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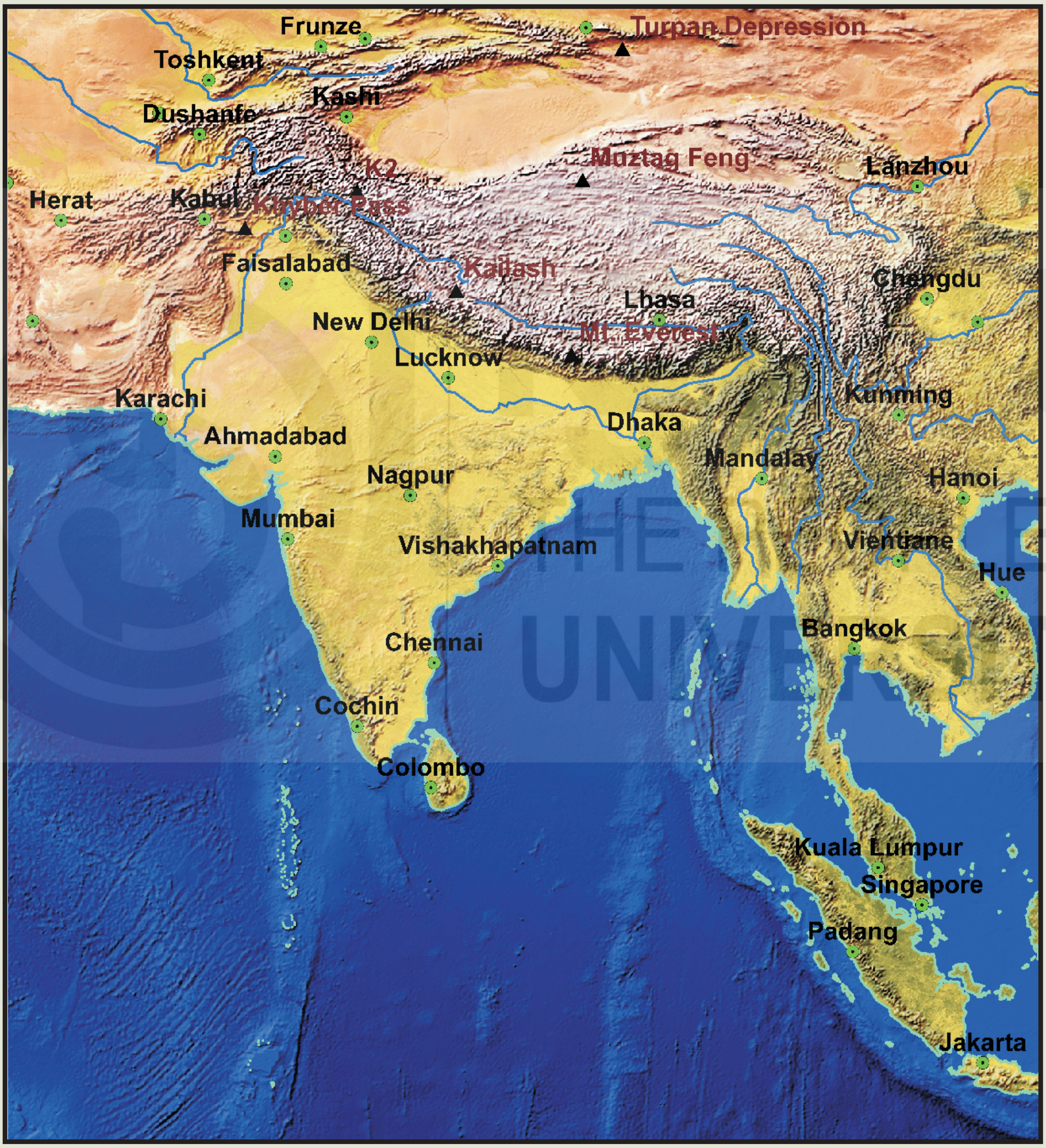
BGGCT-133
GENERAL CARTOGRAPHY



" शिक्षा मानव को बन्धनों से मुक्त करती है और आज के युग में तो यह लोकतंत्र की भावना का आधार भी है। जन्म तथा अन्य कारणों से उत्पन्न जाति एवं वर्गगत विषमताओं को दूर करते हुए मनुष्य को इन सबसे ऊपर उठाती है।"

–इन्दिरा गांधी

" Education is a liberating force, and in our age it is also a democratising force, cutting across the barriers of caste and class, smoothing out inequalities imposed by birth and other circumstances."

– Indira Gandhi

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Block

1

INTRODUCTION TO CARTOGRAPHY

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BGGCT- 133
GENERAL CARTOGRAPHY

GENERAL CARTOGRAPHY THEORY: COURSE INTRODUCTION

So far your study of Geography programme has been confined to physical and human geography courses where you have studied the Earths' surface phenomena and human society and culture as well. Through this course we are introducing a new subject which is called cartography. Study of maps and map making in a scientific way is dealt under the subject of cartography. Since long, humans used cartography as a fundamental element in their societies and culture. We all are aware that geography discipline deals with human society and natural environment both, for which cartography contributes in several ways coupled with technological advancements adopted in the subject domain. Cartography is a dynamic subject and its scope is also widening with contemporary issues and increasing technological problems in our day to day activities. As we know that globe is a three dimensional model. To prepare an accurate flat map (two dimensional) for a particular region by preserving greatly the area, shape, direction, and distance, we need to use some kind of mathematical transformations through map projection. However, it is not possible to flatten the earth without compromising projection properties. The mathematical cartography explains all of these problems in a scientific manner.

Map reading and interpretation enhance our knowledge in the fields of surface processes, environment, weather and climate. Hence, it is important to understand the underpinning concepts on mapping techniques and the procedures applied in the preparation of maps. The knowledge of such details is vested in the subject of cartography. The cartographer employs definite methods in the form of maps, graphs and diagrams that helps to see the nature and trend of distribution and spatial variations. With the advancement of technologies, the subject of cartography is continuously changing in order to meet the demands of technocrats and software equipped map makers.

The present course of General Cartography (Theory), mainly deals with the introduction to cartography, map projections, sources of data, map reading and interpretation, and representation of data with an aim to train the learners in cartographic tools and techniques for geographical studies. The entire course is presented into five blocks.

Block 1 discusses the introduction to cartography dealing with the nature, history and evolution, maps and map scales and their types. We begin the block by explaining the basic concepts, history and evolution of cartography, and explained map types, history of maps, map elements and usage of maps followed by methods of representation, construction and reading of map scales at the end. In **Block 2**, we have introduced the concept of map projection, classification of projections and further discussed about graticule and their properties, and projection terminologies. It also explains the three types of map projections such as cylindrical projection, conical projection, and zenithal projections. **Block 3** is dealing with the different sources of data. It will provide you various data sources covering the most conventional to that of the latest datasets made possible by the satellite and computer enabled technologies.

We have also discussed the different aspects of map reading and interpretation in **Block 4**. It is focused on the important aspects of topomaps including the reading skills by utilizing conventional symbols and signs designated for natural and cultural features on topomap. You will find various diagrammatic techniques to represent the climatic data. The governing elements, interpretation procedures and characteristic features of seasons in weather phenomenon along with weather forecasting are elaborated in this block. At the end,

Block 5 explains the representation of geographical data in which we use various kinds of graphs and diagrams. There are one-two-three dimensional diagrams that are discussed. A detailed focus is also given on the thematic maps and its types along with techniques of their construction.

We hope that after studying this Course on General Cartography, you will be able to understand the subject of cartography in which various themes, methods and techniques are adopted for explaining natural and cultural phenomenon of the planet Earth.

Our best wishes are always with you in this endeavor.

We suggest for any assistance regarding this course, you can contact at: vishalwarpa@ignou.ac.in and knrao@ignou.ac.in

BLOCK 1: INTRODUCTION TO CARTOGRAPHY

We, human beings, always think what we want to do. During this process knowingly or unknowingly, we try to map the various kinds of information of things or phenomenon. We have been trying to explore the new world in this universe and mapping them more in scientific way since long. In this endeavour, we significantly achieved to reduce the entire globe onto paper to digital smart screens now. Study of maps and map making are known to be the domain of Cartography. We can understand that Cartography is a fundamental element in the human society and culture since human evolution.

The nature of cartography not only considers the study of early map as a part of the humanities, but it is also concerned with access to and the shaping of knowledge that takes place in multidisciplinary fields particularly in earth system sciences. Geographers study Cartography more fascinatingly than any other discipline as core subject of geography which deals with human society on one hand and natural environment on the other hand. Cartography subject has slowly developed from wooden carved blocks to engraved copper plates in older days and now three dimensional models with GIS enabled technology which became apparent everywhere as smart maps. Cartography is a dynamic subject and its scope is also widening with contemporary issues and increasing technological problems in our day to day activities.

This block introduces you to the cartography dealing with the nature, history and evolution, maps and map scales and their types spread into three units.

Unit 1 Basic Concepts:

Studying the subject of cartography essentially needs the proper knowledge in the fields of Arts, Science, and Technology. Cartography not only explains the process of making maps but also deals with charts, graphs, globes and relief etc. The subject matter of cartography enables a cartographer or a map maker to develop and create a simplified visual model for the real world phenomenon. In this unit, we have deliberated on the basic concepts, history and evolution of cartography.

Unit 2 Maps:

Maps are essential tools that can be widely used for understanding the variability and characteristics of world's spatial phenomena. You might have seen various types of maps, for example, topographical map, cadastral map, atlas map and wall map. We have explained particularly map types, history of maps, map elements and usage of maps in this unit.

Unit 3 Map Scale:

You can find a scale on every map because map scale is an essential element in map making process. It helps to measure the distances between any two places on the map. Scientifically or technically speaking, without a scale any drawing or sketch is not at all be considered as a map. In this unit, keeping in view the importance of map scales, we have introduced the methods of representation, construction and reading of map scales.

We hope that after studying this block, you will be able to better understand the basic concepts of cartography, what are maps and their types, usage of maps, and map scales in particular.

Our best wishes are always with you in this endeavour.

UNIT 1

BASIC CONCEPTS

Structure

1.1 INTRODUCTION

Cartography is the art and science of making maps. In the ancient times, techniques employed for map making were manual using hand tools, making it a time consuming and difficult method of geographic representation. However, with the advancement of technology, cartographic techniques have continually been changing in order to meet the demands of contemporary issues, mapmakers and map users.

Many of you have studied the Practical Work in Geography at Intermediate or +2 level education. It is generally dealt under the subject of Cartography as a part of Geography courses. This unit will introduce you to some of the essential concepts of cartography. You will study about nature, scope, history and evolution of cartography from Sections 1.2 and 1.3. This unit will also discuss in brief about the earth as a cartographic problem in Section 1.4.

Expected Learning Outcomes

After studying this unit, you should be able to:

- define cartography;
- explain the nature and scope of cartography;
- discuss the history and evolution of cartography; and
- suggest cartographic solution to mapping the earth.

1.2 DEFINITION, NATURE AND SCOPE OF CARTOGRAPHY

Definition

Cartography creates simplified visual model of complex real world either on two or three dimensional surface as maps using science, technology and arts for easy presentation to the diverse user communities.

It communicates geographical properties graphically. Raise Erwin (1962) defined cartography as “the art and science of making maps, charts, globes, and relief models”. Arthur Robinson and others (1978) defined it in a little limited sense as “a technique, fundamentally concerned with reducing the spatial characteristics of a large area, a portion or all of the earth, or another celestial body, and putting it in a form that makes it observable.” F.J. Monkhouse (1970) defined it as “in its widest sense, the whole series of map making, from an actual survey of the ground to printing of map in a more limited sense the drawing of map.” J. Smith (1984) defined as “the science of constructing maps and charts. It includes the making of original surveys, the selection of suitable map projections and decisions on colours, layer tinting and other visual representations.”

Nature

“As a synonym for mapmaking, cartography is often construed to include the collection of geographical information through systematic surveys, formal or otherwise of the physical landscape or its human occupants. In an institutional context, cartography might refer narrowly to the production of artwork for printed maps or more broadly to the overall mission of a commercial firm such as McNally or a government agency such as the Ordnance Survey” (Dictionary of Human Geography, p. 67). Cartography is the combination of all – science, technology and arts and as defined above, nature of the cartography is scientific, technological and artistic and therefore, it may be referred to as interdisciplinary subject. It adopts the scientific approach in data preparation like the logical foundation in conceptualizing any map right from the extent, projection, themes, classification and presentation. It involves geography, geology, geodesy and surveying, engineering, mathematics and geometry, algebra, etc. as scientific disciplines and techniques.

Similarly, the technology is also deeply involved with it. It may vary from the extremely rustic to the most sophisticated ones today made possible by the unimaginable advancements of computers and other related devices. These may include computers and graphic technology, electronic theodolites, electronic total station (ETS), remote sensing, geographical information system (GIS), global positioning system (GPS), along with communication technology. The art is inherent in the nature of cartography because it necessitates good presentation for easy communication to the intended readers or users.

Scope

Scope of cartography is wide. It includes the conceptualization of various aspects including extent, scale, projection, themes, field survey and its methods, data capturing and compilation, analysis and representation etc. It starts with physical features or phenomena to cultural features and phenomena. It captures the real existence or visible objects like physiography, water, rail and roads, forest, settlements, fields, crops etc. and also abstract things like environment, literacy, empowerment and the level of awareness etc. It starts with an extremely small scale to plot level mapping or building level mapping. It includes a very simple geographic projection system to a very complex projection system for the conversion of spherical earth surface into two dimensional representation on the plain paper. At visualization level, it can do both 2D and 3D. Two dimensional visualization gives only two dimensions or flat surface whereas three dimensional visualization gives third dimension i.e. height also. It gives paper output as well as output on soft copy or digital format. It is both static and dynamic in nature as cartography uses GIS enabled cartography which supports both real time query and mapping. Its scope is also widening with changing thematic issues as well as technological advancements.

SAQ 1

What is cartography? Explain.

1.3 HISTORY AND EVOLUTION OF CARTOGRAPHY

The history of cartography can be traced back to the Babylonian era in 2300 B.C. This work was also notable among ancient Greeks as they were well aware of the spherical earth till 350 B.C., later on accepted by all. Later on, Ptolemy (85-165 AD), depicted the world from 60^{o}N to 30^{o}latitudes in his world map and created a landmark. It has travelled from wooden carved blocks in printing work of 15th Century to engraved copper plates during 16th Century (the age of exploration) to modern day hi-tech printing. However, the modern cartography emerged during the World War I with the use of Aerial Photography. It was both scientific and accurate. The ultra modern form of cartography emerged with the emergence of GIS during 1970-80s, where database and final presentation are kept separate from each other. Earlier in paper map, both data and presentations were used to be kept together.

1.3.1 The Ancient Period (upto 600 AD)

Mankind since its early period has developed the practice of making some drawings of their surroundings using various medias ranging from earth and parts of trees to metallic objects. It was present in advanced form among Egyptians, Babylonians and Greeks alike. In fact, the seed of the modern cartography had been sown by the Greek Geographers like Aristotle, Anaximender, Hecateus, Herodotus, Eratosthenese, Hippartus, and Ptolemy, etc., who recognized the earth as spheroid with latitudes and longitudes. Anaximender prepared the first world map followed by Herodotus, Eratosthenes and Ptolemy. They were the first to develop the projection system.

Ancient Romans are known for Peutinger Table (**Tabula Peutingeriana),** or Peutinger Map that mainly shows the road networks in the Roman Empire (Fig. 1.1). In India, the cartographic roots goes back to the Vedic period (1500-500 BC), and in the ancient period (upto 600 AD), with astronomical contributions rendered by great scholars Aryabhatta, Varahmihira and Bhaskara etc. The important discoveries like the rotation of the earth and the calculation of earth's circumference are the major contributions.

Fig. 1.1: Tabula Peutingeriana or Peutinger Map.
(Source:http://www.columbia.edu/itc/mealac/pritchett/00maplinks/early/roman300s roman300s.html)

1.3.2 The Medieval Period (600-1500 AD)

The art and science of map making was termed as 'Cartography' during this period. Like geography, the origin of the word 'Cartography' goes to two words- Charte (Map in French), and Graphie (Writing in Greek), coined in 1839 by a Purtuguese scholar Manuel Francisco de Barros e Sousa Viscount of Santare´m, who used it to describe map study in the same way as historiography refers to the history of historical writing (Wolter, 1975), (Dictionary of human geography, p. 67). During this period, the print technology, especially with the advent of copper plate printing technology made significant progress in cartography during 15th and 16th Centuries. This enabled the duplication extremely easier and quick process compared to the manual A to Z exercise to produce every copy of a map. It progressed with the exploration of new world by various voyagers. These gradual developments finally culminated into new map products like Atlas and other map types. Subsequently, thematic cartography came into existence when socio-economic survey and population Censuses were started. It was greatly followed by the mapping of physical features.

It is regarded as the 'Renaissance Period of Cartography', with significant contributions in the development of cartography especially in the western world. This period witnessed important development due to the advancements in mathematical geography by Arab Geographers. It was the era of great travelers like Columbus, Marco Polo, Magellan, Darke etc., and their contributions in the preparation of maps of various explored lands.

1.3.3 The Modern Period (1500 AD onwards)

The cartographic instruments like 'Theodolite' and 'Plane Table' were also developed in the last quarter of the 16th Century. The navigational maps with compass directions called 'Portolan Charts' was pioneered by the Italians. During this period, for the first time, North America and South America were shown cartographically separate by Waldseemuller in 1507. Mercator in 1569, developed the cylindrical orthomorphic projection which was a landmark achievement.

Fig. 1.2: Mercator's World Map.

(Source: https://www.math.ubc.ca/~israel/m103/mercator/mercator.html)

The development of survey and cartographic instruments drove cartography to its higher path. It is an era of production of maps and atlases which especially originated in the western world. By this time, for the mapping of physical features and resources, the formal survey departments were established and the thrust was laid on the detailed survey, preparation and production of maps.

In India, the Survey of India was set up in 1767, two years later the establishment of British Ordnance Survey in Britain (1765). Survey and

Mapping in third world in these early stages was primarily due to the resource exploitation and meant for the benefits of colonizers only. Later on, everywhere the production of national atlases got started as an outcome of cartographic activities. There has been unprecedented advancement in Cartography during the 20th Century. After the advent of aerial photography, the situation post World War-I gave new dimension to cartography in topographical 3D survey and mapping. It made possible the survey and map making of inaccessible remote areas, which were otherwise inaccessible. At the same time, it made the task of survey and cartography quite faster.

The fast development computing and printing technology revolutionized map making and printing across the globe. These advancements have been added by the amazing achievements in space science and imaging along with other geospatial and survey tools like Aerial Photography, Remote Sensing, GIS, GPS and ETS etc. The subject of cartography has achieved newer heights where survey and mapping has virtually become real time with unimaginable scale and resolutions (mainly spatial and temporal).

You may know that remote sensing is the acquiring of data about an object without touching it. The remote sensing data is available in different resolutions like spatial and temporal. Spatial resolution in remote sensing refers to the minimum size of an object captured by a remote sensing sensor. The details of the information in an image depends on the spatial resolution of the image. Whereas, temporal resolution refers to the time taken by a sensor to revisit and scan the same area.

Cartography is the final stage of a work done in remote sensing and GIS in terms of logical presentation of output as digital or printed maps. It is the science and art of presenter (cartographer) as how best it can be presented for meeting its objective. The advent of very high resolution satellite data in various forms like multispectral stereo data (IKONOS, QuickBird, OrbView and Cartosat), Light Detection and Ranging (LIDAR), and Shuttle Radar Topography Mission (SRTM), which gives information at very-very high resolution at much faster rate with 2D and 3D surfaces. It enables very large scale mapping with more than photo quality information. These new development have given new heights to cartography. India also recorded remarkable achievements in this field due to fast advancements in the space technology (aerial photography and satellite remote sensing with Resourcesat and Cartosat series), and computing along with printing technology. In fact, the designation of cartographer has evolved with these developments to computer cartographer to laboratory technician/GIS expert and changing courses from cartography to GIS laboratory work, etc.

With all above developments, the automated cartography made significant advances in data collection/capture, presentation which otherwise was very tedious task.

SAQ 2

Can you make a difference between early mapping techniques and present day cartography?

In this unit so far, you have studied about nature and scope of cartography and history of cartography. You know that cartography is both an art and science of map making. It is an art because it needs an artistic skill to prepare a map and it is science because it involves testable explanations, knowledge of mathematics and use of sophisticated techniques and modern technology. Have you ever thought that while making a map, we actually have to cater to the problem of representing a portion of the curved surface of earth on a flat piece of paper? This is the central problem of cartography which you will study in the next section.

1.4 EARTH AS A CARTOGRAPHIC PROBLEM

While preparing a map, we first select a suitable map projection which lessens the distortions of transferring the features of spherical earth on a flat piece of paper. You will learn about map projections in detail in Block-2 of this course. Before that, let us first learn about the shape of earth. There is a lot of ambiguity regarding the correct shape of earth, whether it is spherical, ellipsoidal or geoidal. To a layman these terminologies are synonymous. However, to a geographer or earth scientist each of these terms is having different meaning. Let us get acquainted with these terminologies here.

1.4.1 Spherical Earth

A sphere is defined as the set of points in three-dimensional space so that all are located at the same distance 'r' (radius), from a given point which is supposed to be the centre. Twice the radius is called the diameter, and pairs of points on the sphere on opposite sides of a diameter are called antipodes. Refer to Fig. 1.3 to see a sphere with radius 'r' and AB as antipodes or points diametrically opposite to each other.

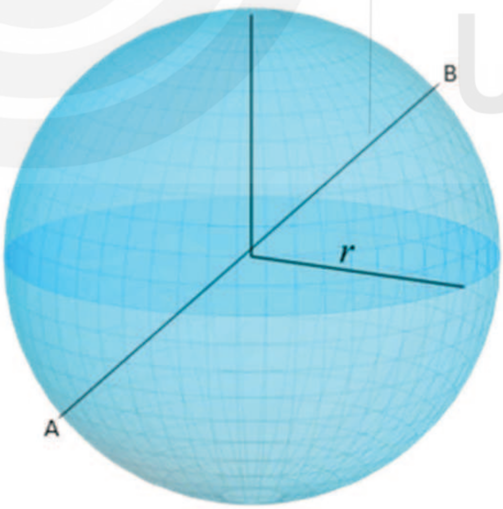

Fig. 1.3: A Sphere.

(Source: Modified after https://en.wikipedia.org/wiki/Sphere#/media/File:Sphere_and_Ball.png, Public Domain)

It is important for you to know that the earth being a member of the solar system, its shape, size and movements are directly governed by its relation to other planets. Many thinkers of ancient times attempted to describe the shape of the earth which ranged from highly erroneous flat disc of Homer to sphere shape of Pythagoras. It was Eratosthenes who first demonstrated that the earth is sphere in shape. He did this by measuring the angle at which sun's rays fell at two places on the same longitude but at different latitudes. He observed that during the summer solstice, mid-day sun's rays reached straight to the bottom of a well at a place called Syene. However, at the same time he noticed that sun's rays were not directly overhead but making an angle q with the vertical at a place called Alexandria which was on the same longitude as Syene. Refer to Fig. 1.4 to understand it better. He found the angle q that sun's rays made with the vertical at Alexandria to be 7°12'. He found the linear distance between Syene and Alexandria to be about 805 km. With the help of all this information, he calculated the circumference of earth to be about 40,070 km. However, his measurements were not so accurate but considering the instruments he used in those times, it was very near to accurate.

You may carefully study the following hint for understanding about the angle (θ).

Hint: Angle 'θ', is equal to the angle formed at the centre of earth between Syene and Alexandria. Since the angle 'θ' is representing 805 km of the circumference, so 360° would represent the entire circumference of earth.

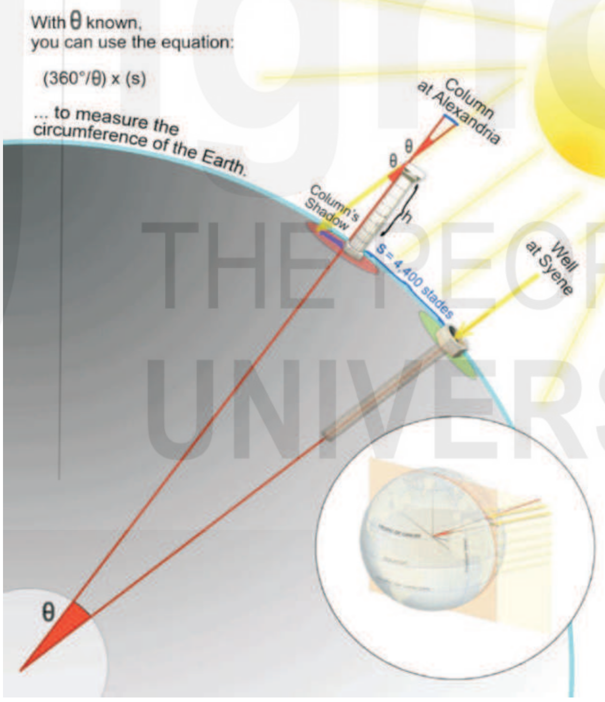

Fig. 1.4: How Eratosthenes calculated the circumference of Earth.
(Source: https://www.flickr.com/photos/nasablueshift/9411406224, CC BY 2.0)

With further discoveries regarding the shape of earth, it was found that earth is not a perfect sphere but a spheroid. Let us learn about it.

1.4.2 Ellipsoidal Earth

Contrary to sphere, which is based on a circle, a spheroid (or ellipsoid) is based on an ellipse. An ellipse is oval-shaped defined by two radii. The longer radius is called the semi-major axis, and the shorter radius is called the semi-minor axis. The amount of polar flattening is given by the ratio, F = (a-b)/a, where 'a' is the equatorial radius and 'b' is the polar radius (Refer to Fig. 1.5). Rotating the ellipse around the semi-minor axis creates a spheroid. Thus an ellipsoid or spheroid is a three-dimensional shape created from a two-dimensional ellipse. So, ellipsoid is responsible for polar flattening and equatorial bulge. A spheroid is also known as an oblate ellipsoid of revolution.

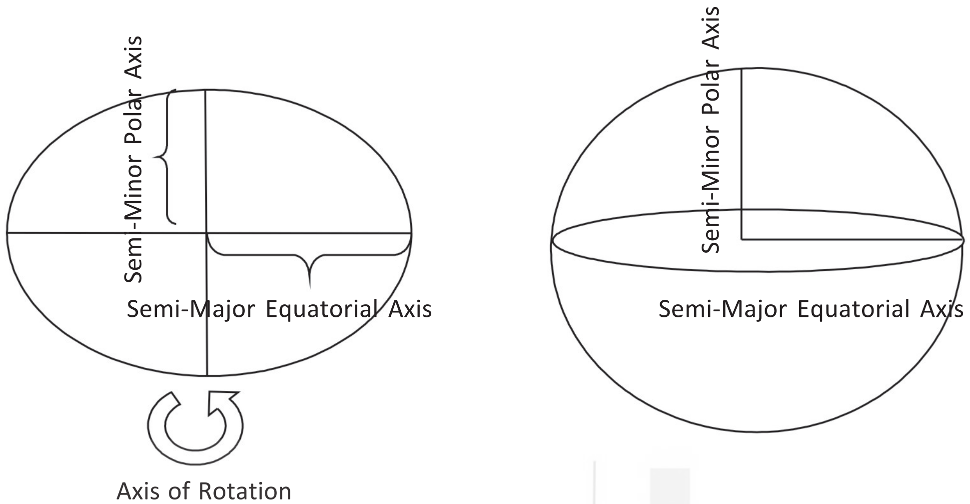

Fig. 1.5: Ellipse (left) and Ellipsoid (right).
(Source: Diagram created by the author- Dr. Satya Raj)

The first scholar to give the nearly appropriate shape of earth was ***Thomas Issac Newton*** in 1786. He described earth as an oblate spheroid, which means that earth is having equatorial radius greater than polar radius. One important thing to be remembered here is that the ellipsoidal surface is smooth and it assumes the earth to be homogenous, as if there are no relief features on earth. The geoid on the other hand accounts for this variation in relief. Let us learn about it.

1.4.3 Geoidal Earth

Although the terms geoid or ellipsoid/spheroid are used interchangeably, there are some basic differences between them. Geoid is defined as the surface of

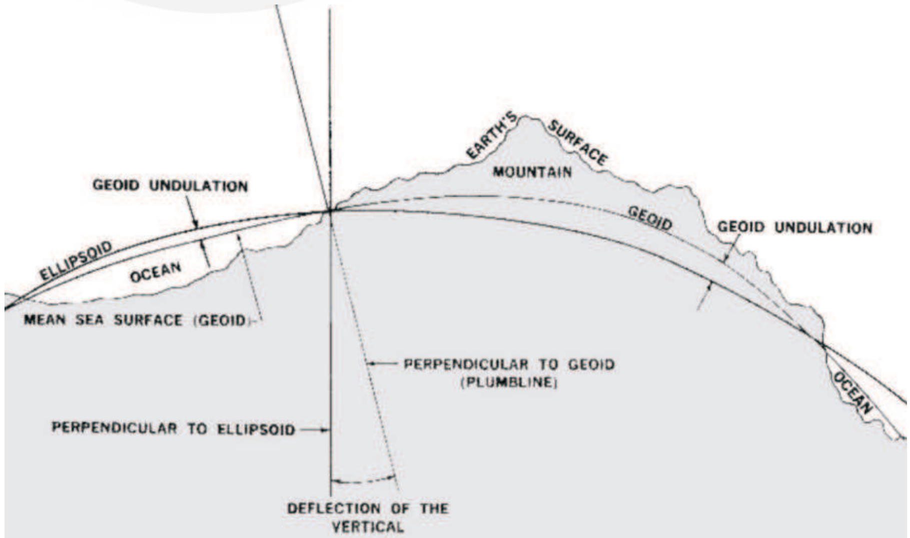

Fig. 1.6: Geoid and Ellipsoid (Reb40 2013, Creative Commons, Public Domain).
(Source: https://commons.wikimedia.org/wiki/File:APN2002-figure201.png)

the earth's gravity field and approximates the mean sea level. At any point, it is perpendicular to the direction of gravity. Since the mass of earth is not uniform at all points, the direction of gravitational force changes and hence, the shape of geoid is also irregular. If the earth would have been devoid of all relief features, that is, mountains, and ocean basins, etc, then the geoid surface would have matched the ellipsoid exactly. Refer to Fig. 1.6 to get a better picture of a geoid and a spheroid.

The force of gravitation is the pioneer in determining current shape of the earth. The gravitational force due to earth's mass is directed towards the center of the earth and is opposed by centrifugal force which detracts it from the Centre. The measured gravity of earth is the result of combination of mass gravitation and centrifugal force (Fig. 1.7). Thus, the gravitational force is weaker at equator than at poles by 0.5 percent.

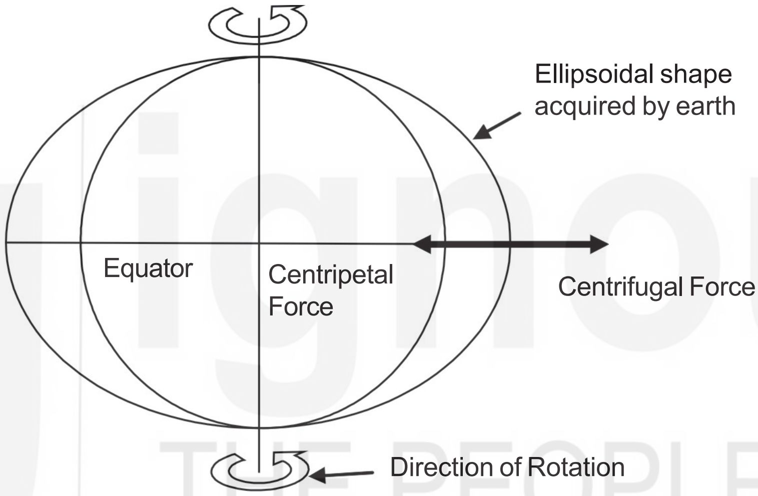

Fig. 1.7: Effect of rotation of Earth on its shape

(Source: Diagram created by the author- Dr. Satya Raj)

Having learnt about the shape of earth, let us now learn about something very interesting. Since earth rotates on its axis, we have day and night. This results in variation of time at different places on the earth and this is systematic as earth completes one full rotation in 24 hours and each and every place happens to be on a particular meridian that comes under the sun. Let us learn how time varies across different longitudes or meridians section.

The earth rotates on its axis in 24 hours. So it completes 360° of rotation in 24 hours. So it takes one hour to rotate for 15°. The rotation of earth thus leads to variation in time at two places situated on different longitudes. The local mean time at a particular place is reckoned from the lower transit of the mean sun and thus different meridian have different local mean time. Also, the difference between local mean times between two places is equal to the difference in their longitudes. To avoid confusion, a standard meridian is selected for each country which is at a fixed number of hours ahead or behind the Greenwich Mean Time. The difference between the standard and local time of any place is due to the difference in the longitudes between the given place and the standard meridian used.

SAQ 3

a) How has earth acquired an ellipsoidal shape and is not a true sphere?

b) If a place 'A' is at 75° E of Greenwich and the time at A is 4 am. What is the time at 'B' which is 90° E of Greenwich?

1.5 SUMMARY

In this unit, you have studied so far:

- The definitions of cartography.
- The nature and scope of cartography.
- The brief history and evolution of cartography.
- The shape of earth i.e. sphere, spheroid and ellipsoidal forms. The earth's shape is not a perfect sphere. It is an oblate spheroid, that is, equatorial radius is greater than polar radius and this is attributed to rotation of earth and the force of gravitation.

1.6 TERMINAL QUESTIONS

1. What are the nature and scope of cartography?
2. How has the map making evolved as modern cartography over time?
3. What is the difference between geoid and spheroid?

1.7 ANSWERS

Self-Assessment Questions

1. Cartography is the art and science of map making.
2. Early cartography was completely manual, time taking, with less precision, while the modern cartography is fully computerized with high level of accuracy.
3. a) The shape of the earth is not a perfect sphere as it is slightly flattened at the poles and bulged at the equator. This is attributed to the centrifugal force experienced during rotation of the earth due to which it bulges out at equator and gives its ellipsoidal shape with a semi-minor axis along the poles and the semi-major axis along the equator.

   b) 5 am (Since 90°-75° = 15° difference between the two longitudes and 90°E is eastward of 75°E, so it will be one hour ahead of A, that is 75°E).

Terminal Questions

1. Explain the nature as interdisciplinary having wide scope of cartography in present day context. Refer to Section 1.3.
2. Discuss the evolution of cartography from ancient time to modern period and explain how it has progressed and transformed from a very

rudimentary manual technique to sophisticated one in the contemporary times. Refer to Section 1.3.

3. Refer to Section 1.4.

1.8 REFERENCES/SUGGESTED FURTHER READING

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UNIT 2

MAPS

Structure

2.1 INTRODUCTION

You have already studied the basic concepts of cartography in the previous Unit-1. In this unit, you will study about maps including their types, history, basic elements and usage of maps. Map is a pictorial representation of the whole earth or a part of the earth on plane surface to scale. From the ancient periods to the present, it is considered as one of the important and effective tools. You will study about the maps and their history in Sections 2.2 & 2.3. Basic elements of maps and usage of maps are discussed in Sections 2.4 & 2.5. In Section 2.6, we will explain about the various equipments generally used in the process of map making.

Expected Learning Outcomes

After studying this unit, you should be able to:

- explain the definition, evolution and types of maps;
- describe the basic elements of map;
- discuss the importance and usage of maps; and
- depict the map drawing equipments.

2.2 DEFINITION AND TYPES OF MAPS

Definition

A map is a pictorial depiction of whole earth or its part into two dimensional surface involving geometrical objects, colours, symbols and texts. The term **map** has been derived from the Latin term *'mappa'* meaning the cloth-paper on which early maps were inscribed. It has been defined by various geographers and scholars from time to time. The most important definitions are as given below:

According to Erwin Rais (1938), "a map is, in its primary conception, a conventionalised picture of the earth's pattern as seen from above." L. Dudley Stamp has defined as "map is a representation of the earth's surface or a part of it, its physical and political features, etc. or of the heavens, delineated on a flat surface of paper or other material, each point in the drawing corresponding to a geographical or celestial position according to a definite scale of projection." The definition by F.J. Monkhouse is "map is a representation on a plane surface (paper, card, plastic, cloth or some other material) of the features of part of the earth's surface, drawn to some specific scale." Harley and Woodward (1987, p. xvi), defined map as 'graphic representations that facilitate a spatial understanding of things, concepts, conditions, processes or events in the human world.'

It may be understood that maps have been very useful tools from ancient times concerned with the demarcation of territory, expansion of territory, exploration of new continents/lands, navigation, resource locations etc. Now the maps are useful in day to day life. It begins with the record of property as every land owner, be it geographer or non-geographer, literate or illiterate, tries to keep the map record of his or her property. It goes very advanced and sophisticated way in public navigation and strategic usage. Maps represent the locations and features of earth surface and their attributes or properties attached to them. The advantage is that it presents in visual form the reality of an area, large or small, in terms of its objects, features and phenomena in spatially arranged relationships. It helps in viewing and reading the topographic features and properties of them on the earth surface drawn on simple small paper. In turn, it also helps in locating distance, direction and bearing, connectivity and contiguity/neighbourhood and proximity, etc. Besides, it also helps in observing and understanding the spatial relationships among all features and their properties on the earth surface and its environment. "A map lets us see the broader spatial relations that exist over large areas or the details of microscopic particles. It is said that a map saves thousand words by its own symbolic language or communication efficiency (Robinson, p. 10). Let us now discuss various types of maps.

Types of Maps

The classification of maps is done based on various criteria. These criteria are: scale, theme and purpose, and techniques of representation.

1. Scale

The types of maps based on the scale are as follows:

a) Large Scale Maps

The maps drawn on or larger than 1:10,000 scale are considered as large scale maps. It goes to as high as very large scale maps to a scale of 1:500. Such kind of maps includes cadastral or land parcel maps, settlement maps, etc. and topographical maps (Fig. 2.1).

Cadastral maps: Cadastral maps are the maps of land properties or land parcels/plots. The term cadastral has been derived from the French term '*Cadestre'* meaning the 'register of territorial property.' There are various terms of these maps used in India like *Khasra*/*Jamabandi*/*Girdwari*/*Khatauni* Map etc. where the term *Khasra* number denotes the plot or parcel number. These maps are drawn to demarcate the parcel or plot boundaries or houses by the government agencies mainly the department of Revenue and Land Records for taxes and other revenue and development purposes accompanied with the tabular information called *Khatian* or *Khatauni*. These both- Cadastral Maps and *Khatian* make the record of property rights, where the records match in both documents- map and *Khatian.* The map contains the parcel/plot wise *Khasra* number and the *Khatian* keeps the record of size, location, extent, type, uses and ownership details. The scale of cadastral maps are generally 1:3990 or 1: 4000 scale and the settlement maps go upto as large as 16, 32 and 64 inches to one mile. These may be called very large scale maps.

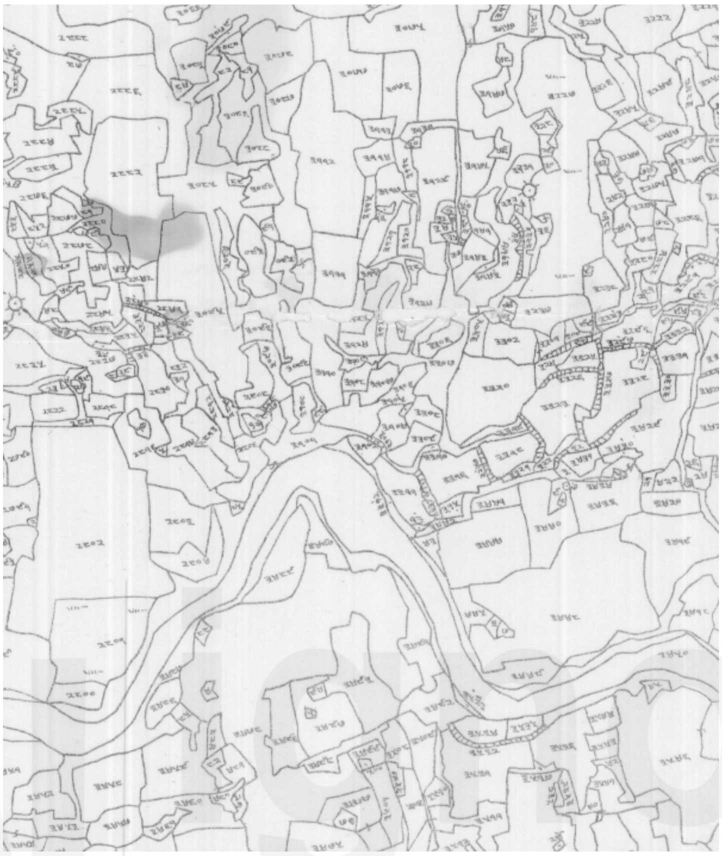
Topographical maps: Topographical maps are prepared to depict earth's surface features including natural and cultural. These two kinds of features form the physical and cultural landscapes showing relief, mountains, drainage, waterbodies, agricultural land, forest, etc., and settlements, roads, railways, location of schools, post offices, other services and facilities, etc., respectively. The scale of topographical maps varies from one inch to one mile to quarter inch to one mile. Different national agencies in various countries prepare the survey based topographical maps on various scales accurately. These maps vary in scale ranging from 1:25,000 to 1:2,50,000. Survey of India prepares topographical maps on various scales, for example 1:25,000, 1:50,000 and 1: 2,50,000. International maps or one million maps are the other products in this category, which represent the world in 2,222 sheets adopted in 1909 using modified polyconic projection.

b) Small Scale Maps

Wall maps: Wall maps are drawn on a smaller scale to show the whole world, a hemisphere, a continent or a country. The scale also varies depending on the area of interest.

Atlas maps: These are very small scale highly generalized maps of the world or different regions of the world. These map show major physical features, settlements, transport networks and important landmarks. In India, various types of atlases are prepared by various government agencies like National Thematic Mapping Organization (NATMO), National Bureau of Soil Survey

(NBSS), All India Land Use & Soil Survey (AILU&SS), National Remote Sensing Centre (NRSC), Census of India, etc.



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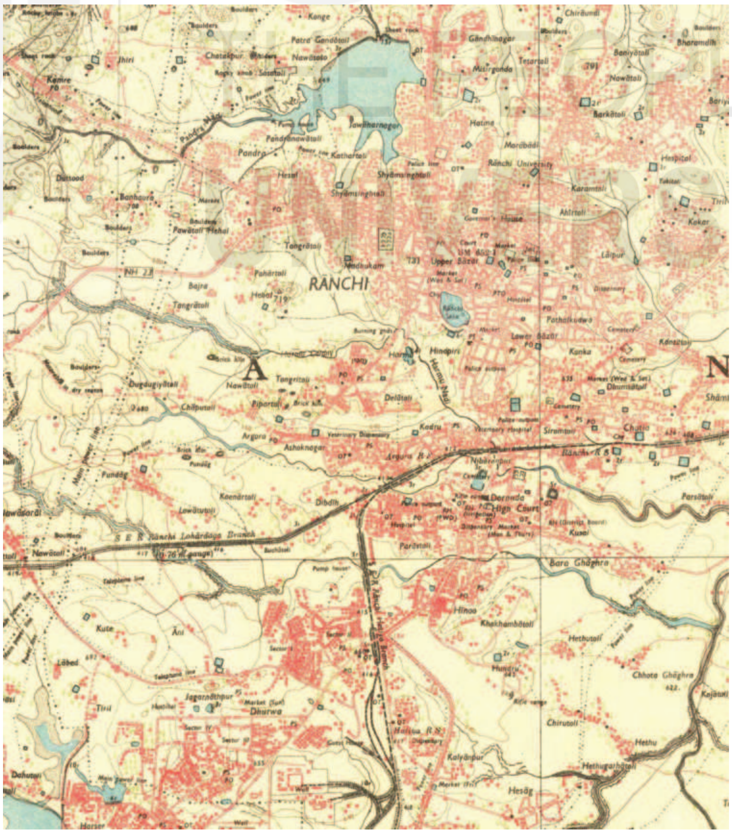


(b)

Fig. 2.1: Examples of large scale map a) cadastral map and b) topographical map.
(Source: Baraik, V.K. (2020): "Languages", Space and Society in Human Geography, IGNOU: New Delhi).

2. Theme and Purpose

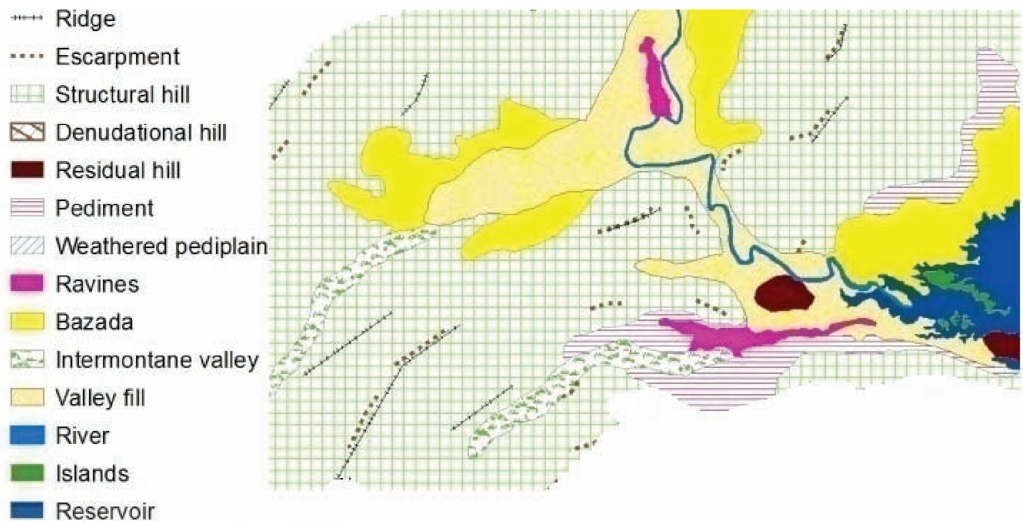
The maps are also classified based on their themes and functions or purposes. These may further be divided as natural and cultural maps based on broad themes (Fig. 2.2).

Physical maps: Physical maps are those maps which represent different physical features. The example of this category of maps are the astronomical maps showing astronomical or heavenly features, orographic or relief maps showing relief features of the earth surface (comprising lowest and highest surfaces, slope, drainage, waterbodies, etc.), geological maps showing geological features (interior of the earth, fold, fault, structure, etc.), weather or climatic maps showing temperature, pressure, wind direction, rainfall, diurnal maps, seasonal maps etc.), vegetation maps showing forest species, type and boundaries, soil map showing soil type, boundaries and land development plan, hydrological maps, slope map, etc. These maps are also prepared in three dimensional models on paper, plastic or clay.

Cultural maps: Cultural maps are those which represent the cultural landscapes of the earth surface. The human beings have modified the pristine natural landscape by building their settlements, industries, transport networks, health and education facilities, dams and bridges, etc. The features created by humans are categorised as cultural features. Depending on the purpose, these are further subdivided as thematic maps. These are historical maps, political maps, administrative maps, military or strategic maps, population maps, socio-cultural maps, land use maps, transport and communication maps, etc. Historical maps show historical events and reigns through boundaries and locations, political maps show political boundaries, administrative maps show various administrative boundaries, military or strategic maps show various strategic points, routes and battle plans etc., population maps show various aspects of population like population size, distribution, density, sex ratio, literacy and education, employment, fertility, etc., socio-cultural maps show ethnicity or races, tribes, castes, religion, languages, etc., under relevant titles, land use maps show the utilizations of land parcel by parcel or in a regionalized way, transport and communication maps show transport and communication, resource maps show various resources, economic maps show economic activities and development over the space, etc.

3. Techniques of Representation

The maps may also be classified based on the representation techniques. These classifications are choropleth, chorochromatic, choro-schematic, isopleths, and dot maps, etc (Fig. 2.3). Choropleth maps are those maps which show the physical and cultural features by various colour/grayscale shades or patterns. Chorochromatic maps show the non-quantitative properties of any feature or phenomena over the space like presence or absence. For example, the racial or linguistic distribution map, land use map, etc. The maps showing the location and distribution of something over the space through alphabets are called Choroschematic maps. For example, iron ore is shown by I, gold is represented by G and so on. The maps using regular line showing a uniform value of something like rainfall, temperature, pressure, etc. are called isopleth maps. When distribution of something like population, trees, animals, etc. are shown by dots representing definite number or quantity, such maps are called dot maps. You may also refer to Block 5 for understanding these maps.



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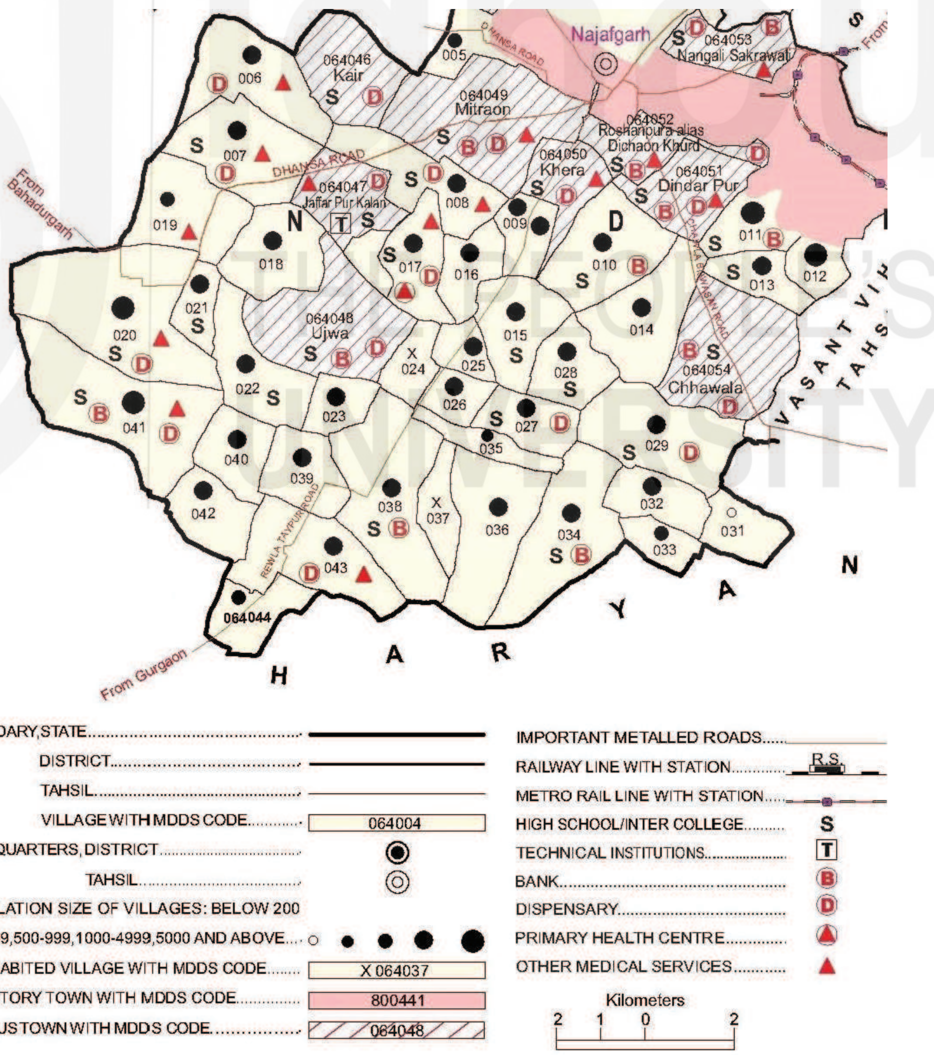


(b)

Fig. 2.2: Examples of a) physical and b) cultural maps.
(Source: Baraik, V.K. (2020): "Languages", Space and Society in Human Geography, IGNOU: New Delhi).

SAQ 1

What is map? What are the bases for classification of maps?

2.3 HISTORY OF MAPS

Maps have been in existence since historical times. It evolved from a very rudimentary shape to the highly sophisticated smart maps in contemporary times. It has evolved from pictorial form without scale to a sophisticated virtual form, which is very close to reality with third dimension. Early maps were of

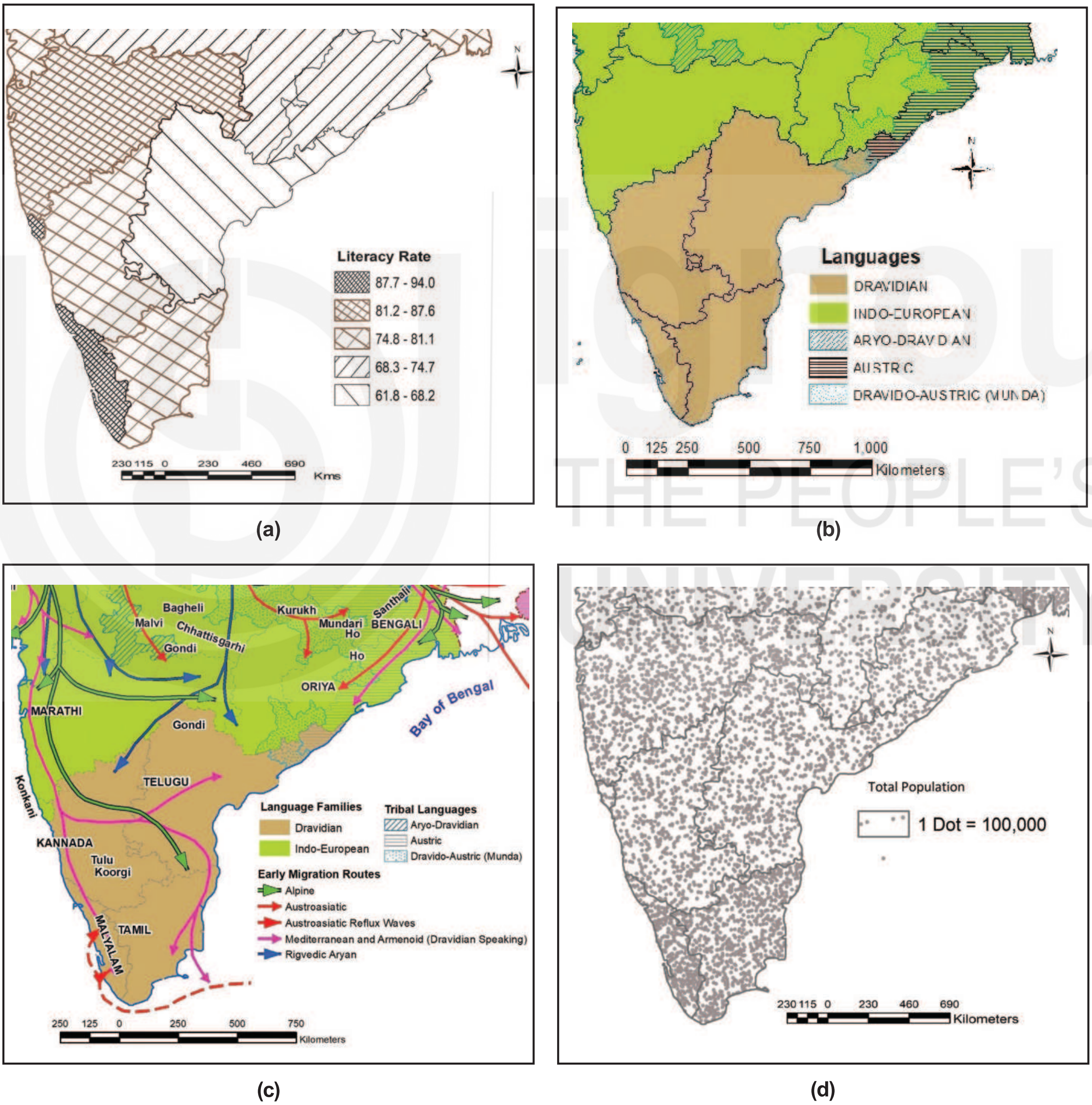


Fig. 2.3: Representation of maps a) choropleth, b) chorochromatic, c) choro-schematic, and d) dot.

(Source: Baraik, V.K. (2020): "Languages", Space and Society in Human Geography, IGNOU: New Delhi).

very notional kind without proper measurements. Egyptians have been the pioneers in making systematic maps for the purpose of revenue. However, Greek geographers prepared the early modern cartographic maps after 16th Century. The oldest maps were from Babylonian civilization engraved on the clay in about 2300 B.C.

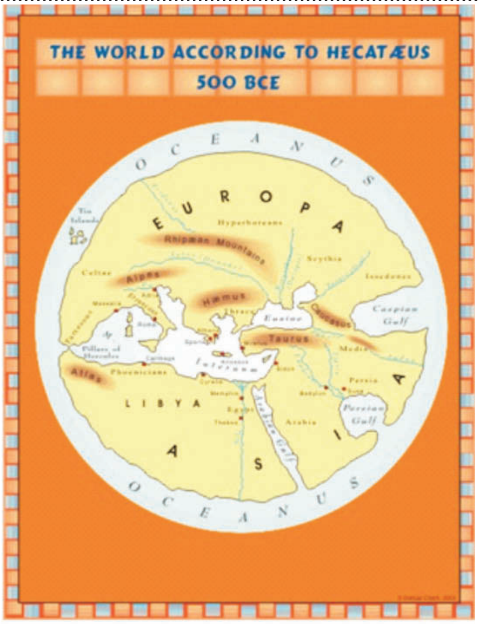
The Greek geographers like Hecataeus (500 BC), Aristotle (384–322 BC), Eratosthenes (276-194 BC), Ptolemy (98-168 AD), etc. in early times discovered the earth's shape and size, poles, equator, tropics, climatic zones, graticules and projections. Various maps including that of world drawn by Ptolemy in his great work '*Geographia'* is the landmark of Greek cartography. He has tried to show the entire world using mathematical aspects of geography, though, the maps were not refined ones. The Romans prepared the disc maps for administrative and military purposes. They prepared *'Peutinger Table'* showing major roads with military posts. The Arab geographers also prepared maps after publication of *Geographia* with world map in 15th Century AD (1482).

"The discovery of Geographia during 15th Century, the invention of printing and engraving, and the age of discoveries, all these exerted a great force in ushering towards the renaissance of map-making. The Italians, Spaniards, Portuguese, the Germans and the Dutch with their successive efforts perfected the art of drawing maps to such an extent that map publishing became a very lucrative business during 16th Century." Till this time, a great influence on map making was from Ptolemy's *Geographia*. Followed by this, Mercator also contributed with greater accuracy than Ptolemy to make the maps.

The French cartographers further excelled in cartography with much greater accuracy with the perfection of triangulation survey and measurement of meridians. Due to the necessity of accurate topographic maps by the army, a cartographic centre was developed in London under army for strategic purpose as the Europe had become the most powerful in maritime. The National Survey was initiated in France by C.F. Cassini and the "Carte Geometrique de La France" was prepared on 1:86,400 scale in 1789. Italy, Germany and Egypt also started the surveys and the Britain commenced its Ordinance Survey in 1791. 1 inch to 1 mile map in England was prepared in 1801. Other European countries also started the National Surveys.

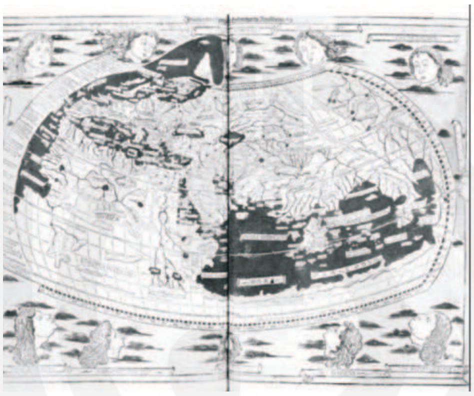
In the medieval period a map called T-O or T and O Map was also popular with religious importance where Jerusalem was placed at the Centre of the world. The world was shown as divided into three schematic parts: Asia, Europe, and Africa. You may see some of these early maps in Fig 2.4.

During 19th and 20th Centuries, the map-making techniques further got accelerated due to remarkable advancements in science and technology, representation techniques of the earth and also the printing technology. Mono colour maps have been replaced by the multicolour maps. A number of national atlases were prepared during this phase. These were further accentuated by the aerial photography during the First World War, which kept progressing with the refinement of computing, computer graphics and printing technology. All these are supported by the rapid advancements in the satellite remote sensing and other surveying tools and technologies. Now also with the



Hecataeus Map (500 BC)

Eratosthese Map (220 BC)



Ptolemy's World Map (98-168 AD)

T-O Map of the World

Fig. 2.4: World maps prepared by various geographers.

(Source: a) b)https://etc.usf.edu/maps/pages/10400/10489/10489.htm, c) https://www.britannica.com/science/map/Maps-and-geography-in-the-ancient-world d) https://www.princeton.edu/~his291/T-O_Map.html)

advancements of GIS technologies, the maps have got transformed into smart maps. These maps have the ability to answer end number of spatial questions. The geo-database has enabled maps to retain the behavioural properties of a geographical feature in the maps and respond to the questions accordingly.

In India, the survey of Raja Todarmal for revenue collection has been regarded as the early beginning in the field of survey and mapping. The Survey of India was established in 1767 by the East India Company and carried forward by the Government of India from the Imperial Government after independence for survey and mapping of the country. First modern survey was started in 1802 with the beginning of Geographical and Mathematical Survey in India by Colonel William Lambton, a Geographer and Geodesist. This survey was later on designated as Great Trigonometrical Survey (GTS), in 1818 and led by Albert Everest after Lambton.

SAQ 2

How has the map evolved historically? Explain.

2.4 BASIC ELEMENTS OF MAPS

There are some basic elements of maps based on which these are drawn. Without these basic elements, maps cannot be complete. These basic elements are scale, projection, reference grid, symbols and legends, neatline, titles, and accuracy etc. (Fig. 2.5).

Scale

Scale is the ratio between the distance on map and the actual distance on the ground. The representation of earth or even a piece of area cannot be done on a piece of paper practically without fixing a proportional geometric shape or symbols representing the features on the earth as paper cannot always be of the same size of the area under representation. For this reason, the maps are drawn on small piece of papers of varying sizes using some representative proportions where certain distance or size of representing features on the paper is true to the fixed proportionate size on the ground. For example, one centimetre line on paper may represent one kilometre distance on the actual ground. This is exactly called '**Scale**.' The formal or scientific definition of scale is the ratio between the distance on map and the actual distance on the ground. It is expressed as:

$$\text{Scale} = \frac{\text{Map distanace between two points}}{\text{Ground distance between the same points}}$$

The map scales are of three types: statement, numeric and graphic. You will study the same in details in the next unit 3.

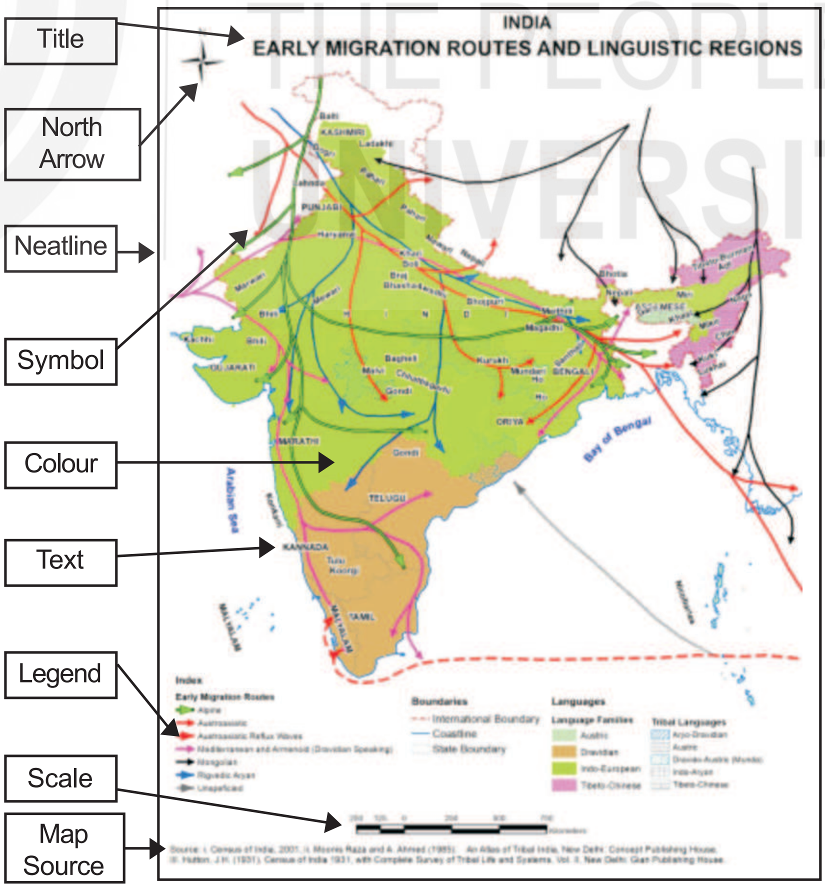


Fig. 2.5: Map showing various elements of the map.
(Source: Baraik, V.K. (2020): "Languages", Space and Society in Human Geography, IGNOU: New Delhi).

Projection

Map projection is the mathematical and geometrical transformation of spherical surface of the earth into two dimensional flat surface to show the whole or part of the globe in the form of a map. In this process, the boundaries of whole world or any part is transferred on the plane surface with graticule or latitudes and longitudes based on certain scale. Through certain mathematical formula or model, the surface geometry is transformed from spherical to two dimensional plane. Since the earth is spherical in shape, no projection is perfect in terms of representation of area, shape, and bearing or direction. In all types of projections, any of these properties are compromised in terms of accuracy. The concept of projection has been in use since the time of Strabo and Ptolemy. However, the first systematic map on projection systems was equidistant polar zenithal map developed by Glareanus in 1510. Later on, Gerhard Kremer prepared the maps of Europe on conical projection with two parallels (1554), and world map in Mercator projection (1595). The development of projection system moved forward with the era of navigations and explorations. Consequently, a number of projections based on various approaches and objectives came into existence. The number was further added due to the need based modifications and improvements. The mapping of world in 2222 independent sheets on modified polyconic or international projections has also been one of such products. Classification of map projections may be done based on the aspects of projection techniques, developable surface, global properties and source of light. You will study more about map projections in Block 2 of this Course.

Reference Grid

Though references to the spatial locations are of different types, these may include pin code, distance and direction from a known point and house number (alpha-numeric). Grid reference defines location of any spatial features on the map. It may be latitude and longitude and also in the form of alpha-numerical grids for reference.

Symbols and Legends

Different symbols are used in the map to represent spatial features and phenomena along with their properties. Legend presents the index of the symbols used in a map with self explanatory description of relevant line, polygon, point, colour, pattern, texture, intensity and alpha-numeric letters or tags, etc.

Conventional signs or map symbols are widely or technically or universally accepted signs, symbols or colours used to represent or show various features, elements and properties of maps. It enables anyone to read and interpret the map anywhere in the world irrespective of languages used due to internationally used system of signs and symbols. This way the information is accurately conveyed by the map makers to the users. Conventional map symbols are the graphics either independent or mixed of geometric and alpha-numeric features with colour and patterns representing physical as well as cultural features of the earth surface and its environments shown in the maps.

It is very essential, therefore, to have knowledge about the conventional signs, symbols and colours for map making as well as map reading or interpretation. There are definite signs for roads, rails, bridges, footpaths, cart track, pack track, milestones, road or highway numbers, spot heights, contours, rivers, river channels, canals and waterbodies like lakes, tanks, wells, etc. For each category of features also there are different signs or symbols for its types like broad gauge and narrow gauge for railways, national highways, state highways, district roads and rural roads under the category of roads; perennial stream/channel or seasonal stream under river, etc. Similarly, colours are also internationally defined like blue for water, brown for heights, green for vegetation, red for roads or settlements, etc. You may see some of the examples of conventional signs, symbols and colours, etc. (Fig. 2.6). For more details, you may refer to Unit 11 of Block 4.

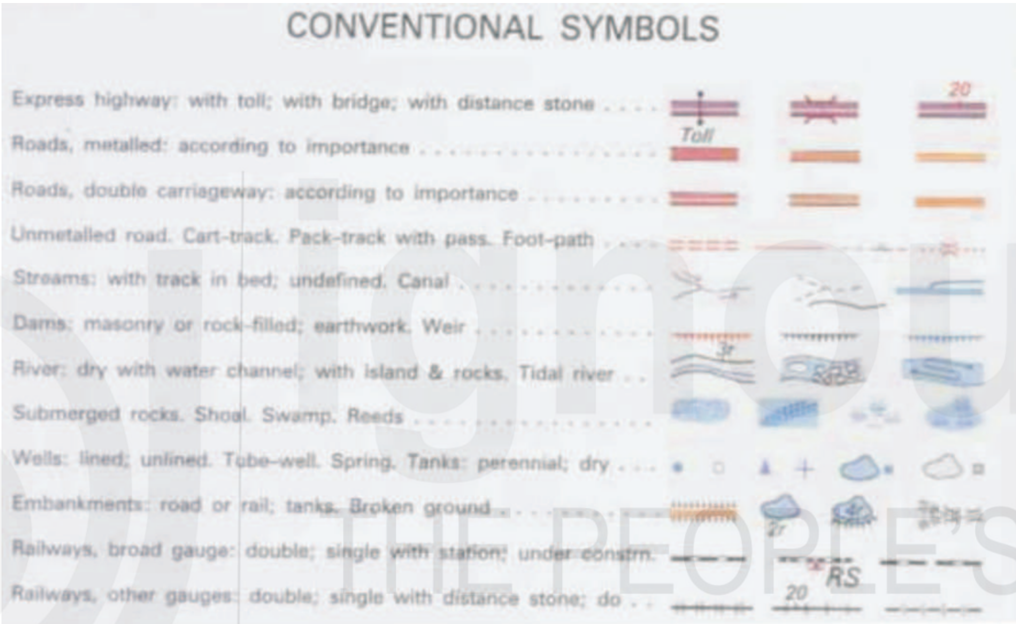


Fig. 2.6: Conventional symbols of topomap.

(Source: http://www.surveyofindia.gov.in)

Neatline

Neatline is the line bordering the geographical data (outline) of the area of representation. It may be called the outer boundary of the map having various designs of lines.

Titles

Titles and sub-titles are the identities of any map written normally on the top of a map. It consists of region name, theme and year/time period etc.

Accuracy

Accuracy is a prime concern in map making, without which map cannot represent the area of interest properly. The aspects of accuracy are positional or planimetric, thematic and conceptual. Positional accuracy is the correct relative positions of features on the map with same positions of the corresponding features on the ground. It may be between the two maps as well. Without positional accuracy, all calculations of area, distance, and direction, etc. may be wrong and may not correspond exactly with the ground reality. Thematic accuracy means the correct representation of the ground reality in the map. In this, if the area or location of something is correctly shown but the property is not shown correctly, there will be inaccuracy. For example, if the playground is shown as rice field, it is thematic inaccuracy. Conceptual accuracy or logical consistency is the whole concept from data under representation, temporal variation of data to projection and symbology.

SAQ 3

What is the importance of conventional signs, symbols and colours?

2.5 IMPORTANCE AND USAGE OF MAPS

Humans have been modifying the earth surface consistently and especially after the development of science and technology more than ever. With some negative alteration to the nature, some are done in positive direction with proper planning like urban planning and design, location, industrial plan, mining plan, plantation and afforestation, agriculture, construction of dams for electricity, potable water and irrigation, construction of transport network and so on. For these activities, the information of the earth surface under interest is essential which is fulfilled in terms of various maps. Any kind of such activities over the earth surface need the maps of various types. Regional comparison is also possible when relevant maps are available.

The globe represents the earth without distortions in terms of relative distances, angles, areas, azimuths, rhumbs and great circles at a certain scale. However, the globe is expensive, time taking in reproduction, storage and carrying inconvenience and difficulty in measurements as only about half of the globe is visible at a time. Therefore, maps get importance over the globe. All these disadvantages are eliminated with the production of maps on a flat surface primarily paper or plastic.

Advantage of map is that it shows all the features or phenomena under interest in systematic and legible manner for easy and meaningful communication but the demerit is that it does not represent the phenomena as it is in the picture. On the other hand, the demerit of the picture is that it shows everything visible under the area of interest irrespective of their relevance. Secondly, the pictures cannot show the phenomena which are not visible but measurable through various techniques and scales.

In nutshell, maps are essential tools to understand our world's spatial variability and character for all the activities we do. Now, smart maps do not only give answer to our spatial query, but also retain the spatial behaviour of the features and inter-relationship among themselves in answering the spatial questions. And due to the new capabilities of maps as smart maps, these have increasingly become the part of our every day life in various forms.

SAQ 4

What is the importance of map?

2.6 MAP DRAWING EQUIPMENTS

There are two modes of cartography and therefore two types of map drawing equipments-Traditional and Digital. The traditional map drawing equipments are less in practice now after the rapid revolution in survey, computing, graphics and printing technologies in the digital formats. However, the modern or digital technologies are primarily based on the traditional techniques only. Therefore, it is inevitable to know the traditional techniques and equipments for understanding the modern tools and techniques. The list of equipments given below is generally used for map making.

Traditional Map Drawing Equipments

- Drawing Table/Drawing Board
- Tracing Table/Light Table
- Papers- Plain and Graph
- Geometrical Instruments
- French Curves
- Pencil and Pens
- Ink and Colours
- Tints and Patterns

Digital Map Drawing Equipments

Hardware: Computer and Peripherals

- Input Devices (Scanner, Digitizer, Keyboard and Mouse, Global Positioning System (GPS)/Differential Global Positioning System (DGPS)/Electronic Total Station (ETS).
- Processing Devices (CPU or Central Processing Unit)
- Display Devices (Monitors)
- Printing Devices (Printers and Plotters)
- Internet Connection for Online Data Sharing, Viewing, Analysis, Map Composition and Sharing

Software:

- Data Transformation from Digital Survey Devices
- Map Making
- Web Mapping

Since last one decade, the rapid technological developments are gradually replacing the traditional map making equipments.

SAQ 5

What are the map drawing equipments?

2.7 SUMMARY

In this unit, you have studied so far:

- Definition of maps and map types based on scale, projection and purpose or usage.
- History and evolution of maps from ancient time to the modern period characterized by sophisticated technologies.
- Basic elements of maps starting from scale and projection to symbology.
- Conventional signs, symbols and colours used in mapping and map interpretation without which any map is incomplete and meaningless.
- Importance and usage of maps which have become the inevitable part of our everyday lives in some form or the other.
- The list of conventional or traditional and digital map drawing equipments.

2.8 TERMINAL QUESTIONS

1. What do you understand by maps? Describe the importance and types of various maps.
2. Describe the historical evolution of maps.
3. Explain the basic elements of maps.
4. What are the importance and usage of maps?

2.9 ANSWERS

Self-Assessment Questions

1. A map is a pictorial depiction of whole earth or its part into two dimensional surface involving geometrical objects, colour, symbols and texts. The bases of classification of maps are scale, projection and purpose or usage of maps.
2. Map has evolved from rudimentary to conventional, then to digital and now smart maps in the digital category.
3. Conventional signs, symbols and colours are the graphics either independent or mixed of geometric and alpha-numeric features with colour and patterns to depict various physical and cultural features of the earth's surface and its environments shown in the maps.
4. Maps have become the part of everyday life in deciding what is located where and what has to be done where.
5. Two broad types of map drawing equipments are traditional/conventional and digital.

Terminal Questions

1. Give definitions of map and discuss the importance and types of various maps. Refer to the Section 2.2.
2. Write about the evolution of maps since early period to the contemporary time period. Refer to the Section 2.3.
3. List and explain the basic elements of maps and also write about their importance in a map. Refer to the Section 2.4.
4. Discuss why maps are important and useful. Refer to the Section 2.5.

2.10 REFERENCES/SUGGESTED FURTHER READING

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UNIT 3

MAP SCALE

Structure

3.1 INTRODUCTION

You have already studied the introduction to cartography in Unit 1. If you have remembered correctly then cartography is nothing but 'an art and science of map making'. When we say it is science which means it follows certain scientific procedure which are universally accepted while constructing a map. Scale is to be specific and is one of the essential parts involved in the construction of map. Therefore, we can say that scale is very essential element of a map as it provides the true measurements of area or length of any feature on the ground. Without scale, a graphic representation will not be called a map and remains a figure or sketch. And, therefore, it is the most important element of a map. Try to find out what are the other essential elements of a map apart from the scale.

In this unit, we will describe the concept of map scale in Section 3.2 followed by representation of scale in Section 3.3. In the Section 3.4, we will explain conversion of scale by solving one example each for the conversion of statement of scale to representative fraction (R. F), and vice versa. In the last section i.e. Section 3.5, we will discuss about four major types of scale i.e. plain scale, comparative scale, diagonal scale and vernier scale and also solve one example each.

In the next Block, you will read in detail about Map Projections where three dimensional image of the earth has been transformed to a two dimensional surface for which map scale is also an essential element.

Expected Learning Outcomes

After studying this unit, you should be able to:

- explain the concept of map scale;
- describe the three methods of representing map scale;
- perform scale conversion;
- describe various types of map scale and methods of construction; and
- interpret the reading of map scale.

3.2 CONCEPT OF MAP SCALE

You might know that without a scale, a map is incomplete and cannot be technically named as Map. Without scale a map is called a sketch. Why it is so? This is because we cannot precisely identify the exact measurement of distances between two places depicted on the map. Now, can you define a map scale? In simpler terms, map scale can be defined as:

"the ratio between the distance on map and the actual distance on the ground."

This can be expressed as:

$$\textbf{Scale} = \frac{\textbf{Map distanace between two points}}{\textbf{Ground distance between the same points}}$$

The representation of earth or even a piece of area cannot be done on a piece of paper practically without fixing a proportional geometric shape or symbols representing the features on the earth as paper cannot always be of the same size of the area under representation. For this reason, the maps are drawn on small piece of papers of varying sizes using some representative proportions where certain distance or size of representing features on the paper is true to the fixed proportionate size on the ground. For example, one centimetre line on paper may represent one kilometre distance on the actual ground.

The above discussion raised a broad question in our mind. The question is what are the factors responsible for deciding the appropriate scale? There are broadly three factors which are as follows:

- The magnitude or size of an area to be represented on a map;
- The extent of details to be represented on the map; and

- The size of the paper in which the map is drawn.

These three questions brought two concepts i.e. small scale and large scale maps. Let us now briefly discuss about these concepts.

- **Small scale maps** are those maps which depicts large area covered on a small size of paper. In this type of map, the scope for detailing about the area is not possible. Therefore, it depicts only important features and details about the area which are not available. Atlas map is the best example of small scale maps.

- **Large scale maps** are just opposite to small scale maps which depicts small area covered on a relatively bigger size of paper. Therefore, this type of maps depicts the earth's surface features in detail. Topographical maps and cadastral maps are the best examples of large scale maps.

Now, you must have understood the concept of map scale. Let us pause for some time and perform the below given activity to recapitulate what we have learnt till now.

SAQ 1

a) What is scale?

b) Differentiate between small scale and large scale maps?

3.3 REPRESENTATIVE METHODS OF SCALE

After defining the scale, one of the obvious questions that come to our mind is about the methods of showing scale on a map. Do you know the different methods of representing the scale on a map? Yes, you are right, broadly, there are three ways of representing scale. These are as follows:

- Statement of Scale
- Linear or Graphic Scale
- Representative Fraction (R.F.)

Each methods of representation have its own merits and demerits. Let us discus them one by one.

3.3.1 Statement of Scale

As the name suggests, in this method, the measurement of the map scale is represented in the form of a statement. The example may be as follows:

1 Centimeter to 1 Kilometer

It means that 1 centimeter distance on map is equal to 1 kilometer distance on the actual ground.

Major advantage of this scale is its simplicity to understand, but it has some disadvantages also. The major disadvantage of this scale is its non-flexibility. Let us understand this. When we enlarge or reduce a map by way of reproduction especially through scanning or photocopying, the scale changes.

But in this form of representation, the scale remains fixed in the form of a statement despite changes in the size of a map. The second major disadvantage is that one has to take stated measurement from somewhere else to calculate it on the map. The person not having the idea of unit of measurement of distance will have difficulty to relate the distances on map and the ground.

3.3.2 Graphic Scale

Graphic scales are those scales, which are depicted through graphs mixed with lines and/or empty or black blocks showing primary and secondary divisions. A line or a linear rectangle is divided into equal primary divisions representing a definite distance on the map corresponding to the ground. Again, the first primary division is sub-divided into secondary sub-divisions. You will learn about the geometrical construction of primary and secondary division of a graphic scale in the Practical Manual. The divisions and sub-divisions are then marked by statement to indicate the distance on the ground.

The graphical scales are constructed from the statement and ratio scales. The other property of the graphic scale is that it also represents comparative measurements and scales of cube roots and square roots. In the Section 3.5, you will read in detail about various types of graphical scale namely plain scale, comparative scale, diagonal scale etc. along with examples.

3.3.3 Representative Fraction (R.F)

It shows the relationship between the map distance and the corresponding ground distance in units of length. This can be expressed as:

$$\text{Representative Fraction (R.F)} = \frac{\text{Map distance}}{\text{Ground distance}}$$

This method of representing the scale is completely independent of unit of measurement. In other words, it is a universal unit. What does this mean? This means that it can be converted into any unit of measurement. That is why it is the most versatile method.

Let us understand the above mentioned statements in detail. This type of scale is expressed as numeric ratio, like 1:1,000,000 meaning thereby 1 unit of distance on the map is equal to 1,000,000 units on the ground. The numerator is always expressed as unity or 1 and remains constant which represents the map distance or unit. On the other hand, denominator is the ground distance, which varies according to the area covered in the map. That is why it is called 'Representative Fraction' or R.F.

One very important point to remember is that larger the value of a denominator, smaller will be the scale and vice versa. In the former case, the map would have large area coverage but fewer details in the map. Contrary to this, smaller the denominator, larger will be the scale with small area coverage but having more details. For example, 'million map' is an example of small scale map, and 1:25,000 map is that of a large scale map. The selection of scale depends on the purpose. The second point to remember is that both the units i.e. numerator 1 or map distance and denominator or ground distance should be in the same unit of measurement like milimeter/centimetre/kilometer or inch/mile. Despite having so many advantages, this method of representation is also not free from disadvantages. The biggest disadvantage of this scale is that it is not as convenient as graphic scale both to measure and read.

After knowing different methods of representation of scale, let us perform the below given exercise which would help you in recapitulating what you have learnt in this section.

SAQ 2

Fill in the blanks with suitable words:

(a) Major disadvantage of statement of scale is that the person not having the idea of unit of ________________ will have difficulty to relate the distances on map and ground.

(b) In graphic scale, a linear rectangle is divided into equal ______________ representing a definite distance on the map corresponding to the ground and the first primary division is sub-divided into ___________.

(c) Representative Fraction is completely independent of ___________ and therefore it is a _____________ unit.

3.4 METHODS OF SCALE CONVERSION

In the previous section, we have discussed three methods of representing scale. Do you know that these scales can be converted from one method to other? In this section, we will describe methods of conversion from statement of scale to Representative Fraction and vice versa with the help of one example each.

Let us understand the steps involved in both the conversion.

3.4.1 Statement of Scale to Representative Fraction

Let us now learn to convert a statement of scale to Representative Fraction with the help of following example.

Example 1: Convert the given Statement of Scale of 1 cm represents 5 km into R. F.

Solution: The below given are the steps to be followed while converting Statement of Scale into R. F.

1 cm represents 5 kms

Or, 1 cm represents 5 × 1,00,000 (1 km = 1,00,000 cms)

Or, 1 cm represents 5,00,000 cms

We can now replace the character “cms” into “units” and read it as:

1 unit represents 5,00,000 Units

Answer is R. F. 1: 5,00,000

3.4.2 Representative Fraction to Statement of Scale

After learning conversion from Statement to R.F., let us now learn to convert a Representative Fraction to statement of scale with the help of following example.

Example 2: Convert the given R. F. 1:1,000,000 into Statement of Scale.

Solution: The following steps are involved in the conversion of Representative Fraction into statement of scale:

1:1,000,000 means that 1 unit on the map represents 1,000,000 units on the ground.

If it is to be expressed in metric system of measurement i.e., in Centimeter, Meter and Kilometer, then the steps are as follows:

1 cm represents 1,000,000/100,000 (1 km = 100,000 cm)

Or 1 cm represents 10 km

Answer: 1 cm represents 10 km.

If it is to be expressed in British system of measurement i.e., in inch and mile measurement, then the steps are as follows:

1 inch = 1,000,000/63,360 (1 Mile = 63,360 inches)

Or 1 inch = 15.78,283 Miles

Answer: 1 inch = 15.78,283 Miles

Till now, we have discussed the concept of scale, representation of scale and conversion of scale. In the following section, we will discuss various types of scale.

3.5 TYPES OF MAP SCALES: CONSTRUCTION AND READING

After defining the scale and describing various methods of representing scale, one of the obvious questions that comes to our mind is about the types of scale. Do you know how many types of scales are there? Yes, you are right, broadly, scale can be classified into five types. These are as follows:

1. Plain Scale
2. Comparative scale
3. Diagonal scale
4. Vernier scale
5. Special types scale.

In this section, we will discuss only one example each for plain scale, comparative scale and diagonal scale. Before discussing about various types of scale, we should know about the following points. These points should be kept in mind, at the time of construction of graphic or linear scale.

Steps Involved in the Construction of Graphic Scale

1. The scale should indicate the actual distance in round figure, such as 10, 20, 30, and so on. However, the length may not be in round or full digit always. It may be in decimal also.
2. Normally, the length of the graphic scale should be between 4 to 6 inch or 10 cm to 15 cm.
3. The division of graphic scale into primary and secondary divisions is made by geometrical methods about which we will discuss in Practical Manual. The value of each division should be mentioned on the upper side of the scale. The left side of the scale has the secondary division, showing the smallest measurement of the scale.
4. As discussed under section 3.3.2, this scale has two parallel lines. Conventionally, the lower line should be thick and each section of the scale may be shaded in alternate manner.

3.5.1 Plain Scale

Plain scales are those which measure up to two units or a single unit through its divisions and sub-divisions. Let us explain this with examples. Example of two units of measurement is 2 kilometer and 200 meter. Examples of divisions and sub-divisions are 5.4 cm and 3.8 meter, etc.

As mentioned above, plain scale represents up to two units, therefore, it consists of a line divided into number of equal main parts and the first main part is sub-divided into smaller parts. Zero (0), is marked at the end of the first main part. From zero mark numbers to the main parts or units towards right and give numbers to the sub-divisions or smaller parts towards left. Give the names of the units and sub-units below clearly. Indicate below the name of the scale and its R.F clearly.

Construction of plain scale is explained below with the help of an example. For your understanding, the process of construction is being explained in a step-wise manner.

Example 3: The R.F. of a map is 1:250,000. Construct a plain scale with primary and secondary divisions to read up to one km.

Solution: Before initiating the construction, we have to perform the following calculation to derive the length of the scale.

The given R. F. of the map is 1:250,000.

As we want to develop a scale in Kilometer, the given R. F. can be expressed as: one cm. represents 250,000 cm.

If we draw a line of 12 cm, it will represent the number of kms in following way:

1 cm. represents 250,000 cm

or If we express it in km. 1 cm = 2.5 km (1,00,000/250,000)

A line of 12 cm will represent 2.5 km x 12 = 30 km.

Steps involved in the Construction

1. Based on the above calculation, we have to read upto 1 km. in this linear scale for 30 km. Therefore, we will divide this scale into six primary divisions. Thus, each primary division will read 5 km.

2. As discussed earlier in this section, the extreme left primary division of the scale will be divided into five equal divisions. Each secondary division will represent a minimum distance of one km.

3. While numbering the scale, zero should be marked after one interval from the left, so that the left hand end of the line can be numbered 5 and the primary divisions to the right of zero can have numbers 5,10,15, 20 and 25. This method of numbering enables us to read off directly the whole numbers as well as the fraction from the scale (Fig. 3.1).

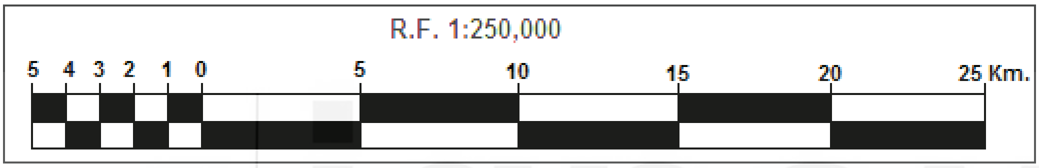

Fig. 3.1: Plain scale depicting primary and secondary divisions.

3.5.2 Comparative Scale

In simpler terms, a comparative scale may be expressed as a pair of scales having a common R.F. but graduated to read different units. Some of the examples of comparative scales are (i) different units; (ii) time scale; (iii) pace scale; and (iv) revolution scale. Let us discuss each of them and their construction with an example each.

i) **Different Units**: As the name suggests, this type of scale depicts reading in two different units. An example of a comparative scale of two different units may be showing distances in meters and yards having common zero point.

Let us solve the below given example for more clarity.

Example 4: A map is on the scale of R.F. 1:100,000. Draw a comparative scale to read the distances in Mile-Furlong and Kilometer-Hectometer.

Calculation

The given R.F. is 1:100,000.

As we want to develop a scale in miles, the given R. F. can be expressed as:

For mile

1 inch represents 100,000 inch

6" will represent $\frac{100000 \text{x} 6}{63360}$ Miles $= \frac{625}{66}$ Miles = 9.46 miles

For our convenience, let us convert it into a round figure of 10 miles. In this case, we have to recalculate the length of the scale. Therefore, the length of the scale will be as follows:

$\frac{625}{66}$ Miles are shown by a line of 6”

1 mile will be shown by a line of $\frac{6 \times 66”}{625}$

10 miles will be shown by $\frac{6 \times 66 \times 10”}{625}$ = 6.3”

For km

1 cm. represents 100,000 cm or 1 km.

Then 15 cm. will represent 1 km. × 15 = 15 km.

Steps involved in the Construction

The following steps are followed while constructing comparative scale for depicting two different units. We have already calculated the length of the scale.

1. We will start the construction of comparative scale by drawing two straight lines. The length of the line representing mile is 6.3” whereas the second line representing kilometer is 15 cm.
2. Divide 6.3” line into 10 equal parts to show the primary division of one mile distance. Similarly, divide the line of 15 cm. into 15 equal parts to show the primary division of 1 km.
3. The first primary division in the extreme left will be divided into two equal parts. Thus, one secondary division will represent 4 furlongs. Similarly, to measure distance in hectometer, divide left primary division into two equal parts. Thus, one secondary division will measure the distance of 5 hectometer.
4. Now draw the comparative scale where the zero of both the scales should coincide with each other (Fig.3.2).

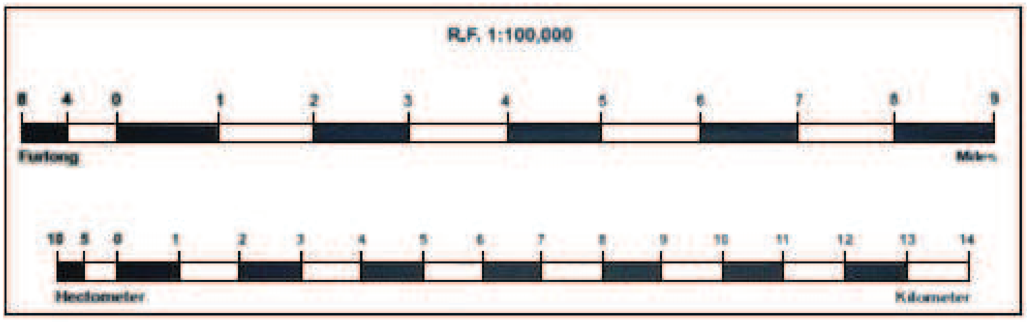

Fig. 3.2: Comparative scale depicting two different scales.

Let us now discuss other forms of comparative scale.

ii) **Time Scales**: As the name suggests, this scale depicts distance along with time like miles and minutes/hours. In this type of comparative scale, one line represents distance travelled whereas the other line represents the time taken to cover the said distance. Like other comparative scale, zero, in both the scales should coincide to each other.

iii) **Pace Scales**: Can you decipher from the name which two parameters are compared in this scale? Yes, this form of comparative scale shows distance and coverage in terms of pace. In other words, this scales has two units i.e. distances covered in miles or kilometres and number of steps taken to cover the said distance. Now, you might be thinking that why do we use such type of scale? Generally, this type of scale is used while conducting a rapid reconnaissance where it may not be possible to use chain and tape due to shortage of time. In those circumstances, the distance can be measured with the help of paces. The length of a pace of the person employed for the purpose should be known and then the distance between two points can be measured by paces. The standard military pace is 30”.

iv) **Revolution Scales**: This is another form of comparative scale that shows distance and revolution of wheels to cover the distance, where speedometer is an excellent example.

3.5.3 Diagonal Scale

Diagonal scales are drawn for greater precision or higher degree of accuracy. Can you imagine how is this precision achieved? Yes, you’re right. We achieve this precision because this scale is specifically used to measure up to three units. For example, in a metric system you can measure kilometers (km), meters (m), and centimeters (cm). Similarly, in British system of measurement you can measure miles, furlongs and yards etc. If you observe closely the previous two scales, they are best suited for measuring up to two units. This scale is used when very small distances such as 0.1 mm are to be accurately measured or when measurements are required up to second decimal. The below given figure depicts micro-distance in a diagonal scale.

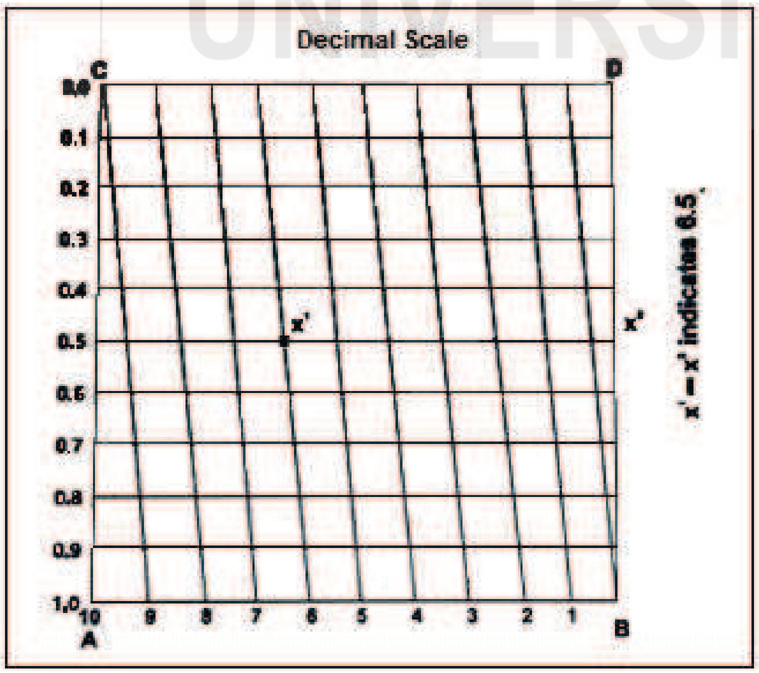

Fig. 3.3: Reading of micro-distance in a diagonal scale.

Example 5: To read the distance of one hundredth part of a mile, draw a diagonal scale on R.F. 1:63,360 and also show the distance of 1.56 mile on the scale.

Solution:

Steps involved in the Construction

1. As per the given exercise, 1" represents 1 mile, as 1 mile is equal to 63,360". Draw a line of 6", and divide it into 6 primary divisions. Thus, one primary division will represent one mile.
2. Divide the first primary division of the left side into ten secondary divisions. Thus, the one secondary division will represent 0.1 mile distance.
3. To read the distance of 0.01 mile draw 10 parallel lines to the main scale. On the left side of primary division mark 10 points of equal distances on the upper most line of the scale. Join these 10 small distances with the diagonals (Fig. 3.4).

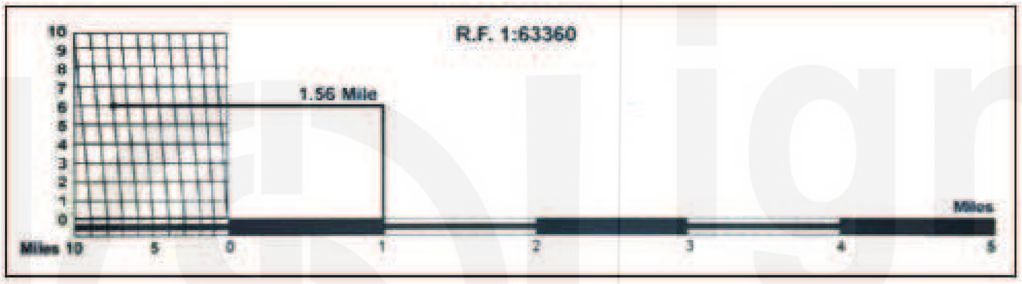

Fig. 3.4: Diagonal scale showing the distance of 1.56 mile.

3.5.4 Vernier Scale

Do you know why this scale is named so? This scale is named after it's inventor Pierre Vernier, a French Mathematician in 1631. Vernier scales are drawn to achieve greater accuracy in the form of fraction of a division in both linear and angular measurements. This scale consists of a small moving scale. This small moving scale has the graduated edge which slides along the graduated edge of a larger sale. The larger scale is known as primary scale and as mentioned above the small graduated scale is known as Vernier scale (Fig. 3.5).

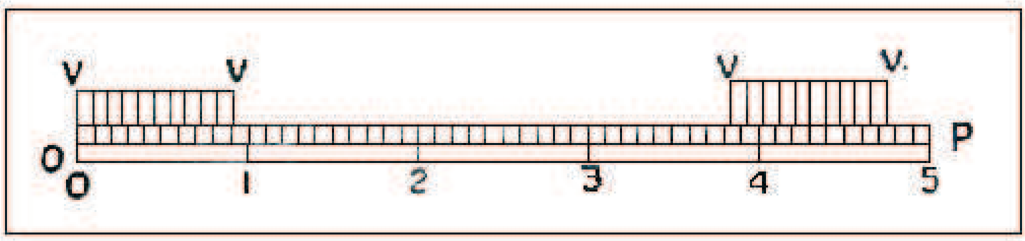

Fig. 3.5: Vernier Scale.

3.5.5 Special Type Scales

Special type scales are drawn to represent two types of distances – horizontal and vertical together. Various types of these scales are a) square root scales (showing proportionate circles with certain radius for representing some quantitative values), b) cube root scales (showing spheres to represent quantities using cube root for volume), c) scales of verticals (showing height depending on focal length of the lens and altitude of the camera taken in areal photography), and d) perspective scales (showing block diagrams or field).

SAQ 3

Match the two columns.

Types of Scale	**Example**
A) Graphic Scale	i) Measures up to three units
B) Comparative Scale	ii) Square Root Scale
C) Diagonal Scale	iii) Time Scale
D) Vernier Scale	iv) Linear Scale
E) Special Types Scale	v) Slide Calipers

3.6 SUMMARY

In this unit, you have studied so far:

- Scale is an essential element of map and without a scale, a map is incomplete and cannot be technically be named as map. Without scale, a map is called a sketch. In simpler terms, map scale can be defined as the ratio between the distance on map and the actual distance on the ground.
- There are three ways of representing scale. These are (i) statement of scale, (ii) linear or graphic scale, and (iii) representative fraction.
- As the name suggests, in this method, the measurement of the map scale is represented in the form of statement. Graphic scales are those scales, which are depicted through graphs mixed with lines and/or empty or black blocks showing primary and secondary divisions.
- The scales can be converted from one form to another form. In this unit, we discussed methods of conversion from statement of scale to representative fraction and vice versa.
- There are five broad types of scales namely plain scale, comparative scale, diagonal scale, vernier scale, and special type scale.

3.7 TERMINAL QUESTIONS

1. State the three factors on which the scale depends.
2. Explain the three representation methods of map scales.
3. What points should be taken into consideration while constructing graphic scale.
4. Describe various types of map scales highlighting its advantages and disadvantages.

5. List the importance of diagonal scale.

3.8 ANSWERS

Self Assessment Questions

1. Scale is the ratio between the map distance to the actual corresponding ground distance.
2. a) Measurement of distance

   b) Primary divisions, secondary divisions

   c) Unit of measurement, universal
3. A-iv; B-iii, C-i; D-v; E-ii

Terminal Questions

1. You have to broadly highlight the factors on which scale depends. Refer to the Section 3.2.
2. Refer to the Section 3.3.
3. Refer to the Section 3.5.
4. Refer to the Section 3.5.
5. Briefly highlight the importance of diagonal scale to answer this question. Refer to the sub-section 3.5.3.

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GLOSSARY

Atlas: Very small scale and highly generalized maps of the world or different regions of the world showing major physical features, settlements, transport networks and important landmarks.

Azimuth: Horizontal angular measurements of coordinate systems from zero degree.

Cadastral Map: Maps showing parcel or property boundaries.

Cartography: It is the art and science of map making.

Comparative Scale: It may be expressed as a pair of scales having a common R.F. but graduated to read different units.

Chorochromatic Maps: Maps showing non-quantitative properties of any feature or phenomena over the space like presence or absence.

Choropleth Maps: The maps showing physical or cultural features by various colours or grey scale shades or patterns.

Choro-schematic Map: The maps showing the location and distribution of something over the space through alphabets.

Cultural Map: Maps representing the cultural landscapes, especially the cultural or institutional properties like race, tribe, religion, literacy, etc. of the earth surface.

Diagonal Scale: Scales drawn for greater precision or higher degree of accuracy with secondary and tertiary scales for the accuracy up to two decimal digits involving diagonal lines of sub-divisions.

Dot Maps: The maps showing the distribution of various features like population, trees, animals, etc. by dots representing definite number or quantity are called dot maps.

Ellipsoid or **Spheroid:** It is a three-dimensional shape created from a two-dimensional ellipse with a property of polar flattening and equatorial bulge.

Geoid: It represents the earth's shape and is the reference surface taking mean sea level surface from which topographic heights and ocean depths are measured.

Great Circle: Equator and all longitudes.

Greenwich Mean Time (GMT): It is a time at the Royal Observatory located at Greenwich, London and is a reference time for entire globe.

Isopleth Maps: The maps using regular line showing a uniform value of weather elements like rainfall, temperature and pressure etc.

Linear or Graphic Scale: Graphic scales are those scales, which are depicted through graphs mixed with lines and/or empty or black blocks showing primary and secondary divisions.

Map: A map is a pictorial depiction of whole earth or its part into two dimensional surface involving geometric objects, colour, symbols and texts.

Neatline: Neatline is the line bordering the geographical data (outline), of the area of representation. It may be called the outer boundary of the map having various designs of lines.

Peutinger Table: Peutinger Table (*Tabula Peutingeriana*) is a historical Roman map showing Roman Empire with major roads and military posts.

Physical Map: The maps which represent the physical features are said to be physical maps.

Plain Scale: Plain scales are those which measure up to two units or a single unit through its divisions and sub-divisions.

Projection: Map projection is the mathematical transformation of graticules (latitudes and longitudes) of the spherical earth on a two dimensional plane surface.

Representative Fraction (RF): It is the expression of scale in terms of ratio between map distance and the actual corresponding ground distance, where the numerator is map distance always expressed as one and the denominator is the same corresponding distance on the ground.

Rhumb Line: A curve crossing at every meridian on the earth's surface at the same angle.

Scale: Scale is the ratio between the map distance to the actual corresponding ground distance.

Statement Scale: When the map scale is represented in the form of statement, it is called statement scale.

T-O Map: It is also called a T and O map. It is a type of medieval world map also called a Beatine map or a Beatus map having religious importance where Jerusalem was placed at the Centre of the World.

Topographical Map: The maps prepared to depict both kinds of surface features including natural and cultural features.

Vernier Scale: These scales are drawn to achieve greater accuracy in the form of fraction of a division in both linear and angular measurements consisting of a small moving scale.

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