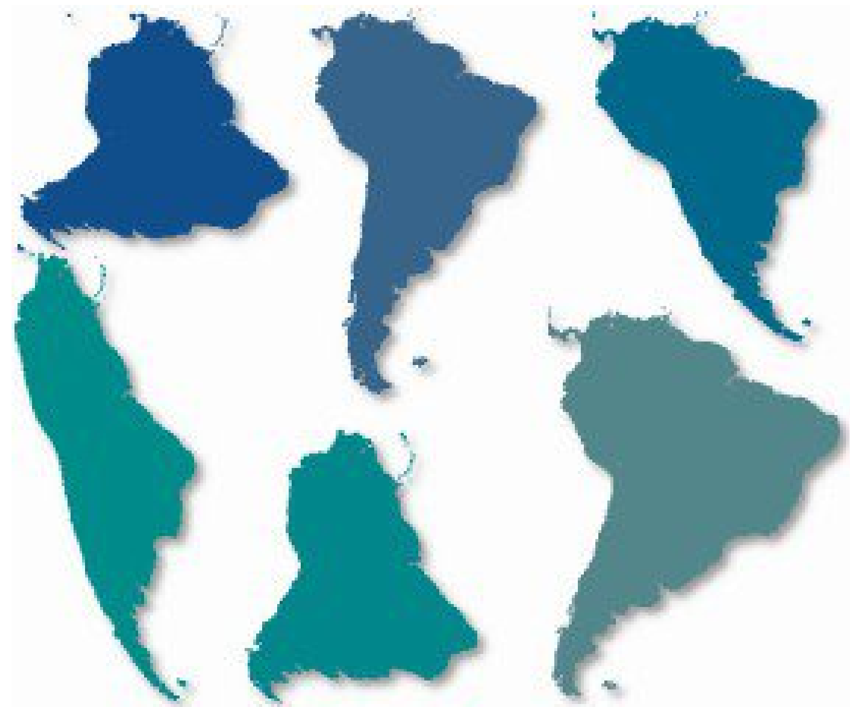
Map projections 1: principles

How can we 'project' a 3D globe onto a 2D display?

..only a globe maintains all spatial qualities without distortion

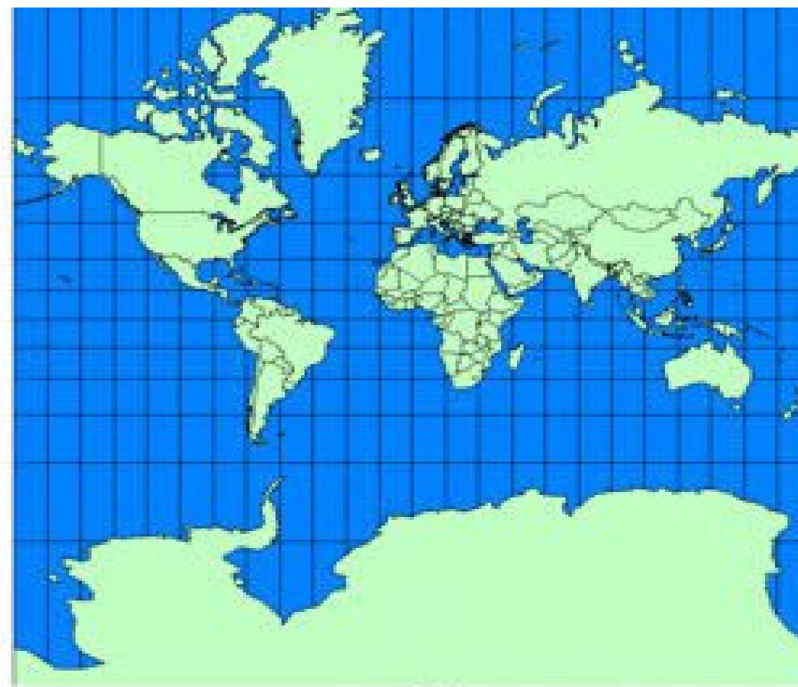


https://imgur.com/t/science_and_tech/53iqEMC

What is a Map Projection?

a <u>mathematical</u> expression giving the 3D surface on a 2D map

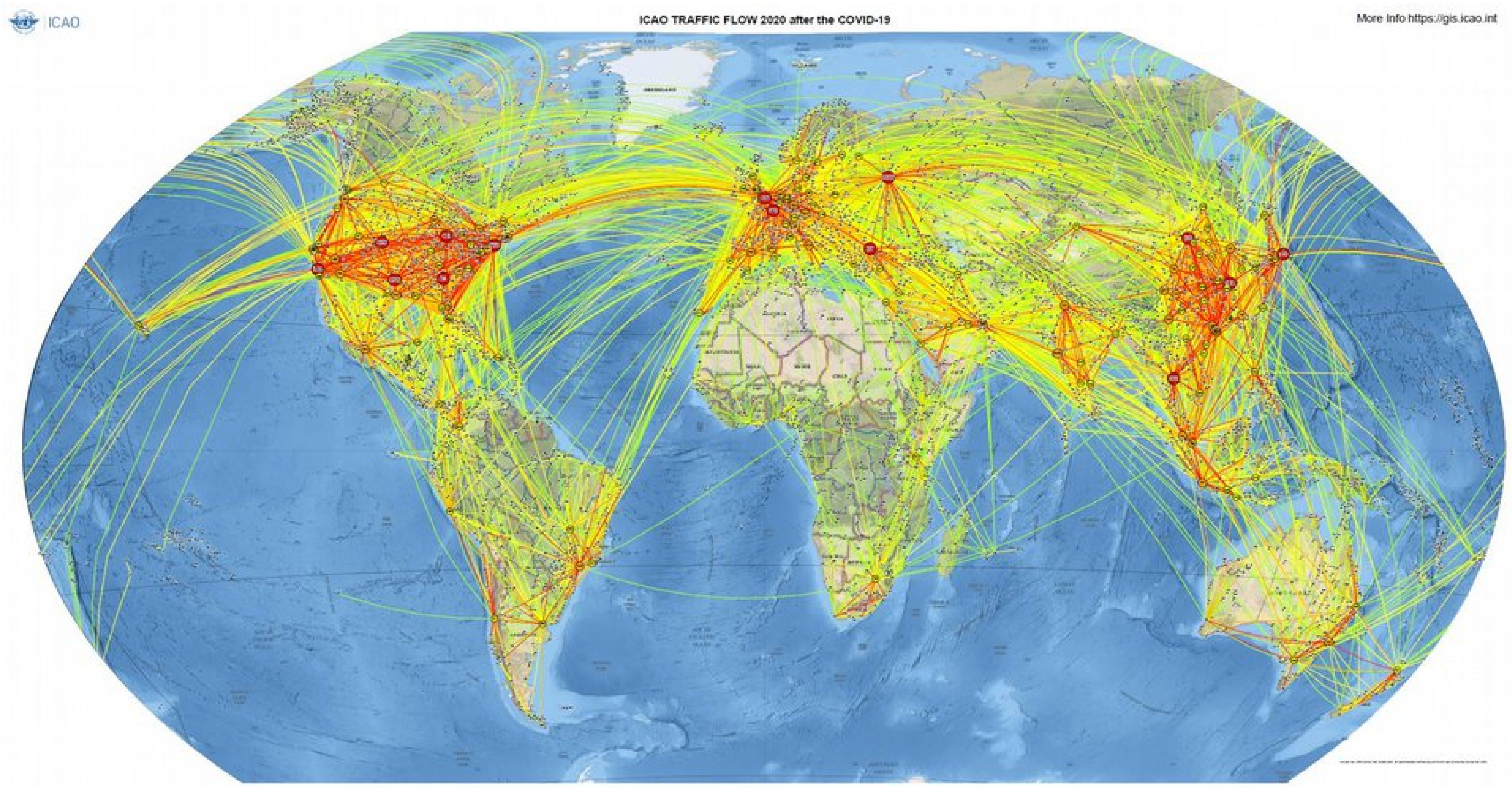
1



2

This process always results in distortion

Why don’t planes fly on straight lines – well they do …

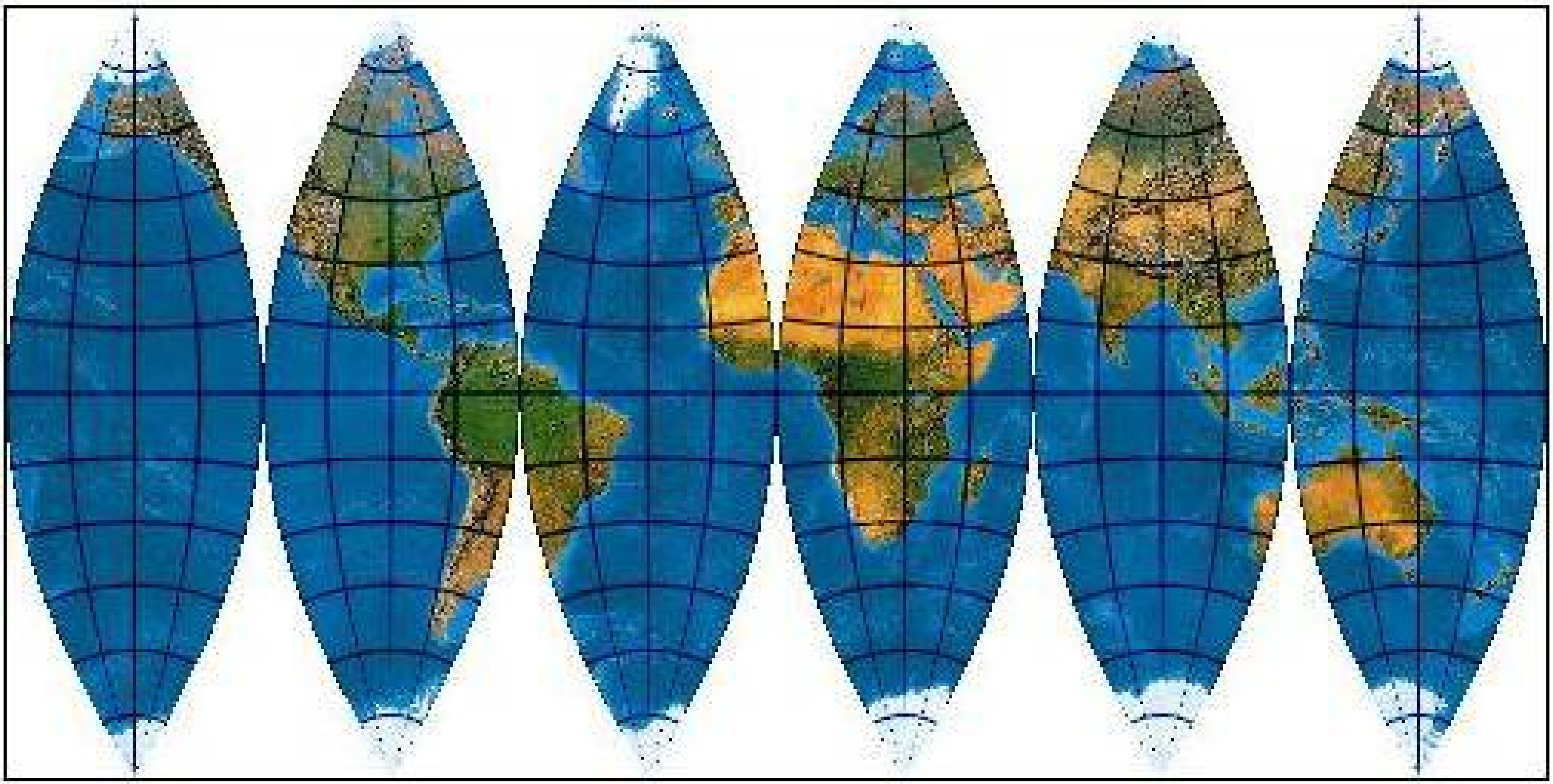


flight routes as 'great circles' … straight line in 3D space

The world could be mapped like orange peel …

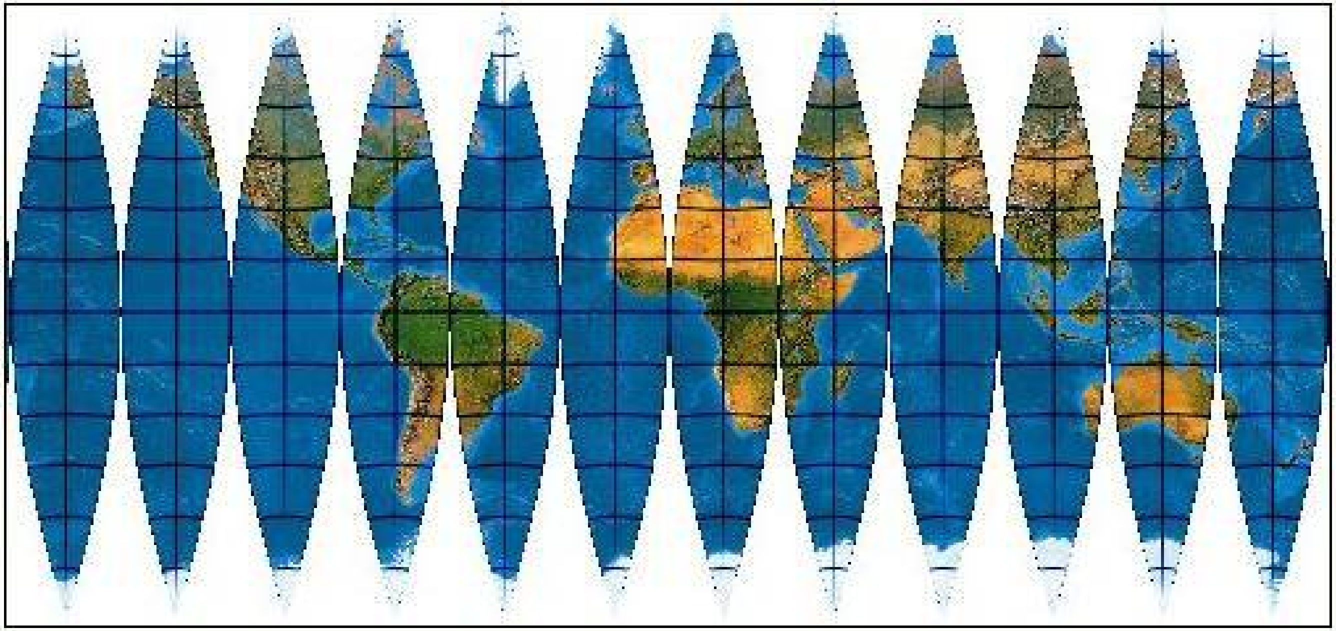
- not a problem locally, but it is for large areas

The world could be mapped like orange peel …
the strips would still have some curvature
.. and gaps between the strips



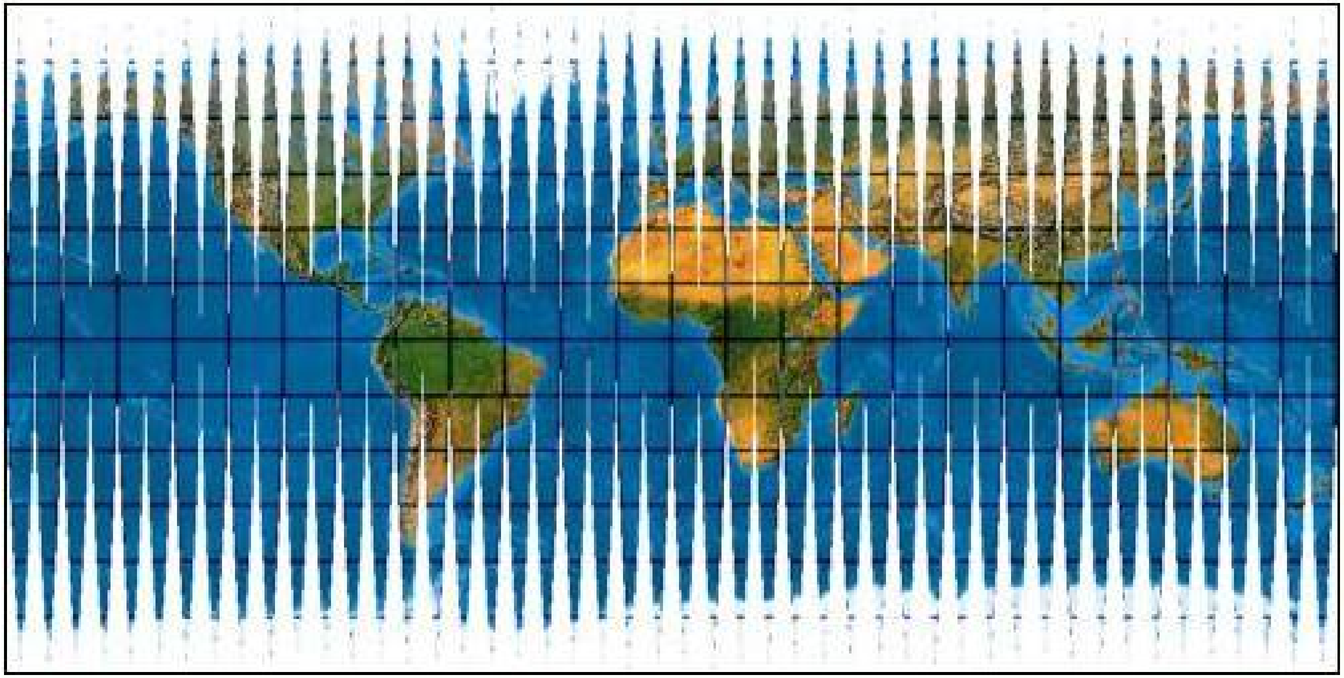
http://boehmwanderkarten.de/kartographie/is_netze_globussegmente.html

12 pieces



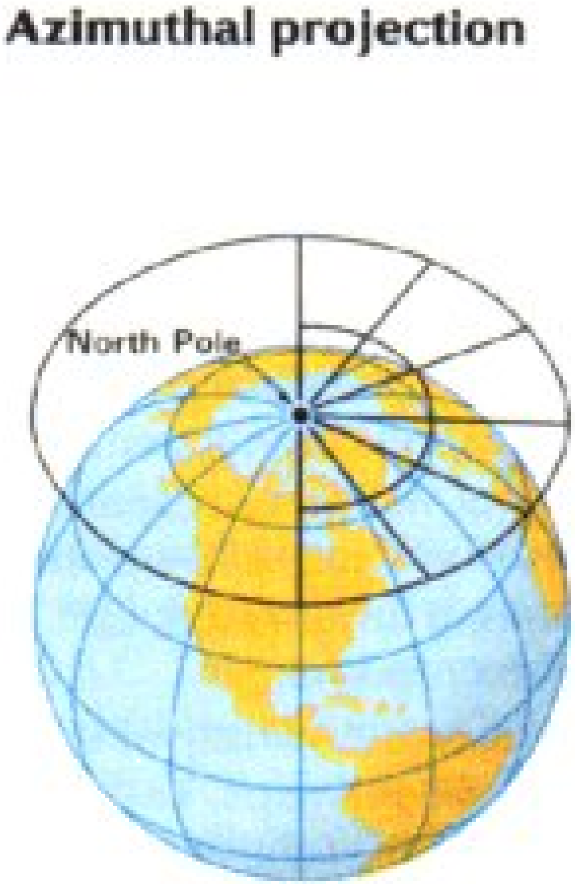
48 pieces

becoming like UTM zones !



Or they can be made by literally 'projecting' the globe onto a map …

Azimuthal (planar) projections



The earliest projections were by the 'ancient' Greeks

Projection Terms

1. Scale Factor (SF)

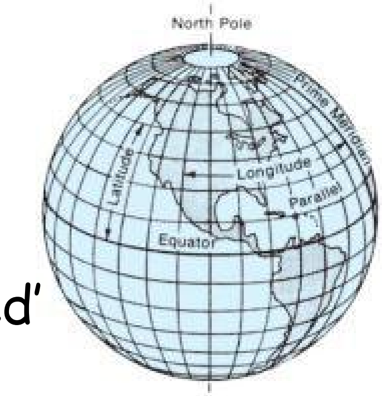
SF = scale at any location /
divided by the 'principal scale'

e.g. if scale = 1:2 million and principal scale = 1:1 million

then SF at that point = 1/2million divided by 1/1million
= 1/2 (0.5)

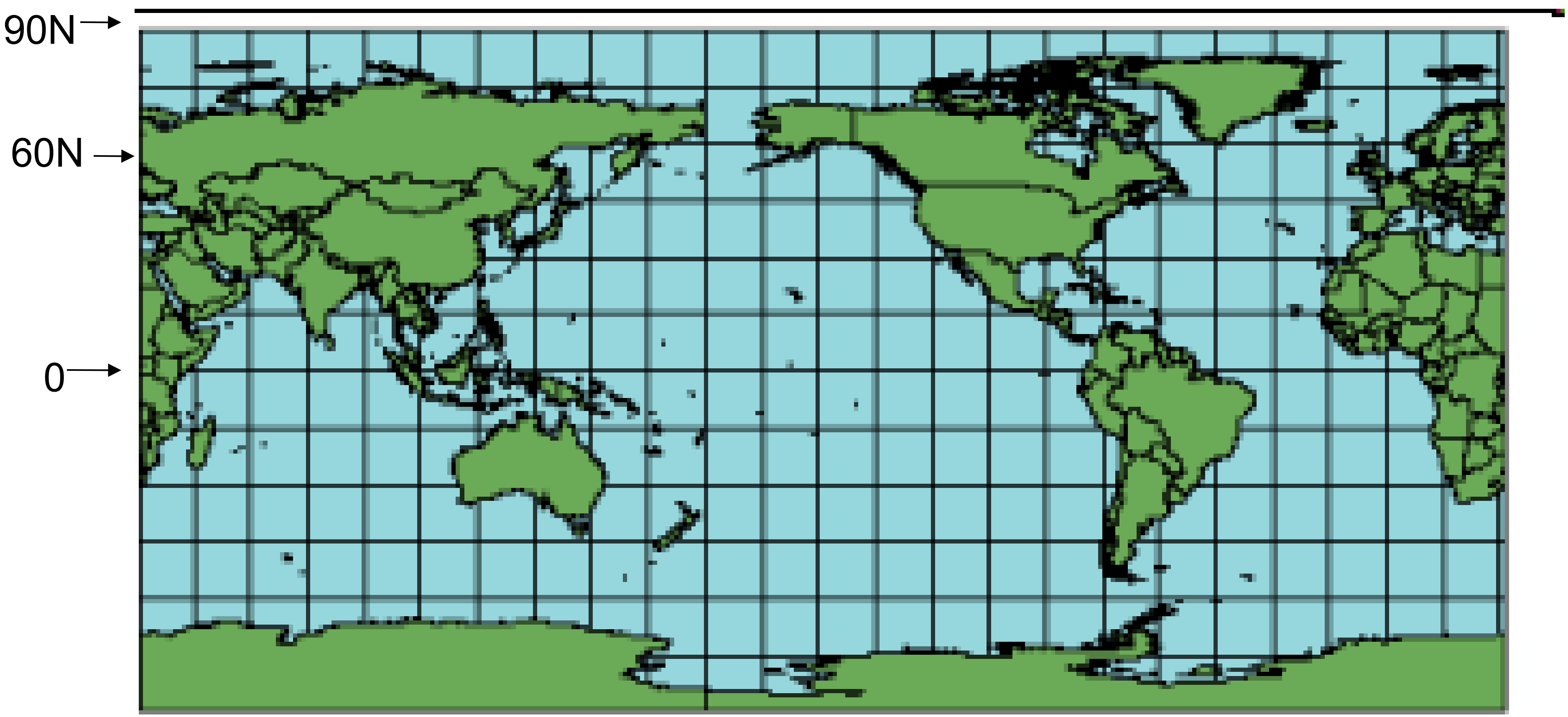
Canadian NTS maps: 'scale factor 0.9996 at UTM zone edge'

e.g. where every line of latitude is equal in length



SF along lines of latitude are: equator SF = 1;

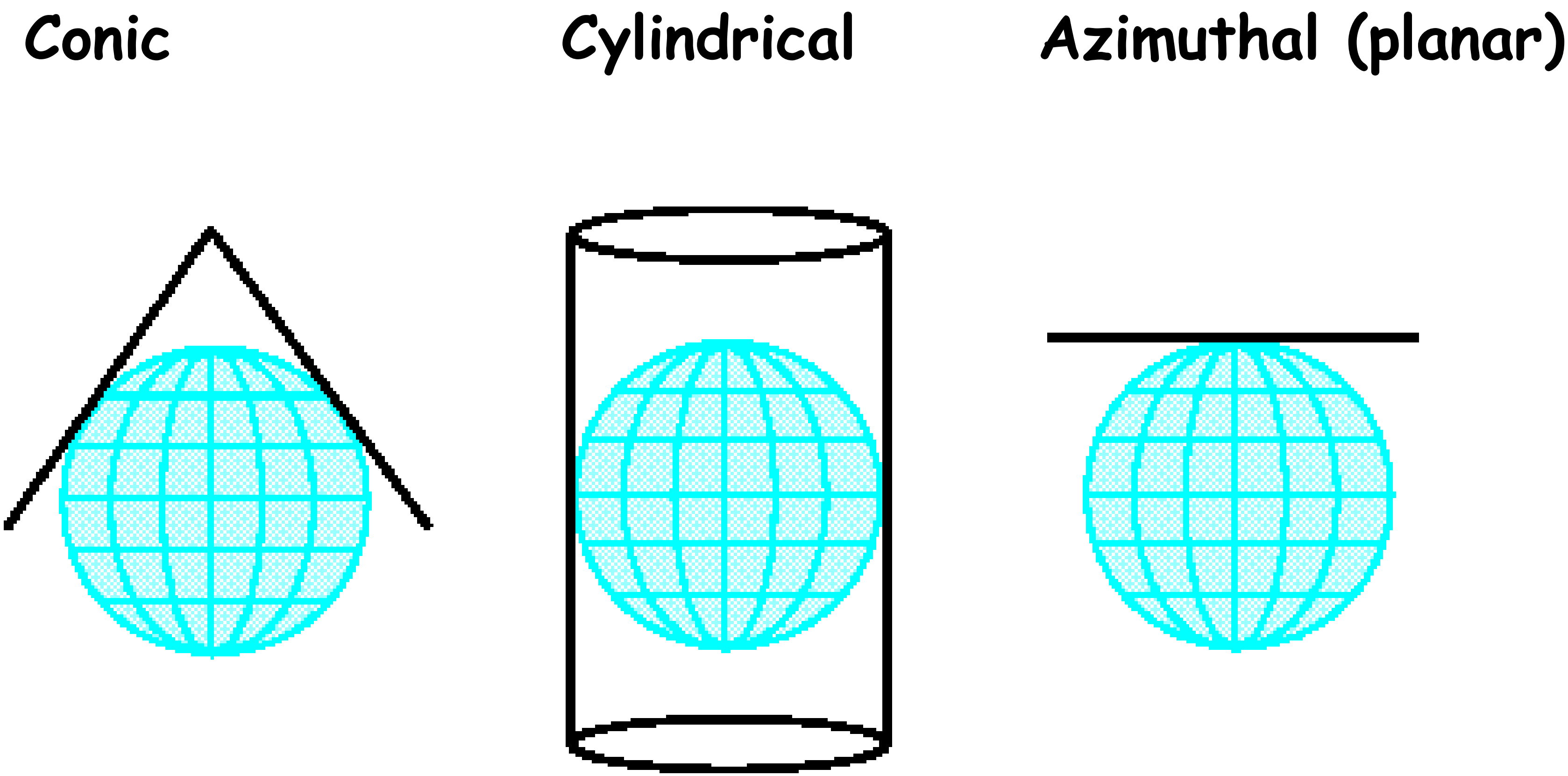
at 60°N/S, SF =2 at 90°, SF = ∞ 'undefined'



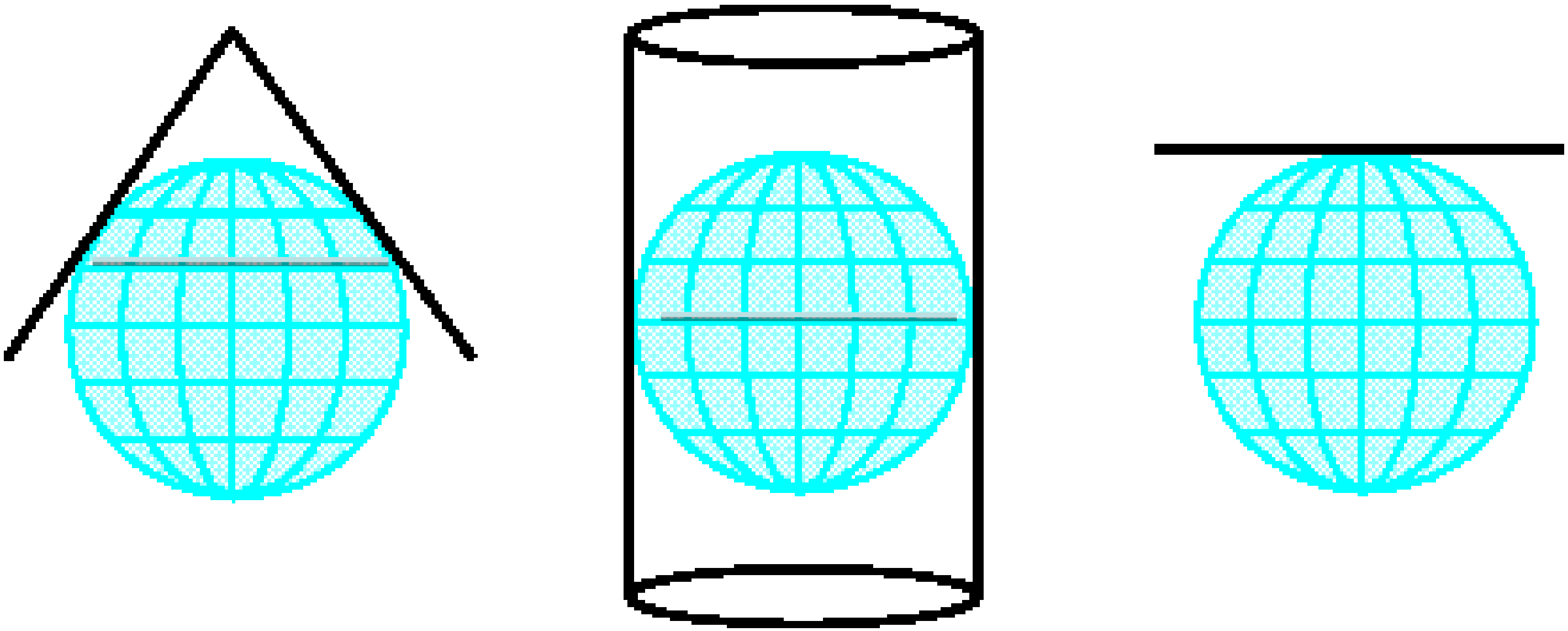
The SF in the other direction (along meridians) is 1

2. Developable surfaces:

A two dimensional surface onto which the globe is projected



3. Standard Line



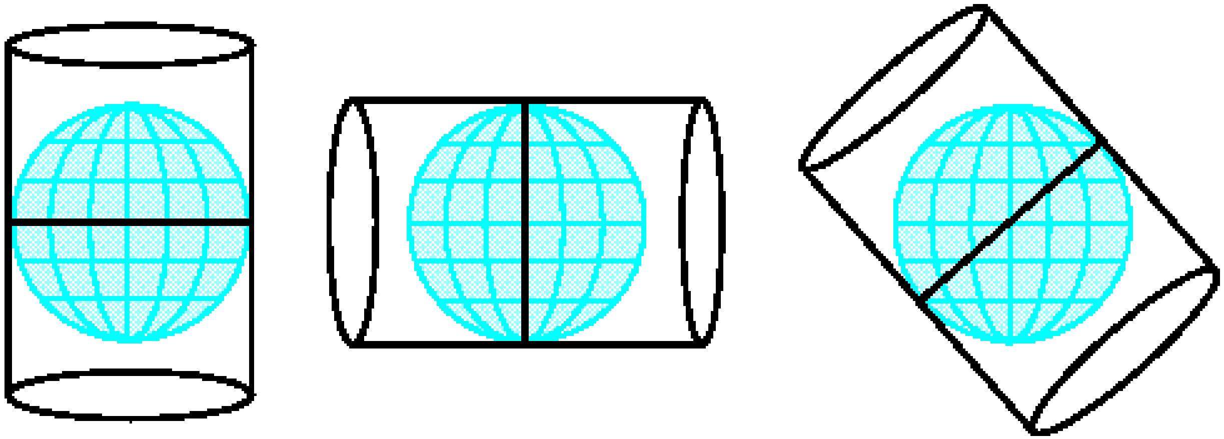
Distortion increases with distance between the 'globe' and the surface

The standard line has a scale factor = 1

(it is often the line of contact)

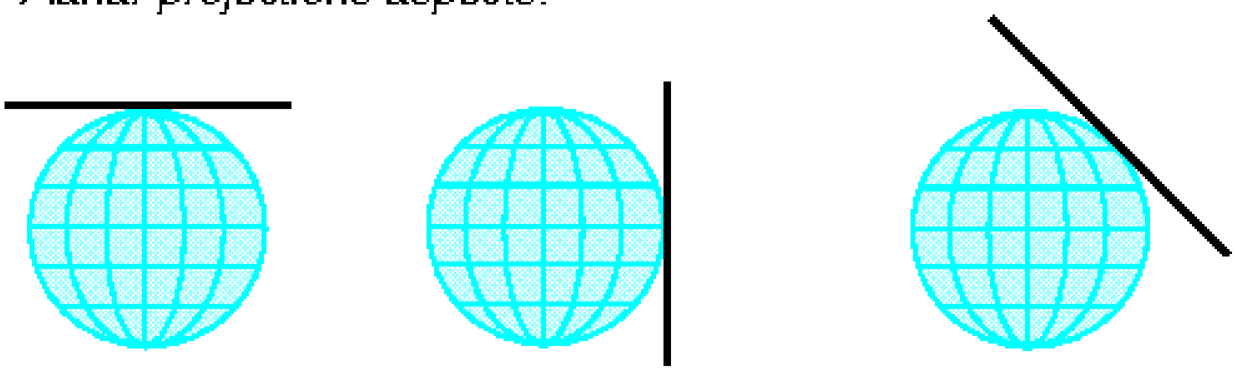
4. **Projection Orientation**

Cylindrical projections:



NORMAL TRANSVERSE OBLIQUE

Planar projections aspects:



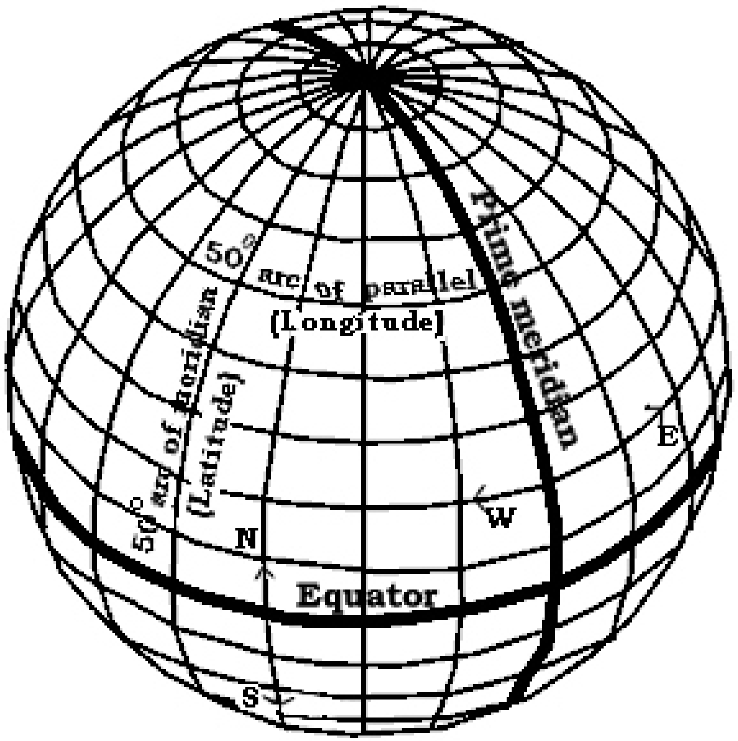
POLAR EQUATORIAL OBLIQUE

5. Distortion: …. compare to the graticule:

- Lines of latitude are 'parallel' and evenly spaced.

- Meridians converge at the poles,
  (half the distance at 60° N/S).

- Scale factor is 1 in all directions.



6. Projection properties

A projection can preserve

- Shapes or
- Areas or
- Distances / directions (but not all)

…..but never more than one of these

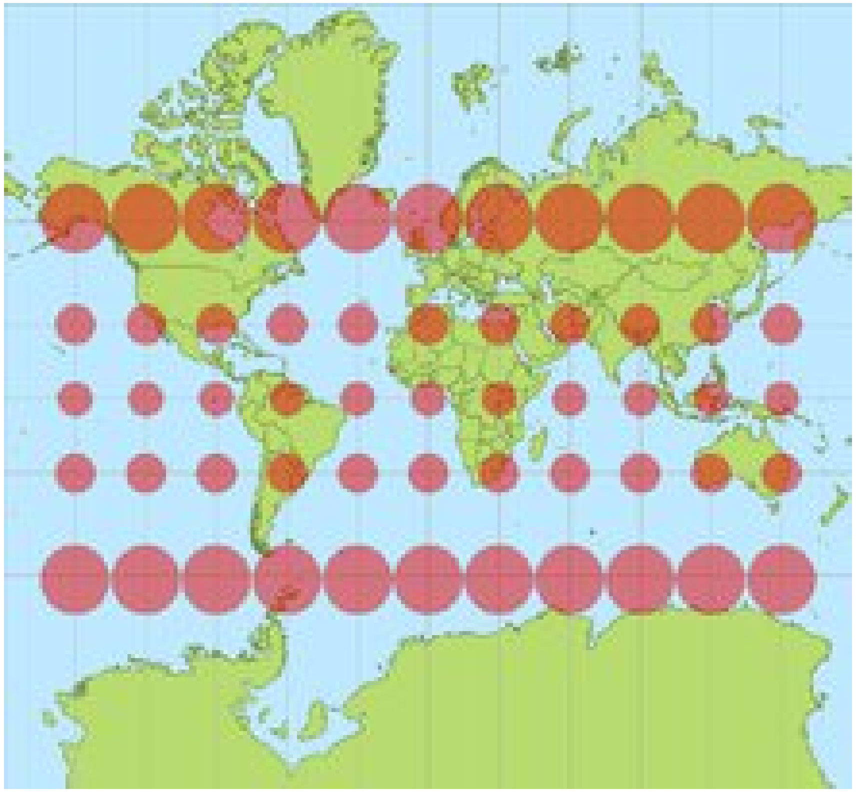
a. Shape

A projection that maintains shape is '**conformal**'

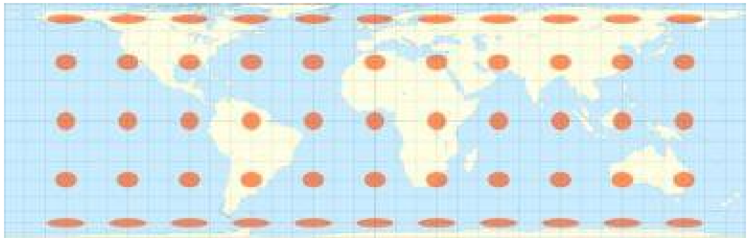
For example a 2x2 square becomes a 1x1 or 4x4 square. Stretching in one direction is **matched** by stretching in the other: that is, the scale factors are equal at a point in the two directions (i.e. there is 'equal-stretching').

Circles ("Tissot's Indicatrix") ->

These indicate the relative area compared to a standard area at the equator (the standard line)



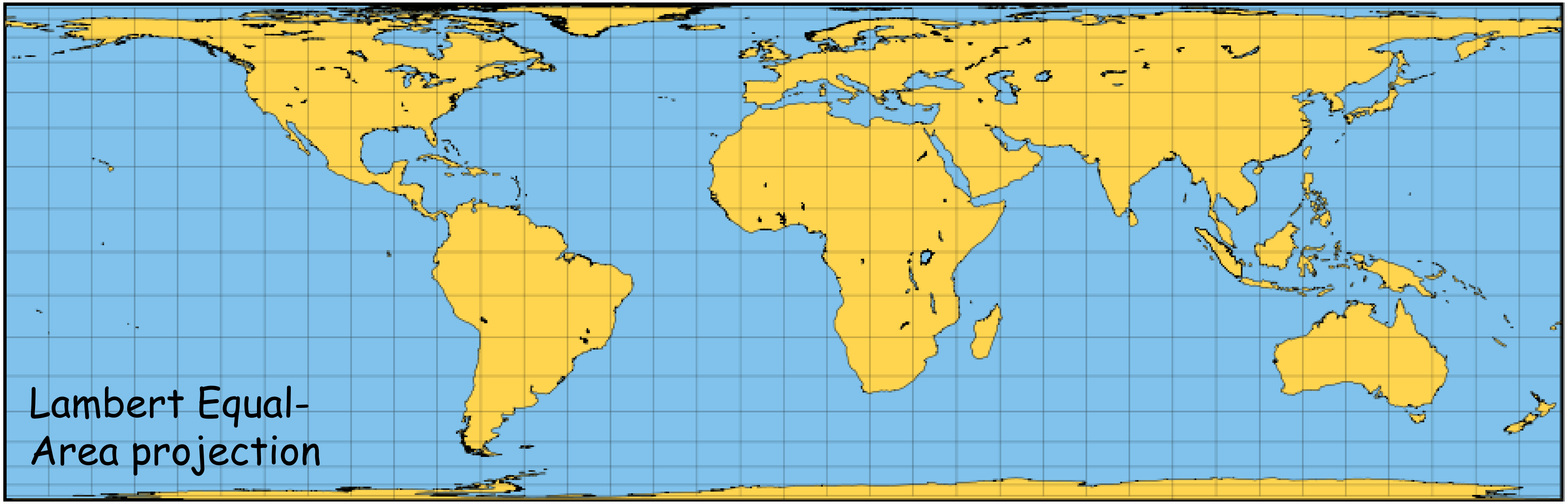
b. Area



A projection that maintains area is **equal area**

This is achieved by sacrificing **shape**: stretching in one direction to counter for earth curvature must be **compensated** by compression in the other.

In other words, the product of the two Scale factors at any point in the two directions (N-S and E-W) = 1.0 (e.g 1 x 1, 2 x 0.5 etc..)



Lambert Equal-Area projection

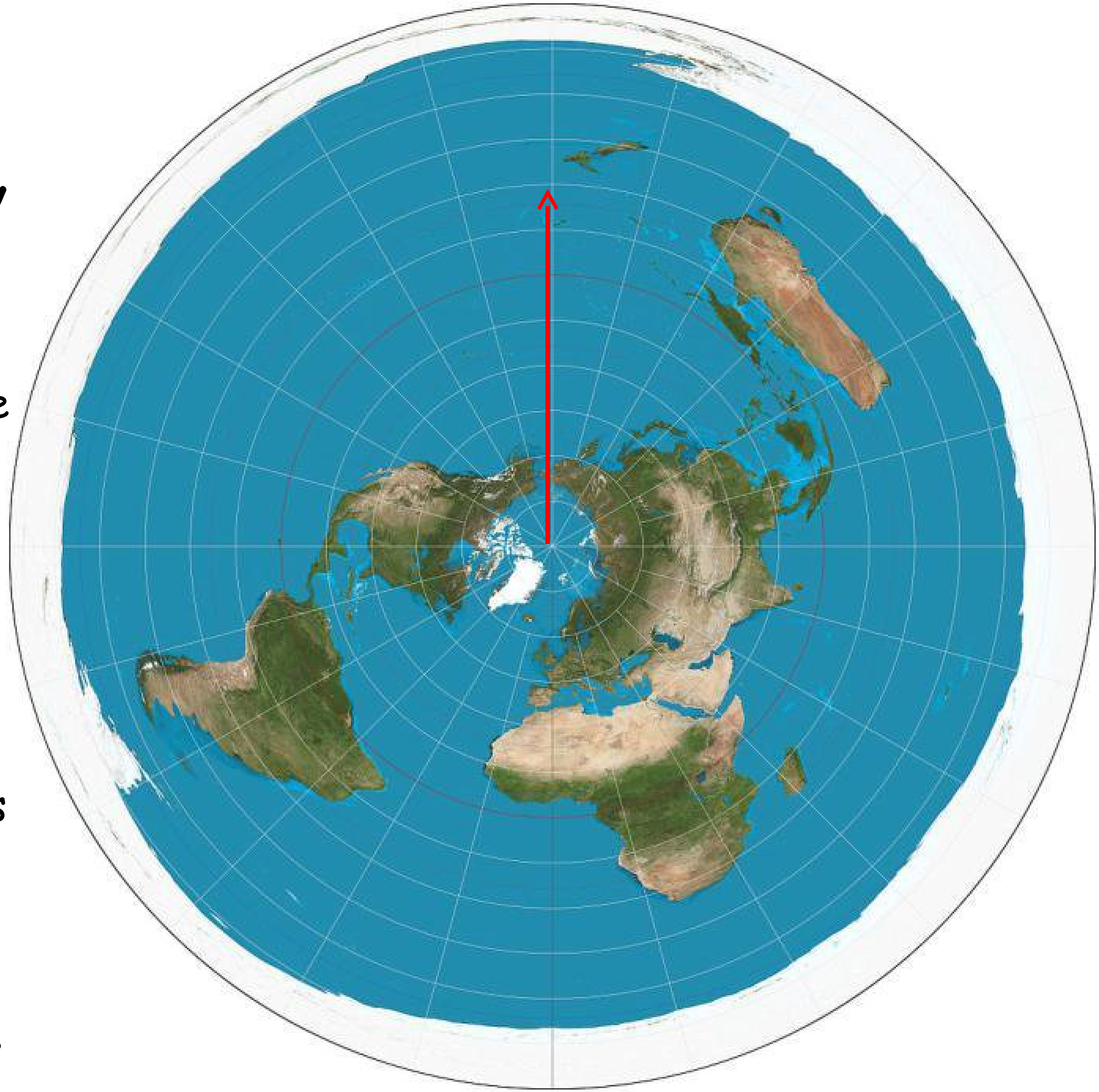
<u>Hence a projection CANNOT preserve both shape AND area</u>

(equal versus compensating stretching)

Projection properties: c.Distance/ direction

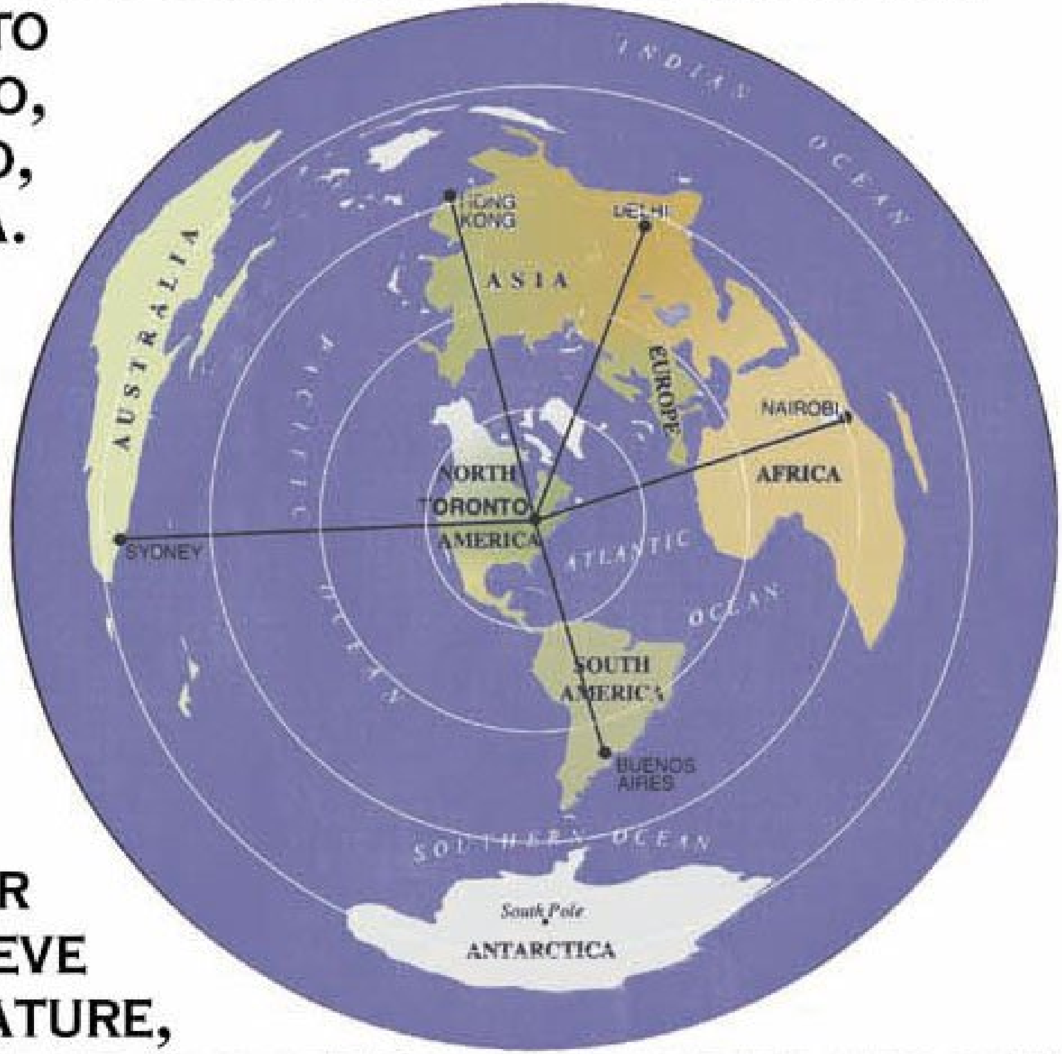
Distances can be correct in one direction from a line or in <u>all directions from a point</u>

In these cases, the projection is **equidistant**



Azimuthal equidistant

GUELKE'S EQUIDISTANT PROJECTION TELLS YOU EXACTLY HOW FAR IT IS FROM ANYWHERE ON EARTH TO TORONTO, ONTARIO, CANADA.



IN ORDER TO ACHIEVE THIS FEATURE, YOU NEED TO SACRIFICE SOME SHAPES AND SIZES.

www.diversophy.com/guelke.htm

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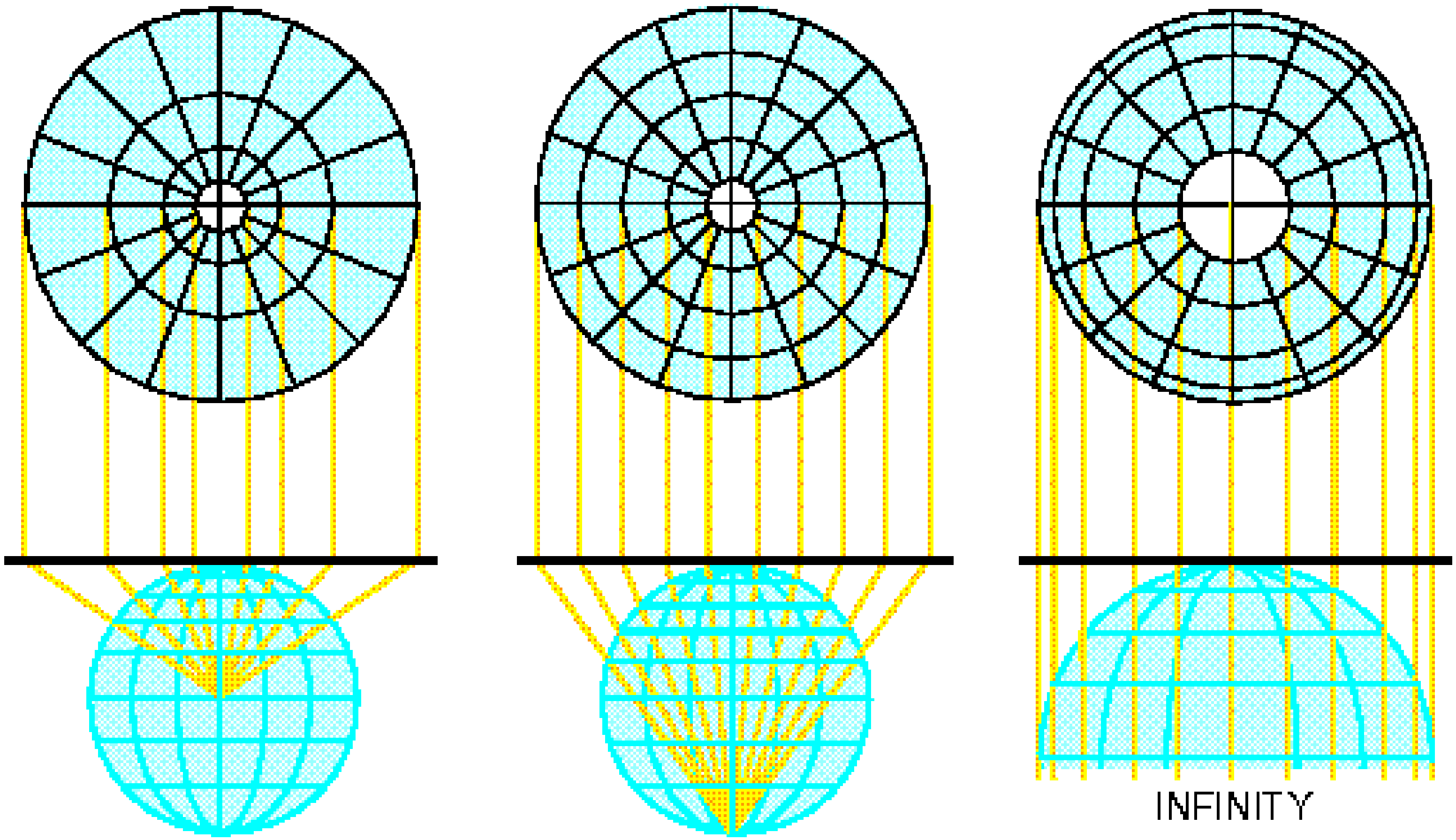
Projection types (based on the developable surface)

I. Azimuthal projections



GNOMONIC	STEREOGRAPHIC	ORTHOGRAPHIC
Great circles= straight lines	Conformal (shape)	'View from space'
Thales 500BC	Ptolemy 125BC	Hipparchus 150BC

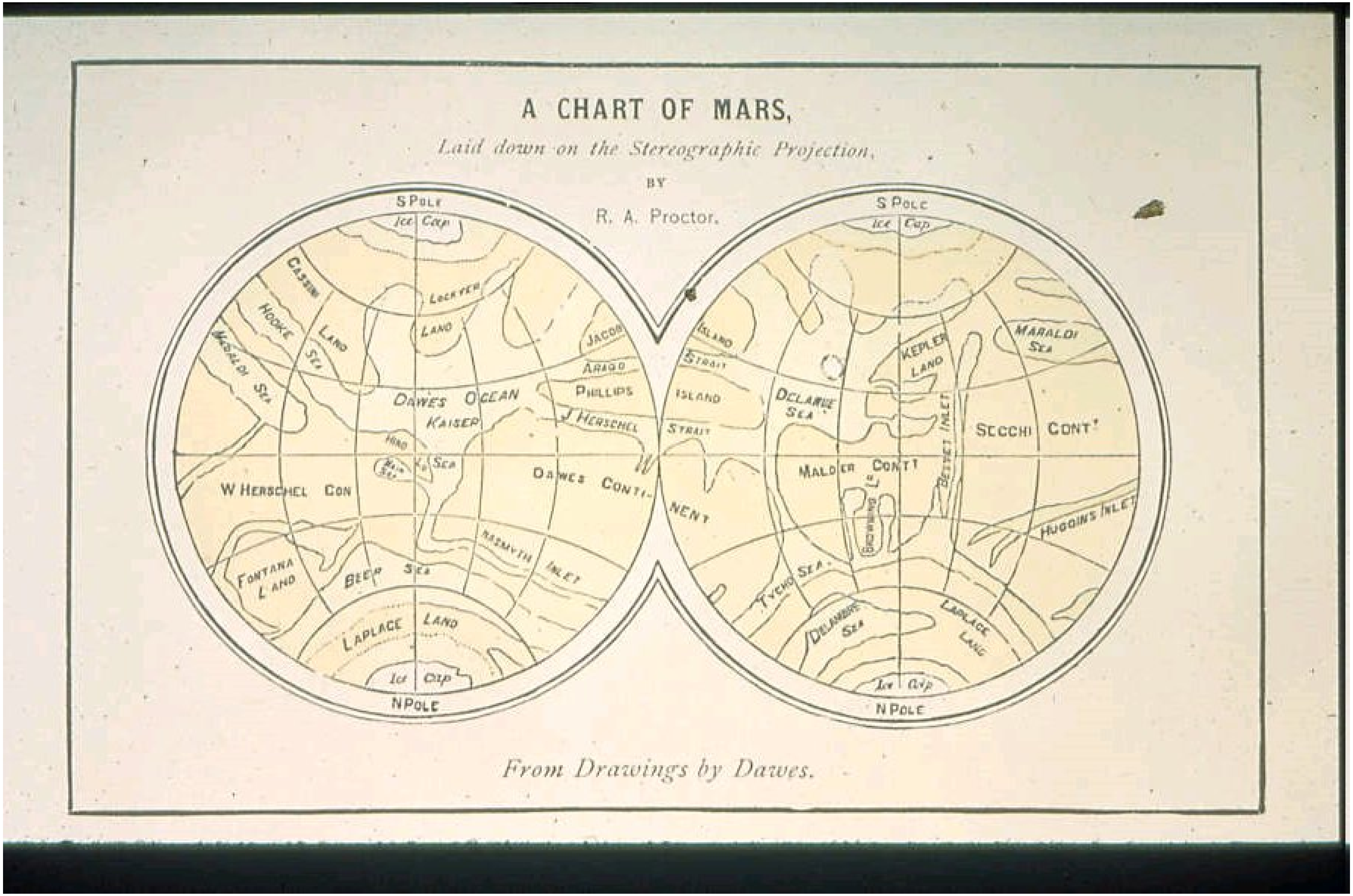
Gnomonic projection

Probably the world's oldest map projection – 6th century BC

– the <u>only one</u> that shows <u>all</u> great circles as straight lines

(but cannot show one entire hemisphere)

First map of Mars, 1867- equatorial stereographic

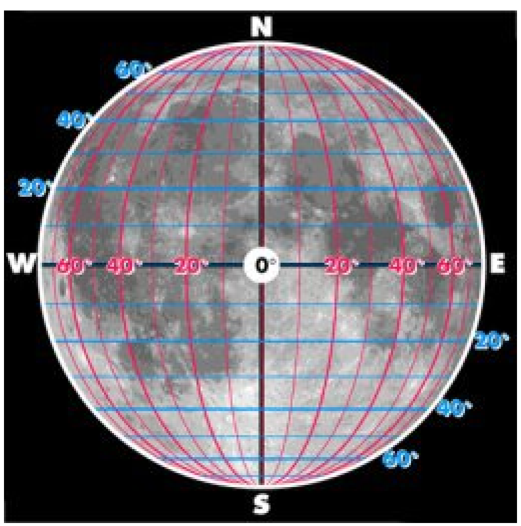


Dark / light = land / 'sea' .. Lines were called 'canals' … names from geography

Photomosaic 1960 (pre-NASA): Orthographic projection

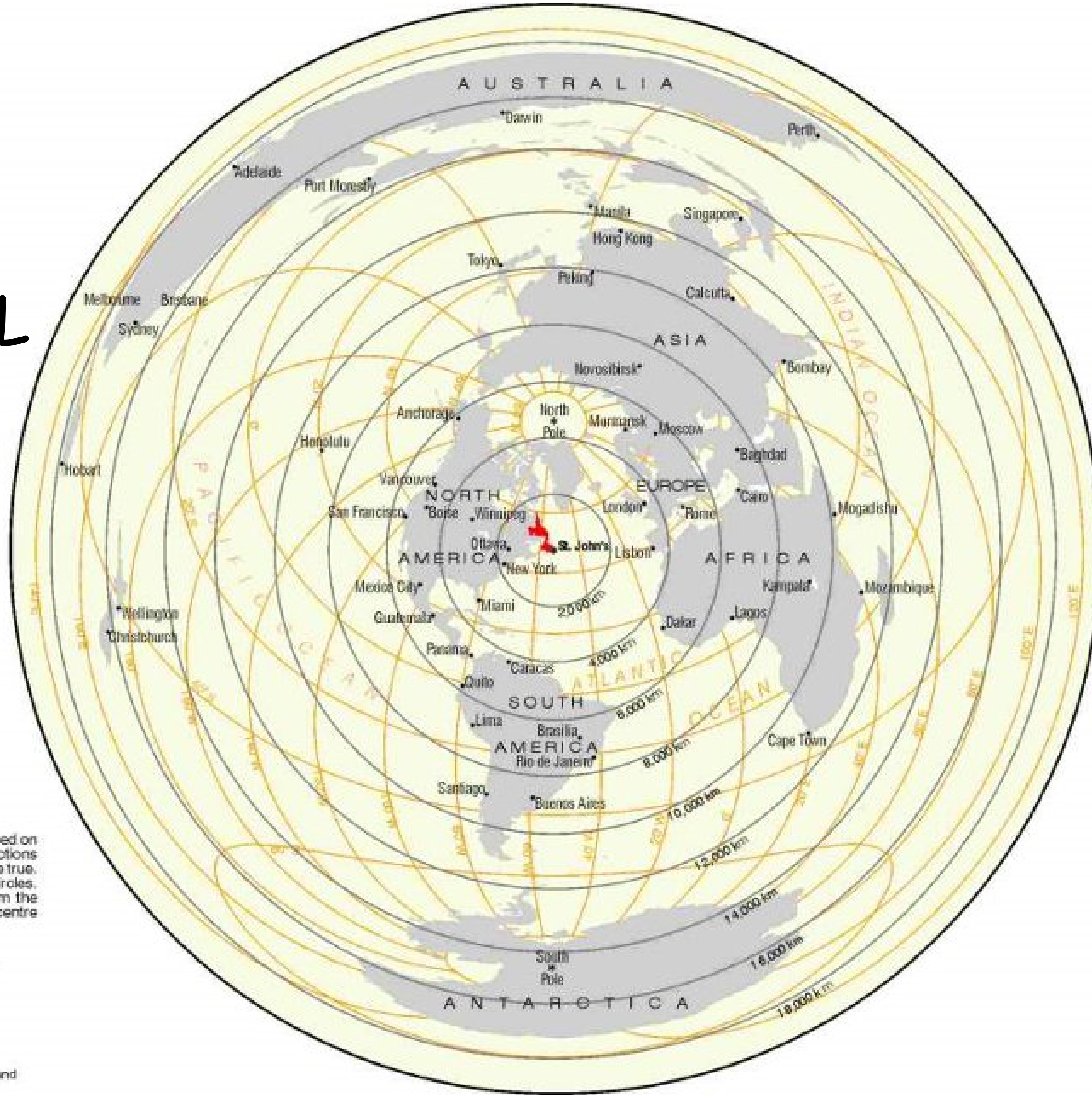
Like Earth, longitude zero is arbitrary – a feature is chosen

The Prime Meridian of the Moon lies directly in the middle of the face of the moon visible from Earth.



Azimuthal equidistant

centred on St. John's, NL



This is an AZIMUTHAL EQUIDISTANT PROJECTION centred on St. John's, Newfoundland. Only distances and directions measured along straight lines radiating from the centre are true. All straight lines passing through St. John's are great circles. Deformation of the earth surface increases outward from the centre and measurements taken other than through the centre are inaccurate.

SCALE along any straight line through the centre

1000 0 2000 4000
Kilometres

1000 0 1000 2000 3000 4000
Miles

© Department of Geography, Memorial University of Newfoundland
St. John's, Newfoundland, CANADA

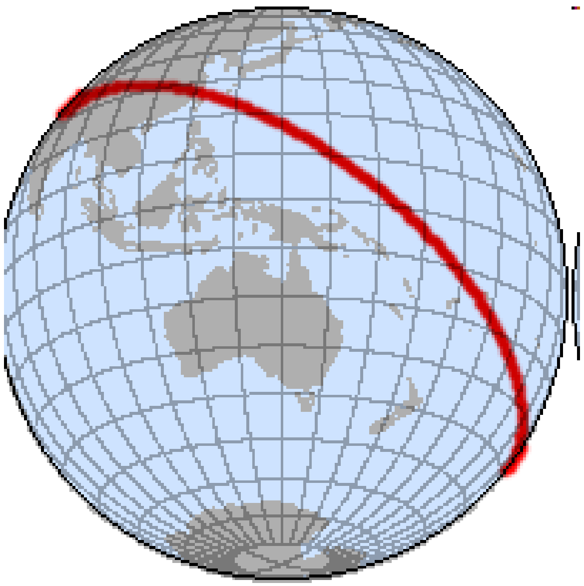
II. Cylindrical Projections 16th century

for early world maps
-They fill a rectangular shape

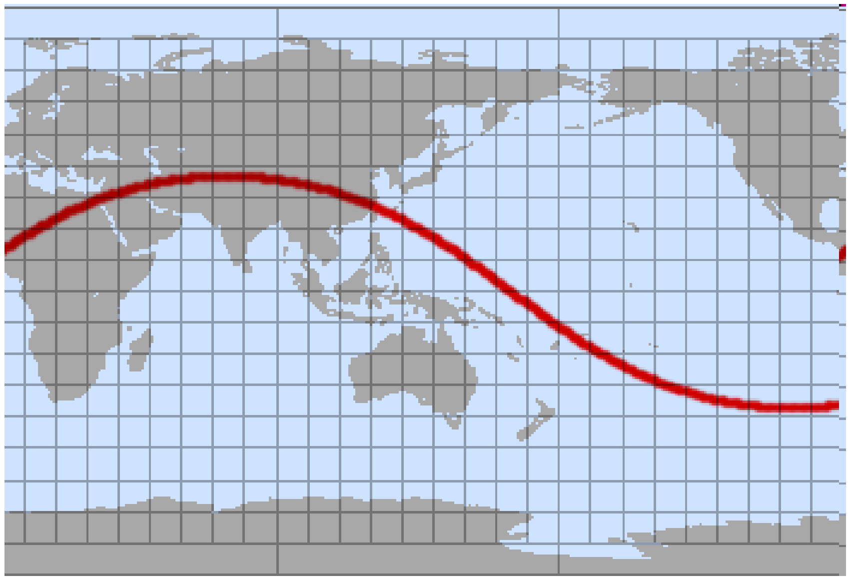
'Great circles' are straight lines in 3D space

e.g. meridians, equator, flight lines … but not any other parallels

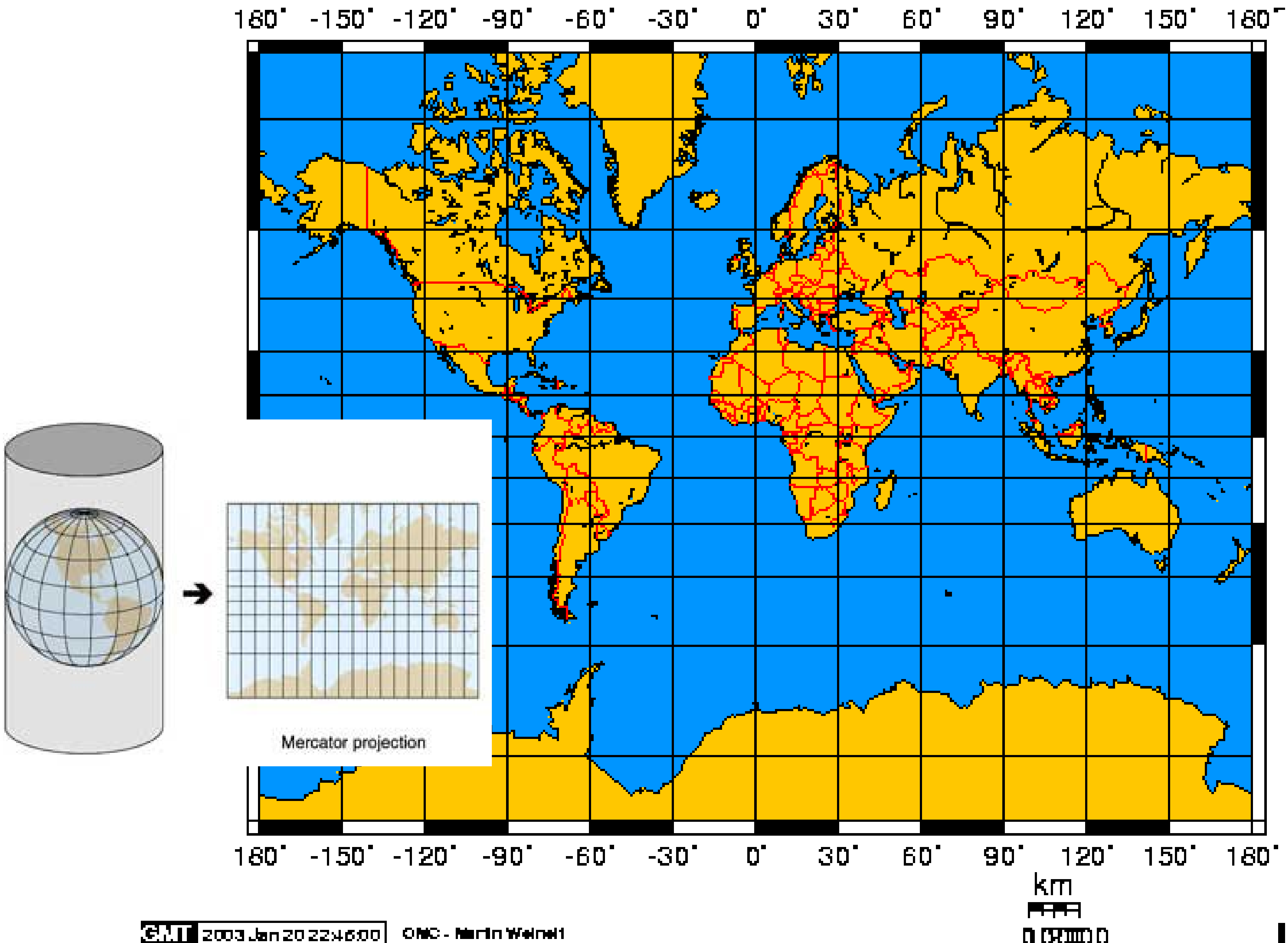
Of all projections, only the polar **gnomonic** retains all great circles as straight lines



e.g. Equidistant rectangular projection



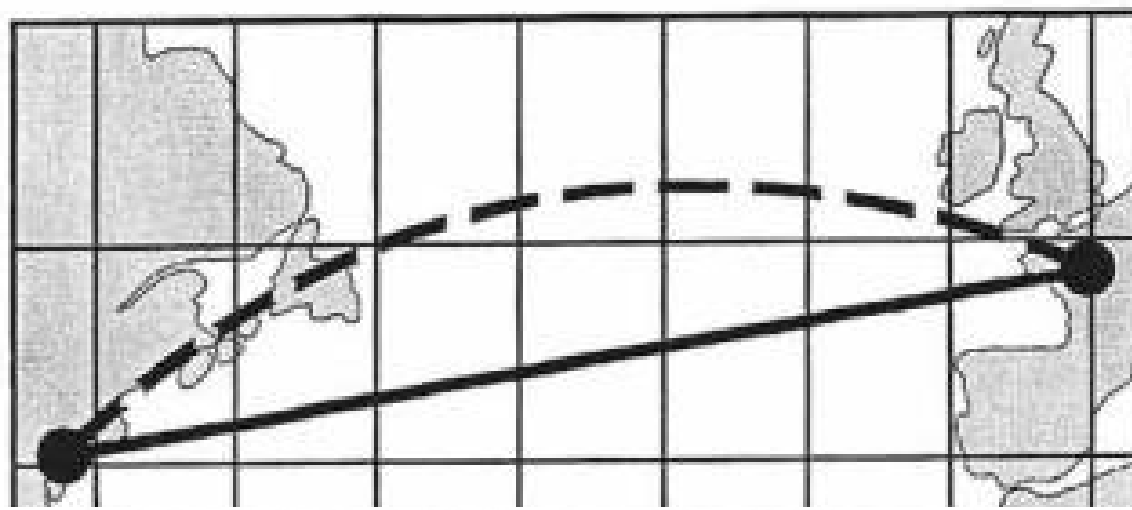
Mercator's Projection 1569 – conformal = shape-preserving

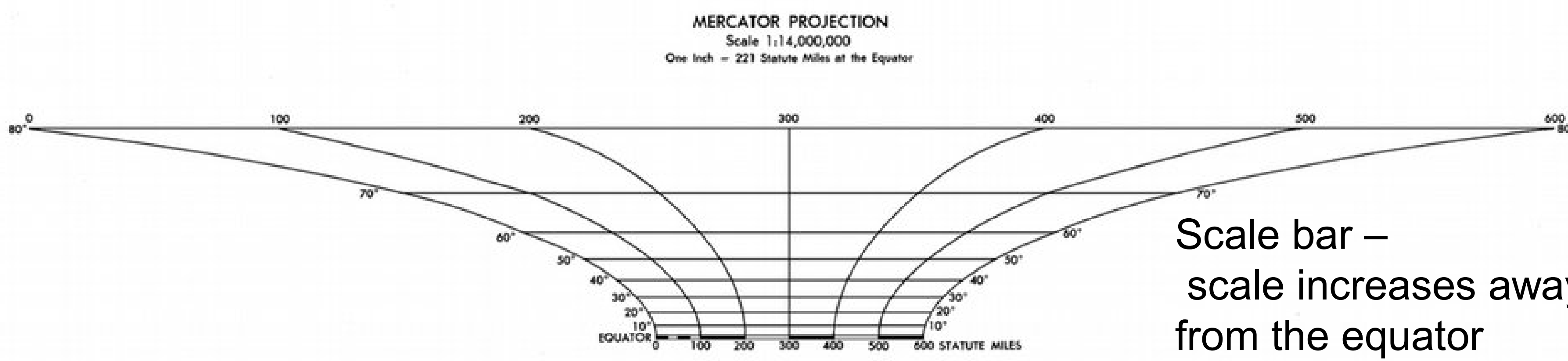


All 'straight lines' have constant compass bearings

= Rhumb lines

It became known as the "Navigator's friend"

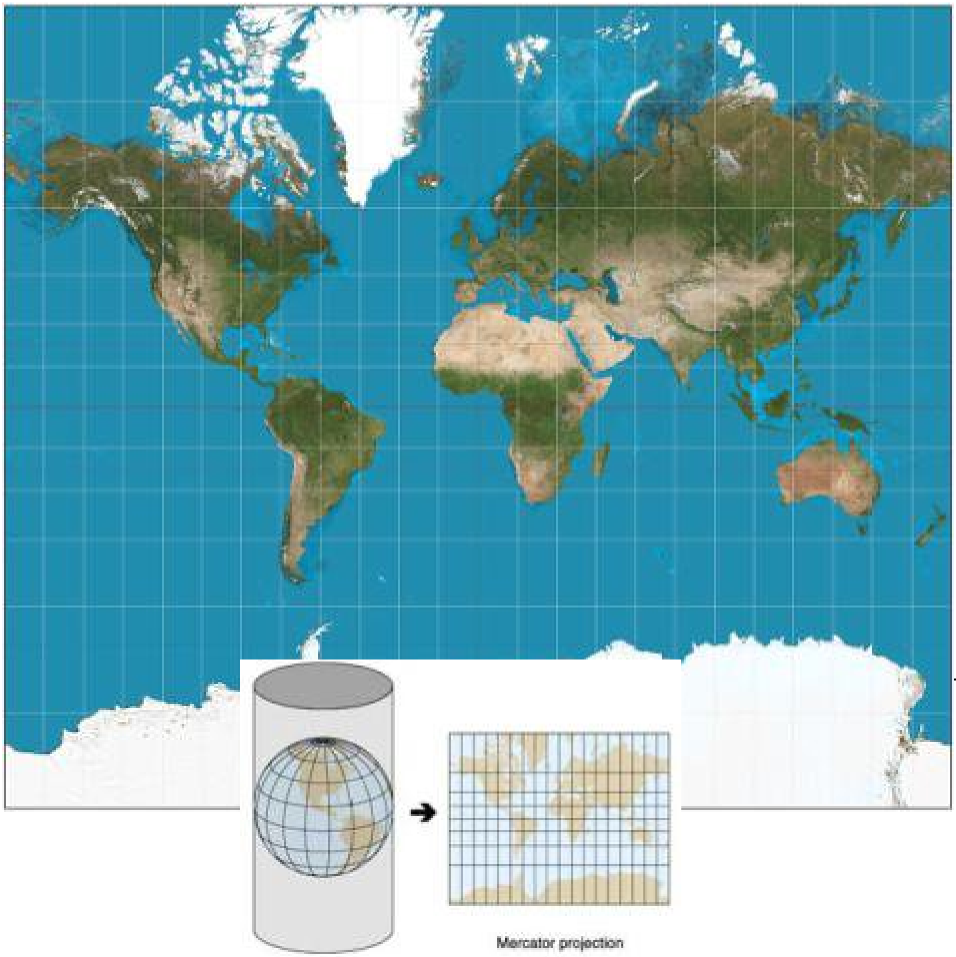




Scale bar –
scale increases away
from the equator

Cylindrical Projections

Mercator (1569) 'normal'

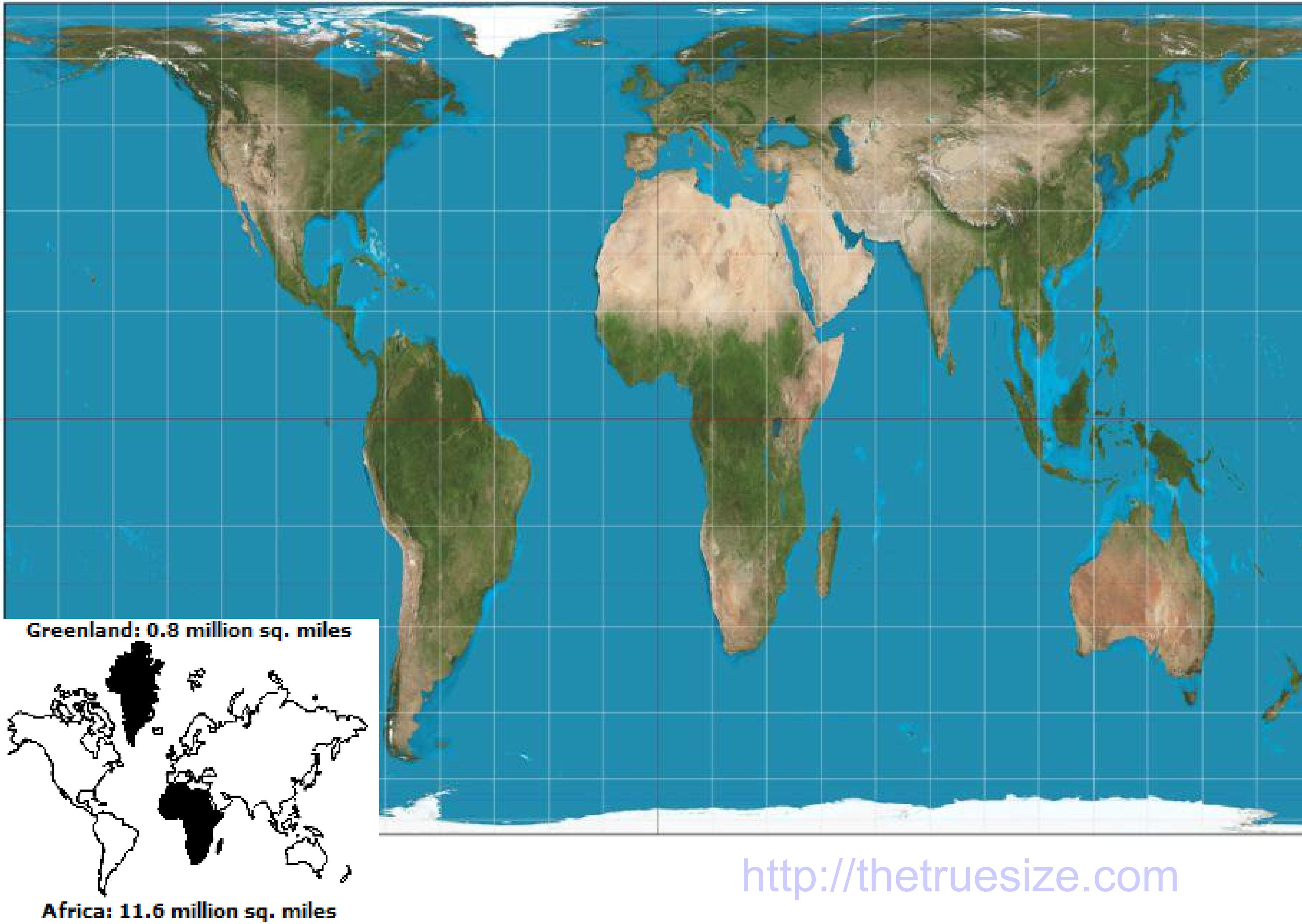


Transverse Mercator (1772)

The TM projection is the basis for the (Universal) UTM system
- Adopted by Canada post WWII
- SYSTEM of 60 TM projections

http://www.progonos.com/furuti/MapProj/Normal/ProjNav/projNav.html

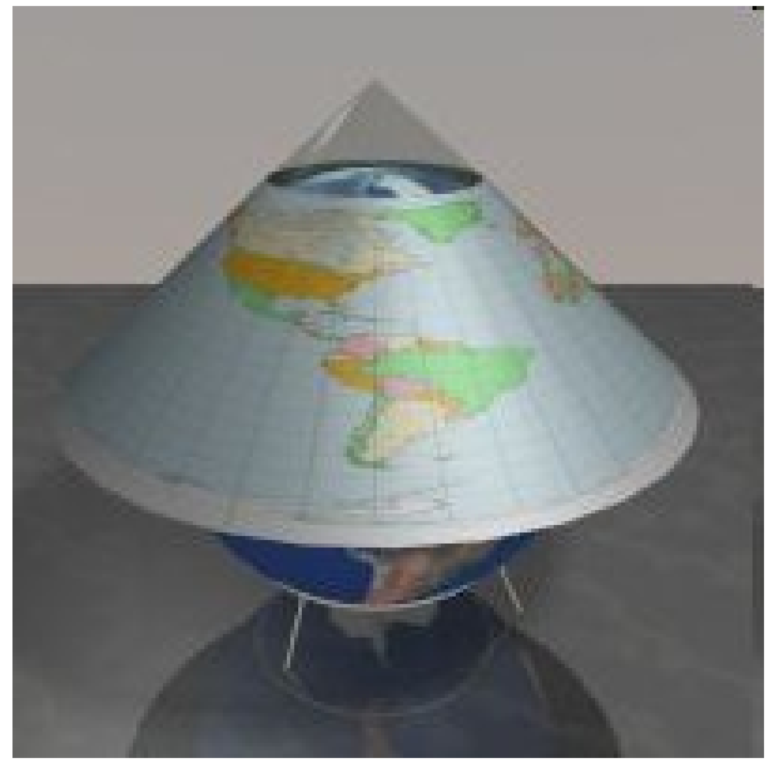
(1885) Gall-Peters projection (1972) – equal-area



http://thetruesize.com

III. Conic projections – 18th century

The cone opens at a line of longitude



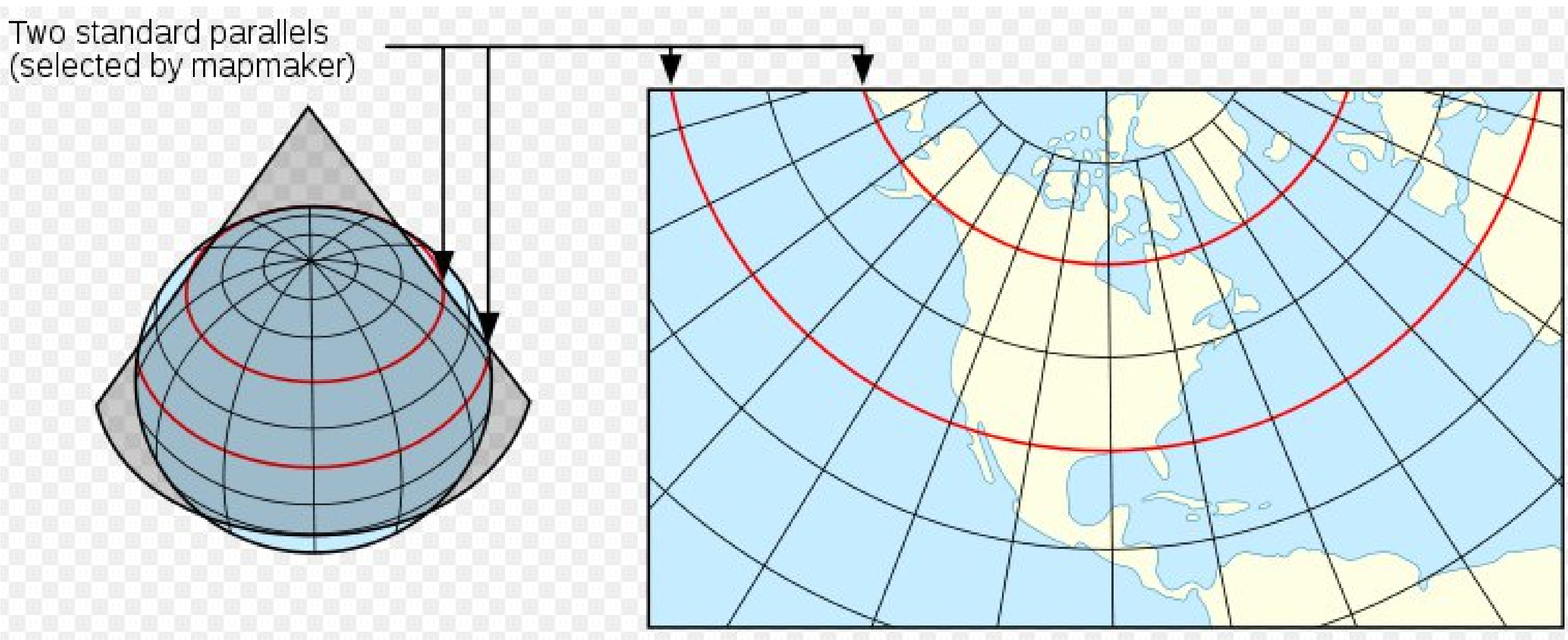
CONIC projections … are all 'normal orientation'

(e.g. Albers)

They can be varied by :

A: angle of the cone

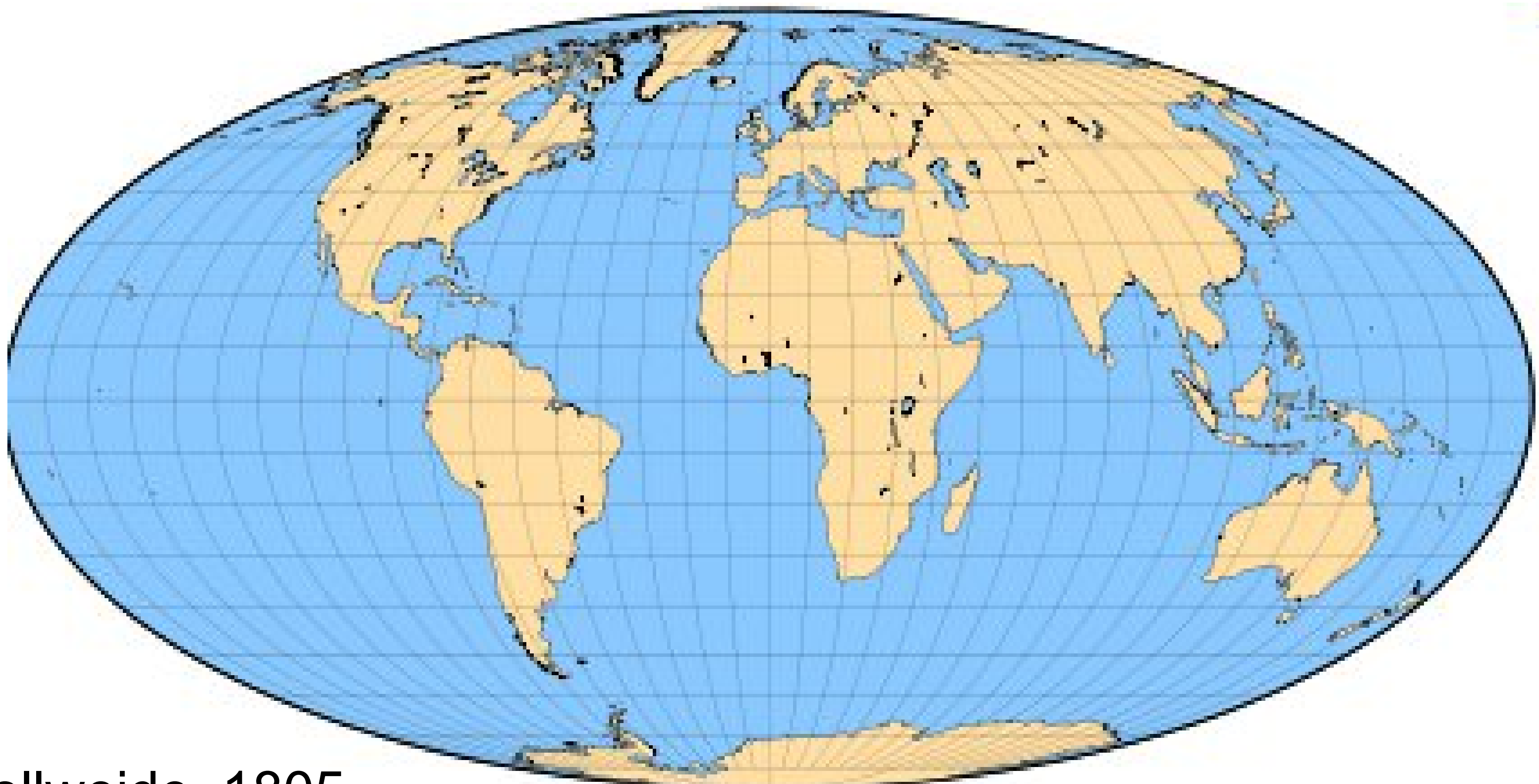
B: 1 or 2 standard lines



IV. Pseudo-cylindrical Projections

-19th century (and 20th)

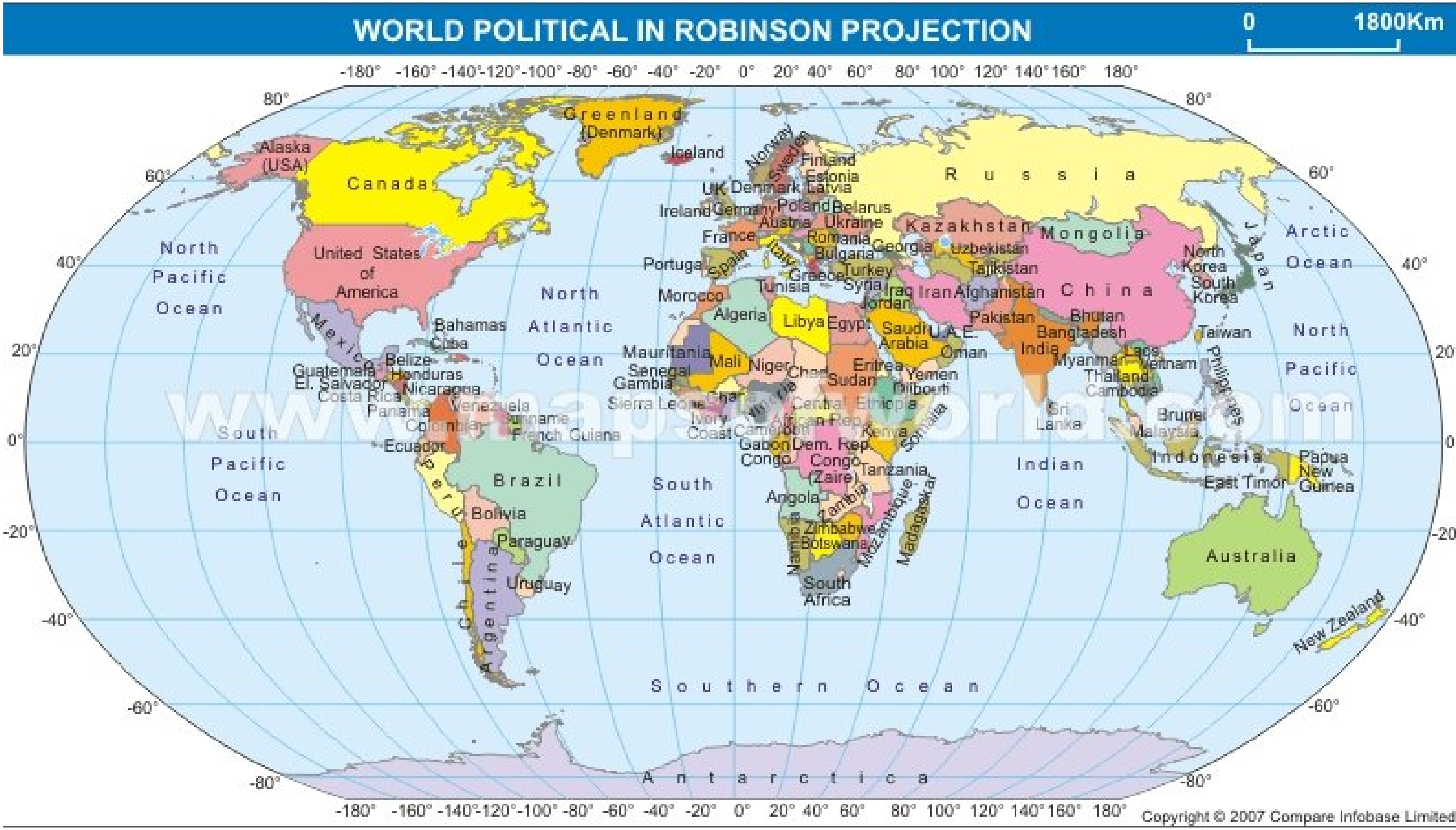
These are geometrically constructed. The parallels are generally equally spaced but are made more proportional to their real length to minimize distortion.



Mollweide, 1805

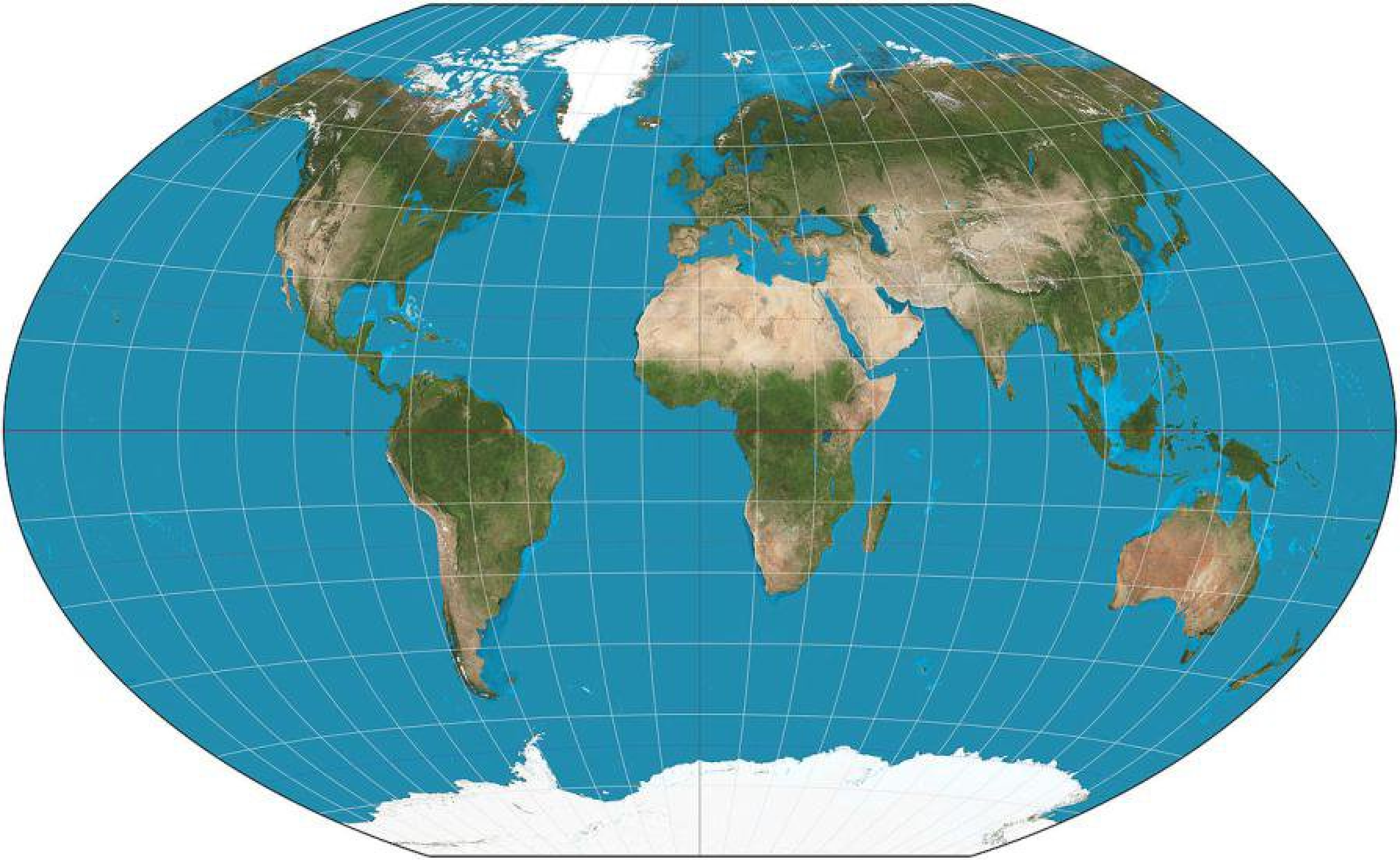
Robinson projection – adopted by National Geographic in 1988

Poles drawn as lines to create better shapes



http://www.mapsofworld.com/projection-maps/robinson/world-political-light.html

The **Winkel tripel (Winkel III)** by Oswald Winkel, adopted by NatGeo in 1998
The name *Tripel* refers to Winkel's goal of minimizing three kinds of distortion: area, direction (shape), and distance.



IVa. Interrupted pseudo-cylindrical (e.g. Goode's)

Projections websites:

http://www.csiss.org/map-projections/

The Moocator Projection

Wednesday: projections in GIS / the digital world