CHAPTER 3

NAUTICAL CHARTS

CHART FUNDAMENTALS

300. Definitions

A **nautical chart** represents part of the spherical earth on a plane surface. It shows water depth, the shoreline of adjacent land, prominent topographic features, aids to navigation, and other navigational information. It is a work area on which the navigator plots courses, ascertains positions, and views the relationship of the ship to the surrounding area. It assists the navigator in avoiding dangers and arriving safely at his destination.

Originally hand-drawn on sheepskin, traditional nautical charts have for generations been printed on paper. **Electronic charts** consisting of a digital data base and a display system are in use and are replacing paper charts aboard many vessels. An electronic chart is not simply a digital version of a paper chart; it introduces a new navigation methodology with capabilities and limitations very different from paper charts. The electronic chart is the legal equivalent of the paper chart if it meets certain International Maritime Organization specifications. See Chapter 14 for a complete discussion of electronic charts.

Should a marine accident occur, the nautical chart in use at the time takes on legal significance. In cases of grounding, collision, and other accidents, charts become critical records for reconstructing the event and assigning liability. Charts used in reconstructing the incident can also have tremendous training value.

301. Projections

Because a cartographer cannot transfer a sphere to a flat surface without distortion, he must project the surface of a sphere onto a **developable surface**. A developable surface is one that can be flattened to form a plane. This process is known as **chart projection**. If points on the surface of the sphere are projected from a single point, the projection is said to be **perspective** or **geometric**.

As the use of electronic charts becomes increasingly widespread, it is important to remember that the same cartographic principles that apply to paper charts apply to their depiction on video screens.

302. Selecting a Projection

Each projection has certain preferable features. However, as the area covered by the chart becomes smaller, the differences between various projections become less noticeable. On the largest scale chart, such as of a harbor, all projections are practically identical. Some desirable properties of a projection are:

1. True shape of physical features
2. Correct angular relationships
3. Equal area (Represents areas in proper proportions)
4. Constant scale values
5. Great circles represented as straight lines
6. Rhumb lines represented as straight lines

Some of these properties are mutually exclusive. For example, a single projection cannot be both conformal and equal area. Similarly, both great circles and rhumb lines cannot be represented on a single projection as straight lines.

303. Types of Projections

The type of developable surface to which the spherical surface is transferred determines the projection's classification. Further classification depends on whether the projection is centered on the equator (equatorial), a pole (polar), or some point or line between (oblique). The name of a projection indicates its type and its principal features.

Mariners most frequently use a **Mercator projection**, classified as a **cylindrical projection** upon a plane, the cylinder tangent along the equator. Similarly, a projection based upon a cylinder tangent along a meridian is called **transverse** (or inverse) **Mercator** or **transverse** (or inverse) **orthomorphic**. The Mercator is the most common projection used in maritime navigation, primarily because rhumb lines plot as straight lines.

In a **simple conic projection**, points on the surface of the earth are transferred to a tangent cone. In the **Lambert conformal projection**, the cone intersects the earth (a secant cone) at two small circles. In a **polyconic projection**, a series of tangent cones is used.

In an **azimuthal** or **zenithal projection**, points on the earth are transferred directly to a plane. If the origin of the

projecting rays is the center of the earth, a **gnomonic projection** results; if it is the point opposite the plane's point of tangency, a **stereographic projection**; and if at infinity (the projecting lines being parallel to each other), an **orthographic projection**. The gnomonic, stereographic, and orthographic are **perspective projections**. In an **azimuthal equidistant projection**, which is not perspective, the scale of distances is constant along any radial line from the point of tangency. See Figure 303.
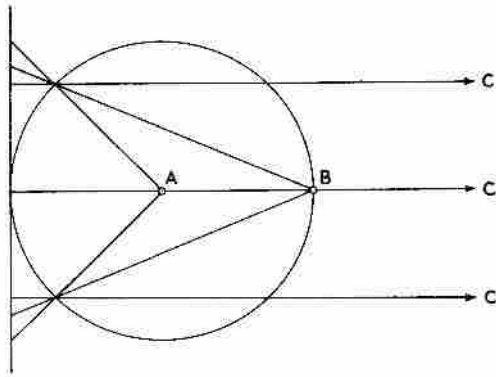

Figure 303. Azimuthal projections: A, gnomonic; B, stereographic; C, (at infinity) orthographic.

Cylindrical and **plane projections** are special conical projections, using heights infinity and zero, respectively.

A **graticule** is the network of latitude and longitude lines laid out in accordance with the principles of any projection.

304. Cylindrical Projections

If a cylinder is placed around the earth, tangent along the equator, and the planes of the meridians are extended, they intersect the cylinder in a number of vertical lines. See Figure 304. These parallel lines of projection are equidistant from each other, unlike the terrestrial meridians from which they are derived which converge as the latitude increases. On the earth, parallels of latitude are perpendicular to the meridians, forming circles of progressively smaller diameter as the latitude increases. On the cylinder they are shown perpendicular to the projected meridians, but because a cylinder is everywhere of the same diameter, the projected parallels are all the same size.

If the cylinder is cut along a vertical line (a meridian) and spread out flat, the meridians appear as equally spaced vertical lines; and the parallels appear as horizontal lines. The parallels' relative spacing differs in the various types of cylindrical projections.

If the cylinder is tangent along some great circle other than the equator, the projected pattern of latitude and longitude lines appears quite different from that described above, since the line of tangency and the equator no longer coincide. These projections are classified as **oblique** or **transverse projections**.
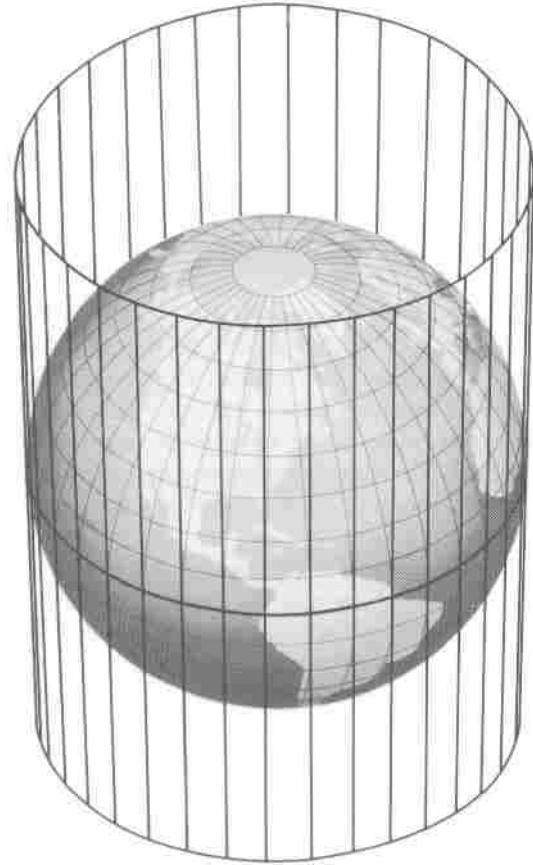

Figure 304. A cylindrical projection.

305. Mercator Projection

Navigators most often use the plane conformal projection known as the **Mercator projection**. The Mercator projection is not perspective, and its parallels can be derived mathematically as well as projected geometrically. Its distinguishing feature is that both the meridians and parallels are expanded at the same ratio with increased latitude. The expansion is equal to the secant of the latitude, with a small correction for the ellipticity of the earth. Since the secant of 90° is infinity, the projection cannot include the poles. Since the projection is conformal, expansion is the same in all directions and angles are correctly shown. Rhumb lines appear as straight lines, the directions of which can be measured directly on the chart. Distances can also be measured directly if the spread of latitude is small. Great circles, except meridians and the equator, appear as curved lines concave to the equator. Small areas appear in their correct shape but of increased size unless they are near the equator.

306. Meridional Parts

At the equator a degree of longitude is approximately equal in length to a degree of latitude. As the distance from the equator increases, degrees of latitude remain approximately the same, while degrees of longitude become
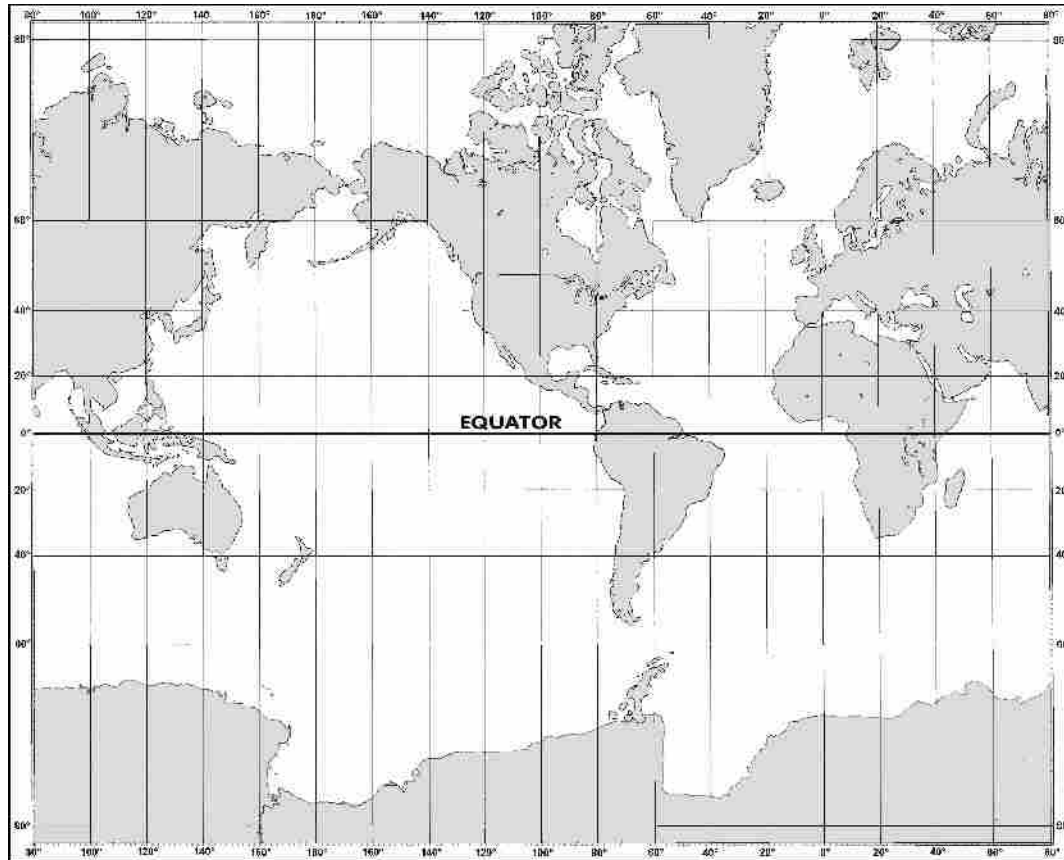
Figure 306. A Mercator map of the world.

progressively shorter. Since degrees of longitude appear everywhere the same length in the Mercator projection, it is necessary to increase the length of the meridians if the expansion is to be equal in all directions. Thus, to maintain the correct proportions between degrees of latitude and degrees of longitude, the degrees of latitude must be progressively longer as the distance from the equator increases. This is illustrated in Figure 306.

The length of a meridian, increased between the equator and any given latitude, expressed in minutes of arc at the equator as a unit, constitutes the number of meridional parts (M) corresponding to that latitude. Meridional parts, given in Table 6 for every minute of latitude from the equator to the pole, make it possible to construct a Mercator chart and to solve problems in Mercator sailing. These values are for the WGS ellipsoid of 1984.

307. Transverse Mercator Projections

Constructing a chart using Mercator principles, but with the cylinder tangent along a meridian, results in a **transverse Mercator** or **transverse orthomorphic pro-**

jection. The word "inverse" is used interchangeably with "transverse." These projections use a fictitious graticule similar to, but offset from, the familiar network of meridians and parallels. The tangent great circle is the fictitious equator. Ninety degrees from it are two fictitious poles. A group of great circles through these poles and perpendicular to the tangent great circle are the fictitious meridians, while a series of circles parallel to the plane of the tangent great circle form the fictitious parallels. The actual meridians and parallels appear as curved lines.

A straight line on the transverse or oblique Mercator projection makes the same angle with all fictitious meridians, but not with the terrestrial meridians. It is therefore a fictitious rhumb line. Near the tangent great circle, a straight line closely approximates a great circle. The projection is most useful in this area. Since the area of minimum distortion is near a meridian, this projection is useful for charts covering a large band of latitude and extending a relatively short distance on each side of the tangent meridian. It is sometimes used for star charts showing the evening sky at various seasons of the year. See Figure 307.
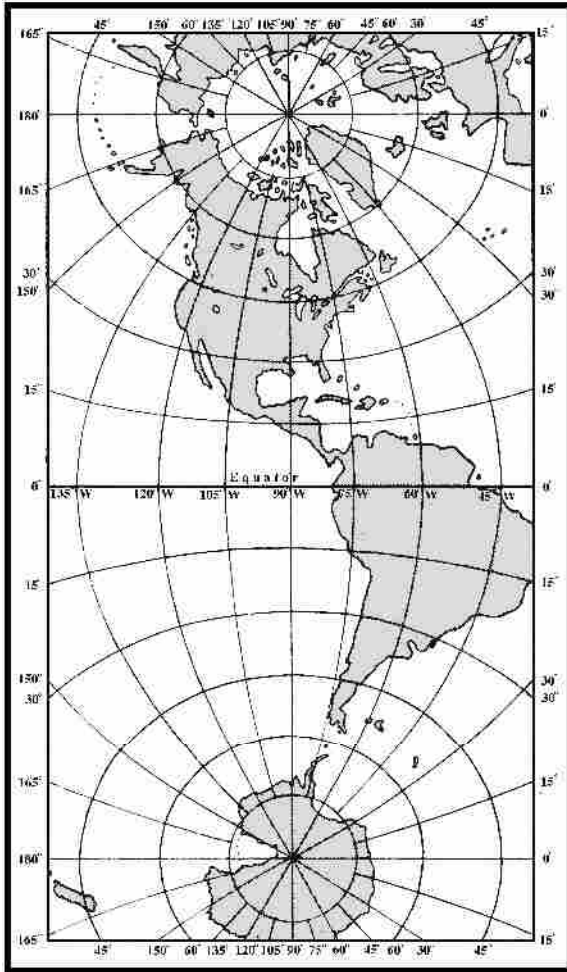
as the latitude changes.

Figure 307. A transverse Mercator map of the Western Hemisphere.

Figure 309a. An oblique Mercator projection.

308. Universal Transverse Mercator (UTM) Grid

The **Universal Transverse Mercator (UTM)** grid is a military grid superimposed upon a transverse Mercator graticule, or the representation of these grid lines upon any graticule. This grid system and these projections are often used for large-scale (harbor) nautical charts and military charts.

309. Oblique Mercator Projections

A Mercator projection in which the cylinder is tangent along a great circle other than the equator or a meridian is called an **oblique Mercator** or **oblique orthomorphic projection**. See Figure 309a and Figure 309b. This projection is used principally to depict an area in the near vicinity of an oblique great circle. Figure 309c, for example, shows the great circle joining Washington and Moscow. Figure 309d shows an oblique Mercator map with the great circle between these two centers as the tangent great circle or fictitious equator. The limits of the chart of Figure 309c are indicated in Figure 309d. Note the large variation in scale
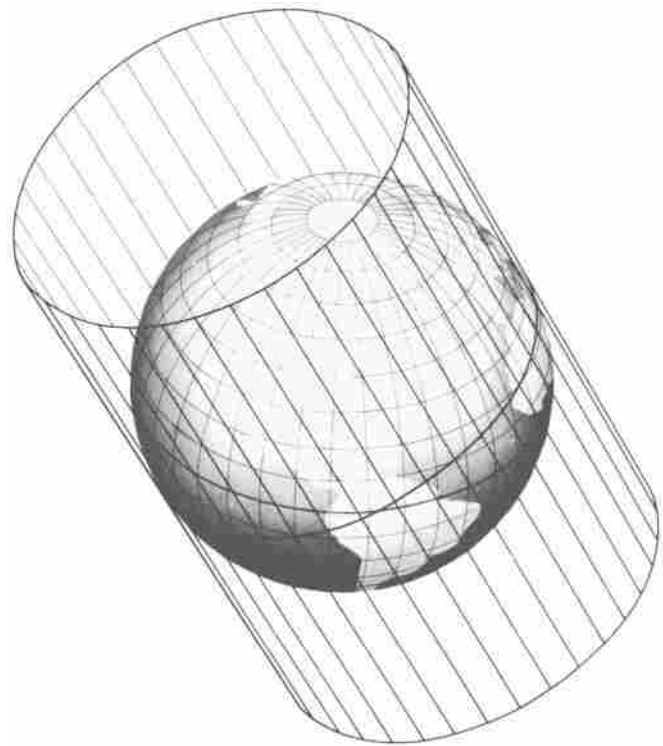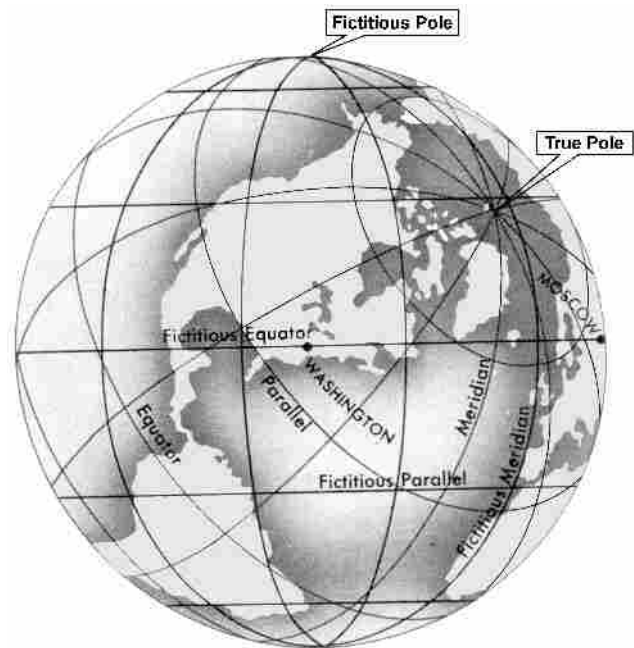

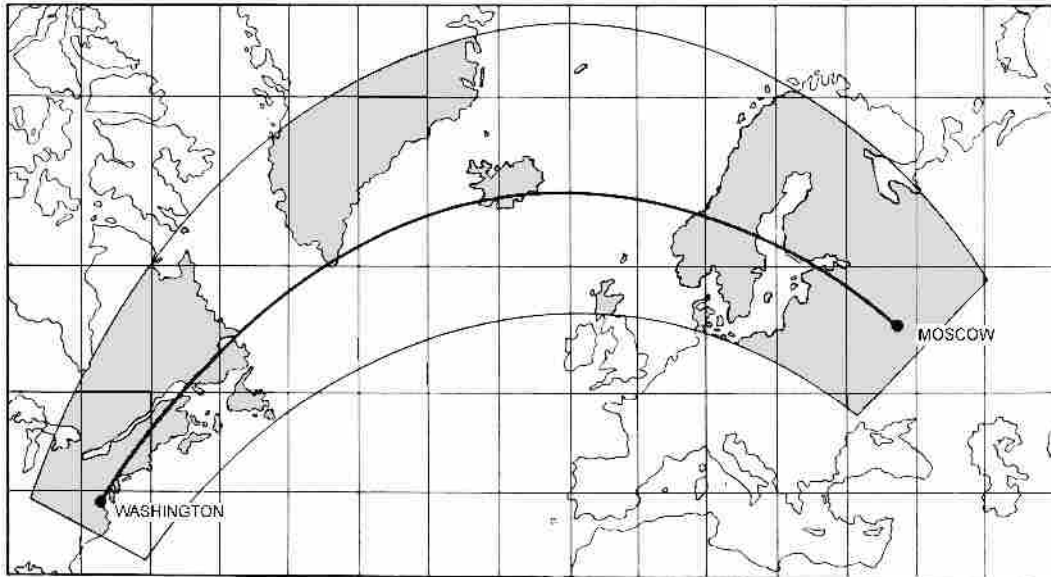*Figure 309b. The fictitious graticule of an oblique Mercator projection.*

Figure 309c. The great circle between Washington and Moscow as it appears on a Mercator map.
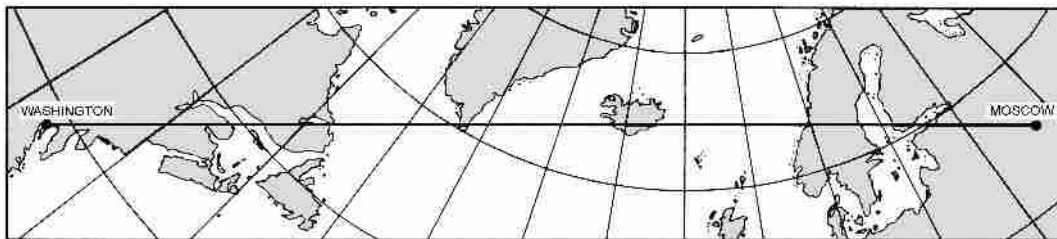

Figure 309d. An oblique Mercator map based upon a cylinder tangent along the great circle through Washington and Moscow. The map includes an area 500 miles on each side of the great circle. The limits of this map are indicated on the Mercator map of Figure 309c.

310. Rectangular Projection

A cylindrical projection similar to the Mercator, but with uniform spacing of the parallels, is called a **rectangular projection**. It is convenient for graphically depicting information where distortion is not important. The principal navigational use of this projection is for the star chart of the Air Almanac, where positions of stars are plotted by rectangular coordinates representing declination (ordinate) and sidereal hour angle (abscissa). Since the meridians are parallel, the parallels of latitude (including the equator and the poles) are all represented by lines of equal length.

311. Conic Projections

A **conic projection** is produced by transferring points from the surface of the earth to a cone or series of cones. This cone is then cut along an element and spread out flat to form the chart. When the axis of the cone coincides with the axis of the earth, then the parallels appear as arcs of circles, and the meridians appear as either straight or curved lines converging toward the nearer pole. Limiting the area covered to that part of the cone near the surface of the earth limits distortion. A parallel along which there is no distortion is called a **standard parallel**. Neither the transverse conic projection, in which the axis of the cone is in the equatorial plane, nor the oblique conic projection, in which the axis of the cone is oblique to the plane of the equator, is ordinarily used for navigation. They are typically used for illustrative maps.

Using cones tangent at various parallels, a secant (intersecting) cone, or a series of cones varies the appearance and features of a conic projection.

312. Simple Conic Projection

A conic projection using a single tangent cone is a **simple conic projection** (Figure 312a). The height of the cone increases as the latitude of the tangent parallel decreases. At the equator, the height reaches infinity and the cone be-

comes a cylinder. At the pole, its height is zero, and the cone becomes a plane. Similar to the Mercator projection, the simple conic projection is not perspective since only the meridians are projected geometrically, each becoming an element of the cone. When this projection is spread out flat to form a map, the meridians appear as straight lines converging at the apex of the cone. The standard parallel, where the cone is tangent to the earth, appears as the arc of a circle with its center at the apex of the cone. The other parallels are concentric circles. The distance along any meridian between consecutive parallels is in correct relation to the distance on the earth, and, therefore, can be derived mathematically. The pole is represented by a circle (Figure 312b). The scale is correct along any meridian and along the standard parallel. All other parallels are too great in length, with the error increasing with increased distance from the standard parallel. Since the scale is not the same in all directions about every point, the projection is neither a conformal nor equal-area projection. Its non-conformal nature is its principal disadvantage for navigation.

Since the scale is correct along the standard parallel and varies uniformly on each side, with comparatively little distortion near the standard parallel, this projection is useful for mapping an area covering a large spread of longitude and a comparatively narrow band of latitude. It was devel-
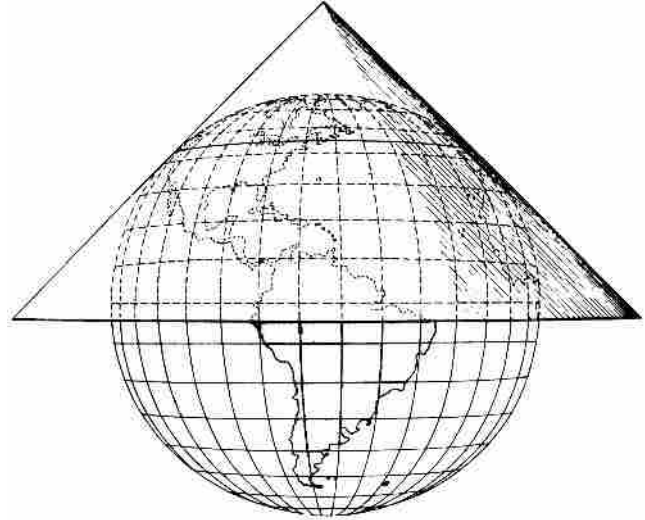

Figure 312a. A simple conic projection.

oped by Claudius Ptolemy in the second century A.D. to map just such an area: the Mediterranean Sea.
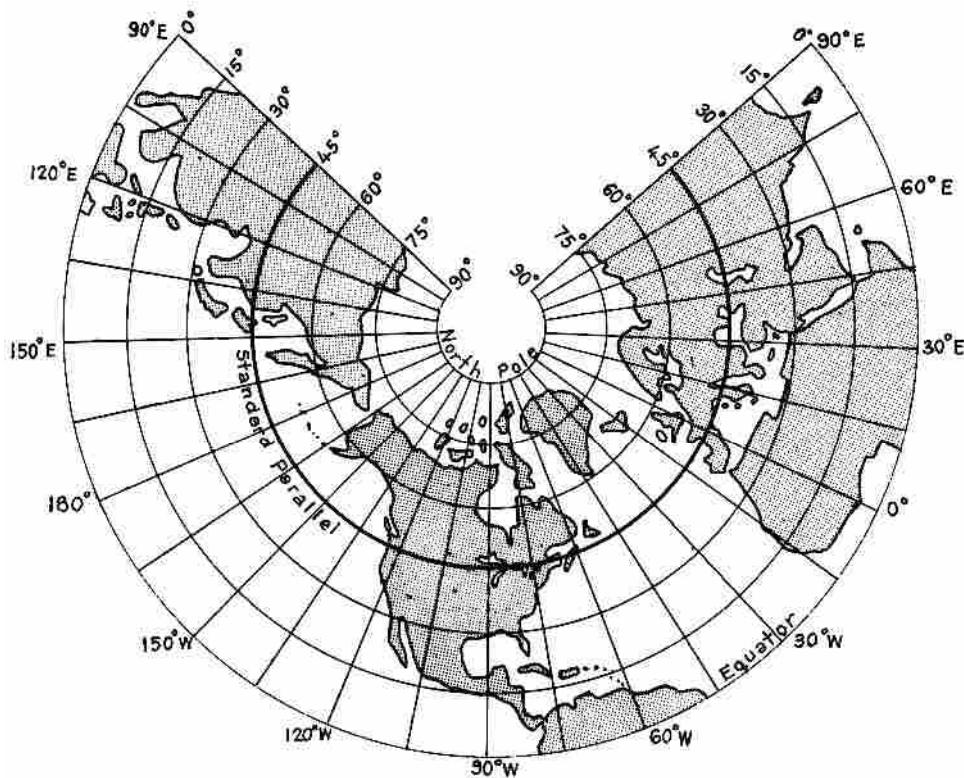

Figure 312b. A simple conic map of the Northern Hemisphere.

313. Lambert Conformal Projection

The useful latitude range of the simple conic projection can be increased by using a secant cone intersecting the earth at two standard parallels. See Figure 313. The area between the two standard parallels is compressed, and that beyond is expanded. Such a projection is called either a **secant conic** or **conic projection with two standard parallels**.
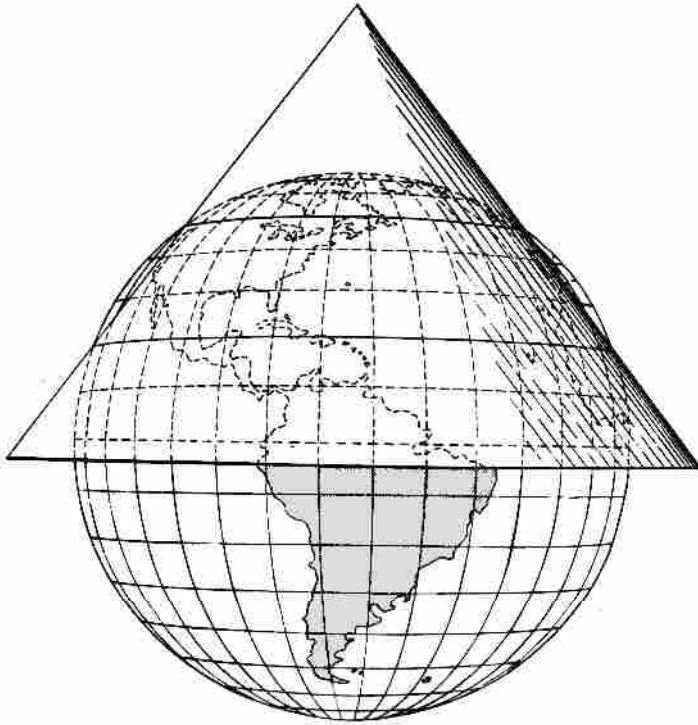

Figure 313. A secant cone for a conic projection with two standard parallels.

If in such a projection the spacing of the parallels is altered, such that the distortion is the same along them as along the meridians, the projection becomes conformal. This modification produces the **Lambert conformal projection**. If the chart is not carried far beyond the standard parallels, and if these are not a great distance apart, the distortion over the entire chart is small.

A straight line on this projection so nearly approximates a great circle that the two are nearly identical. Radio beacon signals travel great circles; thus, they can be plotted on this projection without correction. This feature, gained without sacrificing conformality, has made this projection popular for aeronautical charts because aircraft make wide use of radio aids to navigation. Except in high latitudes, where a slightly modified form of this projection has been used for polar charts, it has not replaced the Mercator projection for marine navigation.

314. Polyconic Projection

The latitude limitations of the secant conic projection can be minimized by using a series of cones. This results in a **poly-conic projection**. In this projection, each parallel is the base of a tangent cone. At the edges of the chart, the area between parallels is expanded to eliminate gaps. The scale is correct along any parallel and along the central meridian of the projection. Along other meridians the scale increases with increased difference of longitude from the central meridian. Parallels appear as nonconcentric circles; meridians appear as curved lines converging toward the pole and concave to the central meridian.

The polyconic projection is widely used in atlases, particularly for areas of large range in latitude and reasonably large range in longitude, such as continents. However, since it is not conformal, this projection is not customarily used in navigation.

315. Azimuthal Projections

If points on the earth are projected directly to a plane surface, a map is formed at once, without cutting and flattening, or "developing." This can be considered a special case of a conic projection in which the cone has zero height.

The simplest case of the **azimuthal projection** is one in which the plane is tangent at one of the poles. The meridians are straight lines intersecting at the pole, and the parallels are concentric circles with their common center at the pole. Their spacing depends upon the method used to transfer points from the earth to the plane.

If the plane is tangent at some point other than a pole, straight lines through the point of tangency are great circles, and concentric circles with their common center at the point of tangency connect points of equal distance from that point. Distortion, which is zero at the point of tangency, increases along any great circle through this point. Along any circle whose center is the point of tangency, the distortion is constant. The bearing of any point from the point of tangency is correctly represented. It is for this reason that these projections are called **azimuthal**. They are also called **zenithal**. Several of the common azimuthal projections are perspective.

316. Gnomonic Projection

If a plane is tangent to the earth, and points are projected geometrically from the center of the earth, the result is a **gnomonic projection**. See Figure 316a. Since the projection is perspective, it can be demonstrated by placing a light at the center of a transparent terrestrial globe and holding a flat surface tangent to the sphere.

In an **oblique gnomonic projection** the meridians appear as straight lines converging toward the nearer pole. The parallels, except the equator, appear as curves (Figure 316b). As in all azimuthal projections, bearings from the point of tangency are correctly represented. The distance scale, however, changes rapidly. The projection is neither conformal nor equal area. Distortion is so great that shapes, as well as distances and areas, are very poorly represented, except near the point of tangency.
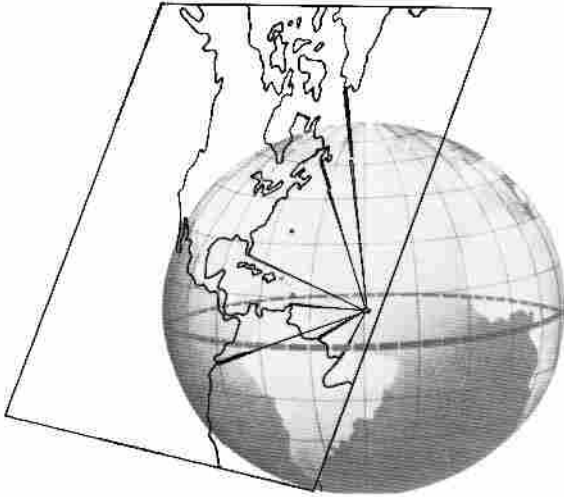
The scale of the stereographic projection increases with distance from the point of tangency, but it increases more slowly than in the gnomonic projection. The stereographic projection can show an entire hemisphere without excessive distortion (Figure 317b). As in other azimuthal

Figure 316a. An oblique gnomonic projection.

The usefulness of this projection rests upon the fact

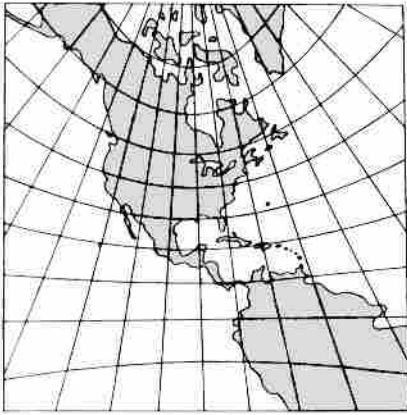

Figure 317a. An equatorial stereographic projection.

Figure 316b. An oblique gnomonic map with point of tangency at latitude 30°N, longitude 90°W.

that any great circle appears on the map as a straight line, giving charts made on this projection the common name **great-circle charts**.

Gnomonic charts are most often used for planning the great-circle track between points. Points along the determined track are then transferred to a Mercator projection. The great circle is then followed by following the rhumb lines from one point to the next. Computer programs which automatically calculate great circle routes between points and provide latitude and longitude of corresponding rhumb line endpoints are quickly making this use of the gnomonic chart obsolete.

317. Stereographic Projection

A **stereographic projection** results from projecting points on the surface of the earth onto a tangent plane, from a point on the surface of the earth opposite the point of tangency (Figure 317a). This projection is also called an **azimuthal orthomorphic projection**.
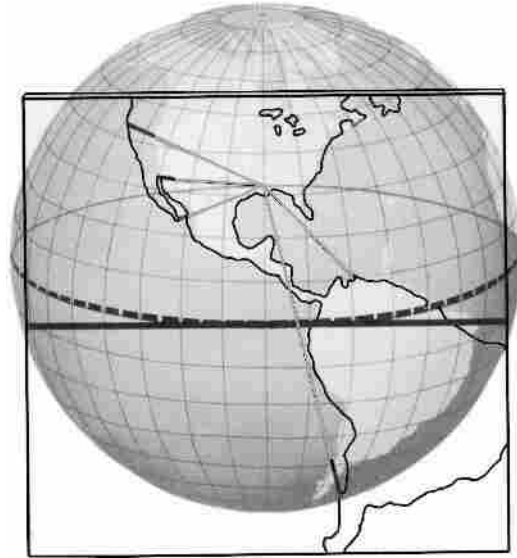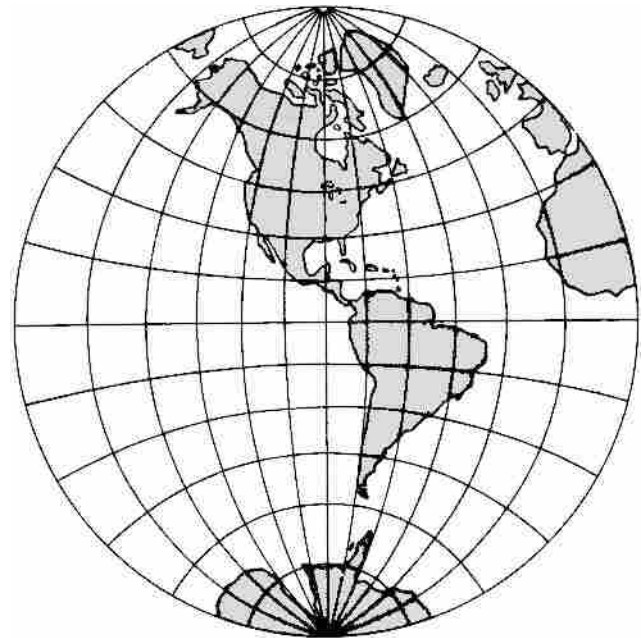

Figure 317b. A stereographic map of the Western Hemisphere.

projections, great circles through the point of tangency appear as straight lines. Other circles such as meridians and parallels appear as either circles or arcs of circles.

The principal navigational use of the stereographic projection is for charts of the polar regions and devices for mechanical or graphical solution of the navigational triangle. A **Universal Polar Stereographic (UPS)** grid, mathematically adjusted to the graticule, is used as a reference system.

318. Orthographic Projection

If terrestrial points are projected geometrically from infinity to a tangent plane, an **orthographic projection** results (Figure 318a). This projection is not conformal; nor does it result in an equal area representation. Its principal use is in navigational astronomy because it is useful for illustrating and solving the navigational triangle. It is also useful for illustrating celestial coordinates. If the plane is tangent at a point on the equator, the parallels (including the equator) appear as straight lines. The meridians would appear as ellipses, except that the meridian through the point of tangency would appear as a straight line and the one 90° away would appear as a circle (Figure 318b).
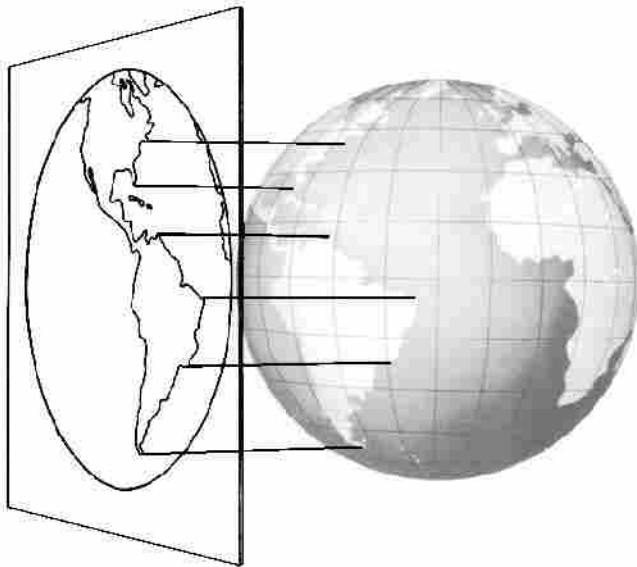
319. Azimuthal Equidistant Projection

An **azimuthal equidistant projection** is an azimuthal projection in which the distance scale along any great circle through the point of tangency is constant. If a pole is the point of tangency, the meridians appear as straight radial lines and the parallels as equally spaced concentric circles. If the plane is tangent at some point other than a pole, the concentric circles represent distances from the point of tangency. In this case, meridians and parallels appear as curves.

The projection can be used to portray the entire earth, the point 180° from the point of tangency appearing as the largest of the concentric circles. The projection is not conformal, equal area, or perspective. Near the point of tangency distortion is small, increasing with distance until shapes near the opposite side of the earth are unrecognizable (Figure 319).

The projection is useful because it combines the three features of being azimuthal, having a constant distance scale from the point of tangency, and permitting the entire earth to be shown on one map. Thus, if an important harbor or airport is selected as the point of tangency, the great-circle course, distance, and track from that point to any other point on the earth are quickly and accurately determined. For communication work with the station at the point of tangency, the path of an incoming signal is at once apparent if the direction of arrival has been determined and the direction to train a directional antenna can be determined easily. The projection is also used for polar charts and for the star finder, No. 2102D.

Figure 318a. An equatorial orthographic projection.

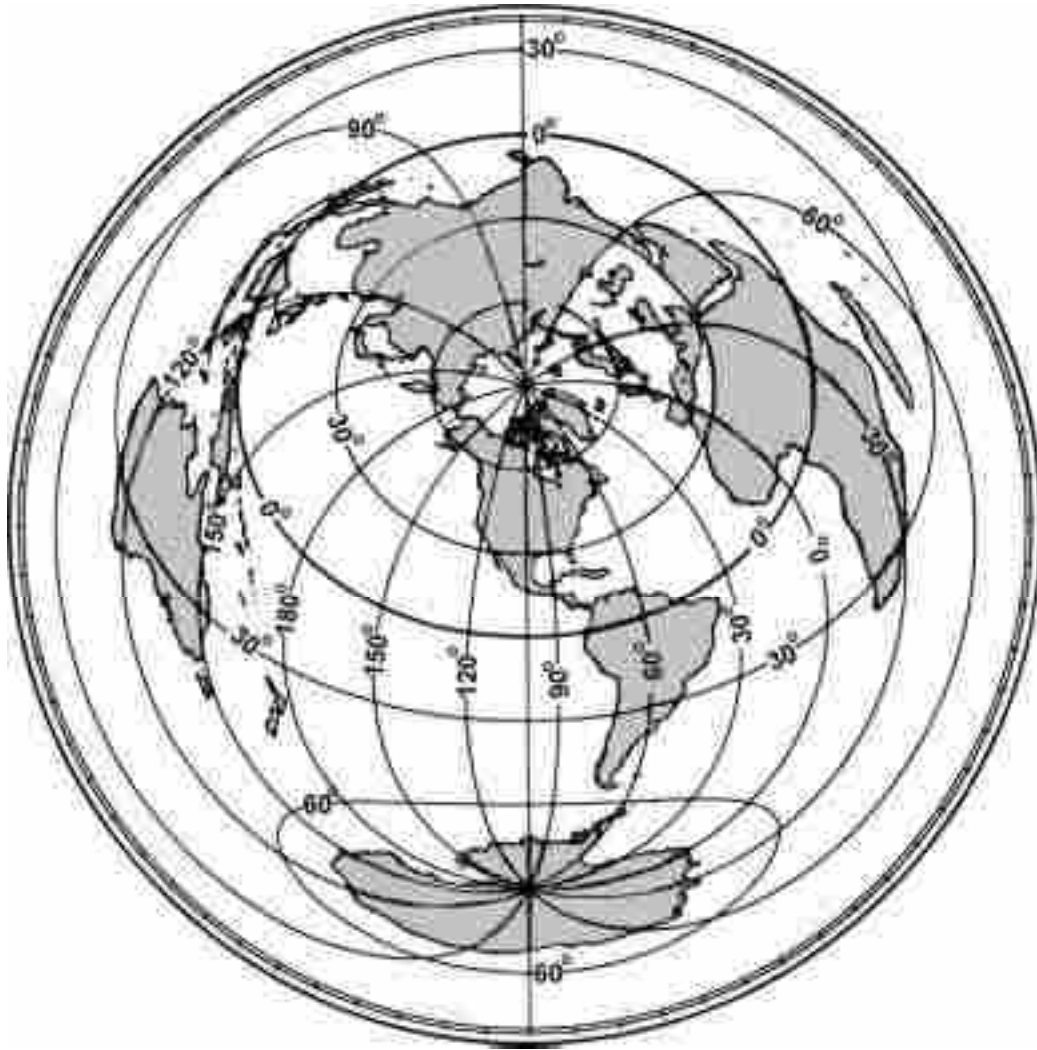*Figure 318b. An orthographic map of the Western Hemisphere.*

Figure 319. An azimuthal equidistant map of the world with the point of tangency latitude 40°N, longitude 100°W.

POLAR CHARTS

320. Polar Projections

Special consideration is given to the selection of projections for polar charts because the familiar projections become special cases with unique features.

In the case of cylindrical projections in which the axis of the cylinder is parallel to the polar axis of the earth, distortion becomes excessive and the scale changes rapidly. Such projections cannot be carried to the poles. However, both the transverse and oblique Mercator projections are used.

Conic projections with their axes parallel to the earth's polar axis are limited in their usefulness for polar charts because parallels of latitude extending through a full 360° of longitude appear as arcs of circles rather than full circles. This is because a cone, when cut along an element and flattened, does not extend

through a full 360° without stretching or resuming its former conical shape. The usefulness of such projections is also limited by the fact that the pole appears as an arc of a circle instead of a point. However, by using a parallel very near the pole as the higher standard parallel, a conic projection with two standard parallels can be made. This requires little stretching to complete the circles of the parallels and eliminate that of the pole. Such a projection, called a **modified Lambert conformal** or **Ney's projection**, is useful for polar charts. It is particularly familiar to those accustomed to using the ordinary Lambert conformal charts in lower latitudes.

Azimuthal projections are in their simplest form when tangent at a pole. This is because the meridians are straight lines intersecting at the pole, and parallels are concentric circles with their common center at the pole. Within a few

degrees of latitude of the pole they all look similar; however, as the distance becomes greater, the spacing of the parallels becomes distinctive in each projection. In the polar azimuthal equidistant it is uniform; in the polar stereographic it increases with distance from the pole until the equator is shown at a distance from the pole equal to twice the length of the radius of the earth; in the polar gnomonic the increase is considerably greater, becoming infinity at the equator; in the polar orthographic it decreases with distance from the pole (Figure 320). All of these but the last are used for polar charts.
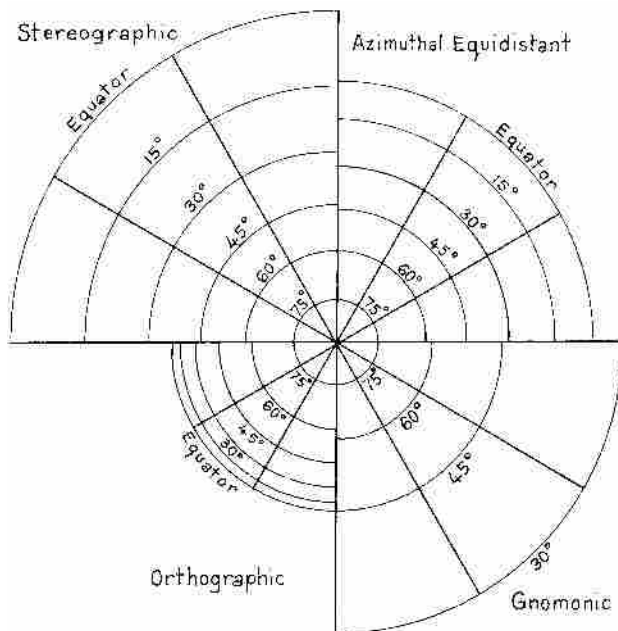

Figure 320. Expansion of polar azimuthal projections.

321. Selection of a Polar Projection

The principal considerations in the choice of a suitable projection for polar navigation are:

1. Conformality: When the projection represents angles correctly, the navigator can plot directly on the chart.
2. Great circle representation: Because great circles are more useful than rhumb lines at high altitudes, the projection should represent great circles as straight lines.
3. Scale variation: The projection should have a constant scale over the entire chart.
4. Meridian representation: The projection should show straight meridians to facilitate plotting and grid navigation
5. Limits: Wide limits reduce the number of projections needed to a minimum.

The projections commonly used for polar charts are the modified Lambert conformal, gnomonic, stereographic, and azimuthal equidistant. All of these projections are similar near the pole. All are essentially conformal, and a great circle on each is nearly a straight line.

As the distance from the pole increases, however, the distinctive features of each projection become important. The modified Lambert conformal projection is virtually conformal over its entire extent. The amount of its scale distortion is comparatively little if it is carried only to about 25° or 30° from the pole. Beyond this, the distortion increases rapidly. A great circle is very nearly a straight line anywhere on the chart. Distances and directions can be measured directly on the chart in the same manner as on a Lambert conformal chart. However, because this projection is not strictly conformal, and on it great circles are not exactly represented by straight lines, it is not suited for highly accurate work.

The polar gnomonic projection is the one polar projection on which great circles are exactly straight lines. However, a complete hemisphere cannot be represented upon a plane because the radius of 90° from the center would become infinity.

The polar stereographic projection is conformal over its entire extent, and a straight line closely approximates a great circle. See Figure 321. The scale distortion is not excessive for a considerable distance from the pole, but it is greater than that of the modified Lambert conformal projection.
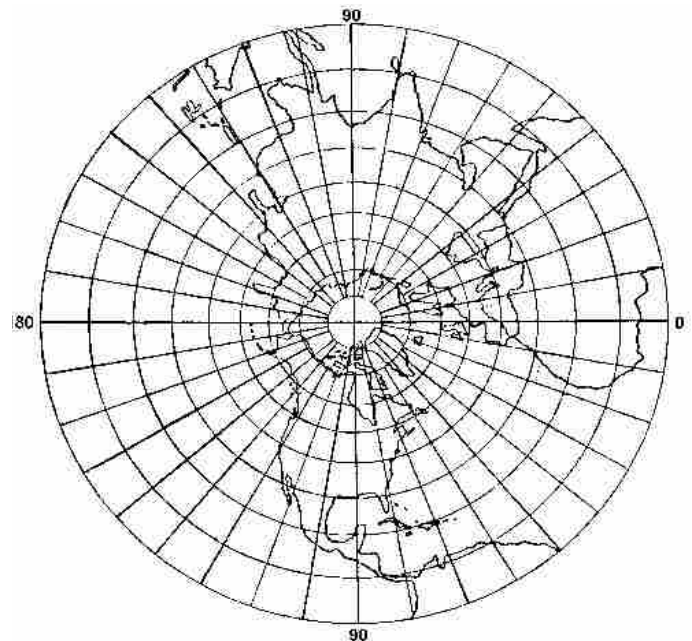

Figure 321. Polar stereographic projection.

The polar azimuthal equidistant projection is useful for showing a large area such as a hemisphere because there is

no expansion along the meridians. However, the projection is not conformal and distances cannot be measured accurately in any but a north-south direction. Great circles other than the meridians differ somewhat from straight lines. The equator is a circle centered at the pole.

The two projections most commonly used for polar charts are the modified Lambert conformal and the polar stereographic. When a directional gyro is used as a directional reference, the track of the craft is approximately a great circle. A desirable chart is one on which a great circle is represented as a straight line with a constant scale and with angles correctly represented. These requirements are not met entirely by any single projection, but they are approximated by both the modified Lambert conformal and the polar stereographic. The scale is more nearly constant on the former,

but the projection is not strictly conformal. The polar stereographic is conformal, and its maximum scale variation can be reduced by using a plane which intersects the earth at some parallel intermediate between the pole and the lowest parallel. The portion within this standard parallel is compressed, and that portion outside is expanded.

The selection of a suitable projection for use in polar regions depends upon mission requirements. These requirements establish the relative importance of various features. For a relatively small area, any of several projections is suitable. For a large area, however, the choice is more difficult. If grid directions are to be used, it is important that all units in related operations use charts on the same projection, with the same standard parallels, so that a single grid direction exists between any two points.

SPECIAL CHARTS

322. Plotting Sheets

Position plotting sheets are "charts" designed primarily for open ocean navigation, where land, visual aids to navigation, and depth of water are not factors in navigation. They have a latitude and longitude graticule, and they may have one or more compass roses. The meridians are usually unlabeled, so a plotting sheet can be used for any longitude. Plotting sheets on Mercator projection are specific to latitude, and the navigator should have enough aboard for all latitudes for his voyage. Plotting sheets are less expensive than charts.

A plotting sheet may be used in an emergency when charts have been lost or destroyed. Directions on how to construct plotting sheets suitable for emergency purposes are given in Chapter 26, Emergency Navigation.

323. Grids

No system exists for showing the surface of the earth on a plane without distortion. Moreover, the appearance of

the surface varies with the projection and with the relation of that surface area to the point of tangency. One may want to identify a location or area simply by alpha-numeric rectangular coordinates. This is accomplished with a **grid**. In its usual form this consists of two series of lines drawn perpendicularly on the chart, marked by suitable alpha-numeric designations.

A grid may use the rectangular graticule of the Mercator projection or a set of arbitrary lines on a particular projection. **The World Geodetic Reference System (GEOREF)** is a method of designating latitude and longitude by a system of letters and numbers instead of by angular measure. It is not, therefore, strictly a grid. It is useful for operations extending over a wide area. Examples of the second type of grid are the **Universal Transverse Mercator (UTM)** grid, the **Universal Polar Stereographic (UPS)** grid, and the **Temporary Geographic Grid (TGG)**. Since these systems are used primarily by military forces, they are sometimes called military grids.

CHART SCALES

324. Types Of Scales

The **scale** of a chart is the ratio of a given distance on the chart to the actual distance which it represents on the earth. It may be expressed in various ways. The most common are:

1. A simple ratio or fraction, known as the **representative fraction**. For example, 1:80,000 or 1/80,000 means that one unit (such as a meter) on the chart represents 80,000 of the same unit on the surface of the earth. This scale is sometimes called the **natural** or **fractional** scale.

2. A **statement** that a given distance on the earth equals a given measure on the chart, or vice versa. For example, "30 miles to the inch" means that 1 inch on the chart represents 30 miles of the earth's surface. Similarly, "2 inches to a mile" indicates that 2 inches on the chart represent 1 mile on the earth. This is sometimes called the **numerical scale**.

3. A line or bar called a **graphic scale** may be drawn at a convenient place on the chart and subdivided into nautical miles, meters, etc. All charts vary somewhat in scale from point to point, and in some projections the scale is not the same in all directions about a single

point. A single subdivided line or bar for use over an entire chart is shown only when the chart is of such scale and projection that the scale varies a negligible amount over the chart, usually one of about 1:75,000 or larger. Since 1 minute of latitude is very nearly equal to 1 nautical mile, the latitude scale serves as an approximate graphic scale. On most nautical charts the east and west borders are subdivided to facilitate distance measurements.

On a Mercator chart the scale varies with the latitude. This is noticeable on a chart covering a relatively large distance in a north-south direction. On such a chart the border scale near the latitude in question should be used for measuring distances.

Of the various methods of indicating scale, the graphical method is normally available in some form on the chart. In addition, the scale is customarily stated on charts on which the scale does not change appreciably over the chart.

The ways of expressing the scale of a chart are readily interchangeable. For instance, in a nautical mile there are about 72,913.39 inches. If the natural scale of a chart is 1:80,000, one inch of the chart represents 80,000 inches of the earth, or a little more than a mile. To find the exact amount, divide the scale by the number of inches in a mile, or 80,000/72,913.39 = 1.097. Thus, a scale of 1:80,000 is the same as a scale of 1.097 (or approximately 1.1) miles to an inch. Stated another way, there are: 72,913.39/80,000 = 0.911 (approximately 0.9) inch to a mile. Similarly, if the scale is 60 nautical miles to an inch, the representative fraction is 1:(60 x 72,913.39) = 1:4,374,803.

A chart covering a relatively large area is called a **small-scale chart** and one covering a relatively small area is called a **large-scale chart**. Since the terms are relative, there is no sharp division between the two. Thus, a chart of scale 1:100,000 is large scale when compared with a chart of 1:1,000,000 but small scale when compared with one of 1:25,000.

As scale decreases, the amount of detail which can be shown decreases also. Cartographers selectively decrease the detail in a process called **generalization** when producing small scale charts using large scale charts as sources. The amount of detail shown depends on several factors, among them the coverage of the area at larger scales and the intended use of the chart.

325. Chart Classification by Scale

Charts are constructed on many different scales, ranging from about 1:2,500 to 1:14,000,000. Small-scale charts covering large areas are used for route planning and for offshore navigation. Charts of larger scale, covering smaller areas, are used as the vessel approaches land. Several methods of classifying charts according to scale are used in various nations. The following classifications of nautical charts are used by the National Ocean Service.

Sailing charts are the smallest scale charts used for planning, fixing position at sea, and for plotting the dead reckoning while proceeding on a long voyage. The scale is generally smaller than 1:600,000. The shoreline and topography are generalized and only offshore soundings, the principal navigational lights, outer buoys, and landmarks visible at considerable distances are shown.

General charts are intended for coastwise navigation outside of outlying reefs and shoals. The scales range from about 1:150,000 to 1:600,000.

Coastal charts are intended for inshore coastwise navigation, for entering or leaving bays and harbors of considerable width, and for navigating large inland waterways. The scales range from about 1:50,000 to 1:150,000.

Harbor charts are intended for navigation and anchorage in harbors and small waterways. The scale is generally larger than 1:50,000.

In the classification system used by NIMA, the sailing charts are incorporated in the general charts classification (smaller than about 1:150,000); those coast charts especially useful for approaching more confined waters (bays, harbors) are classified as approach charts. There is considerable overlap in these designations, and the classification of a chart is best determined by its use and by its relationship to other charts of the area. The use of insets complicates the placement of charts into rigid classifications.

CHART ACCURACY

326. Factors Relating to Accuracy

The accuracy of a chart depends upon the accuracy of the hydrographic surveys and other data sources used to compile it and the suitability of its scale for its intended use.

One can sometimes estimate the accuracy of a chart's surveys from the source notes given in the title of the chart. If the chart is based upon very old surveys, use it with caution. Many early surveys were inaccurate because of the technological limitations of the surveyor.

The number of soundings and their spacing indicates the completeness of the survey. Only a small fraction of the soundings taken in a thorough survey are shown on the chart, but sparse or unevenly distributed soundings indicate that the survey was probably not made in detail. See Figure 326a and Figure 326b. Large blank areas or absence of depth contours generally indicate lack of soundings in the area. Operate in an area with sparse sounding data only if required and then only with extreme caution. Run the echo sounder continuously and operate at a reduced speed.
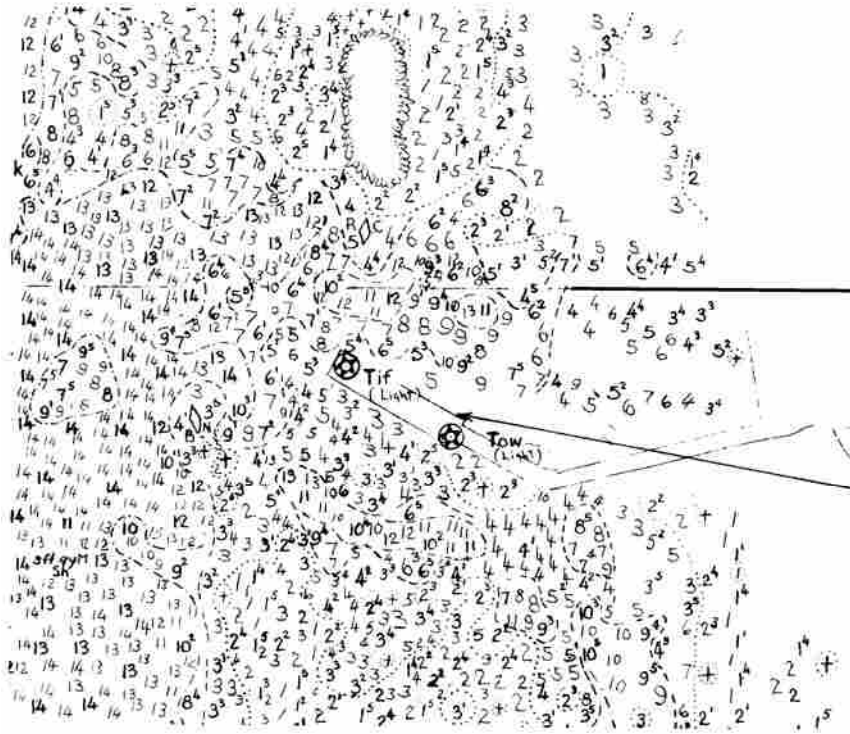
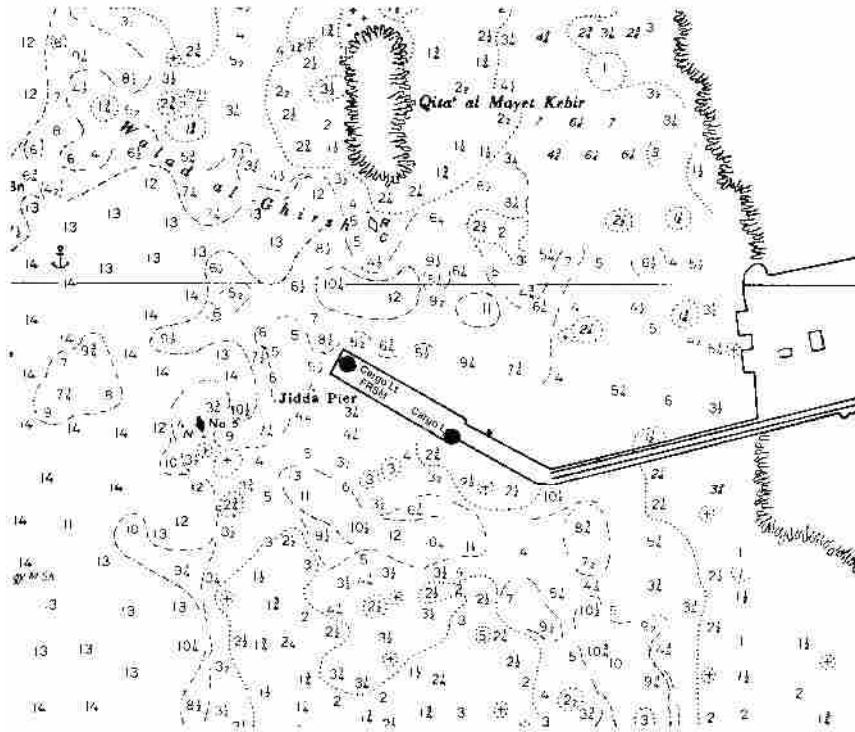*Figure 326a. Part of a "boat sheet," showing the soundings obtained in a survey.*

Figure 326b. Part of a nautical chart made from the boat sheet of Figure 326a. *Compare the number of soundings in the two figures.*

Sparse sounding information does not necessarily indicate an incomplete survey. Relatively few soundings are shown when there is a large number of depth contours, or where the bottom is flat, or gently and evenly sloping. Additional soundings are shown when they are helpful in indicating the uneven character of a rough bottom.

Even a detailed survey may fail to locate every rock or pinnacle. In waters where they might be located, the best method for finding them is a wire drag survey. Areas that have been dragged may be indicated on the chart by limiting lines and green or purple tint and a note added to show the effective depth at which the drag was operated.

Changes in bottom contours are relatively rapid in areas such as entrances to harbors where there are strong currents or heavy surf. Similarly, there is sometimes a tendency for dredged channels to shoal, especially if they are surrounded by sand or mud, and cross currents exist. Charts often contain notes indicating the bottom contours are known to change rapidly.

The same detail cannot be shown on a small-scale chart as on a large scale chart. On small-scale charts, detailed information is omitted or "generalized" in the areas covered by larger scale charts. The navigator should use the largest scale chart available for the area in which he is operating, especially when operating in the vicinity of hazards.

Charting agencies continually evaluate both the detail and the presentation of data appearing on a chart. Development of a new navigational aid may render previous charts inadequate. The development of radar, for example, required upgrading charts which lacked the detail required for reliable identification of radar targets.

After receiving a chart, the user is responsible for keeping it updated. Mariner's reports of errors, changes, and suggestions are useful to charting agencies. Even with modern automated data collection techniques, there is no substitute for on-sight observation of hydrographic conditions by experienced mariners. This holds true especially in less frequently traveled areas of the world.

CHART READING

327. Chart Dates

NOS charts have two dates. At the top center of the chart is the date of the first edition of the chart. In the lower left corner of the chart is the current edition number and date. This date shows the latest date through which *Notice to Mariners* were applied to the chart. Any subsequent change will be printed in the *Notice to Mariners*. Any notices which accumulate between the chart date and the announcement date in the *Notice to Mariners* will be given with the announcement. Comparing the dates of the first and current editions gives an indication of how often the chart is updated. Charts of busy areas are updated more frequently than those of less traveled areas. This interval may vary from 6 months to more than ten years for NOS charts. This update interval may be much longer for certain NIMA charts in remote areas.

New editions of charts are both demand and source driven. Receiving significant new information may or may not initiate a new edition of a chart, depending on the demand for that chart. If it is in a sparsely-traveled area, other priorities may delay a new edition for several years. Conversely, a new edition may be printed without the receipt of significant new data if demand for the chart is high and stock levels are low. *Notice to Mariners* corrections are always included on new editions.

NIMA charts have the same two dates as the NOS charts; the current chart edition number and date is given in the lower left corner. Certain NIMA charts are reproductions of foreign charts produced under joint agreements with a number of other countries. These charts, even though of recent date, may be based on foreign charts of considerably earlier date. Further, new editions of the foreign chart will not necessarily result in a new edition of the NIMA reproduction. In these cases, the foreign chart is the better chart to use.

328. Title Block

The chart title block should be the first thing a navigator looks at when receiving a new edition chart. Refer to Figure 328. The title itself tells what area the chart covers. The chart's scale and projection appear below the title. The chart will give both vertical and horizontal datums and, if necessary, a datum conversion note. Source notes or diagrams will list the date of surveys and other charts used in compilation.

329. Shoreline

The shoreline shown on nautical charts represents the line of contact between the land and water at a selected vertical datum. In areas affected by tidal fluctuations, this is usually the mean high-water line. In confined coastal waters of diminished tidal influence, a mean water level line may be used. The shoreline of interior waters (rivers, lakes) is usually a line representing a specified elevation above a