33

MAP PROJECTIONS

33.1. INTRODUCTION

As you know that the earth on which we live is not flat. It is round in shape like a sphere. A globe is the best model of the earth because it is three dimensional i.e. it has length, breadth and depth. Therefore it shows very accurately the shape and sizes of the continents and oceans. It also shows the direction and distances very correctly. But, globes are very expensive and not easy to carry every where. And it is not possible to have large scale globe showing only a part of the earth. They can not give detail information about network of roads, or distribution industries etc. of a particular region or a country. Maps are cheaper, more convenient and easier to carry than the globe. For making a map, the globe which is of three dimensions has to be transformed into two dimensional surface. Such transformation has to be done very carefully in order to maintain the area, shape and the direction of places on the map, to the maximum possible extent.

You must have observed a network of vertical and horizontal lines on the maps in your atlases or on the wall maps. The vertical lines represent the meridians of longitude and the horizontal lines represent the parallels of latitude. This network of parallels and meridians is called **graticule**. This network facilitates drawing of the maps. Drawing of graticules on a flat surface is called **projection**. A number of methods have been devised to project the parallels of latitude and the meridians of longitude on a flat surface. In this lesson we are going to study some of the important projections, construction and their characteristics and uses.

> A technical person preparing maps, charts and diagrams is known as a cartographer.

Two techniques which are mostly used in the drawing projection: perspective (graphical) and non perspective (mathematical). In perspective or graphical method the graticule of latitudes and longitudes is projected through the source of light. Projections prepared through this technique are known perspective projections.

Secondly, in mathematical technique graticule of latitudes and longitudes are drawn on the basis of mathematical calculations/derivations. Projections prepared through this technique are known as non-perspective projections. It is to be noted that projections drawn on the later method have higher accuracy than the former.

33.2 OBJECTIVES

After studying this lesson you will be able to:

- explain developable and non-developable surfaces for projecting globe on a plane surface;
- classify the map projections according to different developable surfaces;
- choose the map projections according to their uses;
- recognize the types of map projections with the help of patterns of latitudes and longitudes;
- enumerate the characteristics of each type of map projection on the basis of graticule pattern formed by the parallels of latitude and meridians of longitudes;
- explain the function and use of the various types of map projections.

33.3 A QUICK REVISION ABOUT GRATICULA

You know that latitudes are imaginary lines drawn parallel to the equator. The equator, a great circle, divides the globe into two equal parts known as the Northern and the Southern hemispheres. Latitudes range from 0° at the equator to 90° at the North Pole and the South Pole. Latitudes form circles over the globe. The circumferences of these circles decrease from the equator towards the poles.

The imaginary semi-circular lines joining the North Pole to the South Pole are known as meridians of longitudes. They form semi-circles over the globe at a regular distance of one degree each and range from 0° to 180° east and west of Greenwich Meridian. The meridians of longitude cut the equator and all the parallels of latitude at right angles. As the parallels of latitude get progressively smaller towards the poles, distances between two longitudes decrease correspondingly. At the equator, it is equal to approximately 111 km; at the 30° N and 30° S, it is 96.6 km, at the 60° N and 60° S, it is 56 km; and it becomes zero at the poles.

The parallels of the latitude and meridians of longitude help us to determine the location of places accurately on the earth surface. Locations determined through the latitude and longitude are also known as the geographic coordinates of places. In other words, geographic coordinates help us to determine the location, direction and distance of places both on the ground and on the map.

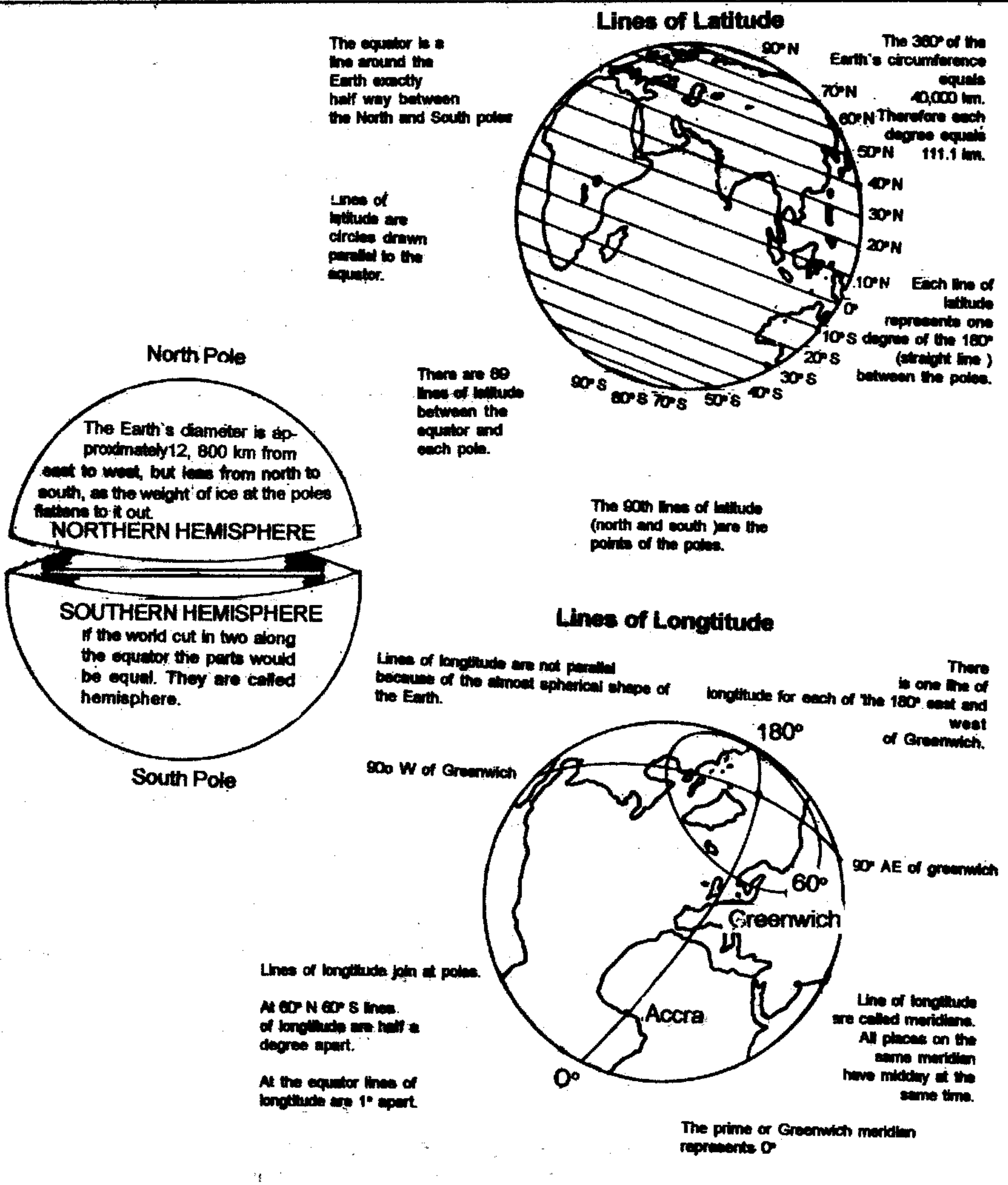


Fig. 33.1 Graticule of Latitudes and Longitudes

33.4 THE GLOBE AND MAPS

(i) Globe

It has already been mentioned earlier that the globe is a model of the earth having length, breadth and depth. It, therefore, has the following properties.

(a) Merits of Globe

1. It represents the earth in its true shape. It, therefore, has the property of conformity.
2. It represents true directions between places. It, therefore, has the property of correct bearing.
3. It maintains the area correctly. It therefore, has the property of equal-area or equivalence.
4. It maintains correct distance between places. It, therefore, has the property of equi-distance.
5. A globe because of the above properties is the ideal model of the earth. It is said to be the closest approximation of the earth.

(b) Demerits of Globe

However, the use of globes involves a number of problems as given below:

(i) If the earth is to represented on different scales, we will need various globes on different scales.

(ii) Their storage and transportation is yet another problem. The problems relating to transportation is partly solved through the folding and deflatable globes. These globes are like the bladder of football and they can be inflated and deflated as the need arises.

(iii) While using a globe, we can see only a part of the earth at one time and rest of it is away from us. This makes comparisons between various areas difficult. (However, most globes can be made to rotate easily).

(iv) We cannot represent a part of the earth separately on a globe which is possible on a map.

(ii) Maps

On the other hand, a map is prepared on a flat surface which cannot have all the characteristics of the globe. However, a map is designed in such a way that it satisfies at least one of the above mentioned properties. In other words, to maintain the correct area, equal-area projections are selected. Similarly for maintaing true shape maps are prepared on orthomorphic projection and for maintaing correct directions azimuthal projections are selected. We will study about these projection latter in the lesson.

In spite of all the above limitations, maps are highly useful in regional or area studies. Maps, like topographical sheets, provide a detailed information about relief, drainage, vegetation, settlements, communication network, etc while all these details may not be easily available on a globe.

33.5 NON-DEVELOPABLE AND DEVELOPABLE SURFACES

A non-developable surface is one which cannot be flattened without shrinking, breaking or stretching. A globe or spherical surface, for example, has the property of non-developable surface. In other words, it is impossible to lay out a flat unbroken network of latitudes and longitudes that will conform to the network of a globe. As such, it is not possible to achieve all the properties required to make a perfect map projection.

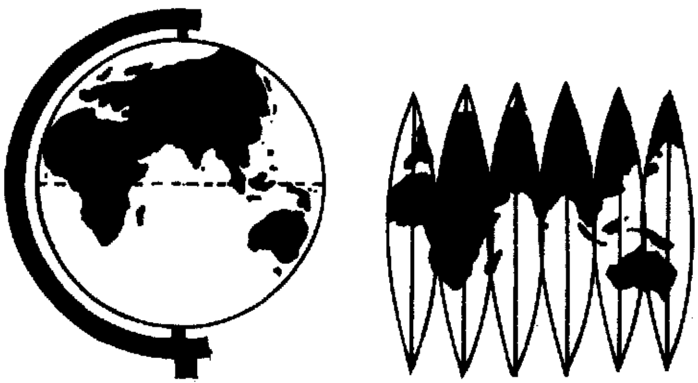


Fig. 33.2 Tearing apart of the Paper Covering the Globe

A developable surface is one which can be flattened and on which the network of latitude and longitude can be projected directly from the assumed globe. The projection of lines is done by the means of the source of light placed at the various positions to achieve various types of projections. Projections prepared by projecting the image of network of parallels and meridians of a globe on any developable surface are called perspective projections. For drawing a conical projection, we have to make a paper cone around the globe; for a cylindrical projection, we have to wrap a paper cylindrically; and for a zenithal projection, the plane has to touch the globe at any point such as the pole.

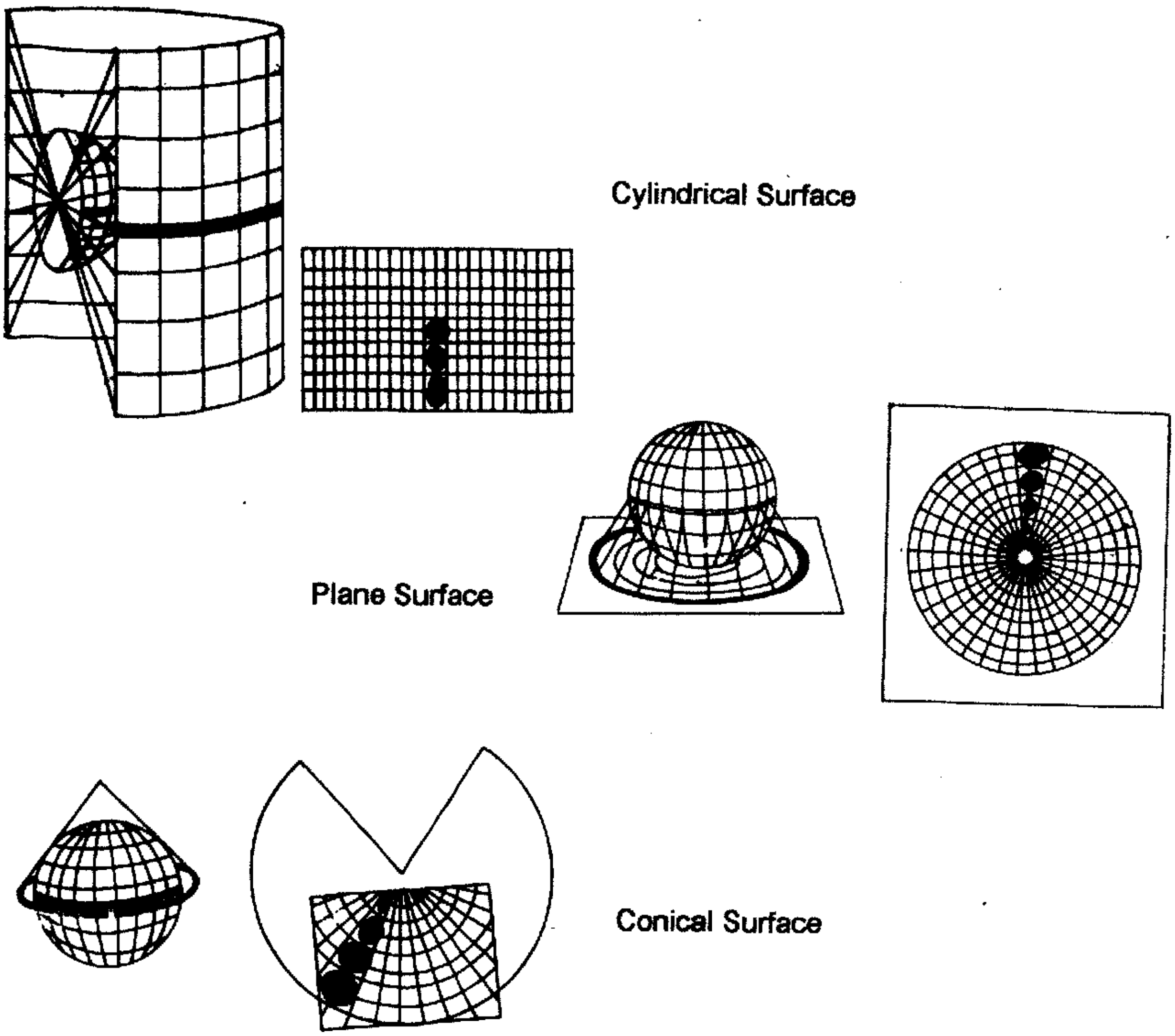


Fig. 33.3 Three types of Developable surfaces

33.6 CLASSIFICATION OF MAP PROJECTIONS

Projections are drawn by various methods and the resulting projections differ from one another. Any coherent study of map projections requires a classification of them. Projections are classified on the basis of a number of criteria. Generally, the more commonly adopted criteria for this purpose are:

(a) the nature of the developable surface,

(b) the properties of the projections,

(c) the method of construction,

(d) location of the source of light in the globe, and

(e) identification and uses.

Classifications on the basis of these criteria are discussed below.

(a) On the Basis of the Nature of the Developable Surface

On the basis of the nature of the developable surface used, the projections are of three types.

(i) Cylindrical Projections: Projections obtained through the use of a cylindrical developable surface are called cylindrical projections. In case of these projections, the globe is covered by a cylinder made of paper and the parallels and meridians are projected on it. When the cylinder is cut open, it provides a cylindrical projection on the plane surface.

(ii) Conical Projections: Projections obtained through the use of a conical developable surface are called conical projections. In such cases, a cone made of paper is put over the globe and the parallels and the meridians are projected on it. The cone is cut open to get the projection on a plane surface.

(iii) Zenithal Projections: These projections are obtained directly on a plane surface. A plane paper is put on the globe, touching it on one point, and the graticule is projected on it. Generally, the developable surface is so placed on the globe that it touches the globe at one of the poles.

(b) On the Basis of Properties

As the spherical surface of the globe cannot be projected on a plane surface accurately, no map projection can be absolutely correct or a true representation of the earth. Some inaccuracies do occur in all projections. The most important qualities sought in any projection are;

(i) Correctness of area;

(ii) Correctness of shape;

(iii) Correctness of direction or bearing; and

(iv) Correctness of scale.

In none of the projections can all these qualities be maintained simultaneously. According to specific requirements, a projection can be drawn in a manner so that the desired quality may be retained. According to their properties, map projections are classified as:

(i) Equal-Area Projections: These projections are also known as homolographic projections. The quality of these projections is that the areas of various parts of the earth are represented correctly on them.

(ii) True Shape or Orthomorphic Projections: They are also known as conformal projections. Shapes of various areas are portrayed correctly on these projections. The shape is generally maintained at the cost of the correctness of area.

(iii) True Bearing or Azimuthal Projections: The projections which show directions or bearings correctly, are called azimuthal projections. On these projections the direction of all points from the centre is correctly represented.

(iv) True Scale or Equi-distant Projections: Projections maintaining scale correctly can be called true scale projections. However, there is no such projection which maintains scale correctly throughout. It can be maintained correctly only along some selected parallels and meridians as per specific requirements.

(c) On the Basis of Method of Construction

The concept of projection itself implies projection of the graticule from a spherical surface to a plane surface with the help of shadows cast from an illuminated globe. However, not all projections are made exactly in this manner. A large number of projections are drawn mathematically, graphically or by either imagining a developable surface covering the globe or just conventionally. According to the drawing technique, the projections are grouped into two categories:

(i) Perspective Projections: These projections are drawn with the help of the shadows cast from an illuminated globe on to a developable surface. Most of the zenithal projections are perspective projections. These projections are also called natural projections.

(v) Non-Perspective or Conventional Projections: These projections are drawn conventionally without the help of the shadows from an illuminated globe. In such projections either no developable surface is used or if used, it is only assumed to be covering the globe and the actual construction of the projections is based on mathematical calculations.

(d) On the Basis of the Location of Source of the Light Illuminating the Globe

The source of light Illuminating the globe can have a number of locations in relation to the point at which the developable surface touches the globe. Three important types of projections on this basis are given below.

(i) Gnomonic Projection: When the source of the light is located at the centre of the globe, the resultant projection is called a gnomonic projection.

(ii) Stereographic Projection: When the source of light is placed at the periphery of the globe at a point diametrically opposite the point at which the developable surface touches the globe, the projection is called a stereographic projection.

(iii) Orthographic Projection: When the source of light is placed at infinity from the globe, opposite the point at which the developable surface touches the globe, the projection is called an orthographic projection.

It is to be remembered that the gnomonic, the stereographic and the orthographic projections are generally drawn when the developable surface is a plane surface. They are therefore considered as types of zenithal projections.

(e) On the Basis, Identification and Uses

As has already been mentioned earlier, map projections are of many types. Each one of them has its own property and identity which differ from one another. On the basis of their certain quality, they can easily be identified and classified under various groups. For example, projection in which the parallels of latitude and the meridians of longitude intersect at right angle, are classified under cylindrical group of projections. (see fig.33.4)

If parallels of latitude form concentric circles or a part of it and the meridians of longitude drawn either straight or curve, then they are classified under the conical group of projections. In these projections, central meridian is always shown with a straight line. (see fig. 33.6).

Zenithal or Azimuthal group of projections are identified with the parallels of latitudes which form concentric circles while the meridians of longitude are radiating from the centre that is the pole. (see fig. 33.7).

As we have to know about the identification of the three groups of projections, it is also necessary to know their uses. Their identity differs from one group to another. For instance, cylindrical projections are best suited to represent the area along the equator. This is the reason why we show the distribution of rice, rubber and any other plantation crop on the cylindrical projections as these crops are mostly grown in the equatorial or tropical regions of the world.

The area lying between equatorial and the polar region can suitably be shown on the conical group of projections. The distribution of wheat and other crops which are mostly cultivated in the temperate regions of the world can be shown on the conical projections. These projections are also used to show the hemisphere or large continents as well as topographical maps.

Zenithal or Azimuthal projections are mostly used to represent the polar or sub-polar regions. These projections are found highly useful for weather maps, astronomical maps and maps for navigational purposes.

As none of the projections can be true representation of the globe, we have to compromise either with area or shape or direction.

Table-33.1 Characteristics of some of the common Projections

Projection	Nature of Parallels And Meridians	Scale along Meridians and Parallel	Representation of Shape, Area and Direction	Uses
Simple Cylindrical	Straight lines intersecting at right angles	Meridian scale correct, parrallel scale correct only at the equator	Shape, area and direction are incorrect. Area exaggerated	Least suitable for world maps. Restricted to tropical area.
Cylindrical-Equal Area	Straight lines intersecting at right angles	Meridian scale not correct. Parallel scale correct along equator and. gets exaggerated Polewards.	Equal area. More or less orthomorphic within 30° from equator. Directions incorrect	Equatorial areas suitably shown. Used for distribution maps of tropical areas.

Projection	Nature of Parallels And Meridians	Scale along Meridians and Parallel	Representation of Shape, Area and Direction	Uses
Mercator	Straight lines intersecting at right angles	Meridian scale increases pole wards. Parallel scale correct along equator	Correct shape. Area greatly exaggerated polewards. Correct directions	Used for navigation and aviation maps. Winds and Ocean currents are also shown.
Simple Council (One Standard Parallel)	Parallels concentric circle. Meridians straight lines intersecting at right angles	Meridian scale correct. Parallel scale correct only along standard parallel	Neither equal area nor correct shape. Directions incorrect	Used for small countries or areas of low latitudinal extent (10°)
Polar Zenithal Equidistant	Parallels concentric circles. Meridians straight lines radiating from pole.	Meridian scale correct. Parallel scale not correct.	Shape not much distorted. Area progressively exaggerated. Directions correct	Suitable for polar areas and a hemisphere. Used to show area extending 50° to 90° latitudes.

33.7 CONSTRUCTION OF SOME IMPORTANT PROJECTIONS AND THEIR CHARACTERISTICS

(a) CYLINDRICAL EQUAL-AREA PROJECTION

This projection is also known as Lambert's Cylindrical Projection in which the distance between latitude decreases towards the higher latitudes. In this projection, the pole is shown with the parallel equal to the equator, hence the shape of the area gets highly distorted at the higher latitudes. Therefore, the projection is non orthomorphic. The parallels of latitude and the meridians of longitude intersect each other at the right angle. Area lying between 45° N and S latitudes can be suitably shown on this projection. The projection is also suitable to show the distribution of tropical crops such as coffee, rice, rubber, etc.

Example:

Draw a Cylindrical Equal-Area Projection for the world map on the scale of 1:320,000,000 with the interval of 15°.

In drawing the projection, the following steps are followed.

Calculations:

Radius (R) of the reduced earth $\frac{640,000,000}{320,000,000}$ = 2 cm (Radius of the actual earth is 640,000,000 cm)

Length of Equator $2\pi R$ or $\frac{2 \times 22 \times 2}{7}$ = 12.57 cm.

Interval along the Equator $\frac{12.57 \times 15^\circ}{360^\circ} = 0.52$ cm

Steps for construction

i) draw a circle of 2 cm radius

ii) mark the circle with the angles of 15, 30, 45, 60, and 75 degrees

iii) draw a line of 12.57 cm (representing equator) and divide it into 24 equal parts at the distance of 0.52 cm.

iv) Ertend all the parallels equal to the length of the equator; and complete the projection as has been shown in fig.33.4.

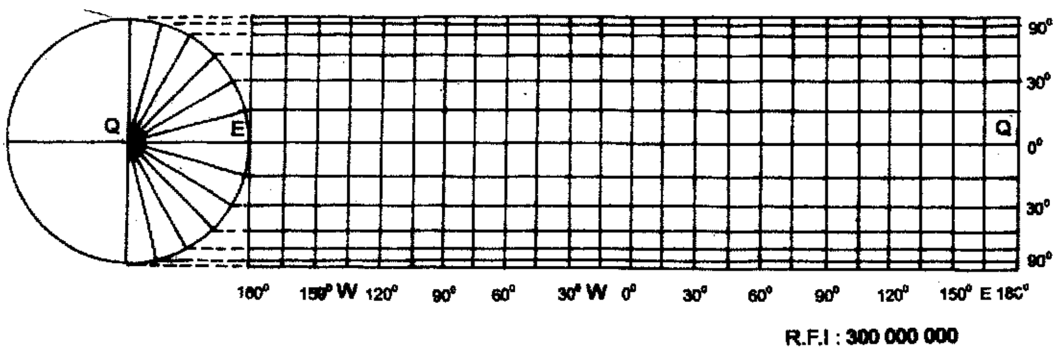


Fig. 33.4 Cylindrical Equal Area Projection

(b) MERCATOR'S PROJECTION

This projection was developed by Mercator G. Karmer, a Dutch Cartographer in 1569. Unlike the Equal-Area projection, this is an orthomorphic projection in which correct shape is shown. Distance between parallels increase towards the higher latitudes. As a result, this is not an equal-area projection. Like other cylindrical projections, the parallels and the meridians in this projection intersect each other at right angle. A straight line joining any two points on this projection gives a constant bearing which is called **lexodrome or Rhumb line.** This projection is used in preparing Atlas maps and the world specially to show the ocean currents, winds and other weather elements. Although this projection gives a distorted picture of the higher latitudes, it is a widely used projection. It is also suitable for navigational purposes.

Example:

Draw a Mercator's Projection for the world map drawn on the scale of 1:320,000,000 at 15° apart.

Calculations:

Radius (R) of the reduced earth is : $\dfrac{640,000,000}{320,000,000} = 2$ cm

Length of the Equator $2\pi R$ or $\dfrac{2 \times 22 \times 2}{7} = 12.57$ cm

Interval along the Equator $\dfrac{12.57 \times 15^\circ}{360^\circ} = 0.52$ cm

Steps for construction:

i) draw a line of 12.57 cm representing equator

ii) divide it into 24 equal parts

iii) calculate the distance for latitudes with the help of given table and draw them to complete the projection as has been shown in fig. 33.5

Latitude	Distance	Latitude	Distance
15°	2x0.265=0.53 cm	60°	2x1.317=2.634 cm
30°	2x0.549=1.098 cm	75°	2x2.027=4.054 cm
45°	2x0.881=1.762 cm		

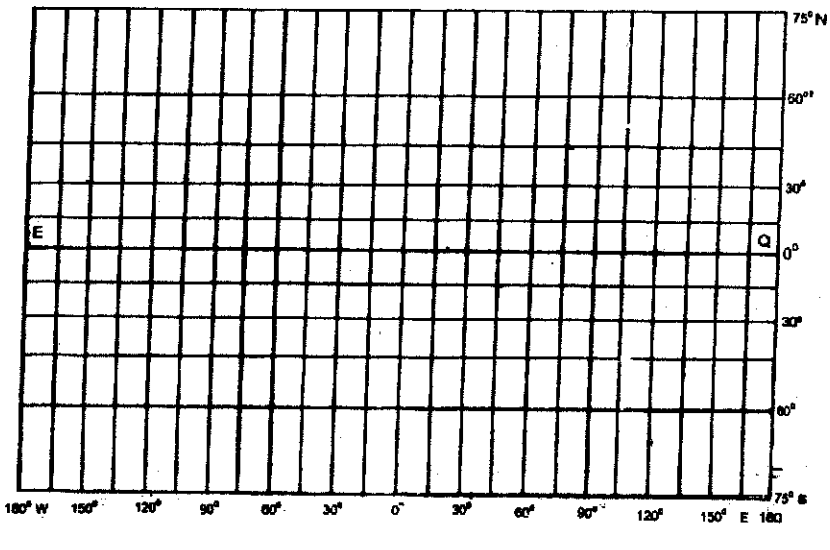


Fig. 33.5 Mercators Projection

(c) SIMPLE CONICAL PROJECTION WITH ONE STANDARD PARALLEL

This is a type of projection in which only one parallel is standard along which the scale is true. In other words, shape and area only along the standard parallel can suitably be maintained on this projection. The parallels form arcs of concentric circles and are equally spaced. The meridians are straight lines, drawn at uniform angular interval and converge towards the pole. The meeting point of merdians does not represent the pole rather the pole is shown by an arc of a circle. The projection in used for areas lying in the middle latitudes having east-west extension. The projection is not used to show areas having large latitudinal extent.

Example:

Draw a simple conical projection with one standared paralel for an area lying between 50° N and 70° N latitude and between 10° E and 40° E longitude with the interval of 5 degree on the scale of 1:128,000,000

Calculation:

Radius (R) of the reduced earth is $\frac{640,000,000}{128,000,000} = 5$ cm

Central meridian is 60 degree

Standard parallel is 25 degree

***Construction*:**

(i) A quadrant of 5 cm radius is marked with the angles of 5° and another of 60°

(ii) A tangent is extended from C that meets on at R.

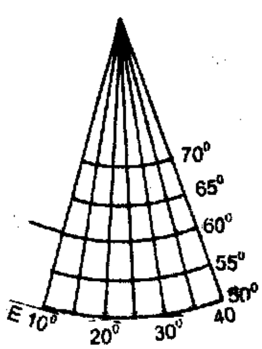
(iii) An arc is drawn by taking the distance of AB. X Y is the perpendicular drawn from ON to OC.

(iv) A straight line is drawn separately by taking the distance of R. C.

(v) The parallels of 50, 55, 65 and 70 are marked on that line by taking the distance of AB.

(vi) The distance of X Y is marked on 60 degree (the standard parallel) for drawing meridians.

(vii) Straight lines are drawn by joinin 'iem with the pole. (see fig 33.6.)



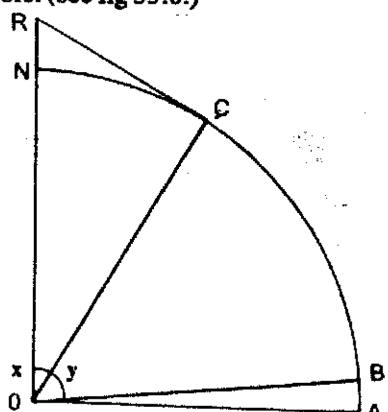


Fig. 33.6 Simple concial projection with one standard parrlel

(d) ZENITHAL EQUI-DISTANT PROJECTION

In Zenithal equi-distant projection parallels are drawn at their true distance. Therefore, it is called equi-distant projection. The parallels in this projection are concentric circles. The meridians are straight lines radiating from the centre or the pole. The distance and direction of any point from the centre are correct but scale along the parallels is not correct. The projection is neither orthomorphic nor equal-area. The projection is preferred to represent the area lying between 50° to 90° latitudes. Partly it is also used to show a hemisphere.

Complete a Zenithal equi-distant projection for Northern hemisphere on the scale of 1:320,000,000 at the interval of 15°. The following steps are to be followed for drawing the projection:

Calculations:

Radius (R) of the reduced earth is $\frac{640,000,000}{320,000,000} = 2$ cm

The distance of each parallel along the meridian is $\frac{2\pi R \times 15°}{360}$

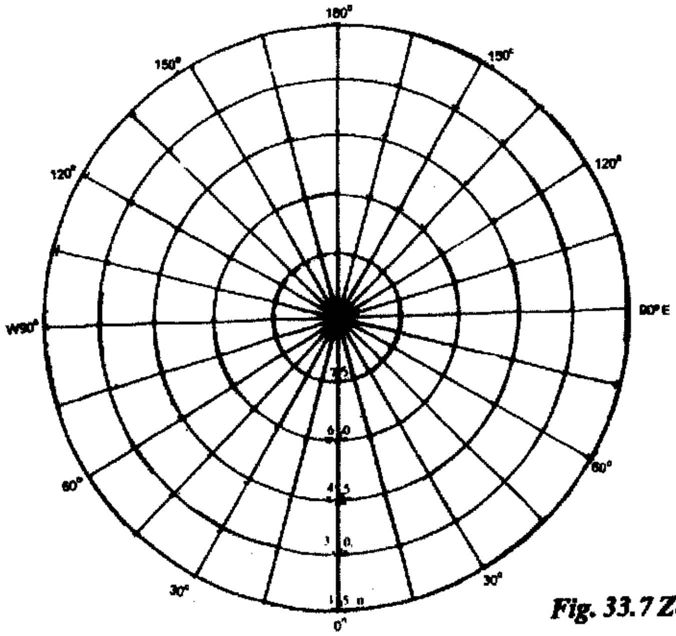
or $\frac{2 \times 22 \times 2}{7} \times \frac{15°}{360°} = 0.52$ cm

Setps for construction

i) draw a vertical line and mark six points from the centre with the distance of 0.52 cm

ii) draw concentric circles from the centre for each six points, which represent paralels of latitude.

iii) draw straight lines from the centre with the interval of 15° which represent meridians of longitude.(see fig. 33.7)



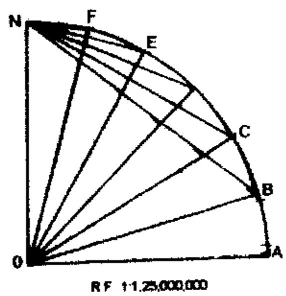


Fig. 33.7 Zenithal Equal Area Projection

EXERCISES FOR PRACTICAL RECORD BOOK

1. Prepare graticule for a Cylindrical Equal-Area projection for the world on the scale of 1:160,000,000 with the interval of 15° apart.

2. Draw a Mercator is Projection for the world map on the scale of 1:2,50,000,000 at an interval of 15° apart.

3. Construct graticules for an area stretching between 30° N to 70° N and 40° E to 30° W on a simple conical projection with one standard parllel with a scale of 1:2,00,000,000 taking on interval of 10°.

4. Draw a Zenithal Equi-Distant Projection for the north hemisphere on the scale of 1:200,000,000 at the interval of 15°.