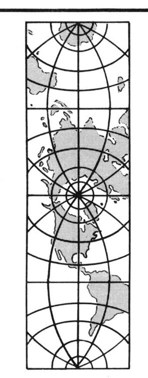
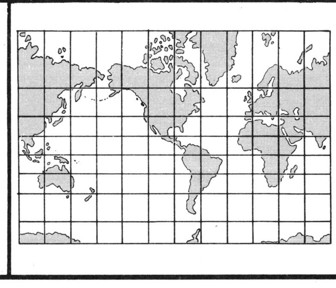
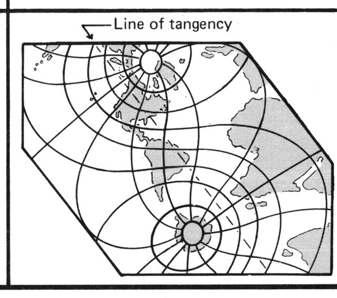
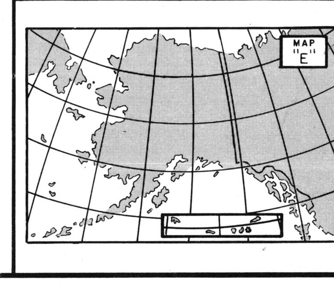
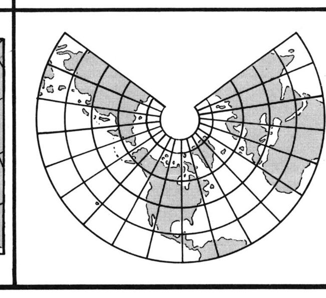
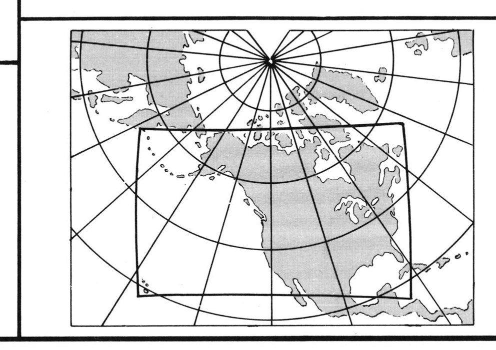
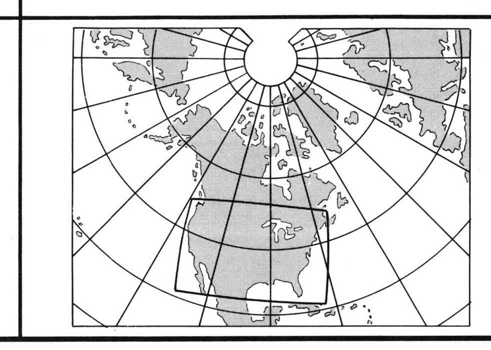
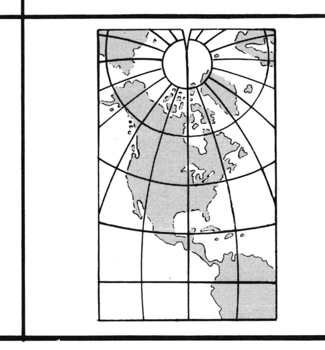
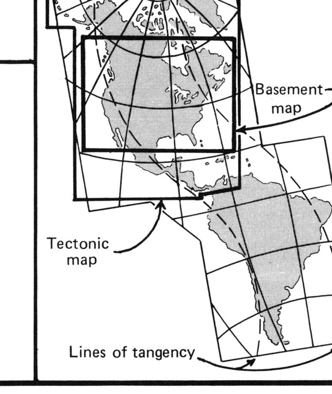
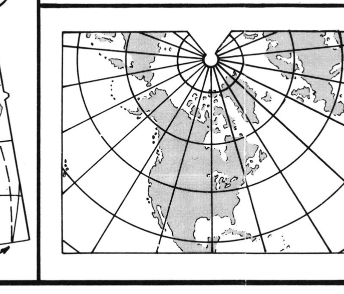
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS INVESTIGATIONS SERIES
MAP I – 1096

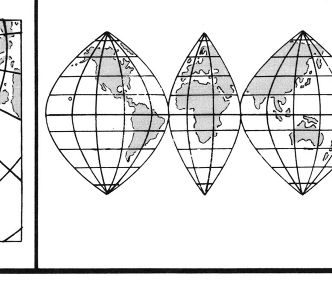
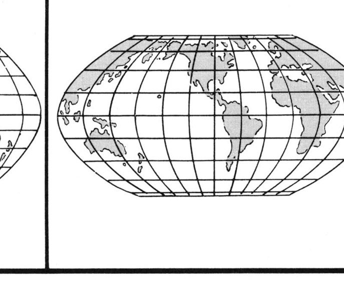
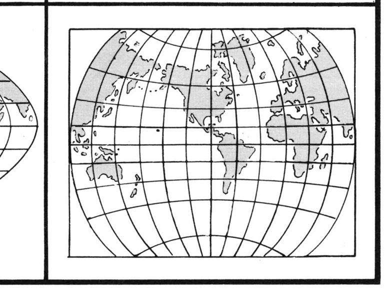
Cylinders

Type of map projection	Mercator	Oblique Mercator	Transverse Mercator	Modified Transverse Mercator
	Conformal			
Lines of longitude (meridians)	Meridians are straight and parallel.	Meridians are curved concave toward the line of tangency.	Meridians are curved concave toward a straight central meridian that is tangent to the globe. The straight central meridian intersects the equator and one meridian at a 90° angle.	On pre-1973 editions of the Alaska Map E, meridians are curved concave toward the center of the projection. On post-1973 editions the meridians are straight.
Lines of latitude (parallels)	Latitude lines are straight and parallel.	Parallels are curved concave toward the nearest pole.	Parallels are arcs concave toward the nearest pole; the equator is straight.	Parallels are arcs concave to the pole.
Graticule spacing	Meridian spacing is equal, and the parallel spacing increases away from the equator. The graticule spacing retains the property of conformality. The graticule is symmetrical. Meridians and parallels intersect at right angles.	Graticule spacing increases away from the line of tangency and retains the property of conformality.	Parallels are equally spaced on the straight central meridian. Graticule spacing increases away from the tangent meridian. The graticule retains the property of conformality.	Meridian spacing is equal and decreases toward the pole. Parallels are approximately equally spaced. The graticule is symmetrical on post-1973 editions.
Linear scale	Linear scale is true along the equator only (line of tangency). Scale can be determined by using a degree of latitude, which equals 60 nautical miles, 69 statute miles, or 110–111 kilometers.	Linear scale is true along the line of tangency only	Linear scale is true along the line of tangency only.	Linear scale is more nearly correct along the meridians than along the parallels.
Notes	Projection can be thought of as being mathematically based on a cylinder tangent at the equator. Any straight line is a constant-azimuth (rhumb) line. Areal enlargement is extreme away from the equator; the poles cannot be represented. Shape is true only within any small area. Reasonably accurate projection within a 15° band along the line of tangency.	Projection is mathematically based on a cylinder tangent along any great circle between the equator and the pole. Shape is true only within any small area. Areal enlargement increases away from the line of tangency. Reasonably accurate projection within a 15° band along the line of tangency.	Projection is mathematically based on a cylinder tangent to a meridian. Shape is true only within any small area. Areal enlargment increases away from the tangent meridian. Reasonably accurate projection within a 15° band along the line of tangency. Cannot be edge-joined for more than a few sheets.	The Alaska Map E is tangent at several meridians, 8° apart. A small transverse Mercator projection 8° wide and approximately 18° long was repeated east and west of an arbitrary point of origin until a projection 72° wide was obtained.
Uses	An excellent projection for equatorial regions. Otherwise the Mercator is a special purpose map best suited for navigation. It can be constructed secant at other latitudes to obtain exact linear scale. Such constructions are used for large-scale coastal charts.	Useful for plotting linear configurations that are situated along a line oblique to the earth's graticule. Examples are: NASA Surveyor Satellite tracking charts, ERTS flight indexes, strip charts for navigation, and the National Geographic Society's maps "West Indies" and "Countries of the Caribbean."	Used where the north-south direction is greater than the east-west direction. Used as the base for the U.S. Geological Survey's 1:250,000-scale series and some of the 7½-minute and 15-minute quadrangles of the National Topographic Maps. 	The U.S. Geological Survey's Alaska Map E at the scale of 1:2,500,000. The figure below represents the 1954 edition. The 1973 edition is similar, but the meridians are straight.
Examples				

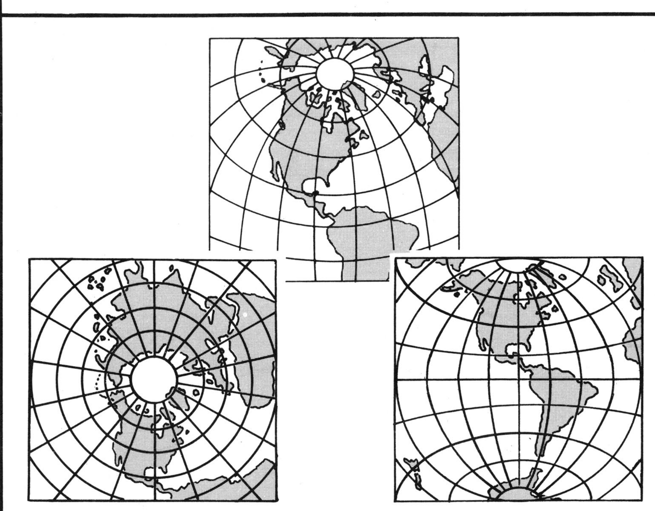
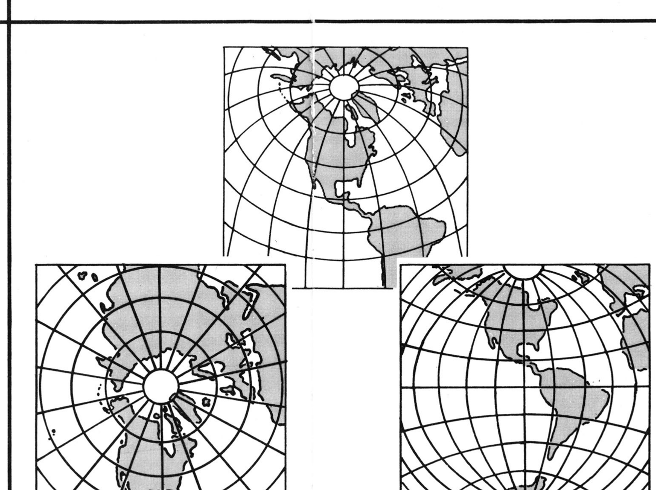
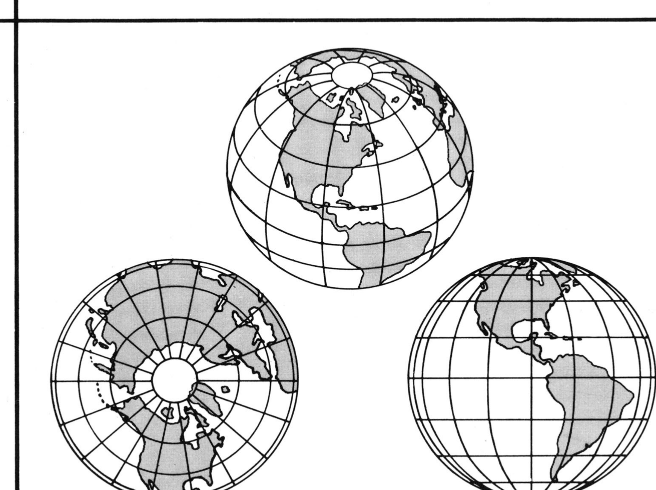
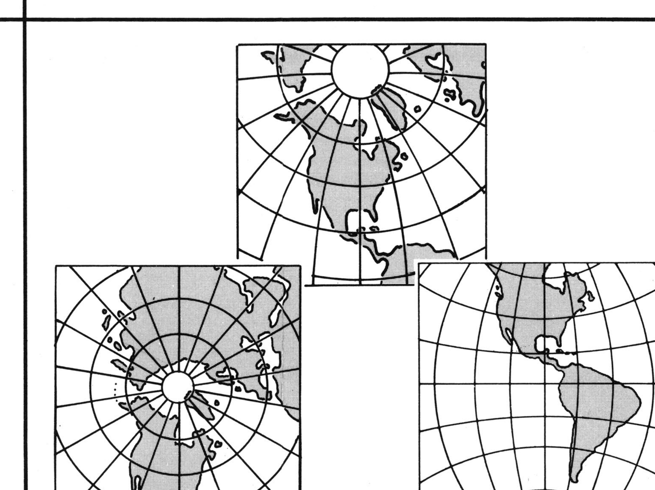
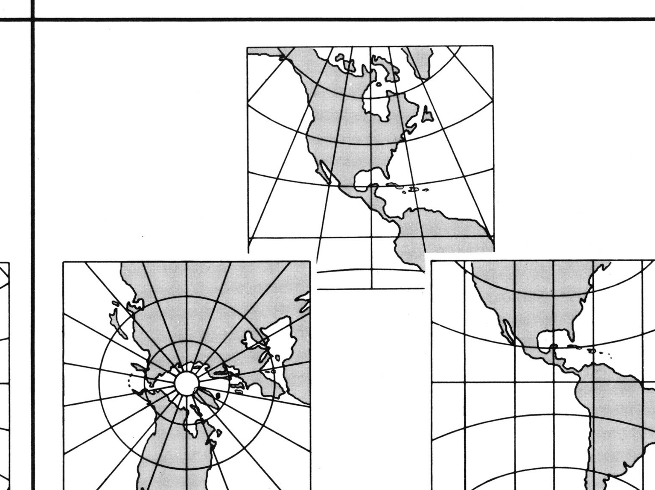
Cones

Type of map projection	Simple Conic	Lambert Conic Conformal	Albers Conic Equal-Area	American Polyconic	Bipolar Oblique Conic Conformal	Kavraisky No. 4
		Conformal	Equal-area		Conformal	Compromise
Lines of longitude (meridians)	Meridians are straight lines converging on the polar axis.	Meridians are straight lines converging at a pole.	Meridians are straight lines converging on the polar axis.	Meridians are curved concave toward a straight central meridian.	Meridians are curved concave toward the center of the projection.	Meridians are straight lines converging on the polar axis.
Lines of latitude (parallels)	Parallels are concentric circles concave toward a pole.	Parallels are concentric circles concave toward the pole and centered at the pole.	Parallels are concentric circles concave toward the pole.	Parallels are nonconcentric circles except for a straight equator.	Parallels are curved concave toward the nearest pole.	Parallels are concentric circles curved concave toward the nearest pole.
Graticule spacing	Meridian spacing increases equally toward the periphery with equal parallel spacing. The spacing of the parallels determines whether the projection will be conformal, equal-area, or a compromise. The graticule is symmetrical.	Meridian spacing is true on the standard parallels and decreases toward the pole. Parallel spacing increases away from the standard parallels and decreases between them. The graticule spacing retains the property of conformality. The graticule is symmetrical.	Meridian spacing is equal on the standard parallels and decreases toward the poles. Parallel spacing decreases away from the standard parallels and increases between them. Meridians and parallels intersect each other at approximately right angles. The graticule spacing preserves the property of equivalence of area. The graticule is symmetrical.	Meridian spacing is equal and decreases toward the poles. Parallels are spaced equally on the central meridian, and the spacing increases toward the east and west borders. The graticule spacing results in a compromise of all properties.	Graticule spacing increases away from the lines of tangency and retains the property of conformality.	Meridian spacing is equal and decreases toward the poles. Parallel spacing is approximately equal. Meridians and parallels intersect at approximately right angles. The graticule spacing results in a compromise of all properties. Graticule is symmetrical.
Linear scale	Linear scale is true on the standard parallel and along meridians.	Linear scale is true on standard parallels. Distance and directional measurements are good. Maximum scale error is 2½ percent on a map of the United States (48 states) with standard parallels at 33° N. and 45° N.	Linear scale is true on the standard parallels. Distance and direction measurements are good. Maximum scale error is 1¼ percent on a map of the United States (48 states) with standard parallels of 29½° N. and 45½° N.	Linear scale is true along each parallel and along the central meridian. Maximum scale error is 7 percent on a map of the United States (48 states).	Linear scale is true on lines of tangency. Scale is compressed between the lines of tangency and expanded beyond them. Linear scale is generally good, but there is as much as a 10 percent error at the edge of the projection.	Linear scale is true along standard parallels only. Distance and direction measurements are reasonably accurate.
Notes	Projection is mathematically based on a cone that is tangent on a parallel.	Projection is mathematically based on a cone that is secant on two parallels. Areal distortion is minimal but increases away from the standard parallels. North or South Pole is represented by a point. Great circle lines are approximately straight. Retains its properties at various scales; sheets can be joined along their edges.	Projection is mathematically based on a cone that is secant on two parallels. No areal deformation. North or South Pole is represented by an arc. Retains its properties at various scales; individual sheets can be joined along their edges.	Projection is mathematically based on several cones tangent to several parallels. Distortion increases away from the central meridian. Has both areal and angular deformation.	Projection is mathematically based on two cones obliquely secant to the globe following the trend of North and South America. Areal enlargement is extreme away from the lines of tangency.	Projection is mathematically based on a cone secant on two parallels. The pole is represented by an arc. Has both areal and angular deformation.
Uses	The Simple Conic projection is used in atlases for portraying mid-latitude areas. It is good for small-scale maps of regions and continents.	Used for large countries in the mid-latitudes having an east-west orientation. The United States (50 states) Base Map uses standard parallels at 37° N. and 65° N. Some of the National Topographic Map Series 7½-minute and 15-minute quadrangles use standard parallels of 33° N. and 45° N. Aeronautical charts for Alaska use standard parallels at 55° N. and 65° N. The National Atlas of Canada uses standard parallels at 49° N. and 77° N. In the figure below the outline represents the United States (50 states) Base Map.	Used for thematic maps. Used for large countries having an east-west orientation. The National Atlas of the United States, United States Base Map (48 states), and the Geologic map of the United States are based on the standard parallels of 29½° N. and 45½° N. as shown below.	Used for areas with a north-south orientation. Only within a small area does it portray true shape, area, distance, and direction. Formerly used as the base of the 7½- and 15-minute quadrangles of the National Topographic Map Series. Individual sheets cannot be edge-joined for more than a few sheets.	Used to represent one or both of the American continents. Examples are the Basement map of North America and the Tectonic map of North America.	A Russian projection that has good compromise characteristics for portraying large areas. The Kavraisky No. 4 is used with other map projections in Russian atlases.
Examples						

Pseudo-Cylinders

Type of map projection	Sinusoidal	Eckert No. 6	Van Der Grinten
	Equal-area	Equal-area	Compromise
Lines of longitude (meridians)	Meridians are sinusoidal curves, curved concave toward a straight central meridian.	Meridians are sinusoidal curves concave toward a straight central meridian.	Meridians are curved concave toward a straight central meridian.
Lines of latitude (parallels)	Parallels are straight lines, as is the equator.	Parallels and equator are straight, parallel lines.	Parallels are curved concave toward the poles except for a straight equator.
Graticule spacing	Meridian spacing is equal and decreases toward the poles. Parallel spacing is equal. The graticule spacing retains the property of equivalence of area.	Meridian and parallel spacing decreases toward the poles. The graticule spacing retains the property of equivalence of area.	Meridian spacing is equal. The parallels are spaced farther apart toward the poles. The poles commonly are not represented. The graticule spacing results in a compromise of all properties.
Linear scale	Linear scale is true on the parallels and the central meridian and along any lines parallel to them.	Linear scale is true along the equator.	Linear scale is true along the equator. Distance and direction measurements are reasonably accurate.
Notes	Projection is mathematically based on a cylinder tangent on the equator. The sinusoidal projection may have several central meridians and may be interrupted on any meridian to help reduce distortion at high latitudes. There is no angular deformation along the central meridian and the equator.	Projection is mathematically based on a cylinder tangent at the equator. Poles are represented by straight lines half the length of the equator. Distortion of shape is extreme at high latitudes.	Projection is mathematically based on a cylinder tangent at the equator. The projection has both areal and angular deformation, but it has good compromise characteristics.
Uses	Used as an equal-area projection to portray areas that have a maximum extent in a north-south direction. Used as a world equal-area projection in atlases to show distribution patterns. The figure below represents an interrupted version of the sinusoidal projection with three central meridians.	Used as an equal-area map projection of the world in atlases such as the Great Soviet World Atlas, 1937. Kavraisky No. 6 map projection closely resembles Eckert No. 6 and is used in the Ocean Atlas, 1953, Vol. 2.	The Van der Grinten is used by the National Geographic Society for a world projection for maps and atlases and is used by the U.S. Geological Survey as a base to show distribution of mineral resources on the sea floor (McKelvey and Wang, 1970).
Examples			

Planes (Azimuthal)

Type of map projection	Azimuthal Equidistant	Lambert Azimuthal Equal-Area	Orthographic	Stereographic	Gnomonic
	Equidistant	Equal-area		Conformal	
Lines of longitude (meridians)	Polar case: the meridians are straight lines radiating from the point of tangency. Oblique case: the meridians are curved concave toward the point of tangency. Equatorial case: the meridians are curved concave toward a straight central meridian.	Polar case: the meridians are straight lines radiating from the point of tangency. Oblique and equatorial cases: meridians are concave toward a straight central meridian.	Polar case: the meridians are straight lines radiating from the point of tangency. Oblique case: the meridians are ellipses, concave toward the center of the projection. Equatorial case: the meridians are ellipses concave toward the straight central meridian.	Polar case: the meridians are straight lines radiating from the point of tangency. Oblique and equatorial cases: the meridians are arcs of circles concave toward a straight central meridian.	Polar case: the meridians are straight lines radiating from the point of tangency. Oblique and equatorial cases: the meridians are straight lines.
Lines of latitude (parallels)	Polar case: the parallels are concentric circles. Oblique case: the parallels are arcs concave toward the poles. Equatorial case: the parallels are arcs concave toward the poles; the equator is straight.	Polar case: parallels are concentric circles. Oblique and equatorial cases: the parallels are nonconcentric arcs around a pole.	Polar case: the parallels are concentric circles. Oblique case: the parallels are ellipses concave toward the poles. Equatorial case: the parallels are straight and parallel.	Polar case: the parallels are concentric circles. Oblique case: the parallels are nonconcentric arcs of circles concave toward the poles with one parallel being a straight line. Equatorial case: parallels are nonconcentric circles concave toward the poles; the equator is straight.	Polar case: the parallels are concentric circles. Oblique and equatorial cases: parallels are arcs concave toward the poles except for the equator, which is straight.
Graticule spacing	Polar case: the meridian spacing is equal and increases away from the point of tangency. Parallel spacing is equal. Oblique and equatorial cases: the graticule spacing increases away from the point of tangency. Angular and areal deformation increase away from the point of tangency.	Polar case: the meridian spacing is equal and increases, and the parallel spacing is equal and decreases toward the periphery of the projection. Oblique and equatorial cases: the graticule spacing is equal and decreases toward the periphery. The graticule spacing in all cases retains the property of equivalence of area.	Polar case: meridian spacing is equal and increases, and the parallel spacing decreases from the point of tangency. Oblique and equatorial cases: the graticule spacing decreases away from the center of the projection.	The graticule spacing increases away from the center of the projection in all cases, and it retains the property of conformality.	Polar case: the meridian spacing increases, and the parallel spacing increases very rapidly from the point of tangency. Oblique and equatorial cases: the graticule spacing increases very rapidly away from the center of the projection.
Linear scale	Polar case: linear scale is true along the meridians only. Oblique and equatorial cases: linear scale is true from the point of tangency.	Linear scale is reasonably accurate, but angular deformation increases toward the periphery of the projection.	Scale is true on the parallels in the polar case and on all circles centered at the pole of the projection in all cases. Scale decreases away from the center of the projection.	Scale increases toward the periphery of the projection.	Linear scale and angular, and areal deformation are extreme, rapidly increasing away from the center of the projection.
Notes and uses	Projection is mathematically based on a plane. The entire earth can be represented. Has true direction and true distance scaling from the point of tangency. The Azimuthal Equidistant projection is used for radio and seismic work as every place in the world will be its true distance and direction from the point of tangency. The polar case is used as the emblem of the United Nations.	The Lambert Azimuthal Equal-Area projection is mathematically based on a plane, and it is the only azimuthal projection that can accurately represent areas and represent true direction from the center of the projection. Used for depicting distribution patterns, measuring defined areas, and portraying areas which have equal east-west and north-south dimensions. The polar, oblique, and equatorial cases are used by the U.S. Geological Survey for the Circum-Pacific Map.	The Orthographic projection is geometrically based on a plane, and the point of projection is at infinity. The earth appears as it would from outer space. This projection is a truly graphic representation of the earth and is the only projection in which distortion becomes a visual aid. Only one hemisphere can be represented. The Orthographic Projection is widely used in the oblique case for hemispheres, continents, the moon, and the planets.	The Stereographic projection is geometrically based on a plane, and the point of the projection is opposite the point of tangency. Circles on the earth appear as straight lines, parts of circles, or circles on the projection. The Stereographic projection is the most widely used azimuthal projection, mainly used in the oblique case for portraying large, continent-sized areas. It is used in geophysics for solving problems in spherical geometry. The polar case is used for topographic maps and navigational charts.	The Gnomonic projection is geometrically based on a plane, and the point of projection is at the center of the earth. Because of the extreme deformation, less than a hemisphere is most commonly represented. It is the only projection in which any straight line is a great circle, and it is the only projection that demonstrates the shortest distance between any two points. Consequently it is used in seismic work as seismic waves travel in approximately great circles. The Gnomonic projection is used with the Mercator projection for navigation.
Examples					

NATURAL PROPERTIES OF THE EARTH'S GRATICULE[1]

1. Parallels are parallel.
2. Parallels are spaced equally on meridians.
3. Meridians and other great circle arcs are straight lines.
4. Meridians converge toward the poles and diverge toward the equator.
5. Meridians are equally spaced on the parallels, but their distance apart decreases from the equator to the pole.
6. Meridians at the equator are spaced the same as parallels.
7. Meridians at 60° are half as far apart as parallels.
8. Parallels and meridians cross one another at right angles.
9. The area of the surface bounded by any two parallels and two meridians (a given distance apart) is the same anywhere between the same two parallels.
10. The scale factor at each point is the same in any direction.

[1] From Robinson (1969, p. 212)

DEFINITION OF TERMS

Case Individual azimuthal map projections are divided into three cases: the polar case which is tangent at the pole, the equatorial case which is tangent at the equator, and the oblique case which is tangent anywhere else.
Conformality A map projection is conformal when (1) meridians and parallels intersect at right angles, and (2) at any point the scale is the same in every direction. The shapes of very small areas and angles with very short sides are preserved.
Developable surface A developable surface is a simple geometric form capable of being flattened without stretching. Map projections can then be grouped by a particular developmental surface: cylinder, cone, or plane.
Equal area A map projection is equal area when every part, as well as the whole, has the same area as the earth, at a reduced scale.
Graticule The graticule is the spherical coordinate system based on lines of latitude and longitude.
Linear scale Linear scale is the relation between a distance on a map projection and the corresponding distance on the earth.
Map projection A map projection is a systematic representation of meridians and parallels portraying a spherical surface (the earth) on a plane surface. Each map projection has specific properties that make it useful for specific objectives.

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______1972, United States, scale 1:2,500,000 (base map, 2 sheets).
______1973, Alaska Map E, scale 1:2,500,000 (base map).
______1975, The United States, scale 1:6,000,000 (base map).

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A SURVEY OF THE PROPERTIES AND USES OF SELECTED MAP PROJECTIONS

By
Tau Rho Alpha and Marybeth Gerin

1978

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