# Chapter 5

# Object Space Coordinate System

## Elements of Photogrammetry with Applications in GIS

Wolf, Paul R.; Wolf, Paul R.; DeWitt, Bon A.; DeWitt, Bon A.; Wilkinson, Benjamin E.; Wilkinson, Benjamin E.. Elements of Photogrammetry with Application in GIS, Fourth Edition McGraw-Hill Education. Kindle Edition.

# 1. Introduction

- Three dimensional object space coordinate systems are important for specifying the relative positions of points in photogrammetry, especially for use of GIS.

- Accepted reference systems: geodetic, geocentric, local vertical, and map projection.

# 2. Concepts of Geodesy

- The geodesy (측지학) involves the size, shape, gravity, rotation, and crustal movement of the earth.

- Three reference surfaces are the physical earth, the geoid(지구체), and ellipsoid.

- The physical earth contains mountains, valleys, plains, and ocean floor.

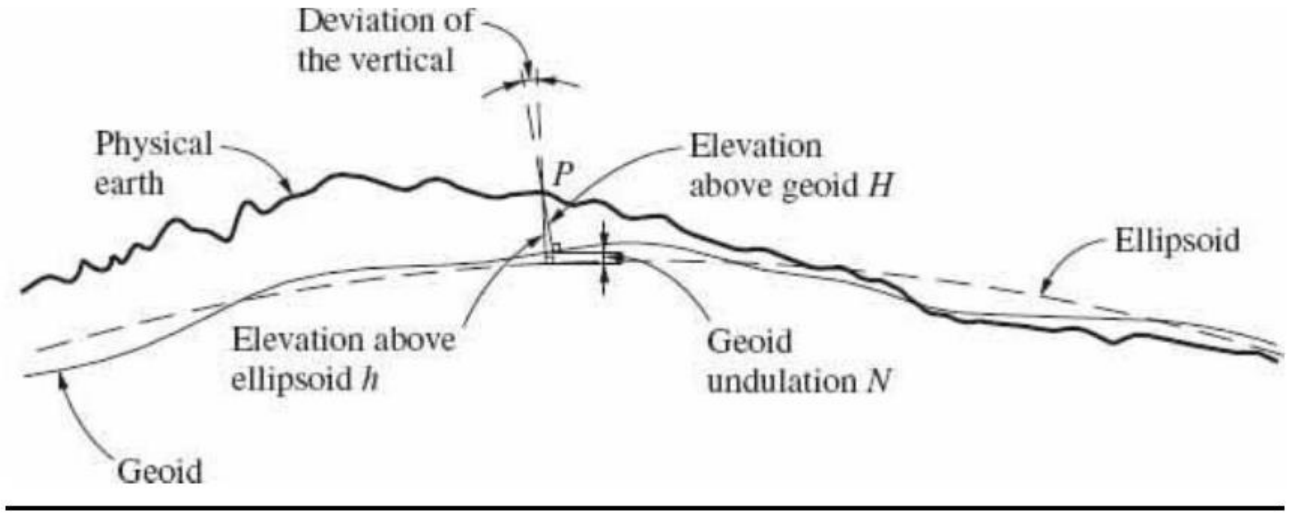


**Figure 5-1** The three fundamental geodetic reference surfaces: physical earth, geoid, and ellipsoid.

- The Geoid is an equipotential gravity surface (mean sea level, perpendicular to the gravity)

# 2. Concepts of Geodesy

- Ellipsoid is a mathematically defined surface generally using semimajor axis - a, and flattening – f which are selected on the basis of geodetic measurements worldwide.

- The flattening f can range from 0 (circle) to 1 (straight line). F of the earth is roughly 0.0033.

| Reference Ellipsoid | Semimajor Axis a | Flattening f |
|---|---|---|
| Clarke 1866 | 6,378,206.4 m | 1/294.9786982 |
| GRS80 | 6,378,137 m | 1/298.25722210088 |
| WGS84 | 6,378,137 m | 1/298.257223563 |

**TABLE 5-1** Parameters for Select Reference Ellipsoids

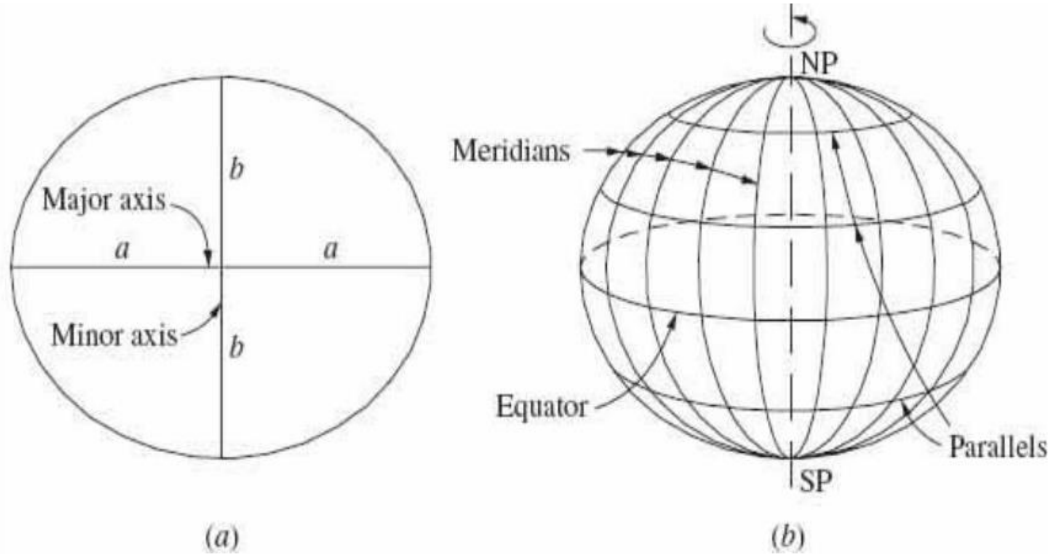


**FIGURE 5-2** Definition of a reference ellipsoid. (*a*) Two-dimensional ellipse showing major and minor axes. (*b*) Three-dimensional ellipsoid formed by rotation of ellipse about the minor axis.

# 2. Concepts of Geodesy

- Relations among the semimajor (*a*), the semiminor (*b*), the flattening (*f*), the first eccentricity (*e*), and the second eccentricity (*e'*):

$$f = 1 - \frac{b}{a}, \qquad b = a(1 - f)$$

$$e = \frac{\sqrt{a^2 - b^2}}{a}, \qquad e^2 = f(2 - f) = \frac{a^2 - b^2}{a^2}$$

$$e' = \frac{\sqrt{a^2 - b^2}}{b}, \qquad e'^2 = \frac{e^2}{(1 - f)^2} = \frac{a^2 - b^2}{a^2}$$

# 3. Geodetic Coordinate System

- Geodetic coordinates are latitude (ϕ, -90~90°), longitude (λ, -180~180°), and height (h, h=H+N)

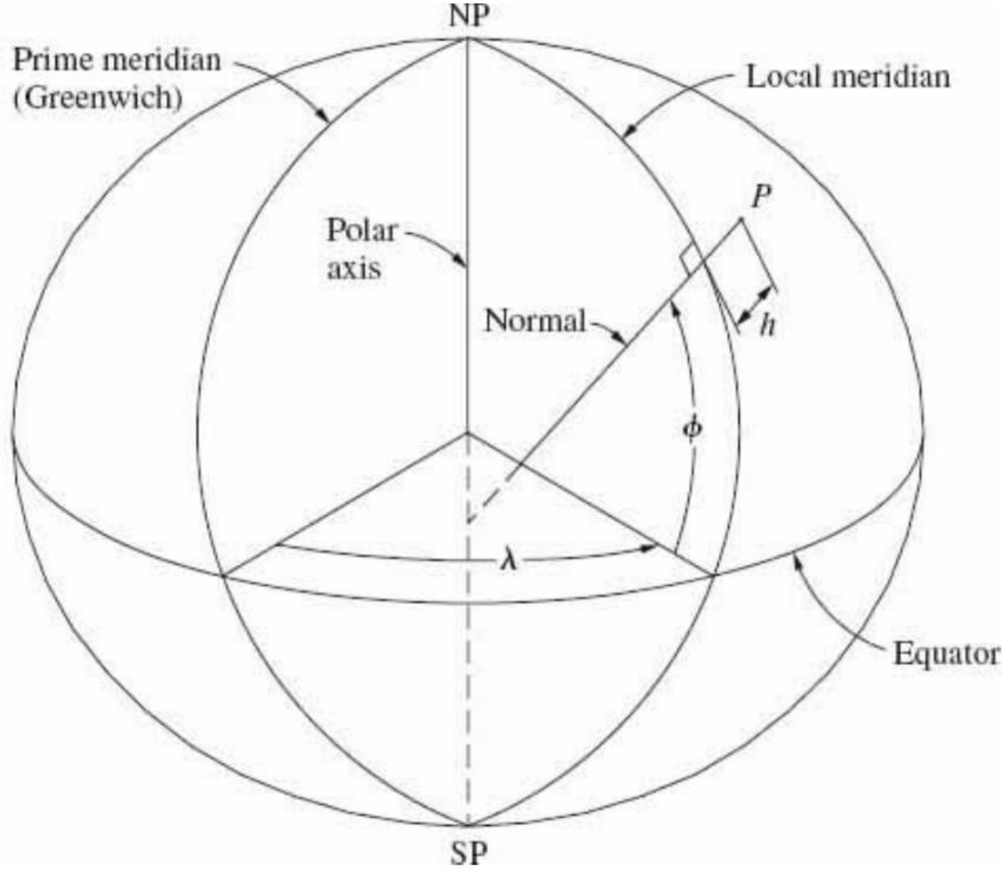


**FIGURE 5-3** Geodetic coordinates of latitude $\varphi$, longitude $\lambda$, and height $h$.

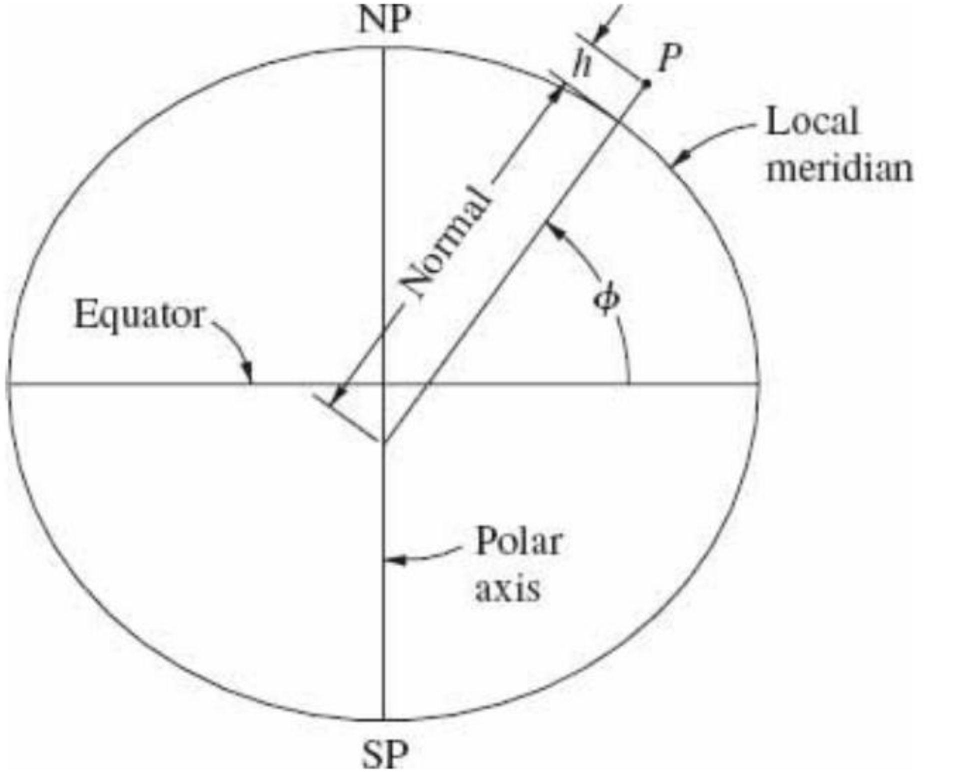


**FIGURE 5-4** Illustration of latitude $\varphi$, normal, and height $h$ in the plane of the local meridian.

# 4. Geocentric Coordinates

- Geocentric coordinates system XY plane in the equator plane and Z axis passing through the north pole; X axis passes through the prime meridian.

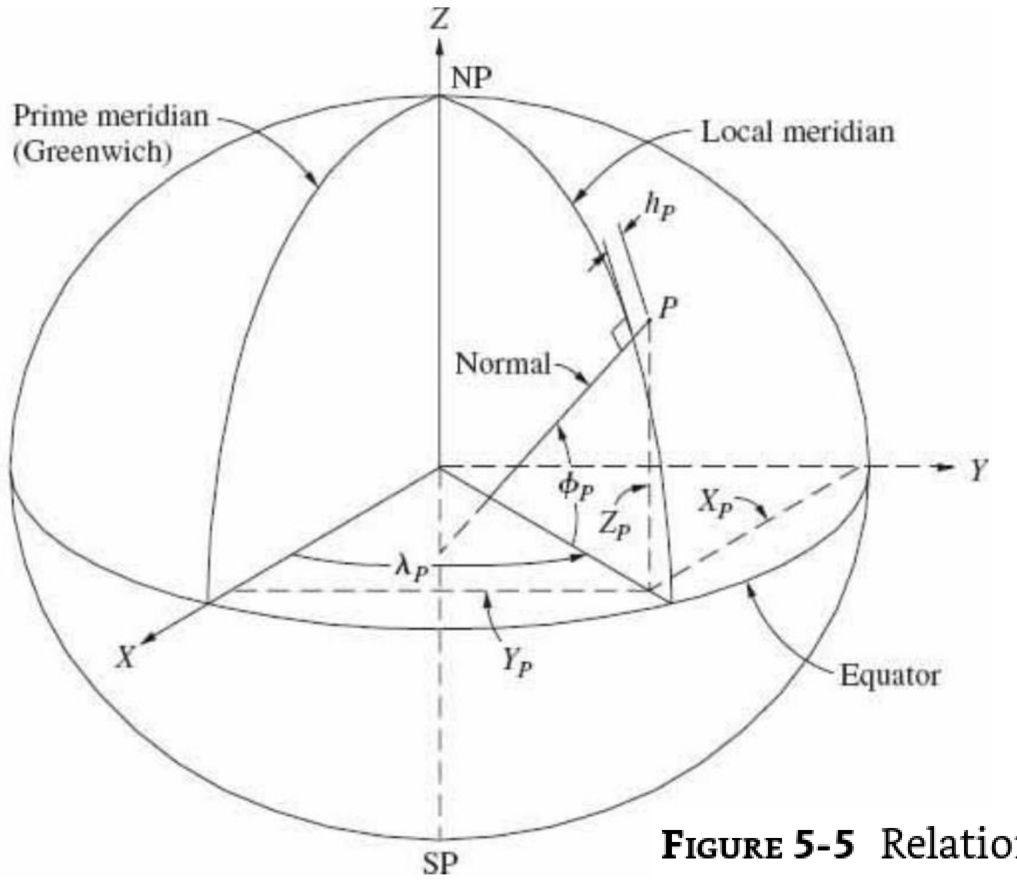


**FIGURE 5-5** Relationship between geocentric and geodetic coordinates.

- It is convenient for satellite geodesy but not advantageous for use in photogrammetry since the coordinate values are very large and does not have obvious relationship with local directions.

# 5. Local Vertical Coordinates

- A local vertical coordinates system has its origin at a specific point within the project area and X & Y axes in a plane tangent to the ellipsoid orienting the east and north, respectively while Z axis extends straight up from the plane ($x_{lp}$, $y_{lp}$, $z_{lp}$).

- The origin can be specified in terms of geodetic ($\phi_o$, $\lambda_o$, $h_o$) and geocentric coordinates ($x_o$, $y_o$, $z_o$).

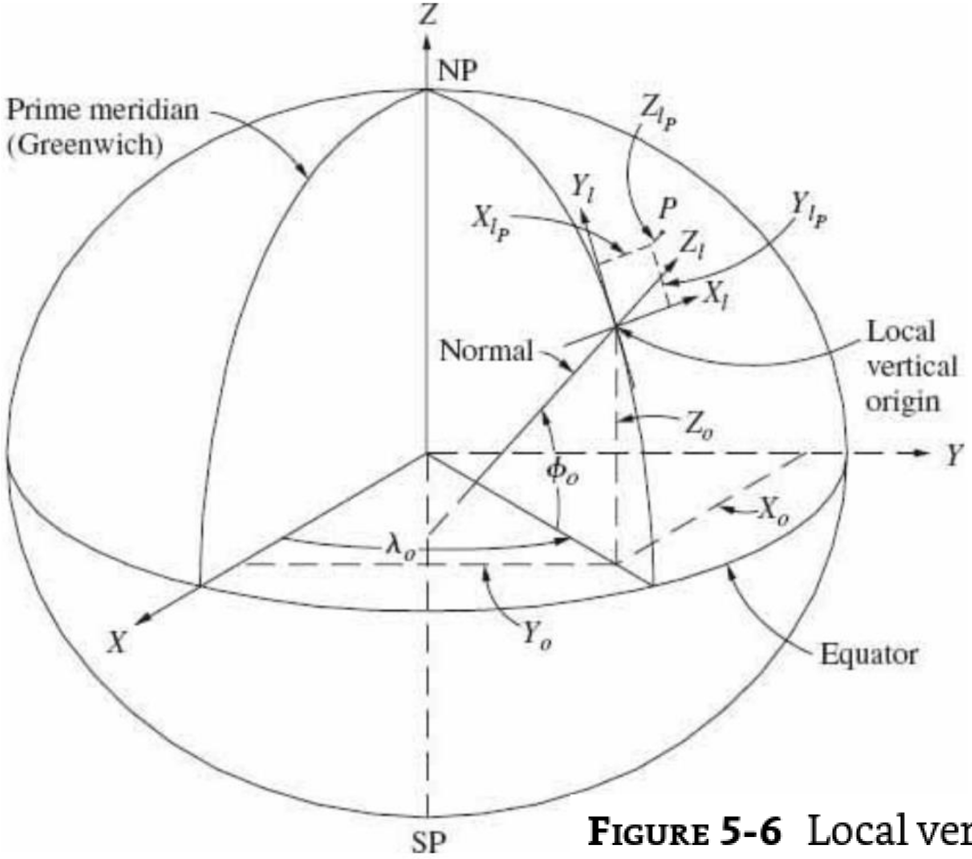


FIGURE 5-6 Local vertical coordinate system relative to geocentric and geodetic systems.

# 6. Map Projections

- Mapping the earth's surface to two-dimensional medium without distortion is impossible due to earth's curved shape.

- Conformal projection is the most often used type in photogrammetric mapping.

- Two particular conformal projections discussed here are *Lambert conformal conic* and *transverse Mercator* which employ the concept of developable surface.

- A developable surface is a surface that may be 3D in its natural form, but can be "unrolled" and laid flat.

# 6. Map Projections

- Lambert conformal conic projection

 - A cone is adopted as its developable surface whose axis coincides with the minor axis of the ellipsoid (NP-SP axis).

 - The cone passes through the ellipsoid along two parallels of latitude called ‘standard parallels’.

 - Scale factor is less than 1 between the standard parallels and greater than 1 outside while it is exactly equal to 1 at the standard parallels.

 - The scale factor varies in the north-south direction but remains the same in the east-west direction. That is why this projection is appropriate for areas having limited extent north-south but wide extent east-west.

# 6. Map Projections

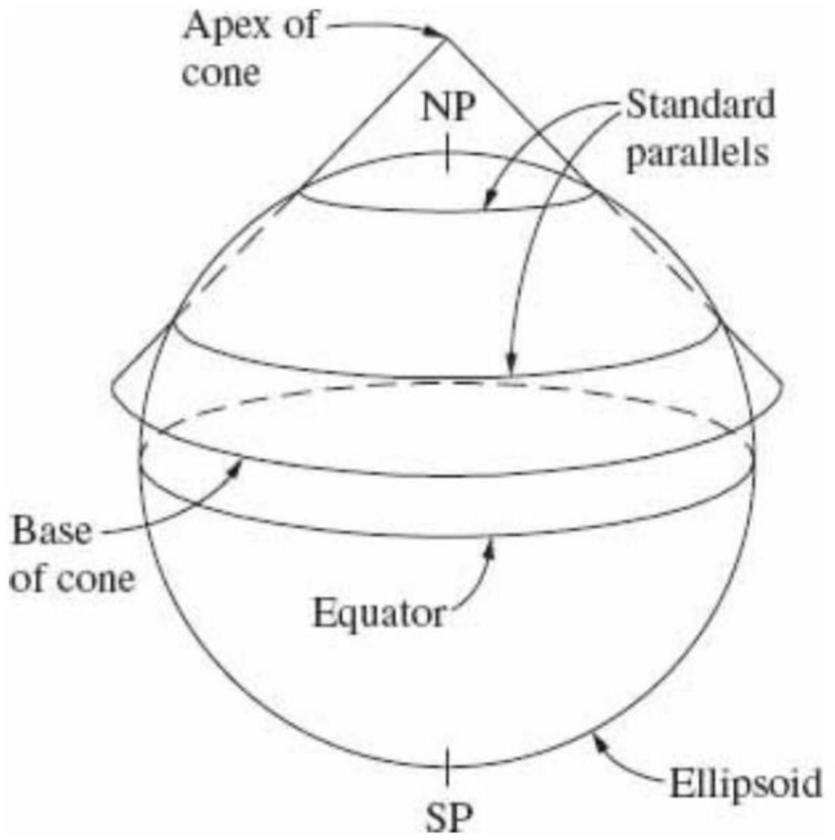


**FIGURE 5-7** Cone used in the Lambert conformal conic projection.

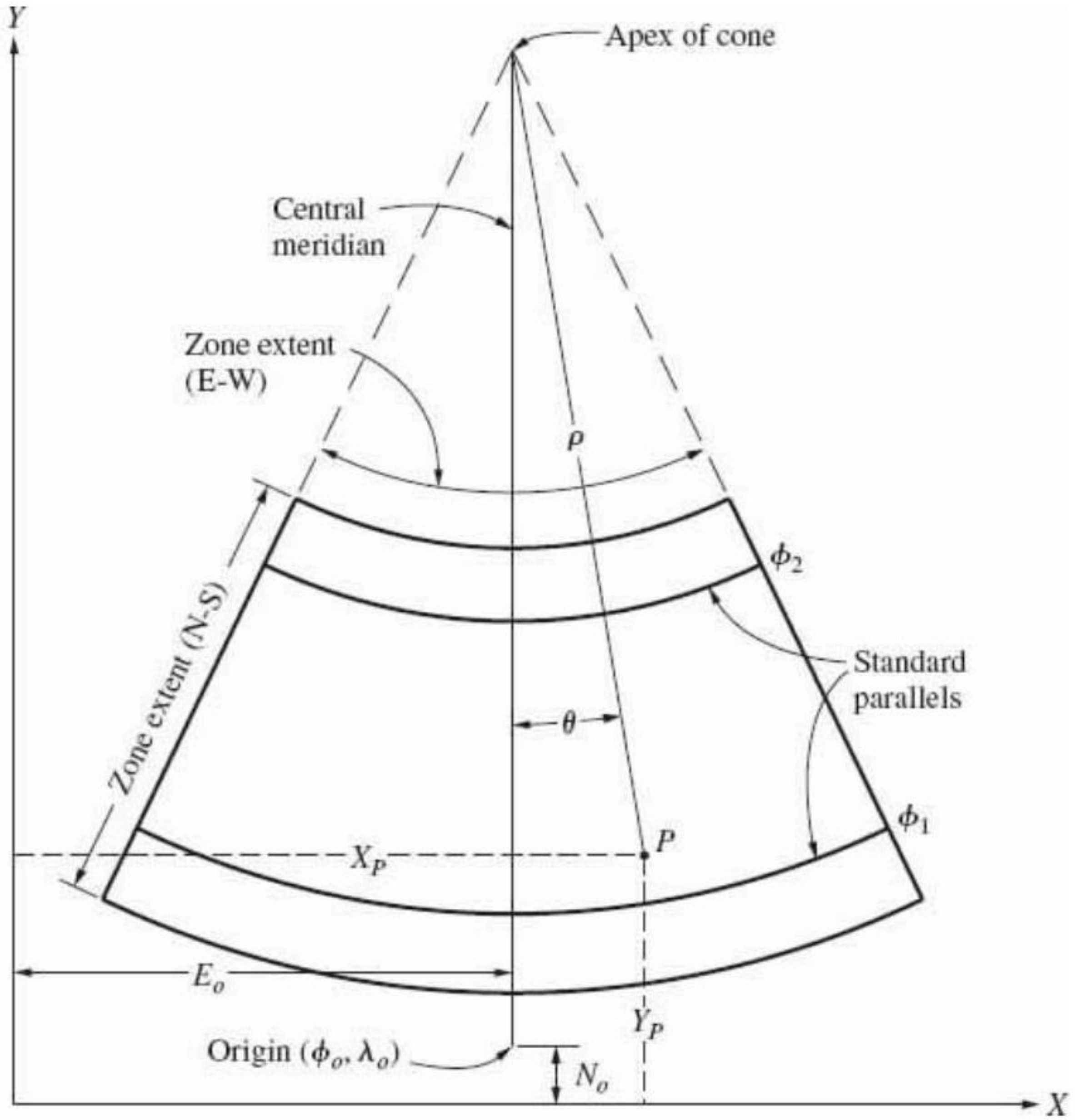


**FIGURE 5-8** The Lambert cone unrolled and laid flat.

# 6. Map Projections

- Transverse Mercator

 - Developable surface is a surface of cylinder which is slightly flattened for the ellipsoidal earth.

 - The cylinder passes through the ellipsoid along two rings called ‘rings of intersection’.

 - Scale factor is less than 1 between the rings of intersection and greater than 1 outside while it is exactly equal to 1 at the rings.

 - The scale factor varies in the east-west direction but remains approximately the same in the north-south direction. That is why this projection is appropriate for areas having limited extent east-west but long extent north-south.

# 6. Map Projections

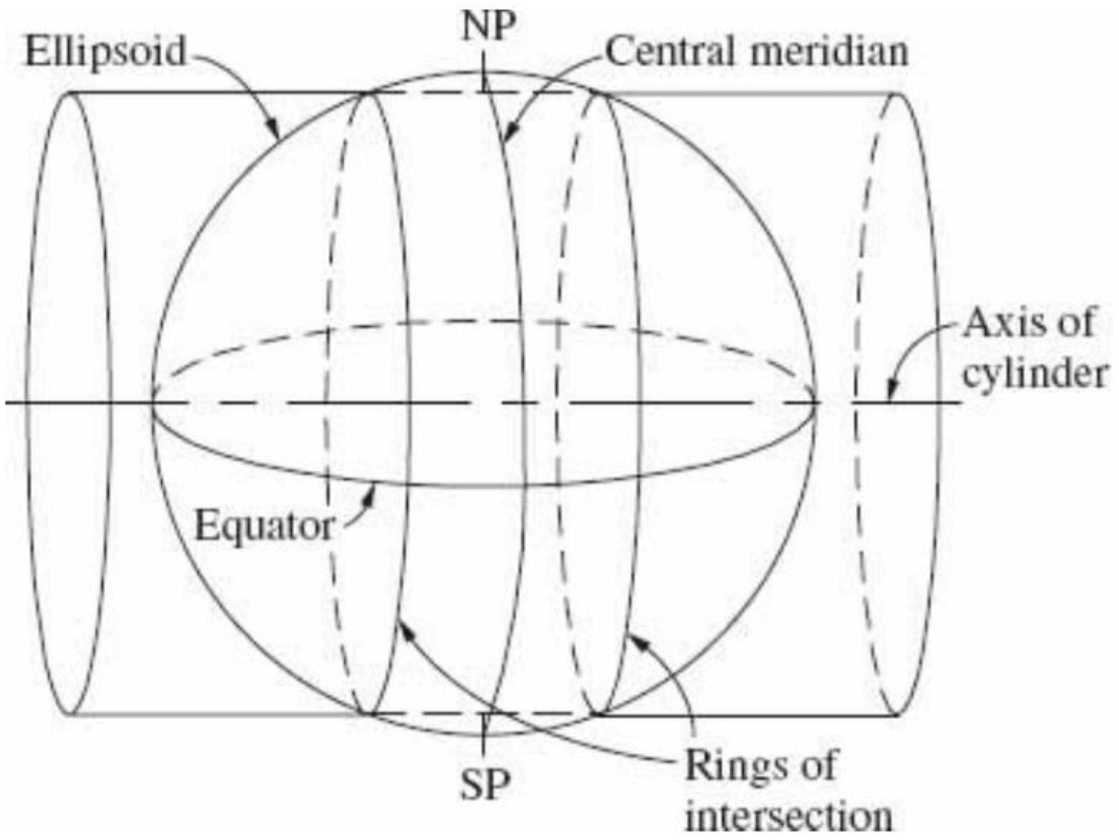


**FIGURE 5-9** Cylinder used in the transverse Mercator projection.

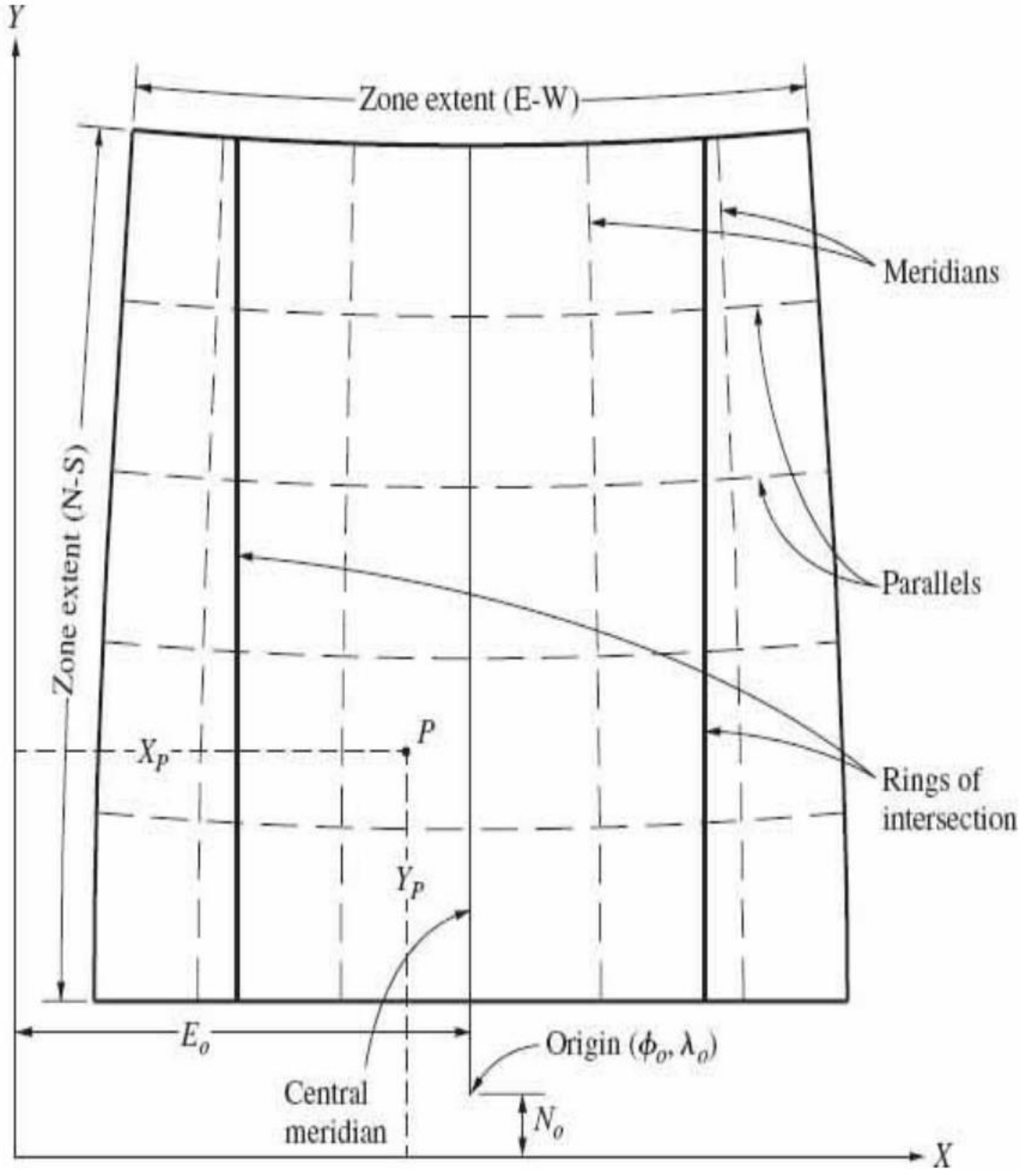


**FIGURE 5-10** The transverse Mercator cylinder unrolled and laid flat.

# 6. Map Projections

- State Plane Coordinate (SPC) system

 - Both the Lambert conformal conic and transverse Mercator projections are used in SPC system in US.

 - In SPC system, each state is divided into one or more zones so that the maximum scale distortion is no more than 1/10,000.

 - Not to exceed the above limitation the north-south dimension of Lambert zone and east-west dimension of transverse Mercator zone are limited to an approximately 254 km.

# 6. Map Projections

➢ Universal transverse Mercator

- Established to provide worldwide coverage between 80° S and 80° N with 60 zones, each having a 6° longitude range: UTM zone 1 extends from 180° west longitude to 174° west longitude with a central meridian of 177° west.

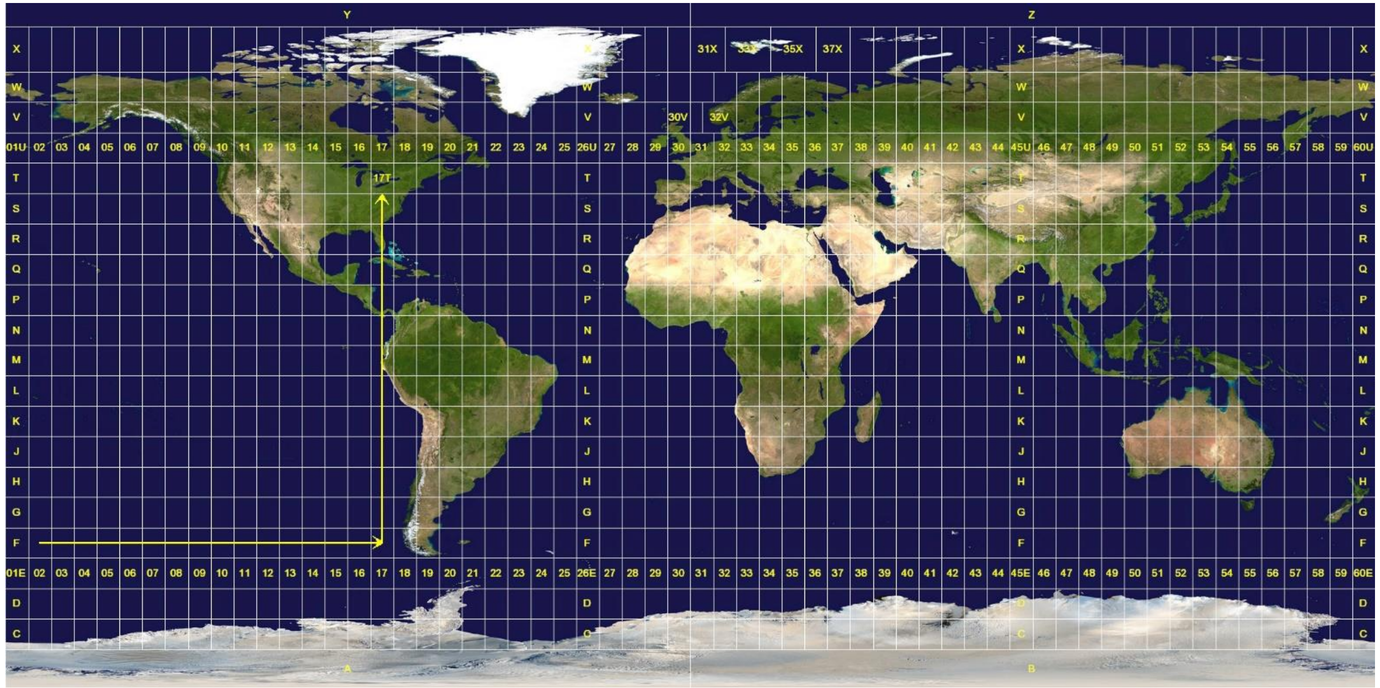


Figure. UTM coordinate system: 60 cells in west-east; c~x divisions in south-north

# 7. Horizontal and Vertical Datums

- Datum is a system of reference for specifying the spatial positions of points consisting of horizontal and vertical components.

- Common horizontal datums in US include the North American Datum of 1927 (NAD27), the North American Datum of 1983 (NAD83), the World Geodetic System of 1984 (WGS84)

- Datums can be considered to be based on three primary components: a reference ellipsoid, an origin, and an angular alignment.

- NGII of Korea shows a lot of datums in Korea.