing and Equidistance

The spacing between contour lines varies based on the map's scale and intended use:

- **Standard equidistance:** For 1/25000 scale maps, the equidistance is typically 10 meters, though this may increase for smaller scale maps like 1/100000.
- **Contour spacing:** The distance between two contour lines depends on the terrain slope. On flat terrain, contour lines are widely spaced, while on steep terrain, they are closely spaced. A steeper slope results in reduced spacing between contour lines.

The choice of equidistance and interpretation of spacing are essential for analyzing terrain morphology and assessing traversal challenges. Equidistance is calculated by dividing the altitude difference between two lines by the number of intervals:

$$Eq = \frac{h_2 - h_1}{number\ of\ intervals}$$

2.3. Properties of Contour Lines

Contour lines follow certain rules and properties that facilitate their reading and application.

2.3.1. Types of Contour Lines

Several types of contour lines exist based on the terrain relief:

- **Primary contours:** Thicker lines representing significant altitudes, spaced every five or ten intervals (e.g., every 50 or 100 meters), aiding in reading. Altitude is often marked on these lines.

- **Normal contours:** Drawn between primary contours in finer lines, adding detail to the relief representation.
- **Intermediate contours:** Represented with dotted lines to increase precision on flat terrain. Their altitude differs by half the equidistance relative to the lines they separate.

These various contour types allow maps to adapt precision to terrain variations, ensuring better interpretation of topography.

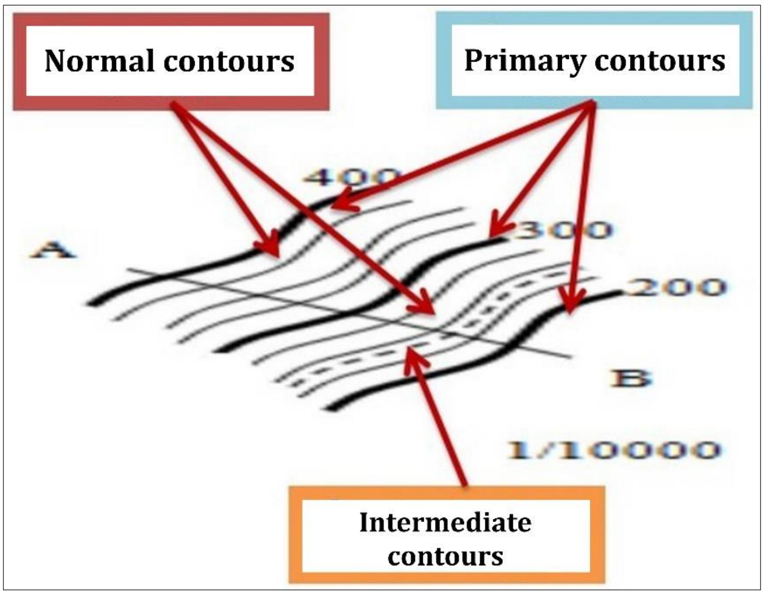
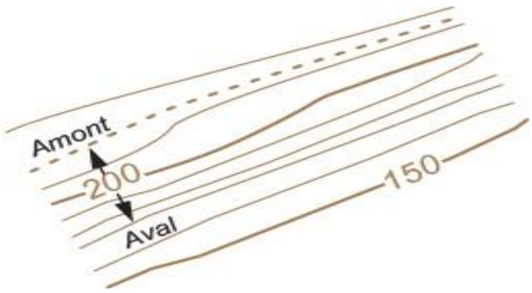


Figure 18. Different Types of Contour Lines

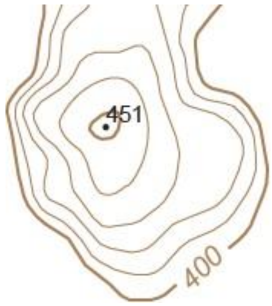
2.3.2. Altitude of Contour Lines

Each contour line corresponds to a specific altitude, which is typically marked on the map. Primary contours, drawn more prominently, allow easy identification of key altitudes.

- The altitude of each contour line is usually shown along its path, with the bottom of the digits indicating the lower slope.



- Benchmark Points: Maps also display points with specified altitudes known as benchmarks. These denote exact altitudes at mountain peaks or the lowest valley points and are often associated with closed contours.



451 is a benchmark (indicating a specific altitude).

- The altitude of an intermediate contour is valued at half the equidistance between two secondary contours or between a primary and a secondary contour. For example, if an intermediate contour lies between the 120 m and 140 m contours (equidistance = 20 m), its value is 130 m; if between 120 m and 130 m (equidistance = 10 m), its value will be 125 m.

2.4. Determining the Altitude of a Point on a Topographic Map

The altitude of a specific point on a topographic map is determined based on the surrounding contour lines.

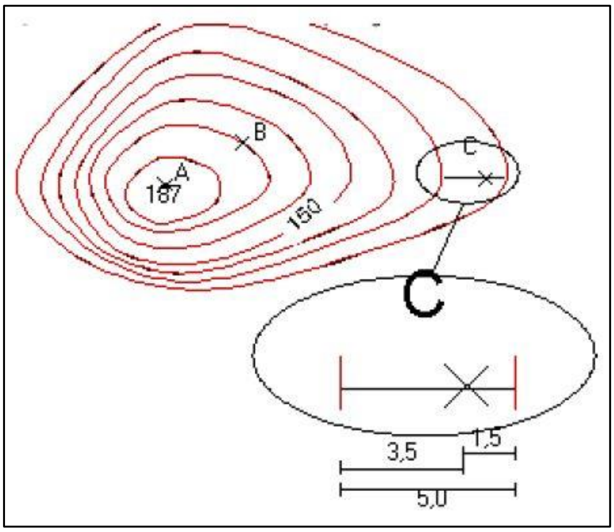


Figure 19. Example of Altitude Calculation for a Point

2.4.1. The Point is a Geodetic Benchmark

If the point is located at an intersection or near a geodetic marker, such as a peak or a monument, its altitude is generally indicated directly on the map. This altitude is shown next to the relevant point (e.g., point A has an altitude of 187 m).

2.4.2. The Point is on a Contour Line

If the point lies on a contour line, its altitude corresponds to that line's altitude. For instance, point B, located on a contour line, has an altitude of 170 m.

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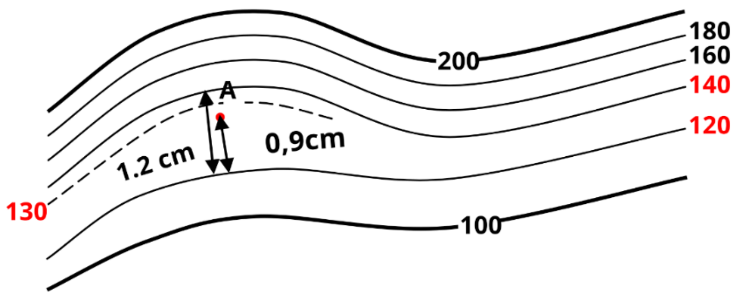
2.4.3. The Point is Between Two Contour Lines

If a point lies between two contour lines, its altitude can be estimated by interpolation, evaluating it based on the point's distance from the surrounding lines. For instance, for point C between two contours (120 m and 130 m), the total distance between the lines is measured, along with the distance between the lowest line (120 m) and the point. Using proportional scaling, the altitude of point C is then calculated. If 5 mm corresponds to a 10 m elevation difference, 1.5 mm equals 3 m, giving point C an altitude of 123 m.

Example :

Determine the altitude of point A in the following figures:



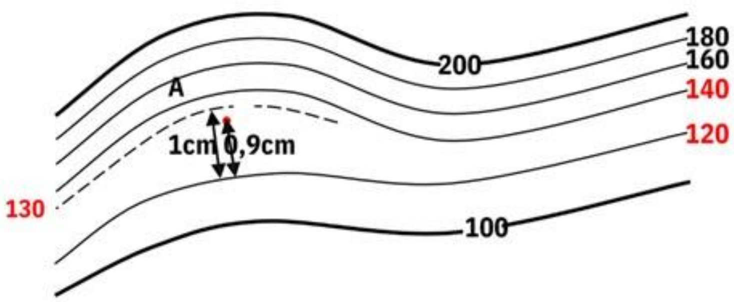
Solution:

a. Determining the Altitude of Point A Without an Intermediate Contour Line:

$$\text{Equidistance Eq} = \frac{\text{Altitude difference between two primary contours}}{\text{Numbre of spaces between them}}$$

Eq = (200 m - 100m) / 5

Eq = 20 m



Select: **h_1= 120 m,** and **h_2= 140 m**

1.2 cm → 20 m

0.9 cm → h

⇒ h= (0.9 cm*20m)/1. 2 cm, ⇒ h= 15 m

So h_A= h1+ h = 120 m + 15 m = 135 m

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b. Determining the Altitude of Point A Using an Intermediate Contour Line:

Select: h1= 120 m, et h2 = 130 m (where $h2$ is the intermediate contour).

1 cm → 10 m

0.9 cm → h

⇒ h= (0.9 cm*10 m)/1 cm, ⇒ h = 9 m

So, hA= h1 + h = 120 m + 9 m = 129 m.

3. Determination of Slope

The slope of a terrain is the angle formed between its surface and a horizontal surface, calculated based on the difference in elevation and the horizontal distance between two points. Contour lines allow for an accurate estimation of the average slope between two points. Slope is used to describe natural sites (mountains, slopes, rivers) or human-made structures (roads, railways, roofs). The slope also influences the flow of water and other gravitational phenomena. It is measured in percentage or degrees and is a key parameter for various geographic studies and projects.

3.1. In Percentage

The slope percentage is calculated by dividing the difference in elevation by the horizontal distance between two points and then multiplying the result by 100. This method is commonly used in field studies, road construction, infrastructure management, and other civil engineering projects. It expresses the slope as a percentage, representing the ratio of elevation to the horizontal distance on the terrain concerned.

→ *Slope formula in percentage:* ***P (%) = (h/ d)* 100***

Where:

P(%) = Slope percentage

h = Difference in elevation

d = Horizontal distance

3.2. In Degrees

Slope can also be expressed as an angle, known as the angle of elevation, measured in degrees. Although this method is less commonly used, it is still applied in certain contexts. To convert the angle of elevation (α) into slope percentage (p), the following formula is used:

P = 100* tan (**α**)

Conversely, to determine the angle from the slope percentage, the formula is:

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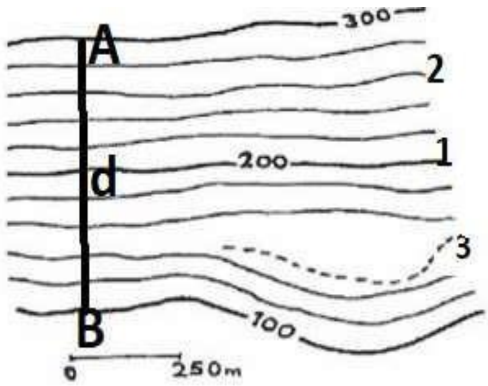
α = Arctan (P/100) and P = (h/d)*100

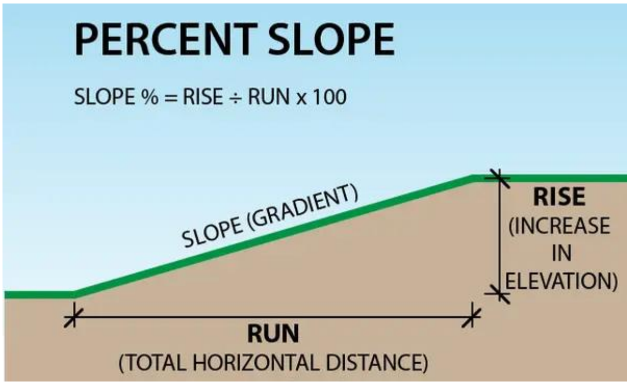
α = Arctan (((h/d) *100)/100)

α (°) = Arctan (h/d)

3.3. Activity 5: Calculating the Slope

Exercise 1 : Calculate the slope in percentage and degrees between points A and B on the following diagram.





Solution :

* Calculate the actual horizontal distance (d):

Scale = 1/25000, so: d = 3 cm * 25000 = 75000 cm = 750 m

* Slope in percentage: P (%) = (h/d) * 100

P (%) = (200 m/750 m) * 100, ⇒ **P (%) = 26.66 %**

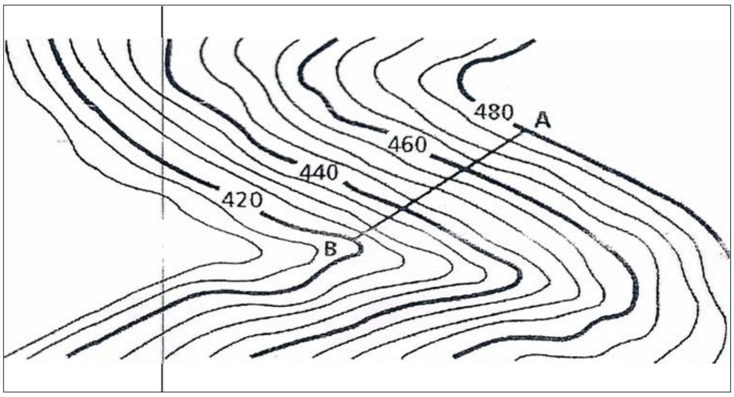
* Slope in degrees: α (°) = Arctan (h/d)

α (°) = Arctan (200 m/750 m) , ⇒ **α (°) = 15°**

***Exercise 2*:** Calculate the slope as an angle (α) and as a percentage between points A and B on the following diagram:

Given: AB = 4 cm

Scale of the map = 1/20000.



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Chapter IV

Map Orientation

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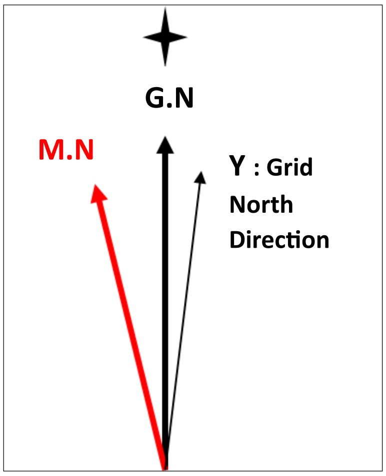
Chapter IV: Map Orientation

Orienting a topographic map is a fundamental operation that ensures the map is correctly aligned with the actual terrain. This process aligns the directions on the map with those in the real world. Proper map orientation is essential for navigation, route planning, and terrain analysis. This chapter explores various methods for orienting a map, focusing on the concepts of true north, magnetic north, grid north, and magnetic declination.

1. The Different Norths on a Topographic Map

Understanding the three types of "north" is crucial for correctly orienting a map. Each type has specific implications for map reading and the use of navigation tools like the compass.



The Three Norths

1.1. True North (Geographic North)

True north, also known as geographic north, refers to the direction of Earth's North Pole, where all meridians converge. It is the standard reference for all topographic maps. On a map, true north is typically indicated by an arrow pointing to the top of the map.

True north is a fixed concept based on Earth's geographic coordinates. However, in practice, it may differ slightly from magnetic north, which is used with a compass.

1.2. Magnetic North

Magnetic north is the direction indicated by a compass needle. It does not align exactly with true north because Earth's magnetic field is not perfectly aligned with its axis of rotation. Magnetic north corresponds to the location of Earth's magnetic north pole, which is mobile and shifts over time due to changes in the magnetic field.

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The difference between magnetic north and true north is called magnetic declination. This variation depends on geographic location and changes over time, as the magnetic pole moves, affecting magnetic readings.

1.3. Grid North

Grid north refers to the orientation of the vertical lines (meridians) on a map, usually within a grid projection system. On topographic maps, especially those with a cylindrical projection, grid lines may slightly deviate from true north. This difference is more noticeable on large-scale maps.

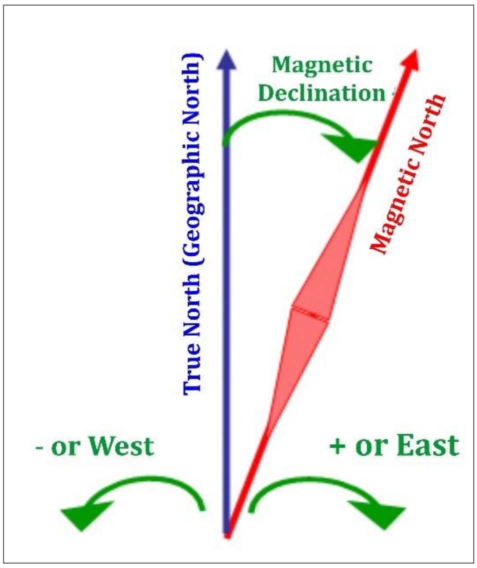
Grid north is commonly used for coordinate calculations and plotting precise routes using grid lines.

2. Definition of Magnetic Declination

Magnetic declination is the angle between true north and magnetic north. It varies depending on the Earth's location and changes over time due to variations in Earth's magnetic field. Declination can be:

- Eastward: When magnetic north is east of true north.
- Westward: When magnetic north is west of true north.

To accurately orient a map with a compass, magnetic declination must be accounted for. It is typically indicated on topographic maps. Declination changes over time because the magnetic pole does not coincide with the geographic pole, and this difference depends on the observation location.



3. Earth's Magnetic Field

Earth's magnetic field is generated by movements in the planet's outer core, primarily composed of molten iron. This field surrounds the Earth and allows compass orientation, while influencing various natural phenomena.

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However, the field is not constant—it fluctuates over time and space. For instance, the magnetic north pole moves several kilometers each year, directly affecting magnetic declination and requiring regular adjustments for navigation readings. These variations, called secular variations, cause the magnetic north pole to gradually shift across the Arctic.

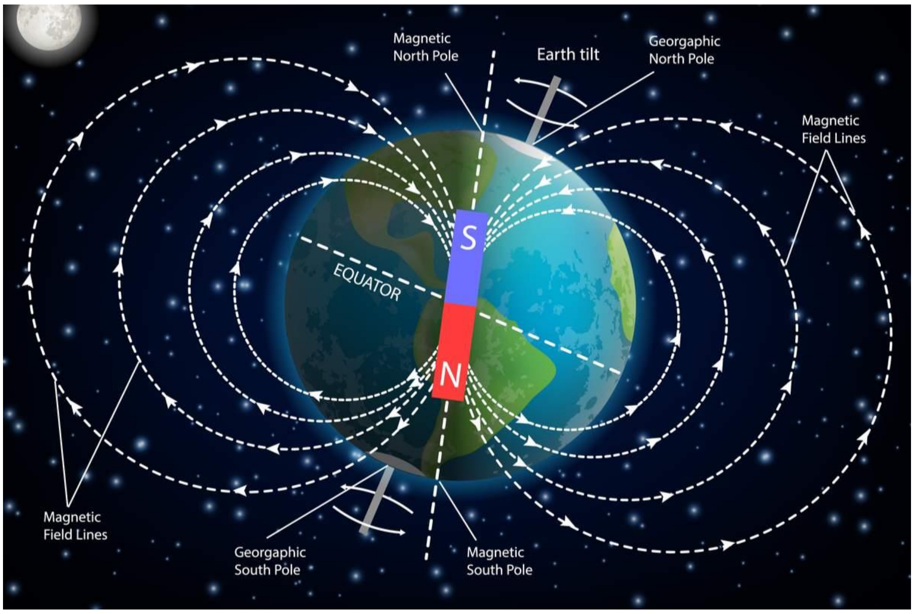


Figure 20. Earth's magnetic field resembles that of a magnet.

4. Calculating Magnetic Declination

Since the position of magnetic north changes annually, it is essential to account for this when calculating magnetic declination. The steps are as follows:

- Refer to the magnetic declination data provided on the map.
- Note the declination for the reference year (e.g., in 2018: 18°36').
- Calculate the time difference between the current year and the reference year (e.g., 2024 - 2018 = 6 years).
- Consider the annual declination change (e.g., decreasing by 1°5' per year).
- Multiply the number of years by the annual change (6 × 1°5' = 6°30').
- Adjust the declination by subtracting the change if it is decreasing or adding it if increasing (18°36' - 6°30' = 12°6').

In this example, the current declination is 12°6'. When using a compass, declination is often rounded to the nearest degree, in this case, 12°.

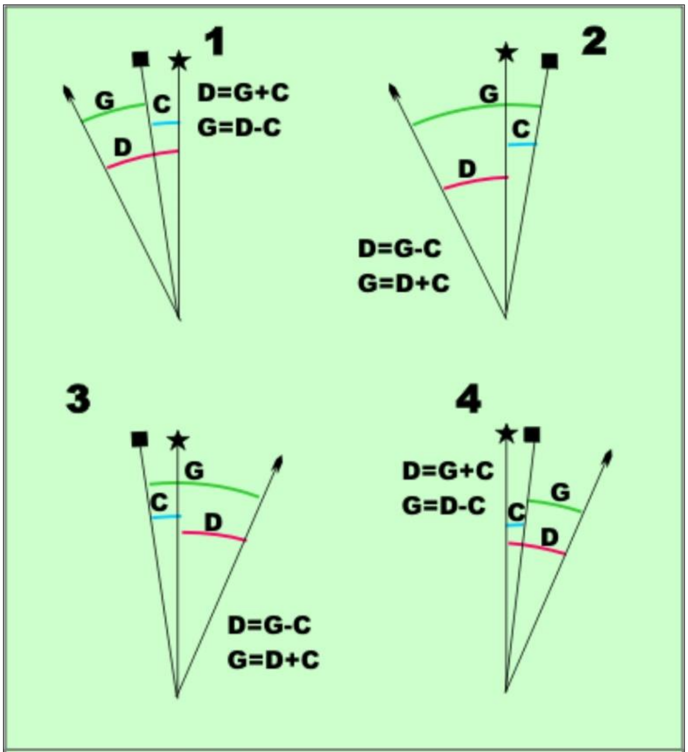
Two Main Methods for Calculating Magnetic Declination:

- *Static Method:* Based on declination data provided on the map, though this can be less precise if the map is outdated.

– *Dynamic Method:* Using updated data from geophysical institutes for greater accuracy.

Note:

Some topographic maps provide magnetic declination relative to grid north instead of true north. In such cases, an additional calculation is needed to determine the actual magnetic declination.



G: Map Declination C: Grid Declination
D: True Magnetic Declination

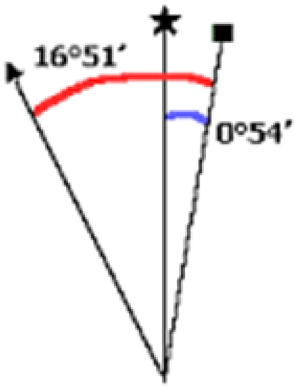
Example:

Consider a 1:500000 topographic map. Somewhere on the map's margin, the following information is provided: "Average magnetic declination at the map center in 2014: 16°51'. Annual variation: decreasing by 0.1'."

1. Determine the actual magnetic declination (true north to magnetic north). The given magnetic declination is relative to grid north, so it requires subtraction:

   True magnetic declination = Map declination - Grid declination.

   Example: 16°51' - 0°54' = 15°57'.



2. Account for the annual variation:

   Current year (2024) minus reference year (2014) = 10 years.

   Annual variation (0.1') × 10 years = 1'.

   Subtract this variation from 15°57':

   15°57' - 1' = 15°56'.

The actual magnetic declination is 15°56' west, as the magnetic north is west of true north in this example.

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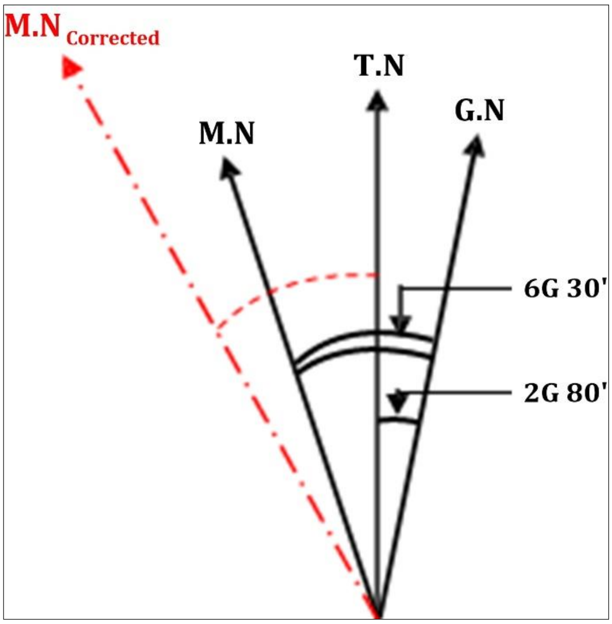
5. Activity 6: Calculating Magnetic Declination

Exercise 01:

Calculate the magnetic declination on January 1, 2021.



The magnetic declination corresponds to the center of the map on January 1, 1998, and increases by approximately 10 centesimal minutes each year.

Solution:

Since the declination is increasing:

Current Declination = Previous Declination + Total Variation Rate

$D_{2021} = D_{1998} + D_{(1998/2021)}$

D1998 = 6G 30’- 2G 80’= 3G 50’

Total Variation Rate = Annual Variation Rate * Number of Years

Annual Variation Rate = 10’ (centesimal minutes)

Le nombre d’années = 2021-1998 = 23 years

D (1998/2021) = 10’ * 23 = 230’

D (1998/2021) = 2G 30’

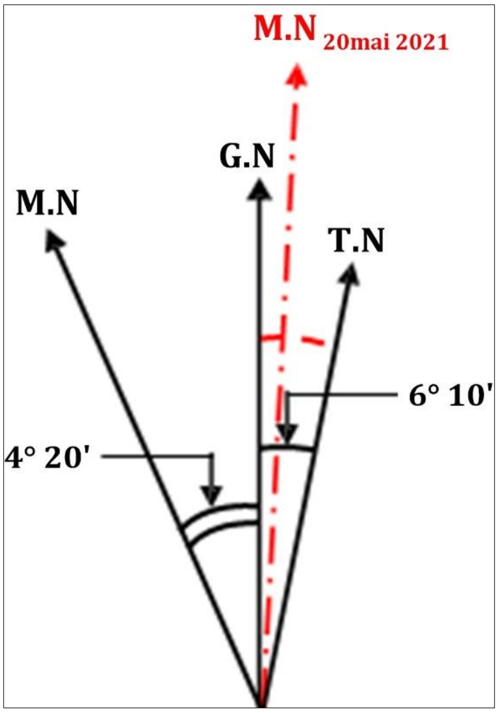
D2021 = D1998 + D (1998/2021)

D2021 = 3G 50’+ 2G 30’

D2021 = 5G 80’

Exercise 02:

Calculate the magnetic declination on May 20, 2021.



The magnetic declination corresponds to the center of the map on January 1, 1987, and decreases by approximately 8 sexagesimal minutes each year.

Solution:

Since the declination is decreasing:

Current Declination = Previous Declination − Total Variation Rate

$D_{\text{May 20, 2021}} = D_{\text{Jan 1, 1987}} - D_{\text{(Jan 1, 1987 to May 20, 2021)}}$

$D_{\text{Jan 1, 1987}}$ = 2° 10’ + 4° 20’ = 6° 30’

Total Variation Rate = Annual Variation Rate * Number of Years

Annual Variation Rate = 8′ (sexagesimal minutes)

Number of Years = May 15, 2021 - Jan 1, 1987 = 34 years, plus 5 months and 20 days.

D (Jan 1, 1987 - May 15, 2021) = 8’ * (34,25 years + 50 days)

D (Jan 1, 1987 - May 15, 2021) = 8’ * 34,5 years + 8’ * 50 days

D (Jan 1, 1987 - May 15, 2021) = 276’ + (8’ * 50 days)

D (Jan 1, 1987 - May 15, 2021) = 276’ + ((8’ * 60) *(50 days /365 days)

D (Jan 1, 1987 - May 15, 2021) = 276’ + (480’’ * 50/365)

D (Jan 1, 1987 - May 15, 2021) = 276’ + 65’’, 75

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D (Jan 1, 1987 - May 15, 2021) = 276’ + 01’05’’, 753

D (Jan 1, 1987 - May 15, 2021) = 277’+ 05’’,753

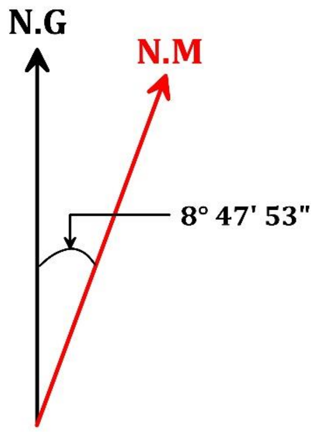
D (Jan 1, 1987 - May 15, 2021) = 277’ 05’’,753

D (Jan 1, 1987 - May 15, 2021) = 4° 37’05’’,753

D May 20, 2021 = 6° 30’- 4° 37’05’’,753

D May 20, 2021 = 1°52’54’’, 247

Exercise 3: Calculate the magnetic declination on September 23, 2006.



The magnetic declination corresponds to the center of the map on March 3, 1992, and decreases by approximately 6 sexagesimal minutes each year.

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Chapter V

The Topographic Profile

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Chapter V: The Topographic Profile

1. Definition of the Topographic Profile

A topographic profile is a graphical representation of a vertical cross-section of the terrain along a line drawn on a map. At a given scale, it illustrates altitude variations and landform features, allowing visualization of slopes, valleys, ridges, and other geomorphological characteristics of the terrain. The purpose is to provide a clear view of altitude changes and landform shapes along a specific section.

2. Principles of Constructing a Topographic Profile

A topographic cross-section offers a schematic representation of the terrain, visually highlighting the features of a region. To create a topographic profile, a curve is plotted on a graph with heights on the vertical axis and distances on the horizontal axis. This precise method requires a detailed map, measuring tools (ruler, pencil, graph paper, or specialized software), and a solid understanding of basic topographic principles.

2.1. Method for Creating a Topographic Profile

The steps for creating a topographic profile are as follows:

- *Drawing the Cross-Section Line:* Select a cross-section line (A-B), marked on the map with a pencil line. (See Fig. 21).

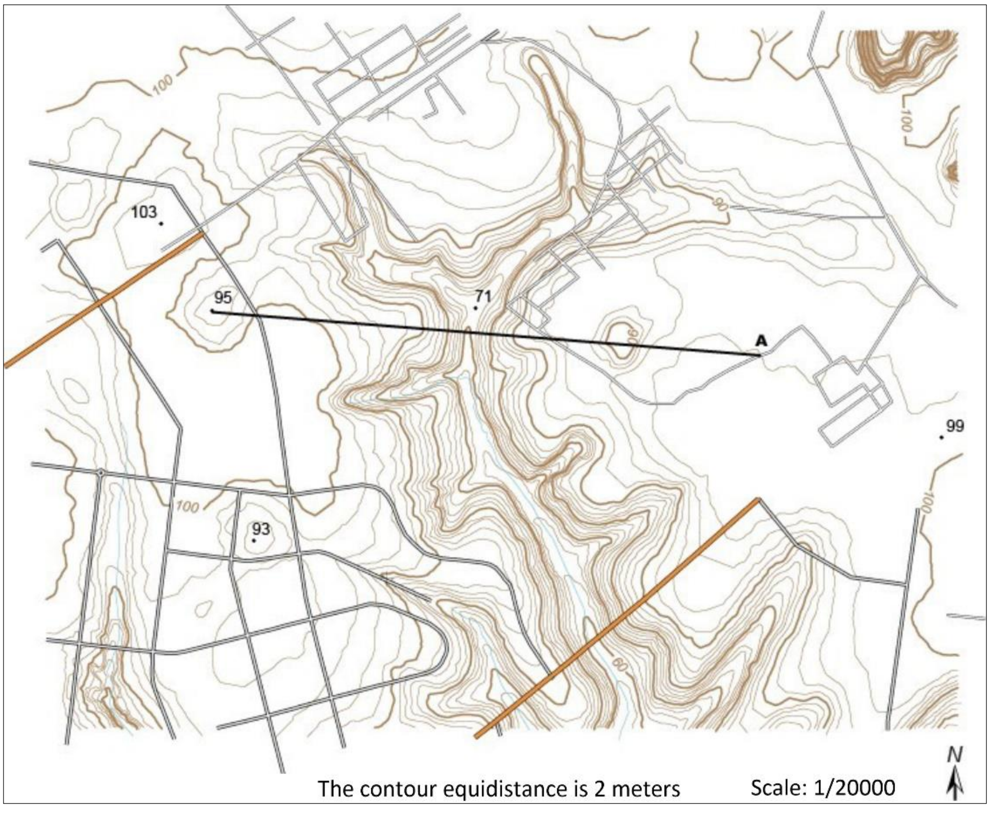

Figure 21. Example of constructing a topographic profile

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– *Plotting Altitudes*:

- ✓ On a piece of graph paper, draw a frame with a length corresponding to the cross-section and indicate both numerical and graphical scales. The base altitude should align with the lowest points of the section.
- ✓ Draw two perpendicular axes on the graph paper: the horizontal axis for distance scale and the vertical axis for altitude scale.
- ✓ Choose the origin of the height axis based on the lowest altitude.
- ✓ Align the top edge of the graph paper with the A-B line.
- ✓ Mark points A' and B', corresponding to A and B, and note their altitudes as well as those of the intersections of contour lines with the A-B line, writing them lightly.
- ✓ Plot the altitude of each intersection of contour lines relative to the distance along the cross-section line. (See Fig. 22)

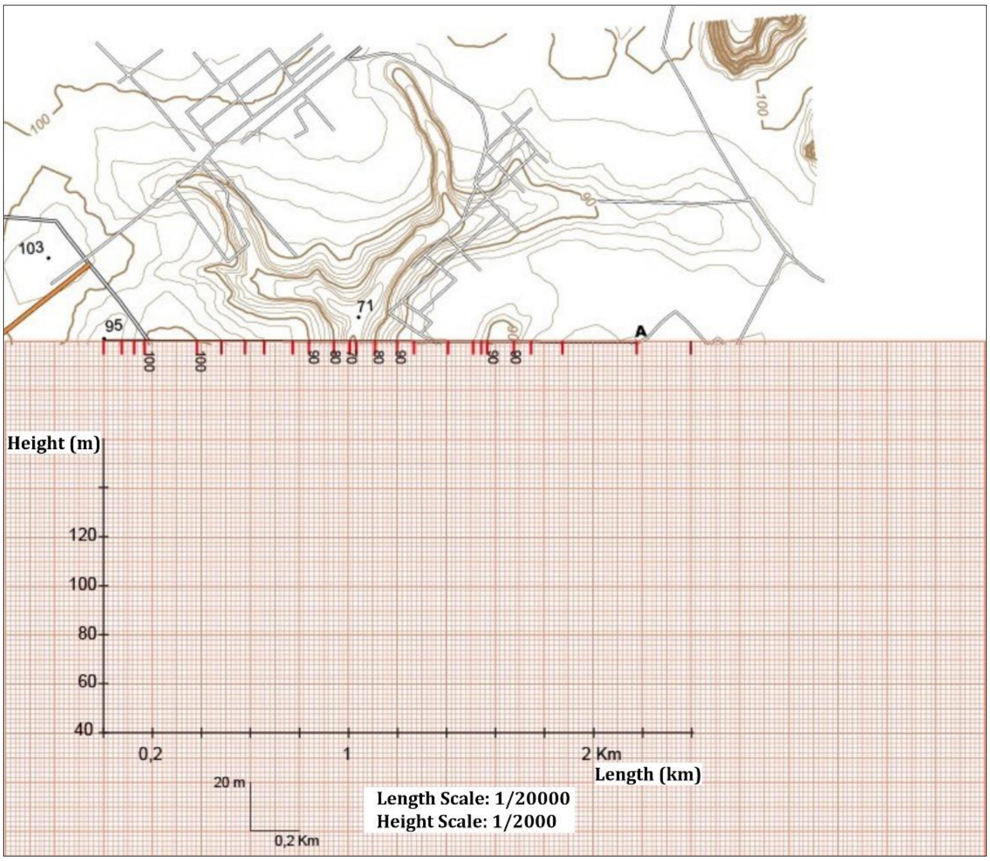

Figure 22: Plotting altitudes of intersection points on the graph paper.

– *Verifying Horizontal and Vertical Scales:*

The horizontal scale must match the map's scale (e.g., 1/25000 or 1/50000). The vertical scale can be exaggerated to emphasize relief variations, particularly on flat terrains, but the exaggeration must be clearly indicated.

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- *Drawing the Profile:*
  - ✓ Project (drop down) the points to their corresponding altitude on the previously drawn height axis. (See Fig. 23)

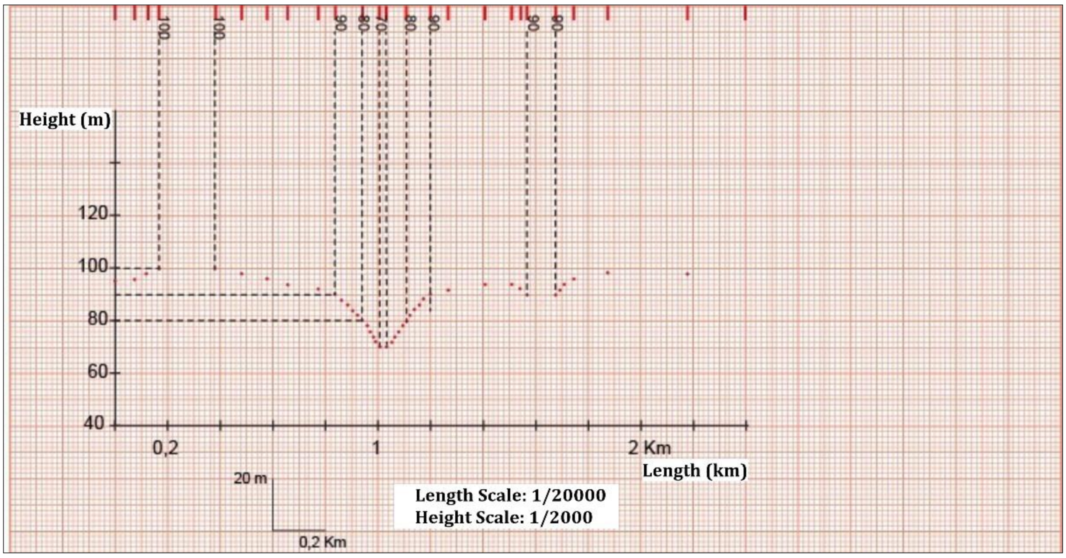
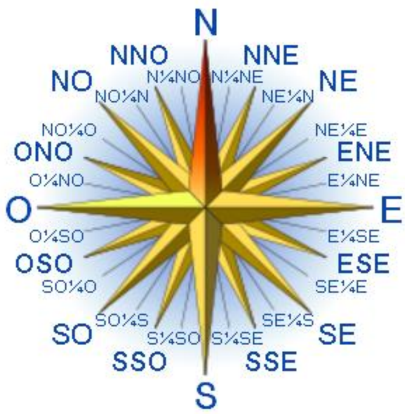


Figure 23: Projecting intersection points onto the height axis.

  - ✓ Connect these projected points with smooth curves, rather than straight lines, to better reflect the topography while respecting the concavities and convexities of slopes.
  - ✓ Erase auxiliary markings used during the construction of the profile.
- *Profile Orientation:* To orient the profile, refer to the compass rose. Draw the compass rose on a transparent sheet and place it at the center of the profile, ensuring that the north-south direction aligns parallel to the nearest meridian to the A-B line.



2.2. Enhancing a Topographic Profile

Enhancing a topographic profile is crucial to make the drawing clear and comprehensible. The following elements should appear on the profile:

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- *Profile Line*: On the sketch, this is the line connecting points of different altitudes corresponding to contour lines crossed by the A-B segment on the map.
- *Orientation*: Indicate the direction of the profile using cardinal points above the vertical axis.
- *Title*: Write the name of the region, location, project, or terrain represented above and at the center of the profile sketch.
- *Landscape Features*: Identify starting and ending points of the profile (e.g., A-B) and key features of the landscape crossed by the profile on the map, without overcrowding the sketch.
- *Source*: Mention the map's reference number, publication year, last verification year, and publisher.
- *Author*: Indicate the name of the profile’s creator.
- *Horizontal Scale (abscissa)*: Use the map's scale. Indicate the numerical scale (e.g., 1/25000) and graphical scale below the horizontal axis.
- *Vertical Scale*: Indicate altitude values (e.g., 50, 100, etc.) and the unit of measurement (e.g., meters) on the vertical axis.

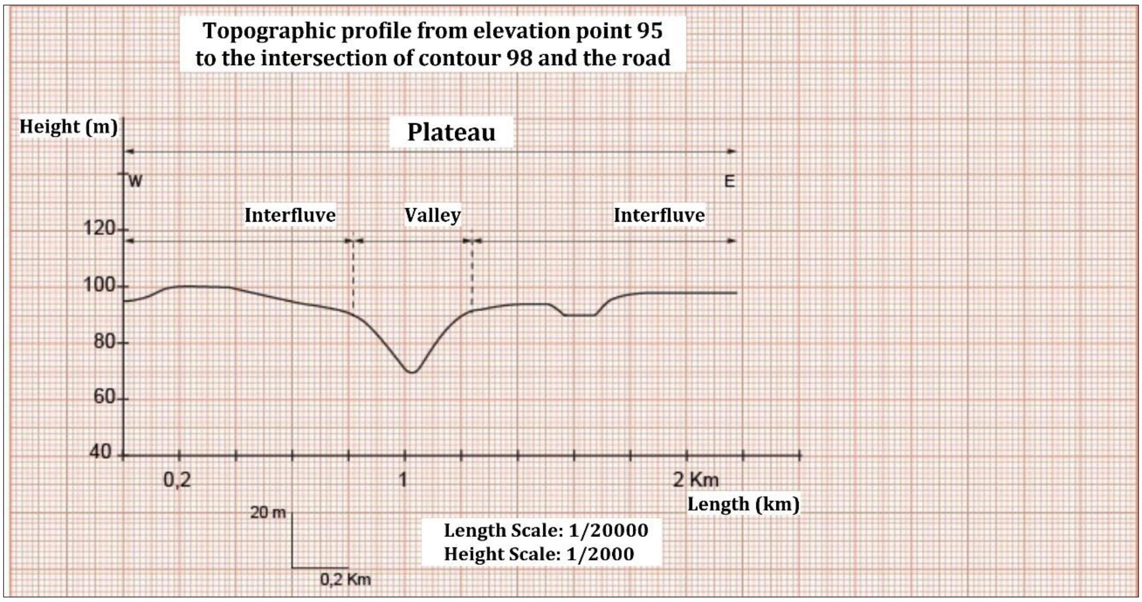

Figure 24. Enhancing a topographic profile

3. Analyzing the Relief from a Topographic Profile

Relief can be considered as a system of slopes, with perfect horizontality being very rare in nature. Slopes combine to form basic shapes that can be classified into several main types of landforms:

3.1. Topographic Forms

By analyzing a topographic profile, several characteristic relief features can be identified. These forms may vary depending on the geological and erosional processes that shaped the terrain.

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3.1.1. Constant Slope

A constant slope is characterized by evenly spaced contour lines, indicating that the same distance is covered for each ascent or descent in altitude. On a topographic profile, this is represented by an inclined straight line, showing that the slope remains consistent throughout the section. (See Fig. 25)

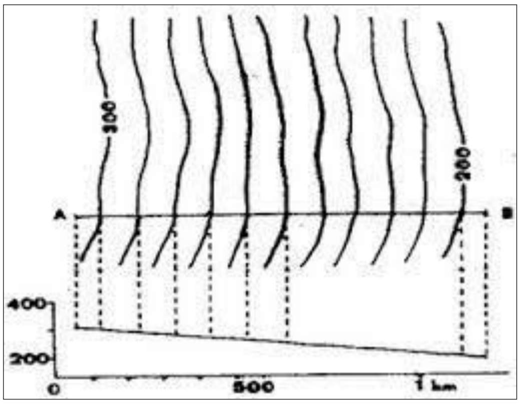

Figure 25. Constant slope

3.1.2. Regularly Variable Slope

A concave slope is marked by contour lines that become increasingly spaced apart toward the bottom, while a convex slope has contour lines that become closer together as they descend. A slope may combine these two types. A regularly variable slope appears as a smooth curve on the topographic profile, reflecting a slope that gradually increases or decreases, such as a climb to a summit or descent into a valley. (Fig. 26)

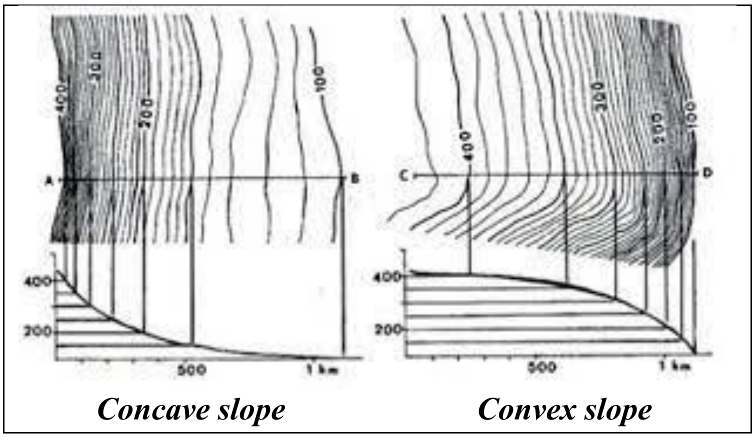

Figure 26. Regularly variable slope

3.1.3. Sudden Slope Variation

A slope break is characterized by a sudden change in contour line spacing, indicating steep terrain, cliffs, or rocky ledges. On the profile, this is shown as abrupt changes in the slope. (Fig. 27)

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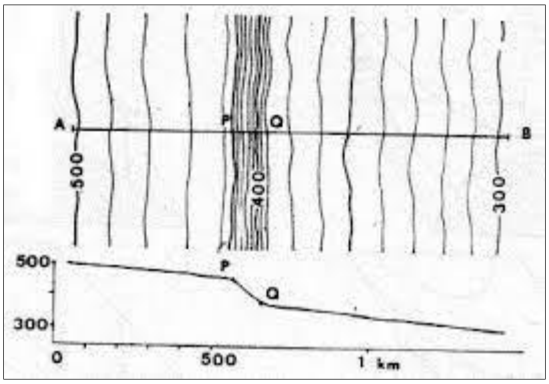

Figure 27. Slope break

3.1.4. Peaks and Basins

Peaks are characterized by concentric contour lines with a central point of higher altitude, while basins also feature concentric contours but have a central point of lower altitude. Occasionally, an arrow may indicate the center of the depression, which may be occupied by a lake. On a profile, peaks appear as the highest points and basins or valleys as the lowest points, enabling the identification of maximum and minimum altitudes for route planning. (Fig. 28)

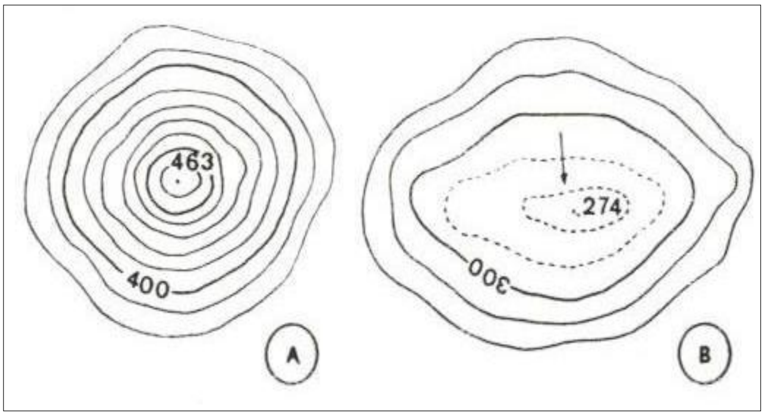

Figure 28. Peaks and basins

3.1.5. Valley Shapes

The thalweg line connects the lowest points in a valley and is recognized by V-shaped contour lines. The tip of the V, more or less acute, indicates the upstream direction of the valley. V-shaped valleys are deep and narrow, typically formed by rivers, whereas U-shaped valleys are wider and rounder, characteristic of glacial regions. (Fig. 29)

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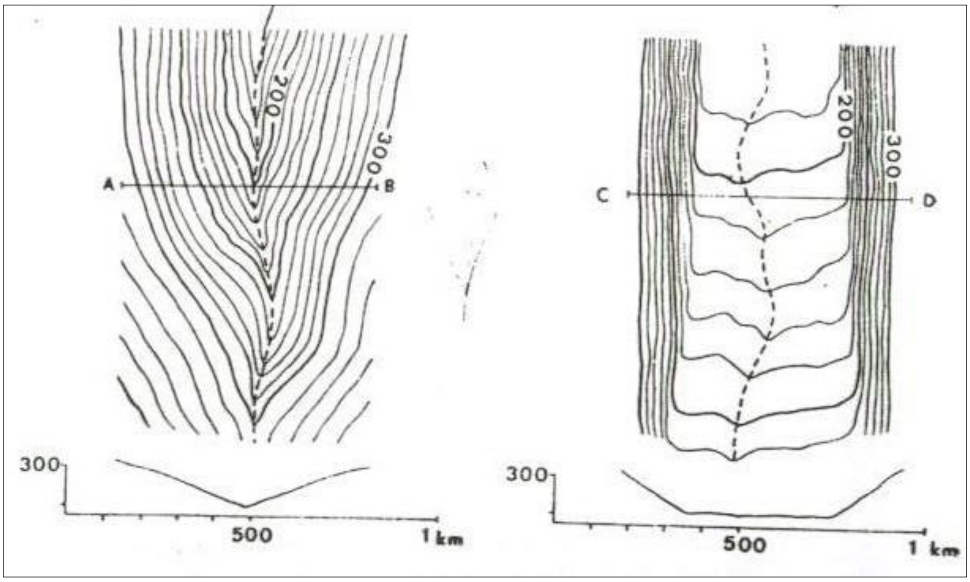

Figure 29. Valley shapes

4. Conclusion

A detailed study of landforms on a topographic map is essential for accurately representing the terrain. It provides cartography professionals with an indispensable tool for navigation, route planning, and project implementation that require a precise understanding of the landscape. This accuracy ensures reliable and functional maps for various applications.

The topographic profile, for its part, offers a clear visualization of the relief, facilitating route planning, slope evaluation, and terrain analysis for projects involving development, construction, or natural risk management.

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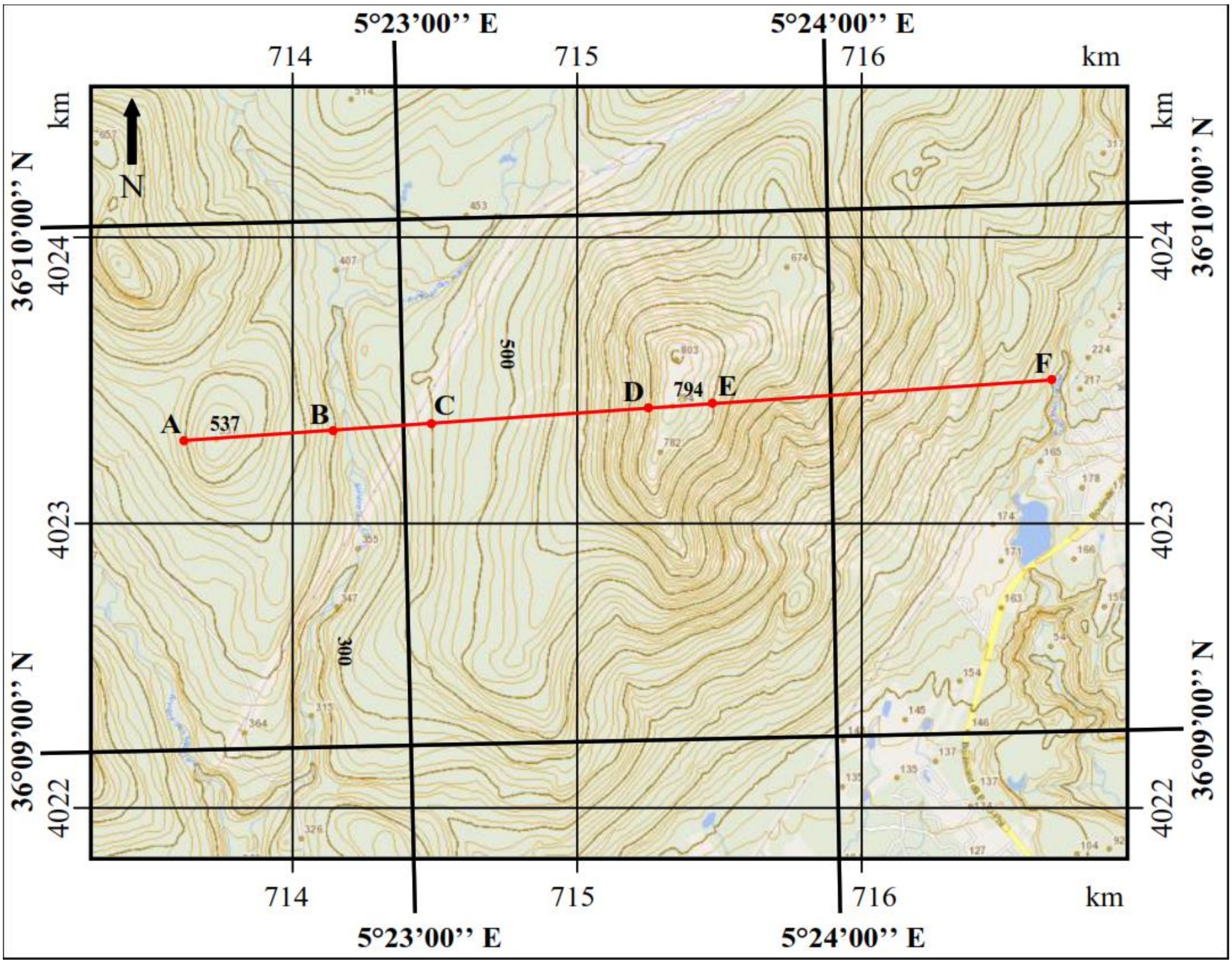
Activity 7: Synthesis Exercise on the Topographic Profile

Questions :

1. Determine the numerical and graphical scale of the map.
2. Determine the map's contour interval.
3. Calculate the geographic coordinates of points A and F.
4. Convert these coordinates to gradians.
5. Calculate the cartographic coordinates (UTM) of points A and F.
6. Calculate the actual horizontal distance between points C and D.
7. Calculate the slope between points C and D in degrees and as a percentage.
8. Calculate the magnetic declination as of July 1, 2018.
9. Draw the topographic profile (A-F).



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