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MAP PROJECTION

The term *Projection* means the presentation of image on screen. A *Map Projection* means the representation of latitude and longitude of the globe on a flat sheet of paper. The network thus formed is called **graticule**.

As the earth's oblateness is little, the earth can be considered conveniently as a *Sphere*. The difficulty arises in the transfer of geographic grid from its actual spherical form (earth) to a flat surface (map). It is not possible to make a sheet of paper smoothly rounded like a sphere. Hence it appears impossible to prepare a correct map on a sheet of paper. Therefore we need to devise ways to present the earth's surface on a flat paper maintaining the area, shape, bearing, scale etc. as far as practicable by means of map projections.

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Cartography. Many of the map projections, though theoretically conceived are difficult to construct and are of very limited use. We will discuss in this chapter a few principal map projections, which are frequently used and easy for construction.

TABLE 2.1

Classification of Projections

Projections	Forms	Types
1. Zenithal Projections	(i) Perspective (ii) Non-Perspective	(i) Normal (Polar) (ii) Oblique (iii) Equatorial
2. Conical Projections	(i) Perspective (ii) Non-Perspective	(i) Normal
3. Cylindrical Projections	(i) Non-Perspective	(i) Equatorial (ii) Transverse (iii) Oblique
4. Conventional Projections		

The Gnomonic or Central Projection

This is a commonly used Zenithal Projection. It is a perspective projection. The source of light is at the centre of the globe and the projection plane touches the globe as tangent at some point, normally at one of the Poles (North or South) or on the Equator. However the point may lie elsewhere.

Polar Case

Graphical Construction (fig. 2.5)

1. Calculate the radius (R) of the Reduced Earth (The radius of the reduced earth is calculated as dividing the earth's radius (2,50,000,000 inches) by denominator of R.F.)*
2. Draw a circle to scale to represent the globe.
3. Draw radii at required angles (given interval) i.e. OD, OA, OB etc. and stretch the lines to the projection plane DD'. The plane DD' is drawn as a tangent touching the point N (Pole).
4. Take the radius NB' to draw the parallel (B'B'). As <NOB = x, i.e. the complement of (B'B') = (90°–x). Say, <NOB=10°, then the parallel has been drawn for 80° (i.e. 90°–10° = 80°). Similarly other parallels can be drawn.
5. Draw the meridians with the help of a protractor at the given interval of longitude from the point N as centre.
6. Label the parallels and meridians conforming the text.
7. Put the scale at the bottom and label the map projection with its title at the top.

* In all constructions for projections radius of the reduced earth shall be calculated accordingly.

Deformation

(3)

Along the two principal directions, it is the balance of the scale factors that determines the nature and magnitude of deformations on a projection. There are four principal types of deformations. These are deformations in *area*, *shape*, *distance* and *direction*, which are mutually exclusive in nature. On a projection transformation, scale factors are simple vectors, their products and resultants determine the specific property of a projection. On the basis of this, projections are classified into five types:

1. **Equal-Area Projections**

   In these, the area of a segment on the generating globe is truly preserved on the corresponding segment of the graticules. At any point of such projections, the product of the two scale factors is unity, or, in other words,

   $$RSF \times TSF = 1$$

   [Radial Scalefactor × Tangential Scalefactor = 1]

   These are also called *authalic*, *homolographic* or *equivalent projections*.

2. **Orthomorphic Projections**

   Here, the shape of a segment on the generating globe is truly preserved on the corresponding segment of the graticules. At any point of such projections, the two scale factors are exactly equal in magnitude. The necessary condition of orthomorphism is, therefore, the equality of scales along the two principal directions, i.e.,

   $$RSF = TSF$$

   These are also known as *true-shape* or *conformal projections*.

3. **Equidistant Projections**

   In these, the distance between any two points on the generating globe is truly preserved between the corresponding points on the graticules.

4. **Azimuthal Projections**
Here the azimuth defining the directions between any two points on the generating globe is truly preserved between the corresponding two points on the graticules.

5. **Aphylactic Projections**
In these, neither of the above four properties is truly and fully preserved. Such projections are genetically neither azimuthal nor equidistant, nor equivalent and nor conformal.

Classification of Map Projection

Map projections are fundamentally classified based on the *extrinsic* and *intrinsic* properties. The extrinsic properties include the exogenic parameters of transformation, i.e., the *nature of*

Table 2.1 Classification of Map Projections

Criteria	Parameter	Classes/Sub-classes		
1. EXTRINSIC	A. Datum Surface	I. Direct or Spheroidal Projection II. Double or Spherical Projection III. Triple Projection		
	B. Plane or Surface of Projection	1st Order (plane)	2nd Order (aspect)	3rd Order (case)
		I. Planar II. Conical III. Cylindrical	a. Tangent b. Secant c. Polysuperficial	i. Normal ii. Transverse iii. Oblique
	C. Method of Projection	I. Perspective II. Semiperspective III. Non-perspective IV. Conventional		a. Gnomonic b. Stereographic c. Orthographic
2. INTRINSIC		I. Azimuthal II. Equidistant III. Equivalent or Authalic or Homolographic IV. Orthomorphic or Conformal V. Aphylactic		
	B. Appearance of Parallels and Meridians	I. Both parallels and meridians are straight lines II. Parallels are straight lines and meridians are regular curves III. Parallels are regular curves and meridians are straight lines IV. Both parallels and meridians are regular curves V. Parallels are concentric circles and meridians are regular curves. VI. Parallels are concentric circles and meridians are radiating straight lines VII. Parallels are irregular curves and meridians are radiating straight lines VIII. Both parallels and meridians are irregular curves		
	C. Geometric shape	I. Rectangular II. Circular III. Elliptical IV. Parabolic V. Butterfly VI. Others		

the poles are 90°N and 90°S. It is measured either to the north or to the south of the equator and is accordingly specified as °N or °S. Through each latitude, circles parallel to the equator and centred on the polar axis may be imagined. These are called *parallels of latitudes* or simply *parallels.* Altogether there are 180 parallels at 1° intervals. Of the parallels only the equator is a great circle. The radius and the length of the parallels gradually decrease from its maxima at the equator to its minima at the poles.

The semicircular lines joining the two poles and intersecting the parallels at right angles are called *meridians* or *lines of longitudes*. All meridians are equal in size. There are 360 meridians at 1° intervals. Of these, the one that passes through Greenwich is taken as the reference line and is called the *prime meridian.* The longitude of a place is described as the angle subtended by the meridional plane passing through a place on the plane of the prime meridian, i.e., 0° at the centre of the earth. It is measured either to the east or to the west of the prime meridian and is accordingly specified as °E and °W.

Graticule

It refers to the net or mesh of mutually intersecting parallels and meridians drawn to a certain scale and based on certain principles. The term *graticulation* is used to specify the procedures by which the network of graticules are drawn.

Generating Globe

It refers to the globe from which projections are generated or developed. Normally it is a small skeleton globe made of glass or wire (Fig. 2.2). The parallels and meridians are shown by black lines (glass globe) or wires (wire globe) placed at their true angular distances apart. Naturally the generating globe is a geometrically accurate earth reduced in size.

Projection Plane

It is a 2-dimensional geometric plane upon which the parallels and meridians are usually projected. In case of a perspective planar projection, the

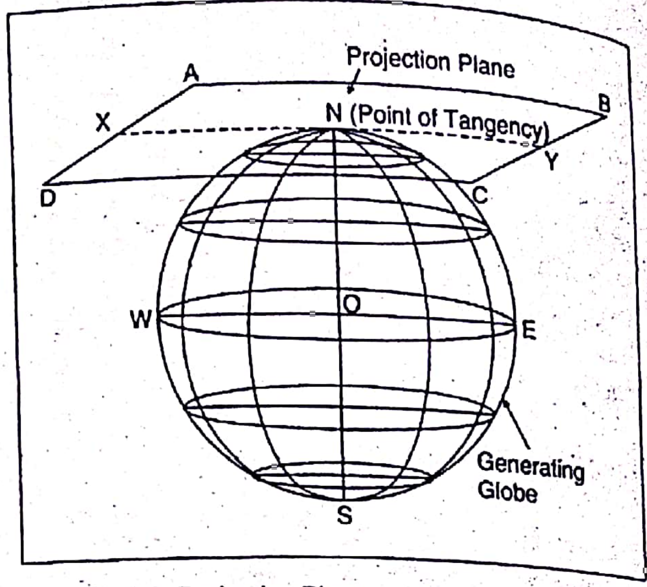

Fig. 2.2 Projection Plane and Generating Globe

projection plane touches the generating globe at a single point (Fig. 2.2).

Developable Surface

In case of planar projections, only a single point is truly represented with the exact one-to-one correspondence. Obviously, from this point of tangency, the distortion on a map increases in all directions. To minimise it, the point of contact with the generating globe is maximised by using projection surfaces that can easily be developed into 2-dimensional geometric planes. Such projection surfaces are known as *developable surfaces*, e.g., a cone or a cylinder. A right circular cone or a cylinder usually touches a generating globe along a parallel and may even intersect it along two different parallels in certain desired situations (Fig. 2.3). Along these parallels, one-to-one correspondence is truly maintained involving no error and are termed as *lines of zero distortion.* When developed, a cone becomes a *sector of circle* and a cylinder becomes a *rectangle* both being parts of a 2-dimensional plane. Notably, when the angle at the vertex of a cone becomes 180°, the cone is developed into a projection plane touching the generating globe at a single point only. Again, when the apex of a cone lies at infinity, the cone is developed into a cylinder touching the generating globe along the equator.

Central Meridian

For a given longitudinal extension, it refers to that meridian, *which lies exactly at the median* or *middle-most* position of that extension. It has only constructional importance and is normally drawn as a straight line. The mesh of graticules on one side of the central meridian (CM) is in fact the mirror image of the other side.

Standard Parallel

The parallel(s), *along which a projection plane or a developable surface touch*(es) or *intersect*(s) *the generating globe*, are called *standard parallel*(s). Along the standard parallels, the tangential scale is essentially 1:1. Hence, these are always the *lines of zero distortion*.

Constant of a Cone

It is defined as the *ratio between the angle at the vertex* or apex of a cone when developed (α) and the angle at the pole of the generating globe (360°)

Therefore, the constant of a *cone*, $n = \dfrac{\alpha}{360°}$

Since α depends on the standard parallel (ϕ_0), n is a direct function of ϕ_0. The two extreme situations are:

i. when $\phi_0 = 0°$, a cone is transformed into a special cylinder with $\alpha = 0°$. (Cylindrical case of projection)

Therefore, $n = \dfrac{0°}{360°} = 0$ ... (i)

ii. when $\phi_0 = 90°$, a cone is transformed into a plane and α becomes 360°.

Therefore, $n = \dfrac{360°}{360°} = 1$

(Polar Case of projection)

Hence, $0 \leq n \leq 1$ is the boundary condition of the Constant of the Cone.

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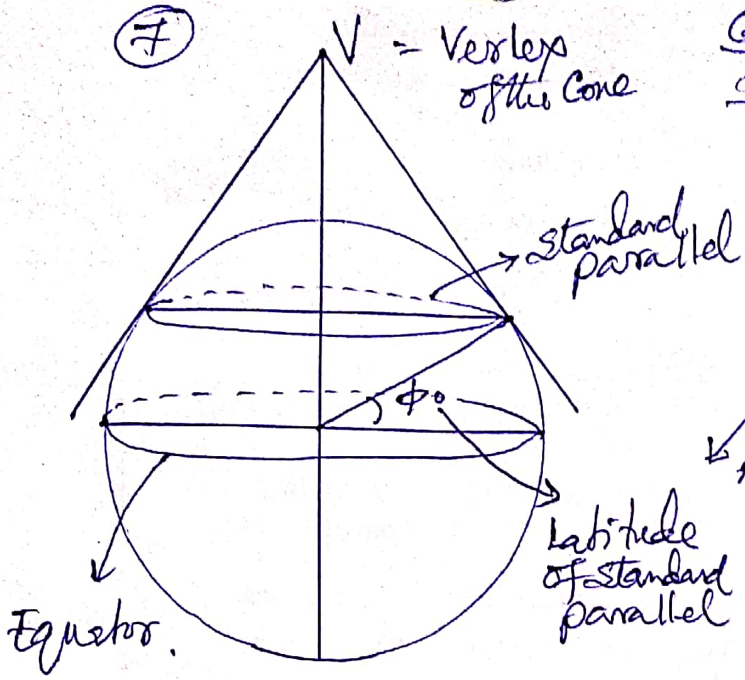
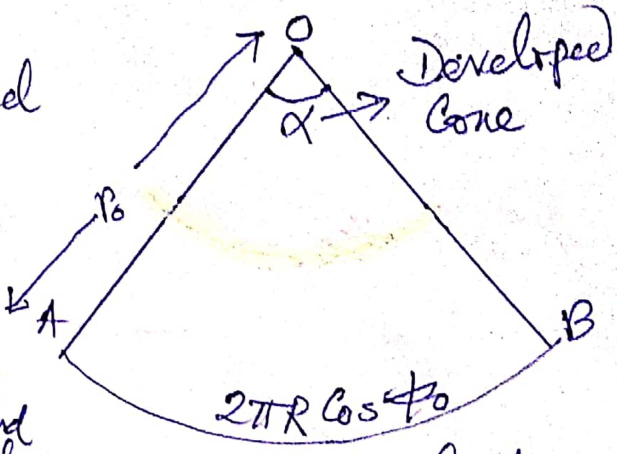
Constant of the Cone in Simple Conical Projection





AB = Standard parallel

Let, Latitude of standard parallel = ϕ_0

Constant of the Cone = $n = \frac{\alpha}{360} = \frac{\alpha}{2\pi}$

From the diagram we get,

$$r_0 \alpha^{c} = 2\pi R \cos\phi_0$$

$$\therefore \frac{\alpha^{c}}{2\pi} = \frac{R\cos\phi_0}{R\cot\phi_0}$$

$$\therefore \frac{\alpha}{2\pi} = n = \frac{\cos\phi_0}{\frac{\cos\phi_0}{\sin\phi_0}} = \frac{\cancel{\cos\phi_0}}{\cancel{\cos\phi_0}} \times \sin\phi_0$$

$\therefore$ Constant of the Cone in Simple Conical projection = $n = \frac{\alpha}{2\pi} = \sin\phi_0$.

(where ϕ_0 = Latitude of Standard parallel) the oblique case $90° > p > 0°$.

Aspects of Projection

This refers to the *attitude* of the plane or the surface of projection. The plane of projection may be tangent at one point only or intersect along a parallel circle. A polyhedric surface, (i.e., one which has more than one plane) may be tangent at a number of points. Similarly, a cone or a cylinder may be tangent along a parallel or may interest along two parallels. A polyconic or polycylindrical surface may even be chosen for a projection. The main objective is to maximise the points of contact in order to minimise the cumulative deformation.

Perspective Projections

In these, graticules are drawn from a transparent generating globe made of glass with the help of a light source. Rays emerging from the sources cast shadows of parallels and meridians on the projection plane, e.g., *Gnomonic projection, Stereographic projection, Orthographic projection* and the *Simple Conic projection with 1 standard parallel.*

Semi-perspective Projections

In these, one set of intersecting lines is geometrically projected and the other set drawn purely to suit a desired property.

Non-perspective Projections

In these, projection is done in accordance to a consistent mathematical principle to satisfy certain objectives.

Conventional Projections

These are non-perspective projections constructed following a set of conventions purely based on mathematical operations postulated by a cartographer to portray the whole globe with certain objectives.

The Great Circle

If a plane intersects a sphere, the resulting section of the curved surface which is traced on the plane, is a circle. If the intersecting plane passes through the center of a sphere, the resulting section is a circle, whose radius is the largest which can occur and is equal to the radius of the sphere itself. This is defined as a *great circle*. Thus a meridian is a part of a great circle. The equator is the only parallel which is a great circle and all other parallels are *small circles*. If the plane does not pass through the centre of the sphere, the radius of the resulting circle is less than that of the sphere. This is called a small circle. The special features of great circle are:

- The axis of two or more great circles cannot coincide.
- Intersecting great circles bisect each other.
- The plane of a great circle divides a sphere into two equal halves.
- The section of all great circles passes through the centre of the sphere; therefore the centre of the sphere is the common centre of all the great circles.
- Only one great circle can be drawn through any two points on the spherical surface which are not diametrically opposite to one another.
- An infinite number of great circles can be drawn through a single point.
- An infinite number of great circles can be drawn on a sphere.
- The shorter arc of the great circle through two points is the shortest distance between the points on the spherical surface.

The Geodesic

Similar to the great circle arc, the shortest possible connection between two points on the ellipsoidal surface is defined as the *geodetic line* or, for convenience, the *geodesic*. Progressing along this curved line from point to point, the tangent continuously changes its azimuth. According to Clairaut's theorem, '*the product of the radius* (r) *of the parallel circle* (ϕ) *and the sine of the azimuth* (α) *of the geodesic is a constant*'. Therefore,

$$r \sin\alpha = (R \cos\phi) . \sin\alpha = k \text{ (a constant)} \qquad \dots (1)$$

The following particulars can be derived from this,

1. For $\phi = 0°$, $R = a$ and $\sin \alpha = k/a$. Hence, the geodesic intersects the equator with azimuth $\alpha = \sin^{-1}(k/a)$

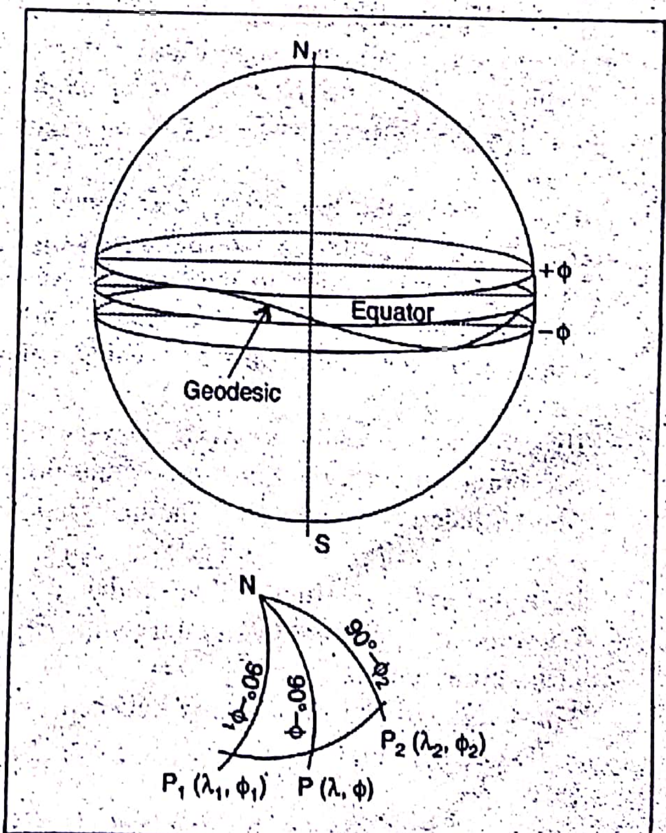


Fig. 2.5 The Geodesic

Polar Zenithal Stereographic Projection

Principle

In this projection, a 2-dimensional plane of projection touches the generating globe at either of the poles. It is a perspective projection, with the source of light lying at the pole diametrically opposite to one at which the projection plane touches the generating globe (Fig. 2.9). The parallels are projected as concentric circles of