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DOCUMENT TITLE

CPL NAVIGATION 2 (AUS)

CHAPTER 2 – MAPS AND CHARTS (GENERAL)

Version 2.1
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CONTENTS ... PAGE

MAPS AND CHARTS (GENERAL)

2.1 Introduction

A map or chart is usually in the form of a flat sheet of paper showing the Earth's surface. The construction of the map and the selection of the information to be shown depends on the purpose for which the map is designed.

The map may be designed for visual navigation, in which case it will show topographical features such as rivers and hills, or it may be designed for radio navigation and so will show the position of NDBs, VORs etc.

For visual navigation we need a map or chart which shows plenty of detail and so we will choose a LARGE SCALE chart (more paper for a given area of the Earth). For Radio Navigation, less detail is required and we need to cover a large area of the Earth on each sheet of the map. For this we will choose a SMALL SCALE chart (less paper for a given area of the Earth).

2.2 Projection Classification

Projections are classified in terms of the following:

- Method of projection
- Principle of projection
- Projection surface orientation
- Projection surface type.

2.2.1 Method of Projection

A map projection can be classified according to which properties of the globe it distorts least:

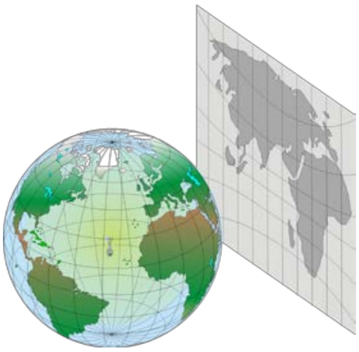
- <u>Equal-Area Projections</u> represent the sizes of the regions in the correct relationship to one another, but distort shapes.
- <u>Conformal Projections</u> show angles and directions at any point accurately, but distort relationships between sizes.

A map cannot be both an equal-area and conformal projection.

2.2.2 Principle of Projection

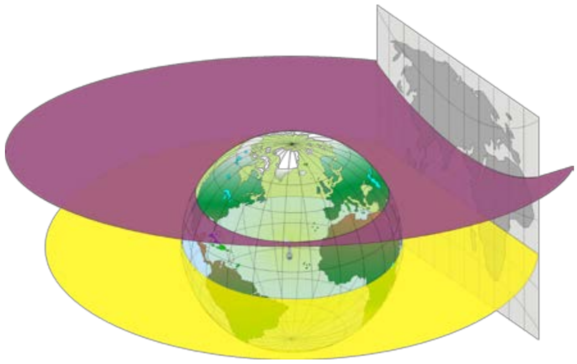
The term projection originates from the close analogy between the map-making process and the projection of an image onto a screen.

Imagine that the reduced earth is made of glass, with the latitude/longitude graticule and required topographic and cultural detail etched onto its surface. Now imagine a point source of light at the centre of the reduced earth. When the light is turned on and a suitable screen placed against the sphere, an image of the markings on the surface is projected onto the screen and could be used as the basis of a map.



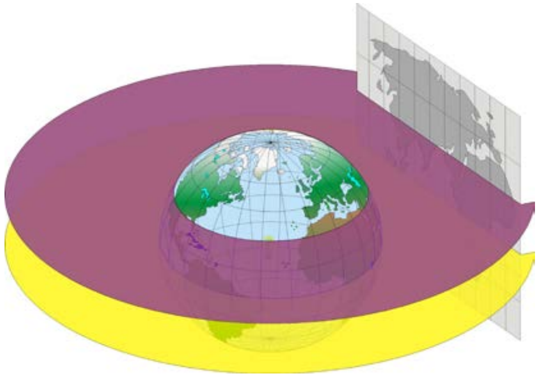
2.2.2.1 <u>Geometric Projections (Perspective Projections)</u>

Geometric Projections rely upon the fact that the light source, any point on the reduced earth, and the corresponding point on the map, are all co-linear, so that the line could be represented by a ray of light.



2.2.2.2 <u>Mathematical Projections (Non-perspective Projections)</u>

Mathematical Projections are projections where the linearity of the system has been discarded in order to produce some other desired property i.e. the light rays are no longer straight lines.

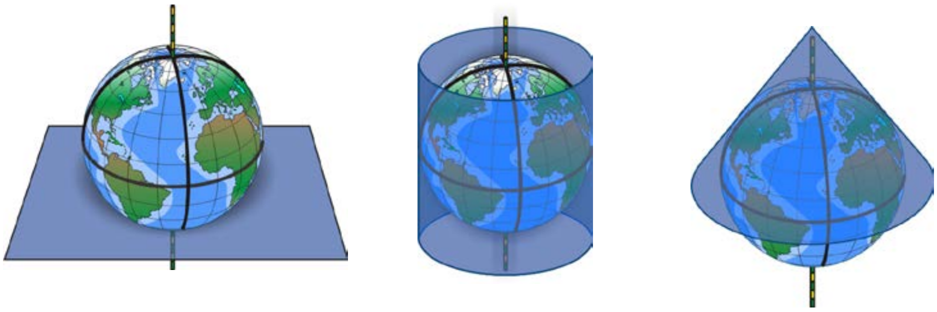


2.2.3 Projection Surface Orientation

The alignment of the projection surface's axis of symmetry with the reduced earth's axis of rotation is also used to distinguish between chart types.

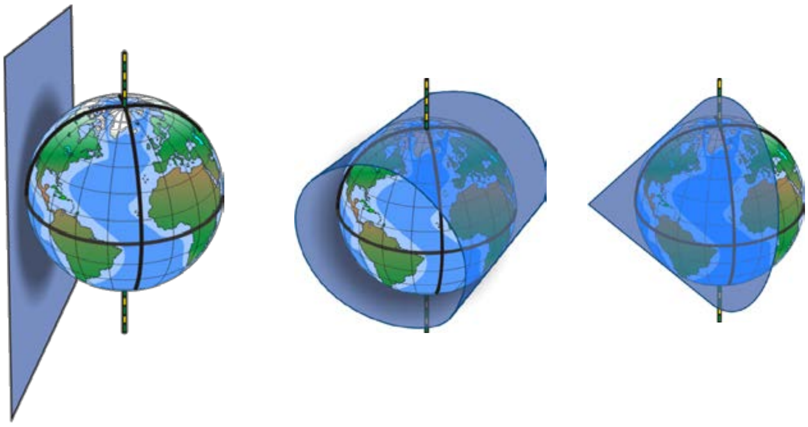
2.2.3.1 <u>Normal Projection</u>

The projection surface's axis of symmetry is aligned parallel to the reduced earth's axis of rotation.



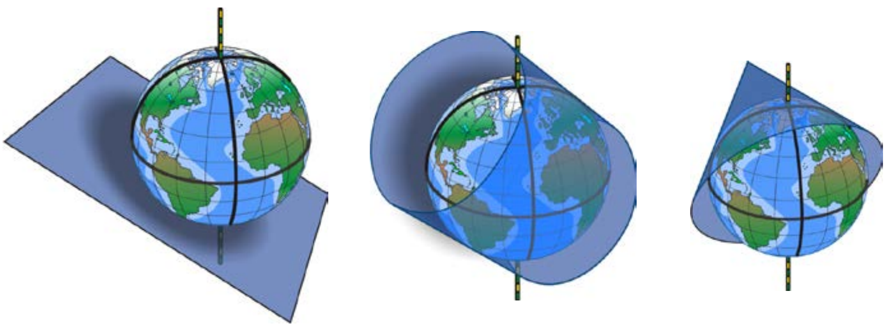
2.2.3.2 <u>Transverse Projection</u>

The projection surface's axis of symmetry is aligned perpendicular to the reduced earth's axis of rotation.



2.2.3.3 <u>Oblique Projection</u>

The projection surface's axis of symmetry is not aligned perpendicular or parallel to the reduced earth's axis of rotation.



2.2.4 Projection Surface Type

Another way of classifying projections is according to the geometrical shape of the surface onto which the projection is drawn, such as:

- Cylindrical Projections.
- Conical Projections.
- Azimuthal Projections.

2.3 General Properties of Normal Projections

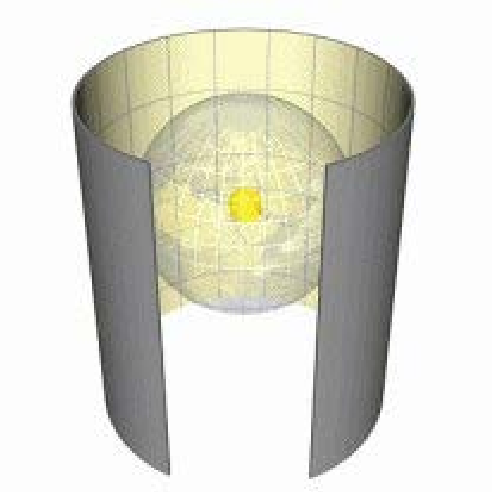
All three normal projections (cylindrical, conical and azimuthal) share some common properties. These common properties are discussed below and similarities will be seen in the examples of aviation map projections that will be discussed later in the chapter.

Pay attention to the point on each projection where the map is free from distortion as this is usually the area that the map is best at mapping. Secondly, take note of how meridians are projected in each of the normal projections and how that differs from meridians on the reduced earth.

2.3.1 Normal Cylindrical Projections

Normal Cylindrical projections are projections of the globe onto a cylinder. Although constructed by mathematical formulae, such a projection can be visualized as follows:

A sheet of paper is placed around a globe with a light source placed in its centre. The sheet then forms a cylinder around the globe.

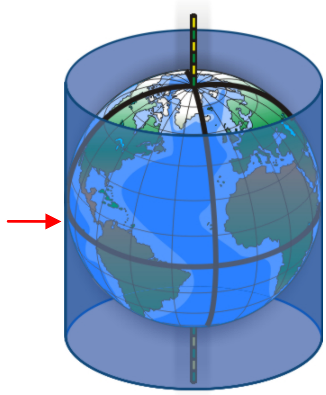


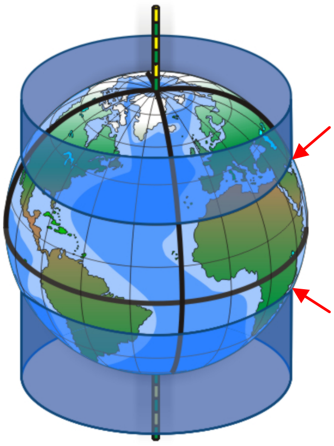
The axis of symmetry (centre axis) of the cylinder is parallel with the axis of the globe and tangential to the reduced earth at the Equator.

The light source placed within the globe projects an image of the meridians and parallels of latitude onto the surface (sheet of paper).

The primary feature of all normal cylindricals is the property of straight and parallel meridians, equally spaced, and at right angles to the Equator and parallels of latitude.

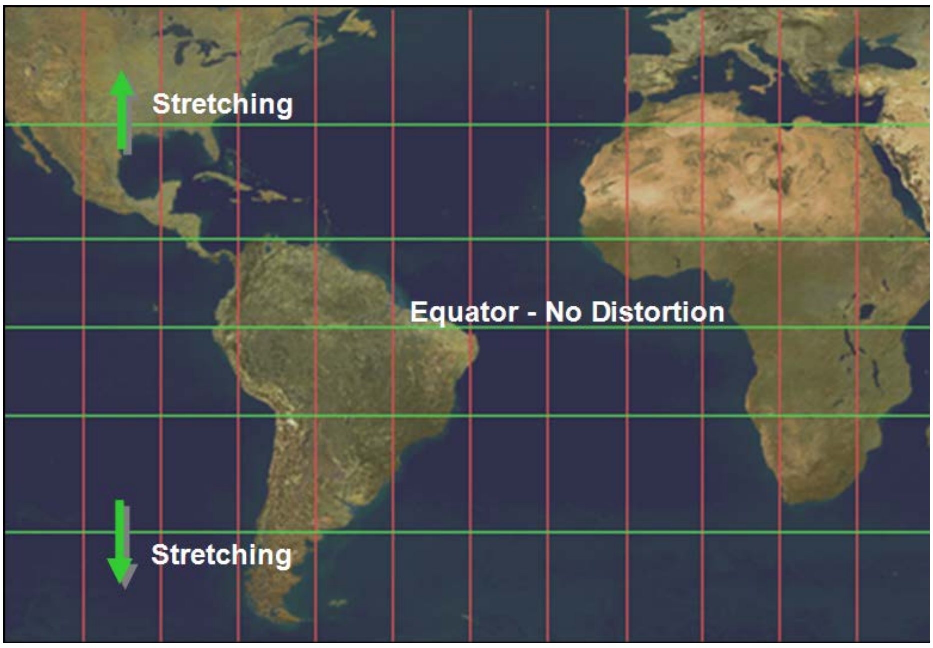
The resulting map is called the Geometric Cylindrical Projection. If the cylinder is tangential to the Equator, the chart will have one line that is free from distortion.





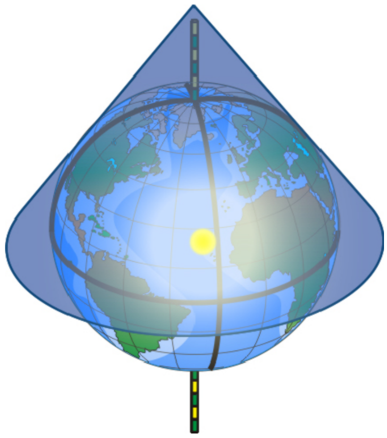
In the event that the cylinder cuts through the reduced earth, the chart will have two lines that are free from distortion.

On a normal cylindrical projection, all meridians will appear parallel on the map and fail to meet at the Poles. As a result, such a map produces exaggerated distortion (or "stretching") near the Poles.



The best-known cylindrical projection is the Mercator Projection.

2.3.2 Normal Conical Projection

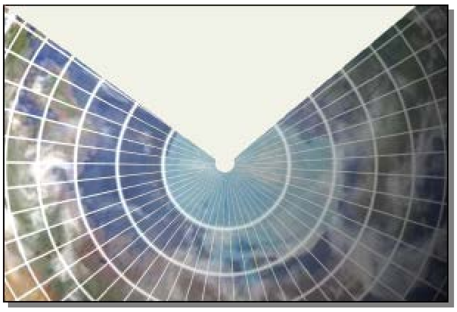


Normal Conical projections are projections of the globe onto a cone. Such a projection can be visualized as follows:

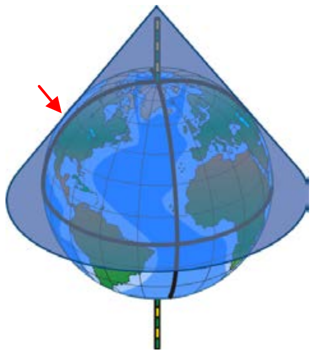
A sheet of paper is rolled in the shape of a cone and then placed around a globe (reduced earth).

The axis of symmetry (centre axis) of the cone runs through the centre of the globe and either Pole. The cone touches the globe along a parallel of latitude between the Pole and the Equator of the globe. The parallel of latitude along which the cone touches the reduced earth is determined by the apex angle of the cone.

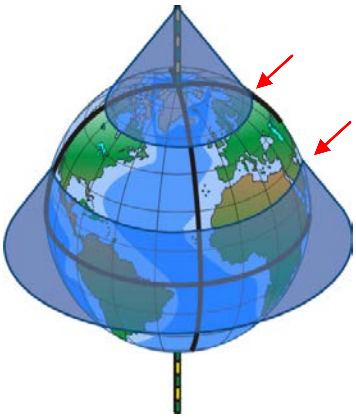
The light source placed within the globe projects an image of the meridians and parallels of latitude onto the cone's surface (sheet of paper).



As the cone is slit and unrolled, the point of projection lies directly above one of the Poles. The meridians are projected as straight lines radiating from the Pole and the parallels of latitude appear as portions of a circle.



If the cone touches the reduced earth along one parallel of latitude, only the area around this parallel of latitude is free from distortion.



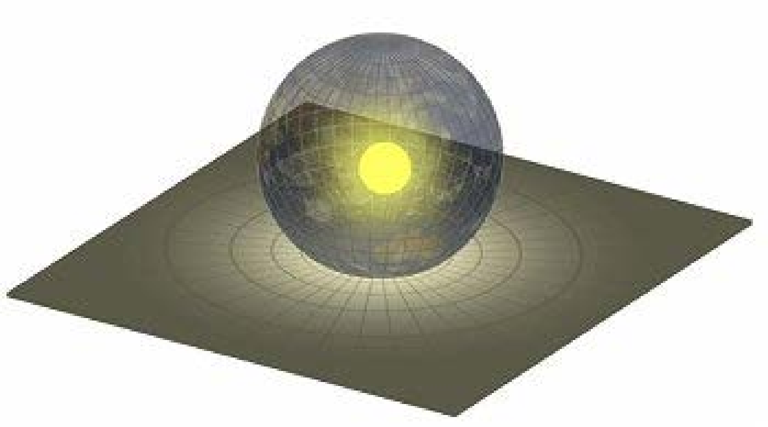
If the cone cuts the reduced earth in two parallels of latitude (secant cone) there will be two parallels without distortion.

Such conical projections are commonly used to map middle latitude areas with large east-west dimensions (e.g. Asia and North America).

The best-known and most widely used conical projection is the Lambert's Conformal Conical Projection.

2.3.3 Normal Azimuthal Projection

An azimuthal projection is a projection of the globe onto a flat surface. Such a projection can be visualized as follows:

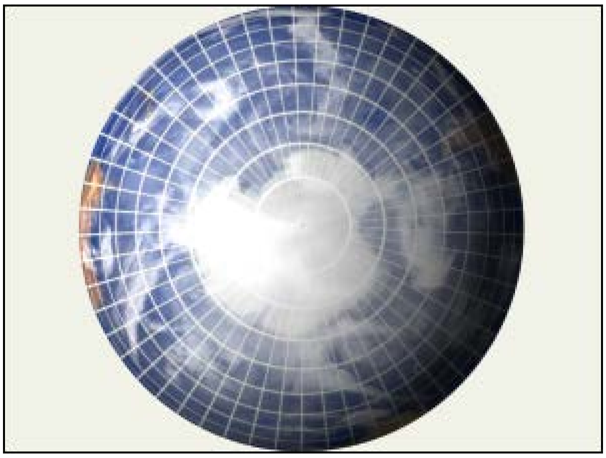


A flat projection surface is placed against the reduced earth. A light source then projects an image of the Earth's surface onto the projection surface.

The plane of projection is tangential to the Earth at one specific point and for a normal azimuthal projections this would be either the North or South Pole.

The point on the map projection where the plane touches the globe is free of distortion, in this case the South Pole.

Azimuthal projections are most commonly used to map compact areas of the earth's surface, such as the Polar Regions.



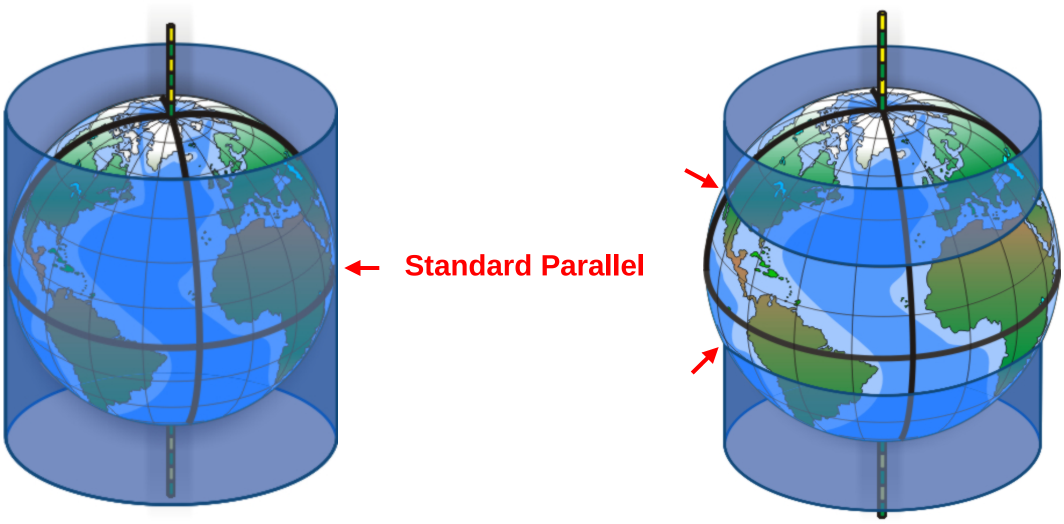
The best-known azimuthal projection is the Polar Stereographic Projection.

2.3.4 Standard Parallel

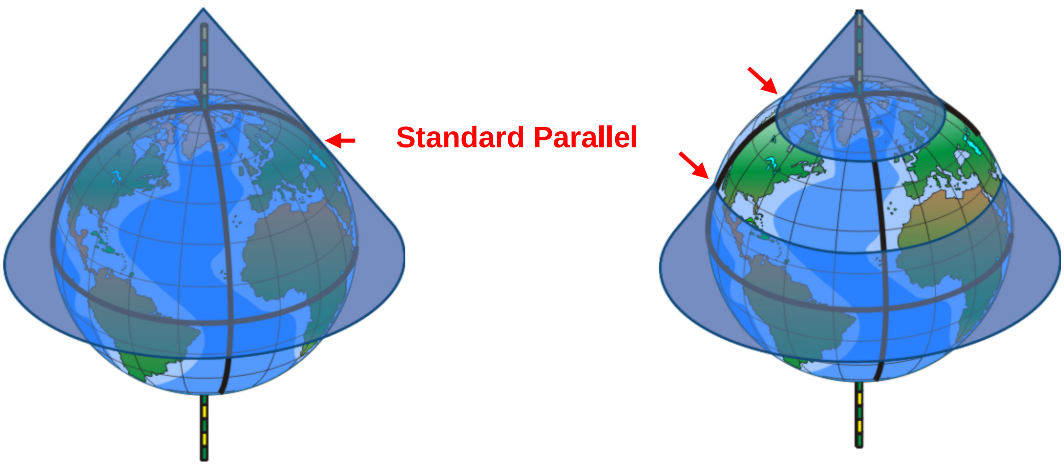
A standard parallel on any projection is that parallel which is drawn to the same scale as that of the reduced earth. This occurs where the projection surface and the reduced earth surface coincide.

It is important to know where the standard parallel is on the chart, as this is the place on the map where scale is not distorted and distance measurement will be most accurate.

Cylindrical Projections have either one or two standard parallels:

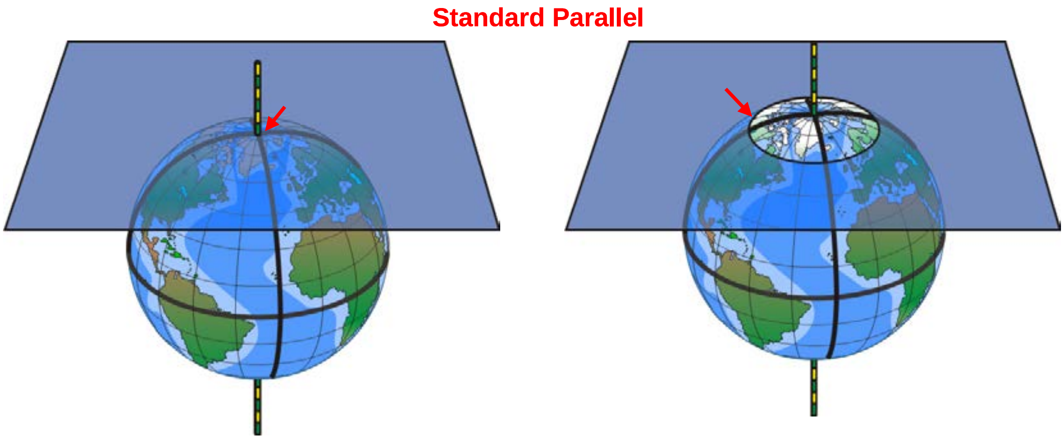


Conical Projections have either one or two standard parallels:



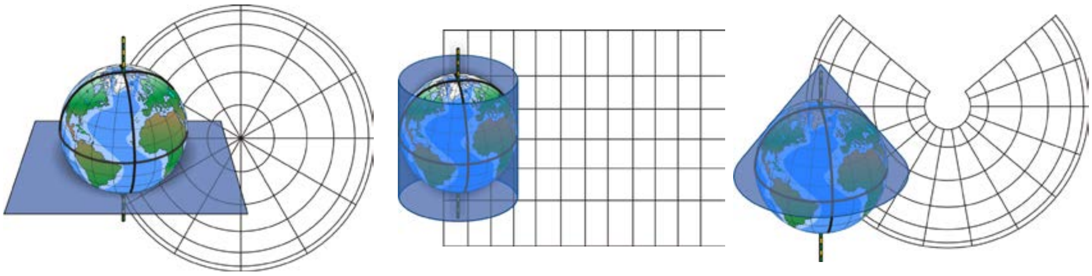
The standard parallel is the line along which scale is correct on the map/chart.

Azimuthal Projections have only one standard parallel, for normal Azimuthal projections it is either the North or South Poles or any parallel of latitude.



2.3.5 Parallel of Origin

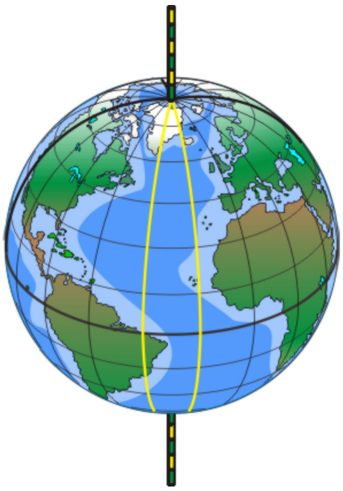
The Parallel of Origin (PoO) defines the angle that two successive meridians will make with one another on the map. On all the navigation charts that will be discussed in this course, meridians are projected as straight lines. As a result of this the angle between any two meridians will be constant on the chart.



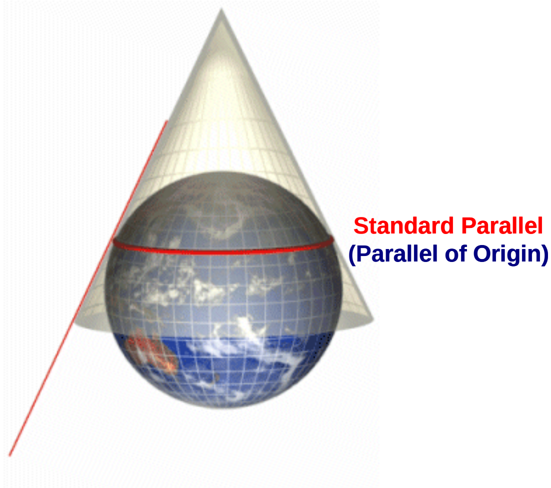
Meridians also converge on Earth; however, the angle between two meridians will change as the latitude increases towards the Poles, contrary to the fixed angle between meridians on the map.

The angle between two meridians on the map is defined by the angle between the same two meridians of the reduced earth, at the Parallel of Origin.

The **PoO** plays a role in determining the **shape of a great circle** on the chart.

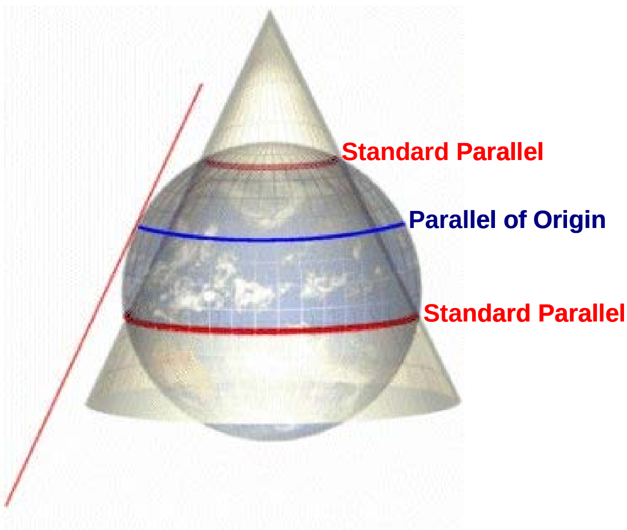


Using the conical projection the relationship between the Parallel of Origin and the Standard Parallel(s) can be explained. If one of the Earth's meridians is straightened on a ***one standard parallel conic projection*** and angled to be parallel to the projection cone the following will become apparent:



- This line only touches the reduced earth at one single point. This point is known as the point of tangency or **Parallel of Origin**.
- On the one standard parallel conic projection, the **Parallel of Origin** and **Standard Parallel** will be the same.

On the other hand, if one of the Earth's meridians is straightened on a ***two-standard parallel conic projection*** and angled to be parallel to the projection cone and then moved out to only touch the reduced earth at one single point the following will become apparent:



- The single point where this line touches the reduced earth is the point of tangency or **Parallel of Origin**.
- On the two standard parallel conic projection, this line **(Parallel of Origin)** lies approximately half way between the **two Standard Parallels**.

2.4 Properties of an Ideal Chart

The theory of projection is to create a reduced earth (small globe) to the scale that is needed, and then project this (by means of a light) onto a sheet of paper. This projection of the reduced earth onto a flat sheet of paper cannot be done without distortion but ideally a chart should have the following properties:

- The Scale should be both correct and constant in every direction.
- The shapes of features, such as lakes, will appear the same on the map as they do on the Earth.
- The bearing measured between any two points on the map will be the same as the bearing between the same points on the Earth.
- Areas that are equal on the Earth will appear equal on the map.
- A straight line drawn on the map will represent either a rhumb line or a great circle.
- Adjacent sheets of the map will fit perfectly N-S and E-W so that maps can be joined on their edges.

In practice it is not possible to achieve all these ideal properties and so we have to choose the properties that are most important for a given purpose and to accept other properties that are less than perfect. On aviation charts it is important to have both scale and bearings correct.

2.5 Orthomorphism

The property that allows us to accurately measure track directions and plot position lines on the map is Orthomorphism, otherwise known as Conformality. An Orthomorphic or Conformal map is defined as one on which the bearing between any two points is same as the **bearing** between the **same** two points on the Earth.

> If a map is Orthomorphic then bearings will be correct.

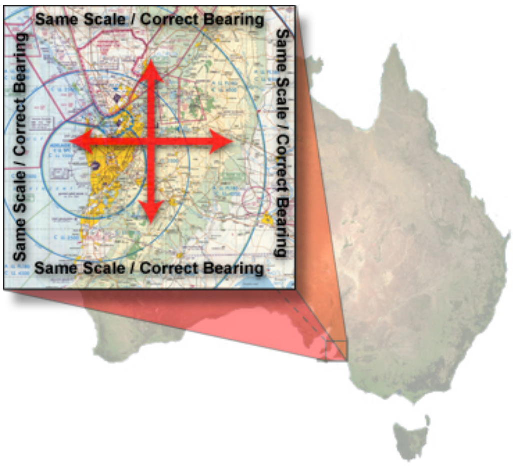
The word "Orthomorphism" is derived from the Greek words “Orthos” which means right (or correct) and “Morphic” which means form (or shape). Thus, the direct translation from putting these two words together is “Correct Shape”.

The need for navigation bearings to be measured correctly is of paramount importance to aviators, navigating the globe, and this requirement is, therefore, met by the orthomorphic projection.

Note: The American equivalent of Orthomorphism is Conformal

2.5.1 Requirements for Orthomorphism

As soon as we commence the process of flattening a spherical surface, distortion of shapes take place, accompanied by inherent distortion of the scale of a map or chart.



Thus, Orthomorphic projections are projections in which a small area is rendered in its true shape.

The scale, although varying throughout the map, is changing at the same rate in all directions at any point, so that very small areas are represented by correct shapes and bearings between points are correct.

In order to achieve Orthomorphism two requirements must be met:

- The scale over a short distance must be the same in all directions.
- Meridians and parallels of latitude on the projection must intersect each other at 90°.

Note: The scale of a projection is not constant, because the projection of a sphere onto a flat surface will cause variation of the scale. Scale is only correct at the standard parallel(s). If the scale is correct, the distance measurement will be accurate.

However, for a chart to achieve orthomorphism, the scale may vary from point to point and it must vary at the same rate, in all directions at any point. Thus, he scale around any specific point must remain the same for short distances in all directions.

2.6 Scale

Flight planning, that is determining direction and distances, must be done on accurate aeronautical maps. The distances on the charts are representative of the actual distances on the Earth.

The distance from Sydney to Adelaide is approximately 1164 km measured on a straight line. This distance is represented on the chart as 6 cm.

The ratio between the two distances is referred to as **Scale**.

Definition: Scale is defined as the ratio of a distance measured on a chart to the corresponding distance on the Earth, both being expressed in the same units.

Formula: Scale = $\frac{\text{ChartLenght(CL)}}{\text{Earth Distance (ED)}}$

Example: Scale Calculation

Calculate the scale of the chart, if the Earth distance between Adelaide and Sydney of 1164 km is represented by a measurement of 6 cm on the chart.

In order to calculate the scale both measurements need to be in the same units, so convert the Earth distance of 1164 km into cm:

1164 km × 1000 = 1 164 000 m

1 164 000 m × 100 = 116 400 000 cm

So 6 cm on the chart is equivalent to 116 400 000 cm on the Earth. To find how much Earth distance only 1 cm on the chart represents:

Map	Earth
6 cm (÷ 6)	116 400 000 cm (÷ 6)
1 cm	= 19 400 000 cm

This means the scale of the chart is 1:19 400 000 or $\frac{1}{19\,400\,000}$

Scale can be expressed in a variety of ways.

2.6.1 Methods of Expression

Scale can be expressed in three ways:

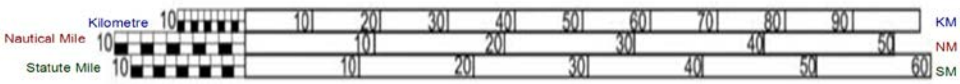
- Statement in Words
- Graduated Scale Line
- Representative Fraction

2.6.1.1 Statement in Words

As with the example given: "1164 km on the Earth is represented by 6 cm on the chart."

2.6.1.2 Graduated Scale Line

This is a scale line printed on a chart (normally on the bottom edge). The line is divided into sections, representing distances on the Earth.



2.6.1.3 Representative Fraction

The representative fraction (RF), also known as the Natural Scale, is the ratio of one unit of length on a chart, to the corresponding number of units on the Earth.

For example:

1:1 000 000 or $\frac{1}{1\ 000\ 000}$ means that 1 unit on the chart represents 1 million of that same unit type on the Earth.

Note 1: The unit used can vary (inches, mm, cm etc.), but whatever the unit used on the chart, the scale is representative of the same units on the Earth.

Note 2: The numerator must always be one.

Note 3: The smaller the denominator, the larger the scale.

(A chart with scale 1:500 000 has a larger scale than 1:1 000 000)

2.7 Relief Portrayal

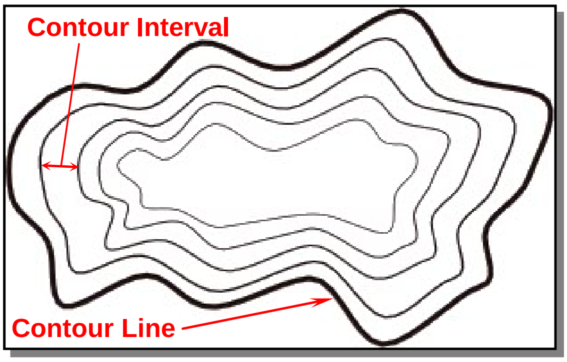
Relief portrayal refers to the methods used to show the elevation of the terrain. Details vary between different types of charts, but the use of contour lines is the basic method of indicating both elevation and shape of terrain features.

Certain methods used on charts only make the user aware of the fact that there is terrain, different to the surrounding area, whilst other methods are very specific in conveying both the shape and elevation of the specific terrain feature or obstruction.

2.7.1 Contour Lines

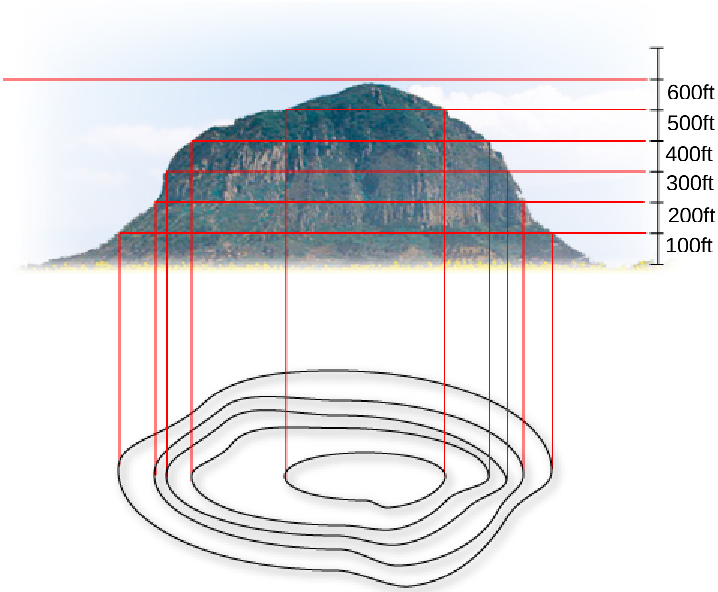
An important aspect of map reading is the ability to associate map features with ground features. Contour lines are commonly used for this purpose.

A **contour line** is an imaginary line on the earth's surface connecting points of equal height above sea level.

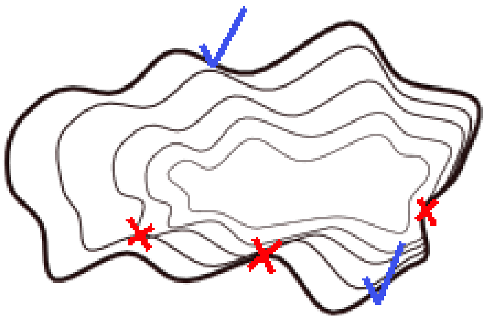


A **contour interval** is the difference in elevation between adjacent contour lines, and will vary from map to map depending on the scale. Generally the contour interval is reduced on larger scale charts.

A visual picture of a relief feature is made by mental interpretation.



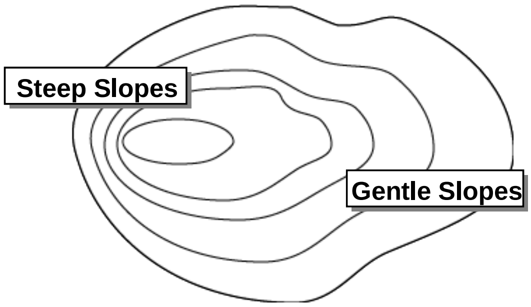
2.7.1.1 <u>Characteristics of Contour Lines</u>



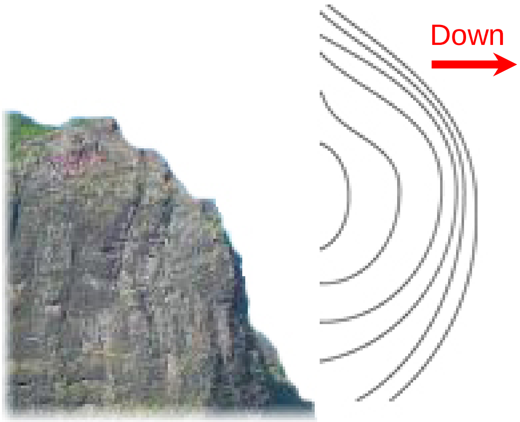
The ability to interpret a contour line becomes easier with time, and understanding the following concepts will assist you:

Two different contour lines of the same elevation cannot merge and continue as one line.

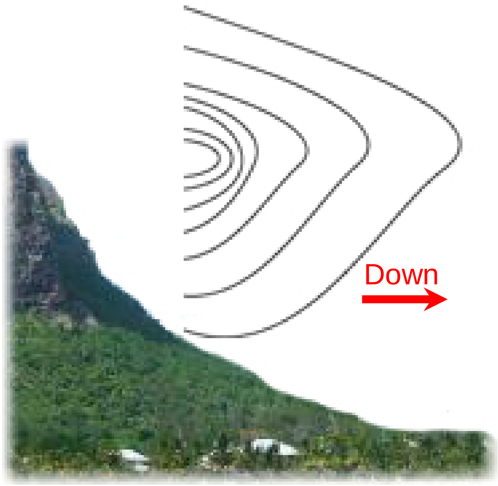
On steep slopes the contour lines are spaced closely, and on gentle slopes the contour lines are spaced far apart.



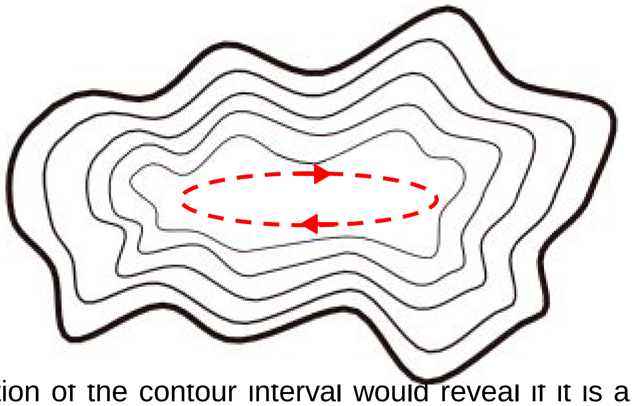
Contour lines widely spaced at the top and closely spaced at the bottom indicate a convex slope.



Contour lines closely spaced at the top and widely spaced at the bottom indicate a concave slope.



A closed contour line with one or more higher ones indicates a hill, and with one or more lower ones enclosed, indicates a depression without an inlet.

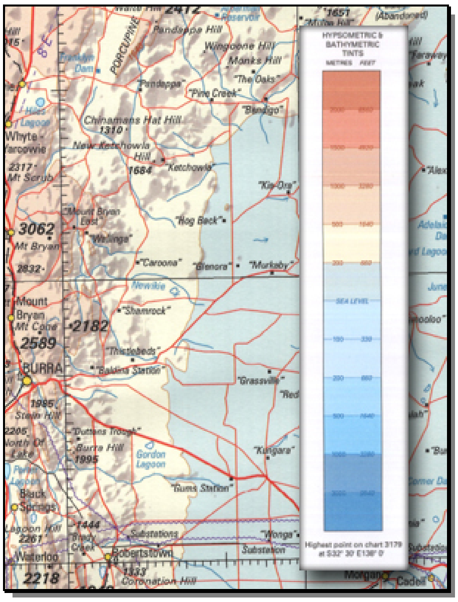


Careful examination of the contour interval would reveal if it is a depression or a hill. Increasing contour values towards the centre would represent a hill.

> A contour line cannot have an end within the limits of a map. It must either close upon itself, or else extend continuously until it disappears at the edge of a map.

2.7.2 Layer or Hypsometric Tinting

This method is often used in conjunction with contours. The spacing between contours is coloured with tints that vary according to the maximum height above mean sea level in that area, the colours becoming deeper as the height increases.



Layer tinting is used on all three Australian topographical aviation charts (WAC, VNC and VNC) but not on any of the radio navigation charts (Jeppesen or ERC).

Always examine the legend included on each chart to verify the extent or limit of a certain type of tint colour, as differences occur between chart types regarding the range of elevation that a certain colour depicts.

2.7.3 Hill Shading

Many topographical maps also utilize the 'North-West Light', by which the north western side of hills appear to be in sunlight and the south eastern side in light shadow. This further assists the user to visualize the shape of the terrain, especially the position of the ridge lines.

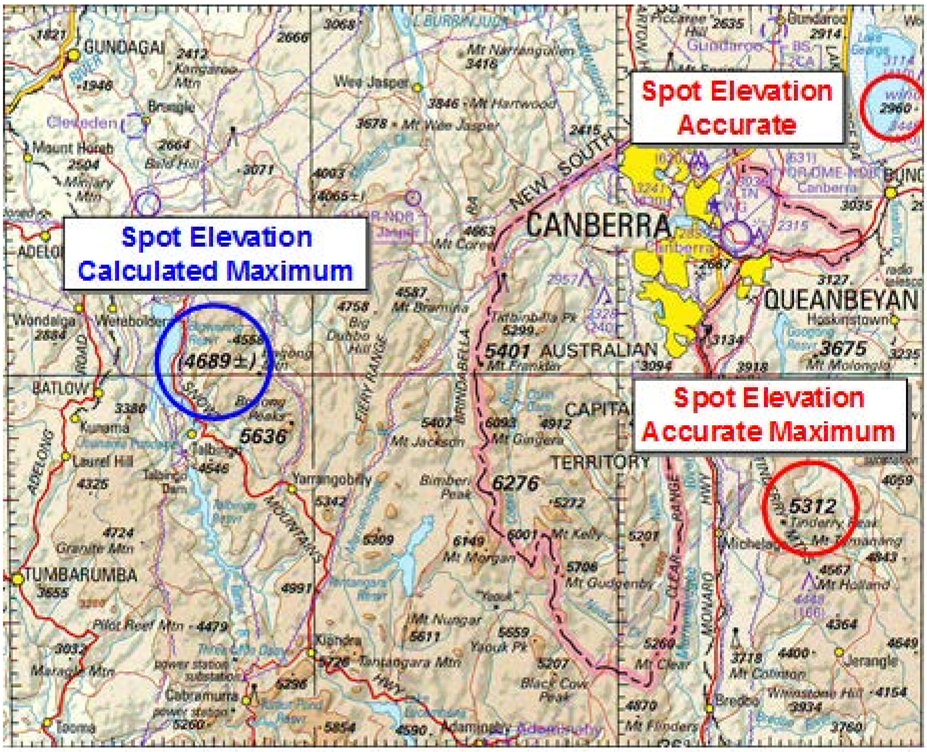
The hill shading technique is only used on the WAC and not on the VNC or VTC series of charts.

2.7.4 Spot Elevations

Spot elevations are points on the map with the height above sea level written next to it. This point is generally the highest point in a certain area and can also be used in areas that are flat and featureless - and thus lack contour lines - to help establish the overall elevation of the terrain.

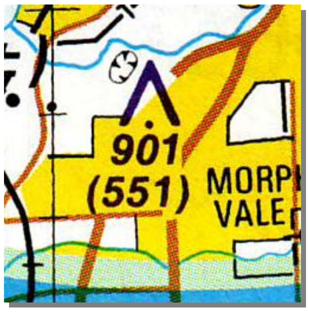
Consult the chart legend to determine if it is metres or feet. Elevation depicted on Australian maps is shown in feet amsl.

If a spot elevation has not yet been properly surveyed, its elevation will have a ± symbol next to it, indicating that the elevation has been calculated and is not exact.



In the WAC extract above various spot elevations in feet above mean sea level can be seen. Values in bold depict the maximum elevation for the block of latitude and longitude.

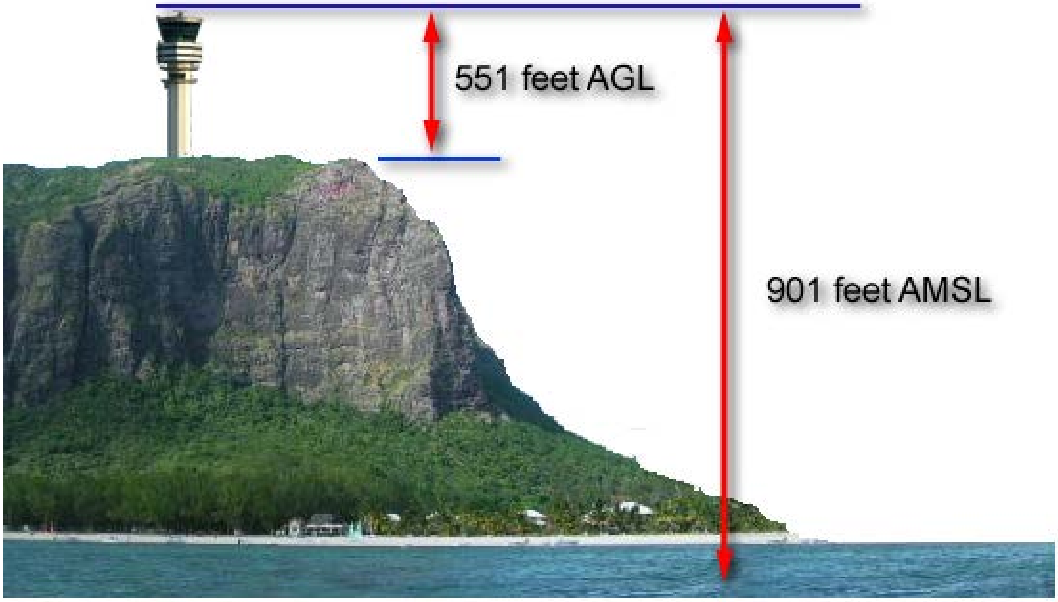
2.7.5 Obstacles



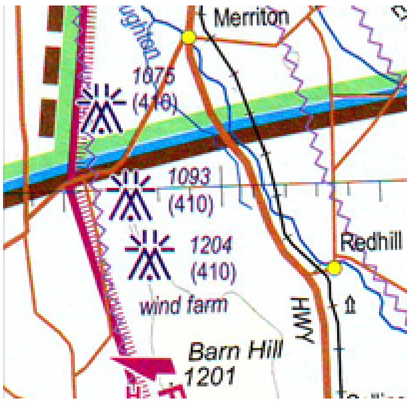
Heights of obstacles are shown both AMSL (above mean sea level) and AGL (above ground level).

In the example to the right, the unlit mast is 901 feet AMSL and 551 feet AGL. This example is taken from a VTC chart.

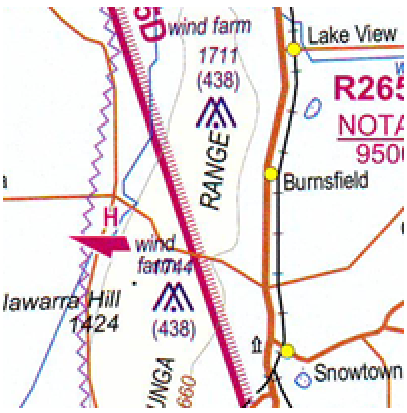
In the picture below, a side perspective is shown:



In the pictures below, the group of obstacles on the left is lit (it has lighting on the top). The group of obstacles on the right is unlit (Has no lighting on the top).



Group Obstacle (Lit)



Group Obstacle (Unlit)

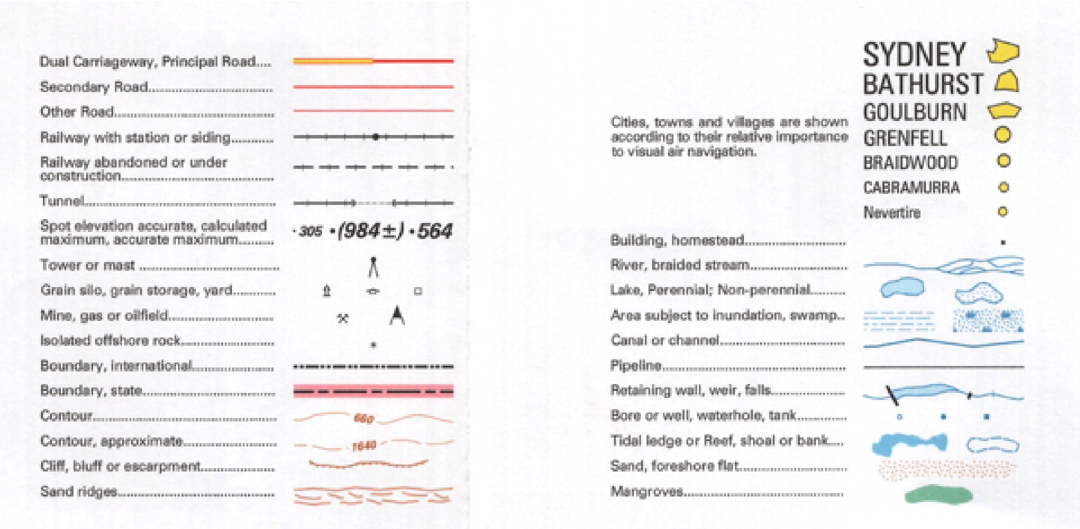
Usually the obstruction light is red in colour and located at the top of the mast to make it more visible at night and some obstructions have white flashing lights all along the length of the obstruction to increase daytime visibility as well.

2.8 Geographical Features

The depiction of features like water courses, lakes, marshes etc, is sometimes included under the general heading of relief portrayal. Details of these, and all other relief symbology is shown in the 'legend', which usually appears on the margin of the chart.

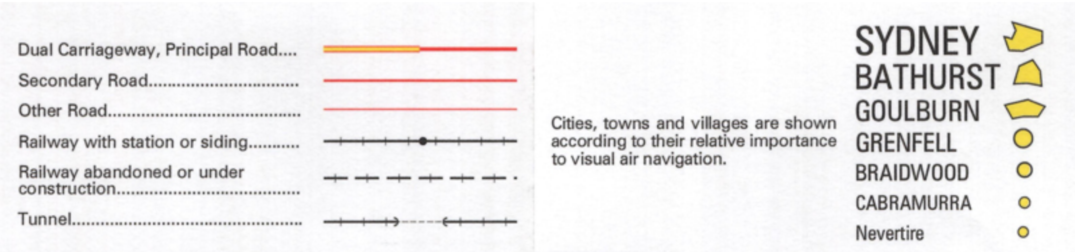
Because these symbols are often the key features used to perform visual navigation and identify turning points, it is important that these symbols are committed to memory so that it is not necessary to refer to the chart legend during flight, whilst map reading.

The chart symbols used by ICAO member countries are designed to conform to the standards laid out by ICAO but small differences do occur in practice between different map manufacturers.



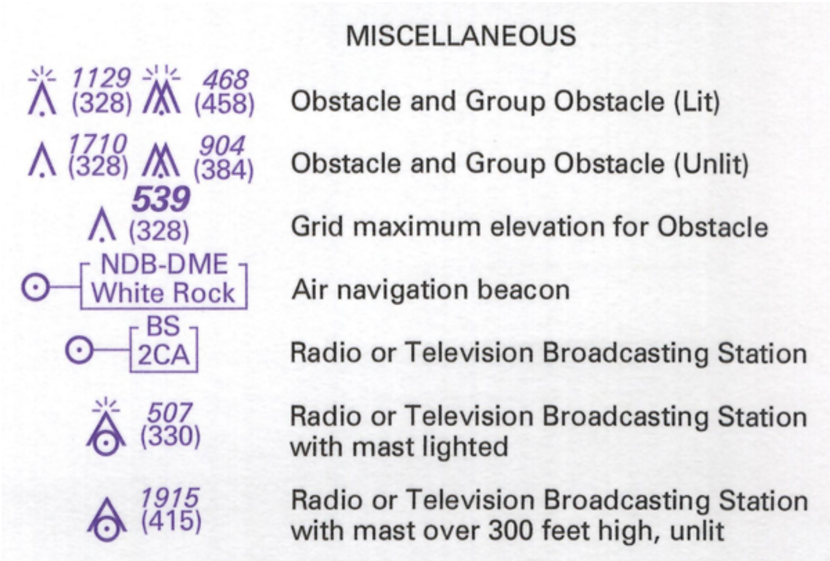
2.9 Cultural Features

All topographical charts employ special symbols to portray cultural, i.e. man-made features, such as towns, roads etc. Normally, the system provides discrimination on the basis of size or importance, e.g major highways from minor roads, cities from towns etc. Details are presented in the legend.



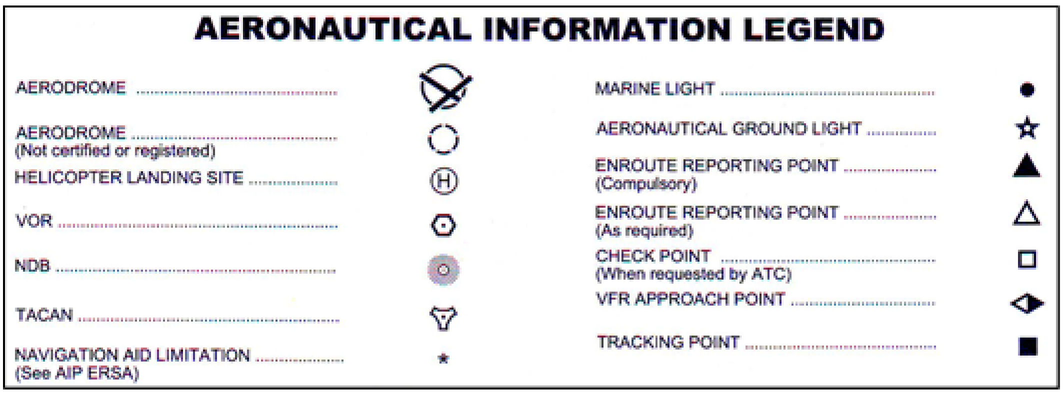
2.10 Aeronautical Chart Symbols

Aeronautical charts display information on the physical, electronic, and regulatory structure of all aspects of controlled airspace. The amount of detail is governed by the specific purpose of the chart and varies from minimal on topographical maps and plotting charts, to almost total detail on, a radio navigation chart. The types of symbols used also differ considerably in detail, and the chart in use must be studied carefully in this regard. Representative examples of approved aeronautical symbols are presented below.



The legend extract depicted above is from the WAC. The WAC contains very little detail regarding radio navigational beacons such as the NDB, VOR and DME. Consequently a standard symbol is used on the WAC to represent any of the aforementioned beacon types.

On the VNC, VTC and radio navigation charts there is much more information depicted on the chart with regards to the radio navigational beacons and a standardised symbol is used for each beacon type, as can be observed in the VNC legend extract depicted below:



2.11 Lambert's Projection - Projection Types

A great improvement on the Mercator projection, devised by Johannes Lambert, was first published around 1772. It is widely known as the Lambert's Conical Orthomorphic projection, Lambert's second projection or Lambert's Conformal Conic Projection.

The Lambert's Conical Orthomorphic is a mathematical projection. Its scale is **very nearly** constant and great circles are **almost** straight lines across the entire chart.

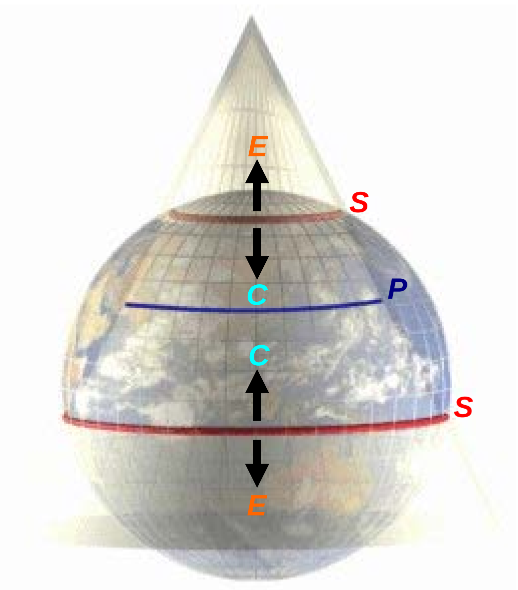
The Lambert's Conical Orthomorphic projection has **two** standard parallels.

With the **ICAO's (International Civil Aviation Organisation)** blessing, this projection is now progressively replacing the Mercator projection as a plotting chart in aviation.

2.11.1 Chart Properties

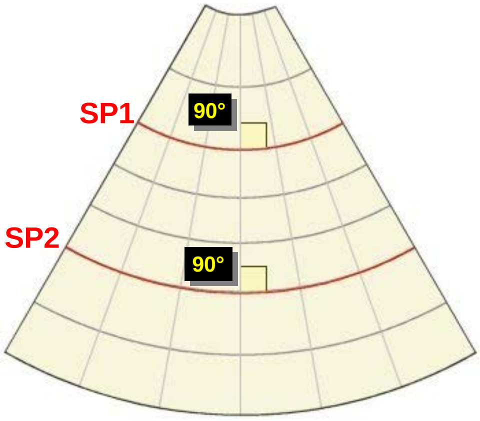
The Lambert's Conformal Conic has the following characteristics:

- The scale is correct along the two standard parallels (***S***).
- The scale contracts (denominator of representative fraction increases) between the two Standard Parallels (***C***).
- The scale expands (denominator of representative fraction decreases) outside of the Standard Parallels (***E***). The expansion increases the further away from the standard parallels you are.
- The **Parallel of Origin** (***P***) is situated approximately halfway between the two Standard Parallels.

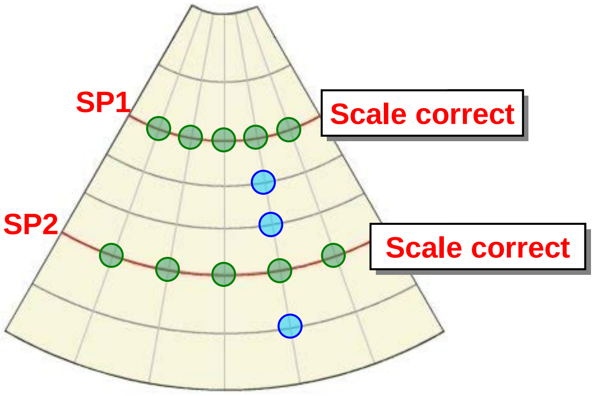


- The chart is made orthomorphic/conformal by mathematical manipulation.

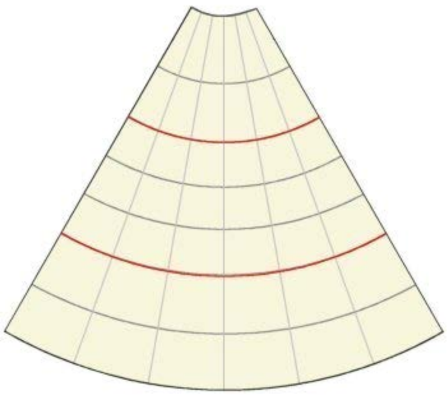
- Viewing the graticule of the Lambert's Conformal Conic, it can be observed that the meridians (straight lines originating from one common point) intersect each parallel of latitudes at 90°. This is one of the requirements for Orthomorphism.



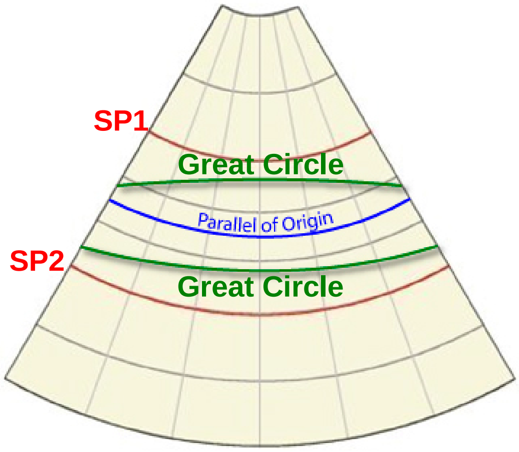
- Although the scale on a Lambert's Conformal Conic varies away from the standard parallels, at any point the scale change in all directions is the same and thus the second requirement for Orthomorphism is met.



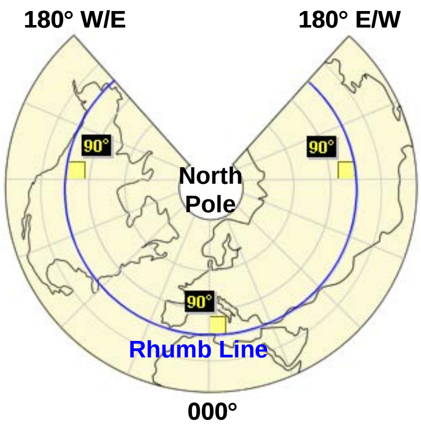
- Meridians are straight lines which meet at a common point beyond the limits of the chart. Parallels are concentric circles concave to the nearer Pole.



- It is not an equal area projection so equal areas on the Earth will not necessarily appear equal on the chart.
- Great circles are curves, concave to the Parallel of Origin (PoO). On charts with a small latitude coverage, such as the WAC series, great circles can be considered to be straight lines.



- Rhumb lines are curves, concave to the nearer pole.



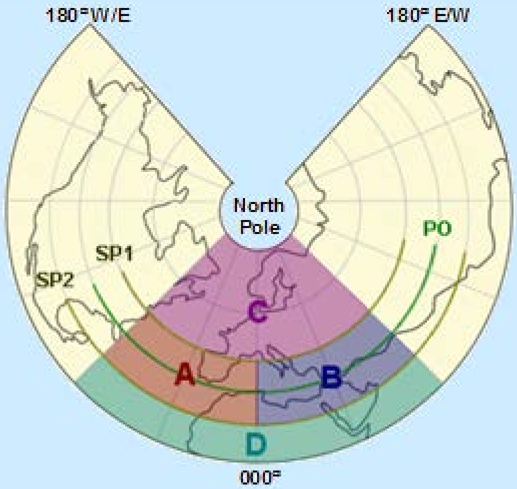
- The distortion of shapes is small.

2.11.2 Chart Fit

- Adjacent sheets will fit E-W, provided they have the same scale and the same standard parallels. It is common for E-W adjacent sheets to have the same standard parallels and most Lambert's charts fit perfectly E-W, like the WAC series of charts.
- N-S adjacent sheets do not normally share the same standard parallels and will thus not fit N-S like the Australian WAC. In the event where they do share the same standard parallel and have the same scale they will fit N-S like some of the TPC (Tactical Pilotage Charts) used by the military.

Example:

Sheet A is a section of a projection in between two Standard Parallels (SP1 and SP2).



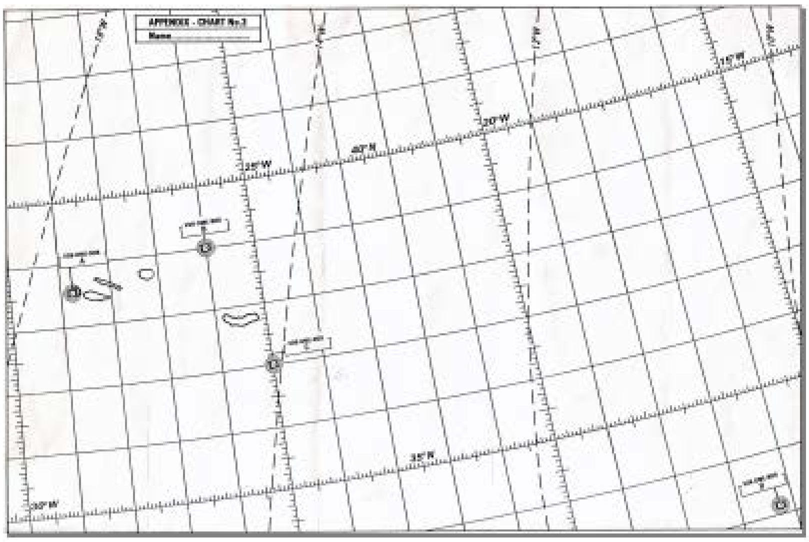
Sheet A and **Sheet B** will fit East-West, as they share the same Standard Parallels.

Sheet C and **Sheet D** will fit North-South to Sheet **A** and **B** as they are from the same section of a large projection with the same Standard Parallels.

2.11.3 Uses of the Lambert's Conformal Conic Projection

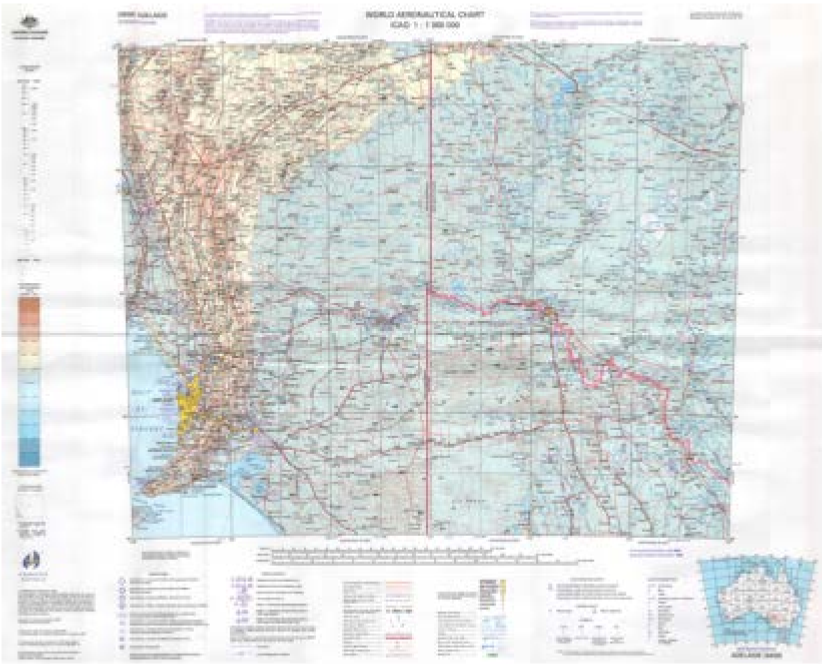
2.11.3.1 As a Plotting Chart:

- The chart is orthomorphic (conformal), therefore bearings are correct and the chart can be used for plotting.
- On charts with a small range of latitudes, scale errors are small, so distance is easily and accurately measured for in-flight plotting.
- Adjacent sheets with the same Standard Parallels fit to give continuity.



2.11.3.2 <u>As a Topographical Chart:</u>

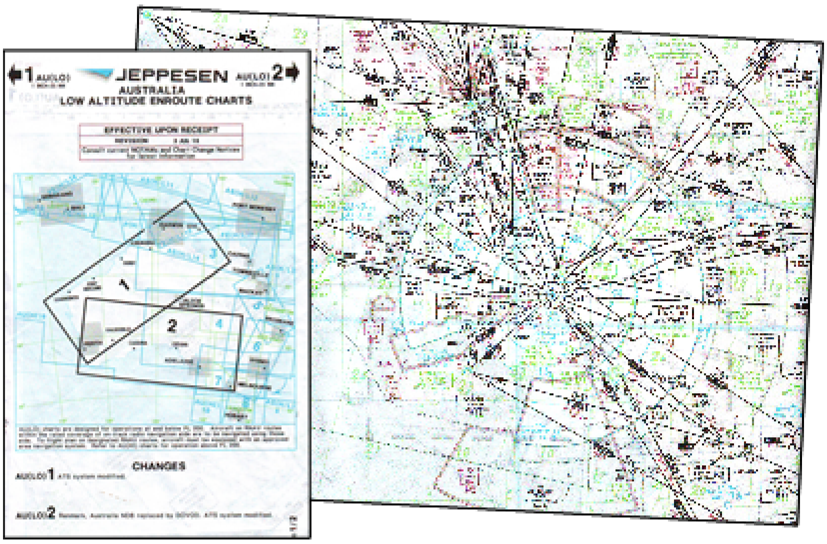
When charts cover a small range of latitudes, scale error and distortion of shapes are small and so the Lambert's projection is ideal as the basis for topographical charts.



Note: The Lambert's projection with its two standard parallels is particularly suitable for regions having a great Eeast/West extent, e.g. Australia, or the USA

2.11.3.3 <u>As a Radio Navigation Chart:</u>

With the exception of charts having large latitude coverage, the Lambert's projection displays great circles approximately as straight lines. As radio waves follow great circle paths across the earth's surface, radio bearings can be accurately represented by straight lines on most Lambert's charts.



2.12 Mercator Projection

Gerardus Mercator (orig. Gerard de Cremer) was born in Rupelmonde, Flanders (now Belgium) in 1512. He studied to become a geographer at the University of Louvain and later became the leading mapmaker of the 1500's.

Mercator won lasting fame for his map of the world that he drew up in 1569.

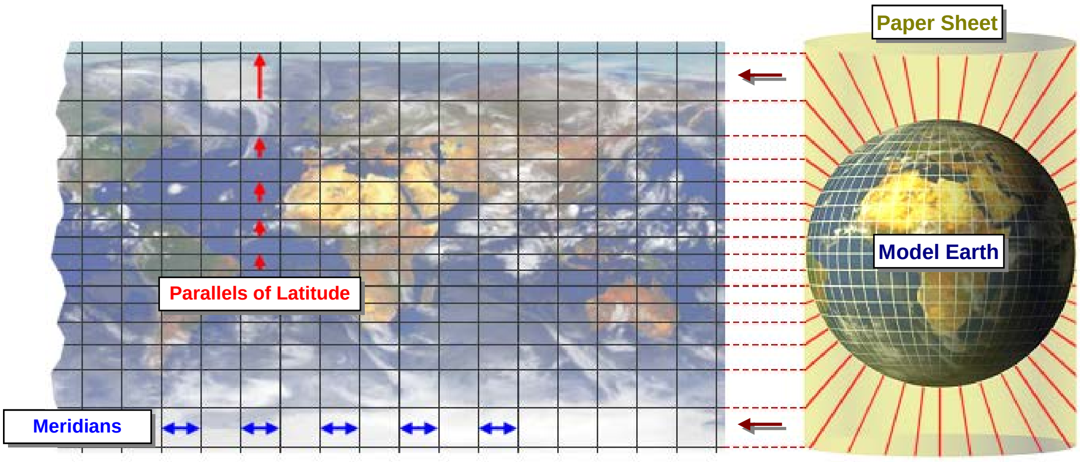
The type of projection that he used was named after him and it is still used today even though certain geographical features are exaggerated in size.

Mercator also produced a collection of maps that he named "ATLAS". This title marked the first use of the word Atlas to describe a collection of maps.

2.12.1 Construction

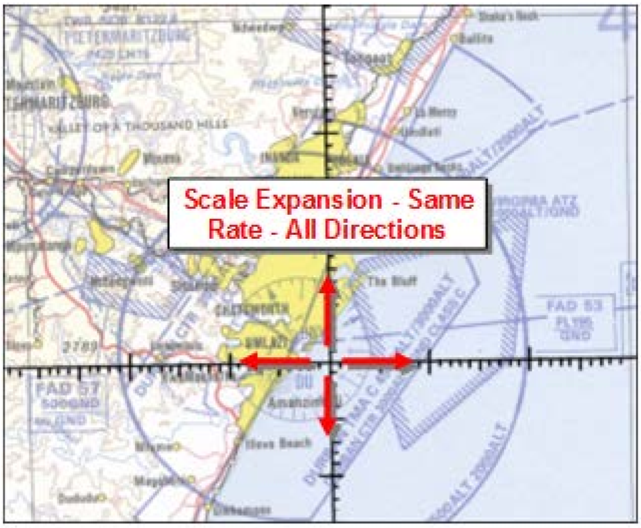
The Mercator projection is based on the normal cylindrical projection where a light source inside a reduced earth projects parallels of latitude and meridians on a flat sheet of paper as follows:

- Parallels of latitude are projected as straight lines with the spacing between them increasing away from the Equator.
- Meridians are projected as equally spaced parallel straight lines.



The meridians and parallels of latitude cut each other at right angles (90°)

The Mercator projection has excellent properties close to the Equator where it is suitable for both radio navigation and topographical purposes.



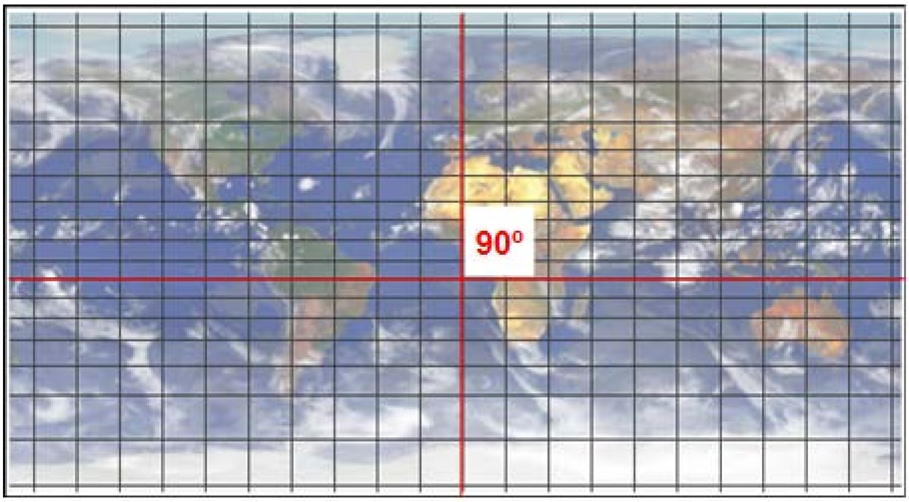
Away from the Equator **scale expansion** is mathematically controlled so that the **scale expands at the same rate in all directions**.

Most modern navigation systems, such as GPS, and INS, as well as the use of Airway systems that are defined by radio beacons, provide great circle information during the navigation process. This requires a map that can represent great circles as straight lines.

Because a straight line on a Mercator projection is a Rhumb line (everywhere on the chart), this type of chart is **not suitable** for **modern** day navigation systems, which require great circle tracks to be represented as straight lines for navigation.

2.12.2 Chart Properties

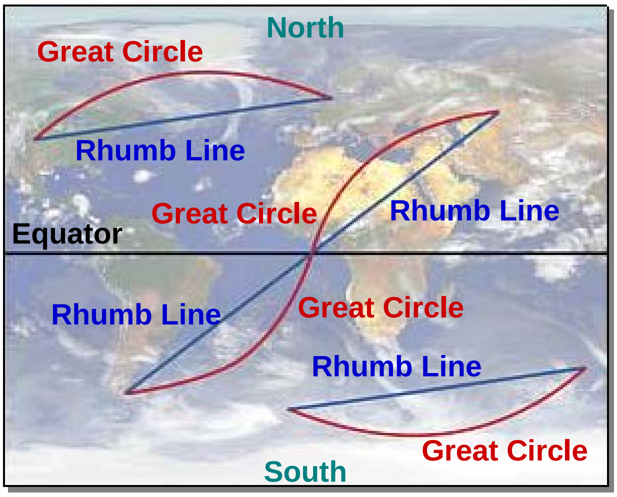
- Meridians and parallels of latitude appear as straight, parallel lines that cross at 90°.



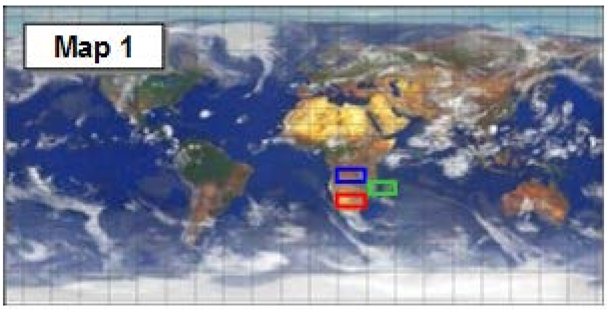
- Scale is correct at the Equator but expands at an increasing rate as latitude increases.

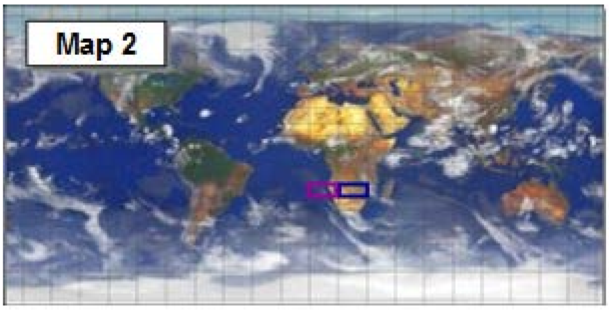
- The projection is made orthomorphic through mathematical manipulation.
- It is not an equal area projection and sizes of areas in high latitudes are exaggerated compared with areas at low latitudes.
- The distortion of shapes of small areas is small because the chart is orthomorphic. However the shapes of large areas, especially at high latitudes, will be distorted due to severe scale expansion.

- Great circles are curves, concave to the Equator. However great circles close to the Equator will appear approximately straight. Meridians and the Equator will appear as straight lines.

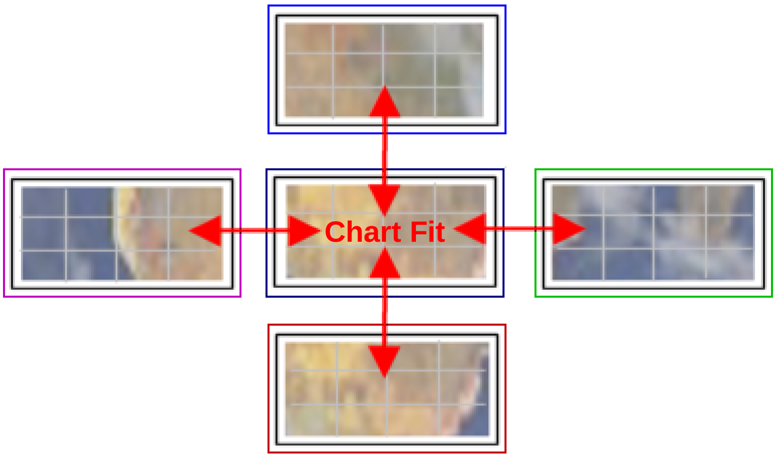


- All rhumb lines appear as straight lines (anywhere on the chart).
- Adjacent Mercator charts, that were derived from bigger maps with the same scale at the Equator, will fit accurately on the four cardinal headings.

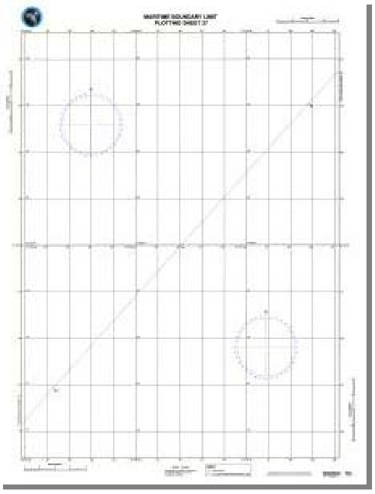




Two Mercator charts (from adjacent areas) that were derived from bigger maps with different scales at the Equator will, therefore, not fit accurately.



2.12.3 Uses of the Mercator Projection



2.12.3.1 As a Plotting Chart:

- The chart is orthomorphic and so bearings can be correctly measured and drawn.
- The rectangular graticule is convenient to use.
- The chart cannot be used above latitudes 75°N/S as the rapidly expanding scale makes the accurate measurement of distance almost impossible.

2.12.3.2 As a Topographical Chart:

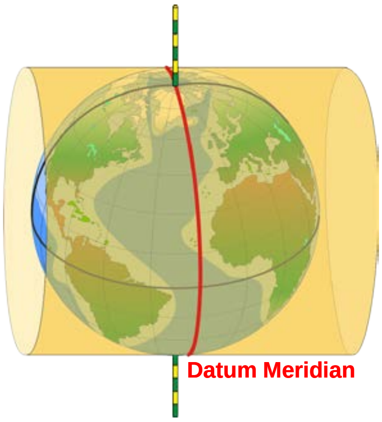
Variation in the scale of the Normal Mercator is very gradual in low latitudes. Between latitudes 5°N and 5°S (300nm either side of the Equator), scale can be considered as almost constant. The shapes of areas will appear correct and so the chart is ideal for topographical purposes in countries close to the Equator.

2.12.3.3 As a Radio Navigation Chart:

Great circles at latitudes close to the Equator appear straight. Radio bearings will appear as straight lines on charts with low latitude coverage around the Equator. At higher latitudes great circles need to be converted into rhumb lines before they can be plotted.

2.13 Transverse Mercator Projection

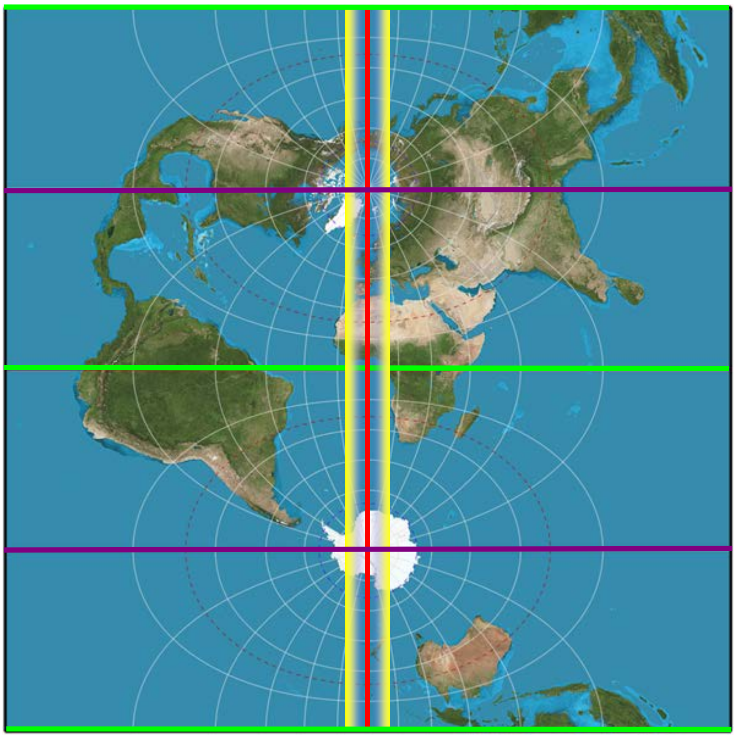
The basis of the Transverse Mercator Projection is similar to the Normal Mercator in that a projection surface in the form of a cylinder is wrapped around the reduced earth. In the case of the Transverse Mercator, the cylinder touches the Earth at a chosen datum meridian (and its anti-meridian).



The Transverse Mercator has excellent properties in a narrow band centred on the datum meridian. In this band, the limits of which lie at 300nm either side of the datum meridian, the Transverse Mercator is suitable for both topographical and radio navigation purposes.

2.13.1 Construction and Appearance of Graticule

The appearance of the graticule is complicated so that the chart is not suitable for plotting, except in the **narrow band** close to the datum meridian.

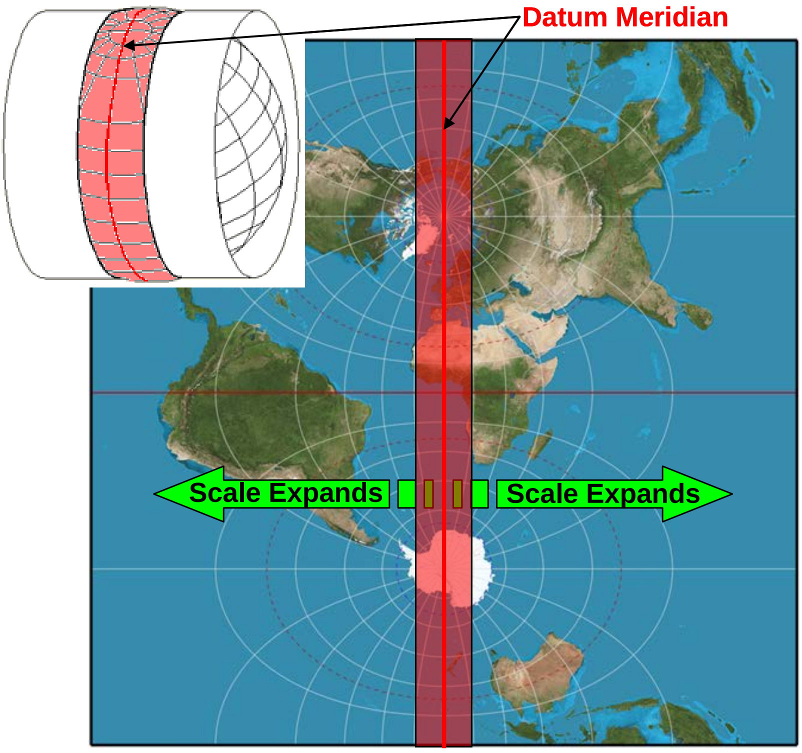


The **datum meridian**, **meridians perpendicular** to it and the **Equator** appear as **straight lines**. Other meridians appear as complex curves, concave to the datum meridian. Parallels of latitude (except the Equator) appear as ellipses, concave to the nearer Pole.

Different areas of the world can be mapped by selecting specific datum meridians that pass through the area to be mapped.

2.13.2 Chart Properties and Uses

- Great circles will appear as straight lines in the narrow band (**approximately 300nm either side of the datum meridian**). Otherwise, with some exceptions, great circles appear as complex curves. The exceptions being the Equator, datum meridian and any meridian at 90° to the datum meridian, all appearing as straight lines.
- Rhumb lines generally appear as complex curves.
- Scale is correct along the datum meridian and increases with increasing distance away from the datum meridian.



- The chart is orthomorphic, so bearing measurements are accurate.
- The distortion of shapes is small within the narrow band along the datum meridian and increases away from the datum meridian.
- Adjacent sheets will fit N-S and E-W if based on the same scale and datum meridian.
- The chart is ideal for countries having a large N-S extent and limited E-W extent, such as the UK, Finland and Korea.

> **Note**: The Australian VCT (Visual Terminal Chart) series is based on the Transverse Mercator.

2.14 WORKSHEET 1 - FORM OF THE EARTH AND CHARTS (GENERAL)

1. Which of the following statements is false?

   a. Meridians are examples of great circle tracks.

   b. Meridians join places with equal longitude.

   c. Meridians are examples of rhumb line tracks.

   d. Meridians are parallel lines joining North and South Poles.

2. Which of the following statements is true?

   a. A minute of longitude represents a constant distance on the surface of the Earth.

   b. A nautical mile is 1/1000th of the average distance between the Equator and either Pole.

   c. Minutes of latitude can be used to measure distance in nautical miles.

   d. A distance flown East or West of 60nm will represent a change of longitude of 1 degree at all latitudes.

3. The shortest track between A (35°S 100°E) and B (35°S 110°E) is defined by:

   a. The great circle

   b. The parallel of latitude

   c. The rhumb line

   d. 090°.

4. The scale of a map refers to the:

   a. Amount of detail that is shown

   b. Size of the sheet of paper on which the chart is printed

   c. Amount of the Earth shown on a map

   d. Ratio of chart length to the Earth distance that the chart length represents.

5. The term "orthomorphism" is used to describe charts which:

   a. Show equal areas of the Earth as equal areas on the chart

   b. Have constant scale

   c. Show shapes of large areas correctly

   d. Have the same scale N/S and E-W about any point.

6. All the properties of an "ideal" chart can never be achieved together on any projection:

   a. But great circles and rhumb lines can appear straight at all latitudes on the same chart.

   b. But equal areas and correct bearings can be achieved on the same chart.

   c. But all distances can be correct.

   d. So charts must be chosen according to which properties are most important.

7. The term "relief" when applied to a map refers to:

   a. The means used to show scale

   b. The coverage of the chart in latitude and longitude

   c. How the height of the ground is shown

   d. Topographical features such as rivers, coastlines and lakes.

2.14.1 ANSWERS – WORKSHEET 1

1D	2C	3A	4D	5D	6D	7C

2.15 WORKSHEET 2 - LAMBERTS CONFORMAL CONIC

1. The AIP chart RNAV1 has Standard Parallels at 9°S and 35°S. A scale of 1:8,000,000 is depicted on the chart border. Which of the following could be the scale at 22°S?

    a. 1 : 7,400,000

    b. 1 : 8,000,000

    c. 1 : 7,000,000

    d. 1 : 8,600,000.

2. Your proposed route cannot be shown on a single chart so you decide to join two sheets, each based on a Lambert's projection. Which of the following statements is true?

    a. The sheets will fit as they are based on the same type of projection

    b. The sheets will fit if they have the same scale

    c. The sheets will fit N-S if they have the same scale at a common latitude

    d. The sheets will fit E-W if they have the same scale and the same standard parallels.

3. To measure a rhumb line track on a Lambert's chart, you should:

    a. Measure the straight line at the mid longitude

    b. Measure the straight line at the point of departure

    c. Measure the straight line at the mid standard parallel

    d. Draw a curved line and try to measure its direction at any meridian.

4. Which of the following statements is true? On a Lambert's Conformal Conic chart:

    a. Scale is constant

    b. Meridians are straight lines and parallels of latitude are curved so the chart cannot be orthomorphic

    c. Straight lines very closely approximate to great circles

    d. Rhumb lines are straight lines

5. You fly outbound from a VOR on the 270° radial. How would your track appear on a Lambert's chart?

    a. Approximately as a straight line

    b. Curved concave to the nearer pole

    c. You are flying along a parallel of latitude so your track will be curved

    d. Curved concave to the equator.

2.15.1 ANSWERS – WORKSHEET 2

1D	2D	3A	4C	5A

2.16 WORKSHEET 3 - NORMAL MERCATOR

1. Jeppesen chart A/S (H/L) 3 is based on a Normal Mercator projection. This projection is suitable for radio navigation because:

    a. Radio waves follow rhumb lines which appear as straight lines

    b. The area of coverage is equatorial so great circles appear approximately as straight lines

    c. Scale is constant

    d. It is not orthomorphic.

2. On a Normal Mercator, how does scale vary?

    a. Scale expands North and South of the Equator but scale East-West is the same at all latitudes

    b. Scale is constant

    c. Scale expands with increase in latitude

    d. Scale expands North of the Equator and contracts South of the Equator.

3. On a Normal Mercator, a line 10cm in length is drawn at 30°S. A similar line 10cm in length is drawn at 60°S. Which of the following statement is correct?

    a. The line at 30°S represents the greater Earth distance

    b. The line must represent the same Earth distance

    c. The line at 60°S represents the greater Earth distance

    d. The line represent the same Earth distance if drawn N-S but different Earth distance if drawn E-W.

4. On a Normal Mercator, how does the graticule appear?

    a. Parallels of latitude are curved concave to the nearer Pole and meridians appear as parallel straight lines.

    b. Meridians converge towards the Poles and parallels of latitude are shown as straight lines.

    c. Parallels of latitude are curved so meridians are also curved, cutting the parallels at 90°.

    d. Meridians are straight and parallel, 90° to the Equator. Parallels of latitude straight and parallel to the Equator.

5. For which purpose would the Normal Mercator be a suitable projection?

    a. A radio navigation chart for the whole of Australia

    b. A plotting chart for the polar regions

    c. A meteorological chart for high latitudes

    d. A topographical map of equatorial regions.

2.16.1 ANSWERS – WORKSHEET 3

1B	2C	3A	4D	5D

2.17 WORKSHEET 4 - TRANSVERSE MERCATOR

1. Which Australian AIP chart is based on the Transverse Mercator projection?

   a. WAC

   b. ERC

   c. VTC

   d. VEC

   e. VNC.

2. How does scale vary on a Transverse Mercator?

   a. Scale increases with increase in latitude

   b. Scale increases with increase in longitude

   c. Scale increases with increasing distance from the datum meridian

   d. Scale must be constant as the chart is orthomorphic.

3. For which purpose would the Transverse Mercator be a suitable projection?

   a. A topographical chart of the equatorial regions

   b. A radio navigation chart for an E-W route across the Pacific

   c. A map of a country which is long N-S but narrow E-W

   d. A small scale plotting chart covering the Indian Ocean

4. How do rhumb lines appear on a Transverse Mercator?

   a. Complex curves except the datum meridian, meridians perpendicular to it and the Equator

   b. Straight lines cutting all meridians at the same angle

   c. Curves concave to the Parallel of Origin

   d. Any rhumb line cutting the datum meridian at 90° will appear as a straight line.

5. In relation to a Transverse Mercator, which of the following statements is true?

   a. Equal areas on the Earth will appear equal on the chart as the Transverse Mercator has constant scale.

   b. Shapes and areas are approximately correct within a band 300 nm either side of the datum meridian.

   c. The chart is not orthomorphic as the meridians and parallels of latitude do not cross at 90°.

   d. Meridians appear as parallel straight lines.

2.17.1 ANSWERS – WORKSHEET 4

1C	2C	3C	4A	5B