Rocky Mountain Oilfield Testing CENTER

GPS and GIS – Getting Lost Faster Than Ever Before!

A three part presentation of some risks associated with current practice in managing spatial data

Overview

- **“The Forgotten Earth Science” - Geodesy**
- **A brief introduction to Map Projections**
- **GPS basics**

Multiple Choice!

With the advent of GPS satellite positioning and modern computer mapping tools,

A. **There is no problem with managing spatial data – it takes care of itself.** ☐

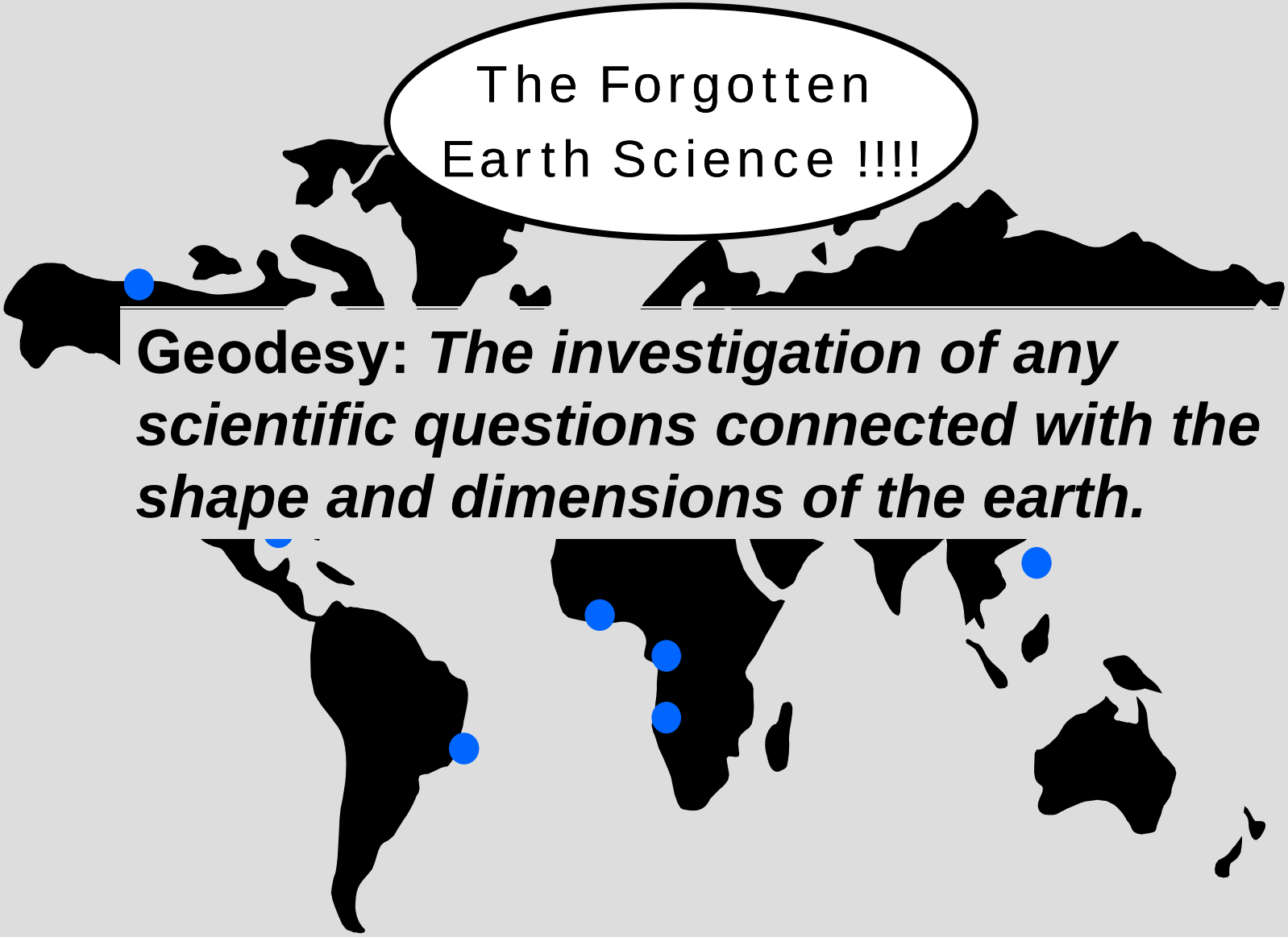
B. **All field surveys should be carefully checked – in house we have no problem** ☐

C. **All field surveys are now perfect and we have to manage the in house data carefully** ☐

D. **We now have all the same problems we had before, both in the field and in house, only there are two or three order of magnitude more data, more sources and more applications to manage, and we can get confused and misplace data more and faster than ever before** ☒

- **And the answer is…..**

Part I - Geodesy



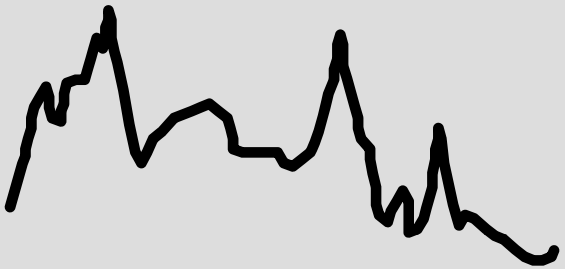
Geodesy: ***The investigation of any scientific questions connected with the shape and dimensions of the earth.***

Geodetic Terminology (ISO compliant)

- **Topography**
- **Geoid**
- **Ellipsoid (or Spheroid?)**
- **Coordinate System (i.e., system of axes)**
- **Prime Meridian**
- **Geodetic Datum**
  - **Local Datums**
  - **Geocentric Datums / Global Datums**
- **Ellipsoid and Datum are <u>NOT</u> synonymous!**
  - **Assuming otherwise can lead to a costly mistake.**
- **Geographic Coordinate Reference System (CRS)**
  - **GeogCRS have often been called "Datums"**

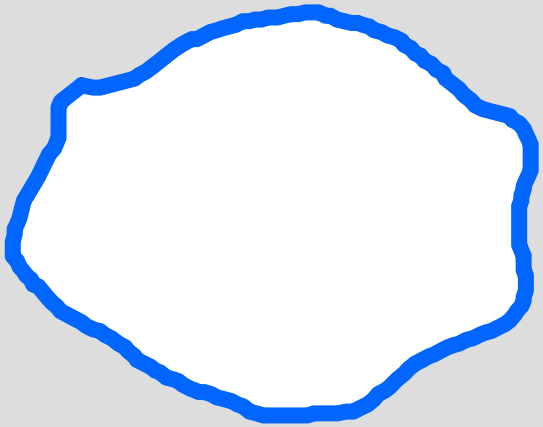
Geodesy Reference Surfaces

Terrain Surface



Geoid Surface (irregular)

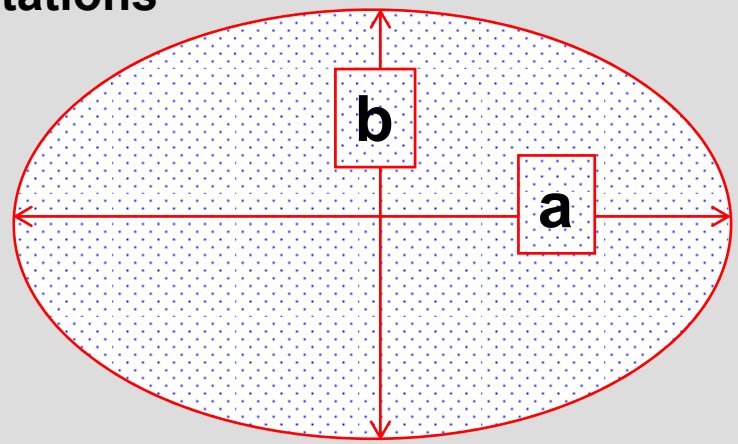
Equipotential surface which approximates to MSL



Ellipsoid Surface (Mathematical)

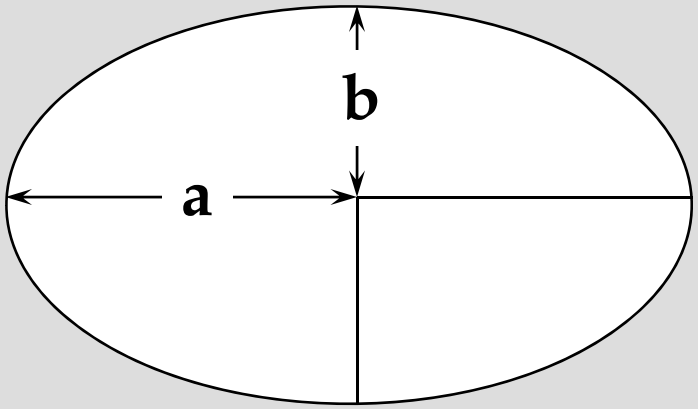
Surface where Computations are made

$$f \text{ (flattening)} = \frac{a-b}{a}$$



Ellipsoidal geometry

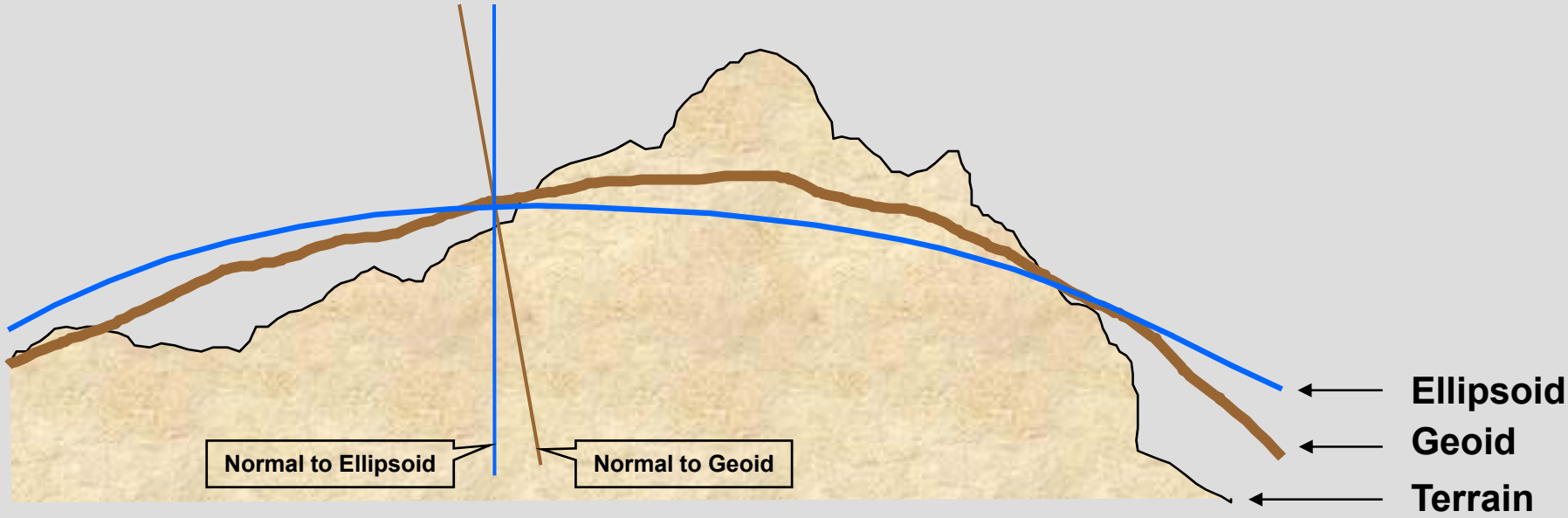
a	**semi-major axis**
b	**semi-minor axis**
e	**eccentricity**
f	**flattening**

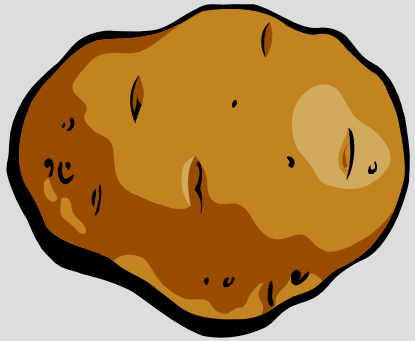


$$e^2 = \frac{a^2 - b^2}{a^2} \qquad f = \frac{a - b}{a}$$

for the earth $a \cong 6378000$ m and $f \cong 1/300$

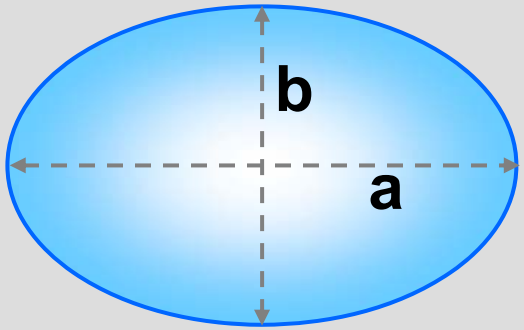
Geodesy Reference Surfaces





Geoid

Equipotential surface which approximates to MSL

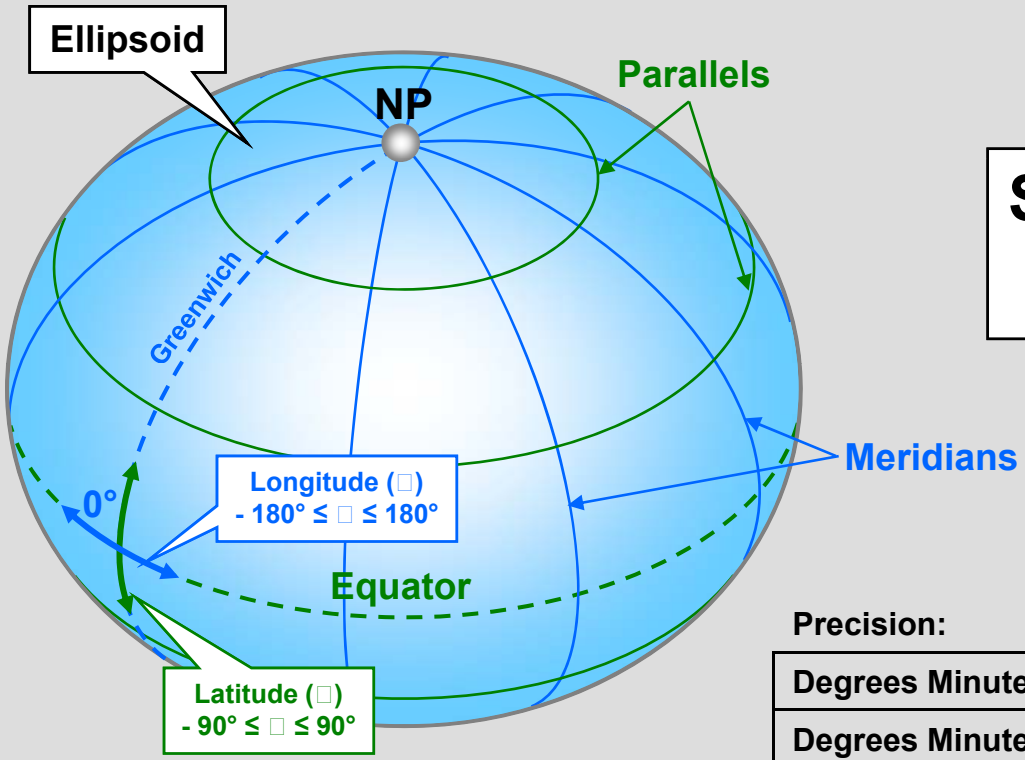


Ellipsoid

Surface where Computations are made

$1/f = a/(a-b)$

Parallels and Meridians



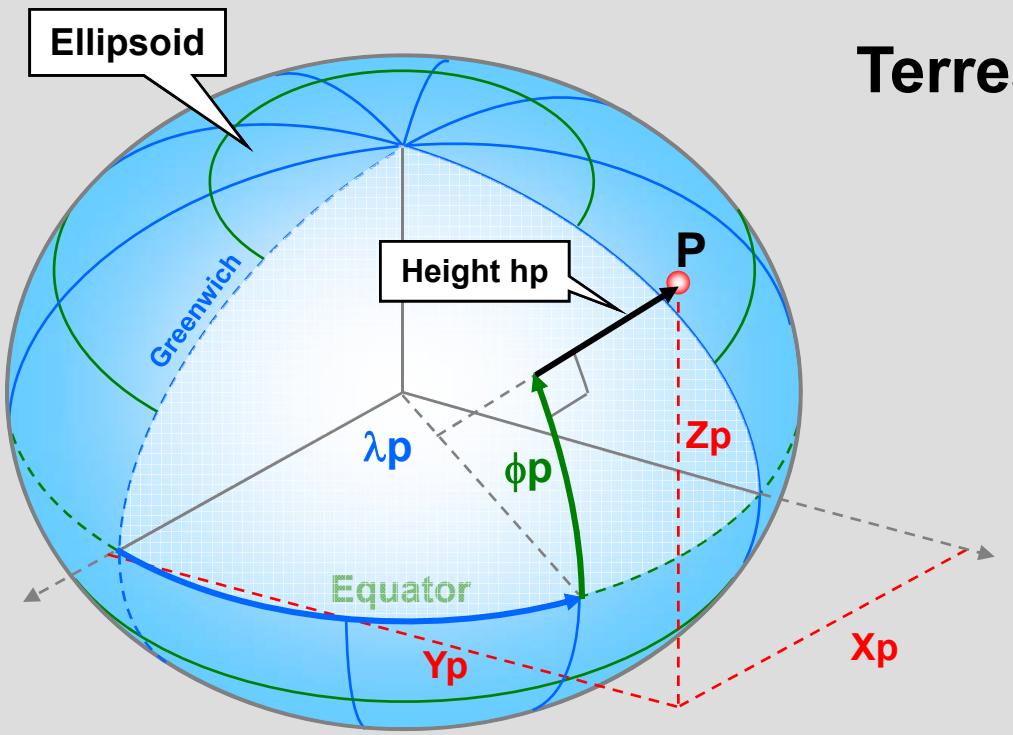
Software Convention:

N,E (+); S,W (-)

Precision:

Degrees Minutes Seconds	34° 27’ 07.45” N	118° 41’ 32.68” E
Degrees Minutes	34° 27.1242’ N	118° 41.5447’ E
Degrees	34.452070° N	118.692412° E

Geodetic Coordinate Systems



Terrestrial Coordinate Systems

Relationships

$X = (\nu + h) * \cos \phi * \cos \lambda$

$Y = (\nu + h) * \cos \phi * \sin \lambda$

$Z = [(b^2 * \nu / a^2) + h] * \sin \phi$

(NB Some older datums have a reference (0º) meridian at another place than Greenwich)

- **Paris**
- **Rome**
- **Madrid**
- **Washington**

Since 1884, the internationally agreed standard is Greenwich

Geodetic Datum Definition

- **A <u>Geodetic Datum</u> is an ellipsoid of revolution attached to the earth at some point.**
- **There are two types**
  - **Regional derived by astronomic observations**
  - **Global**
- **In ISO 'parlance'**

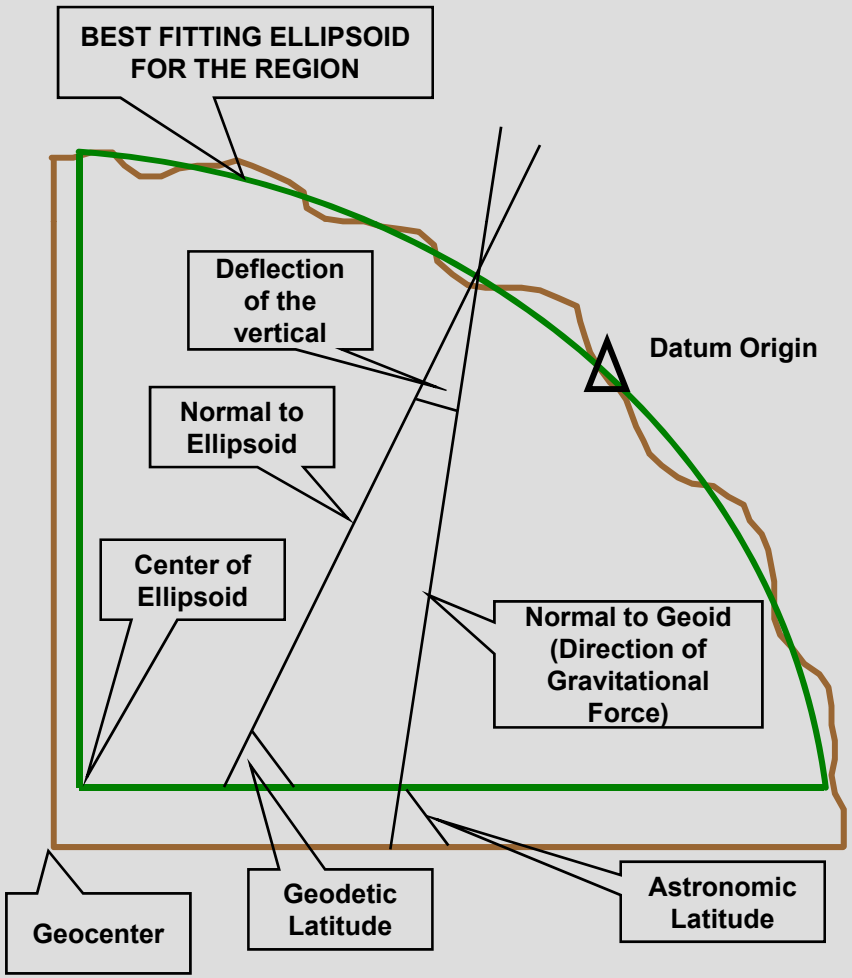
  'Datum' = 'Geographic Coordinate Reference System'

Astrogeodetic Datums

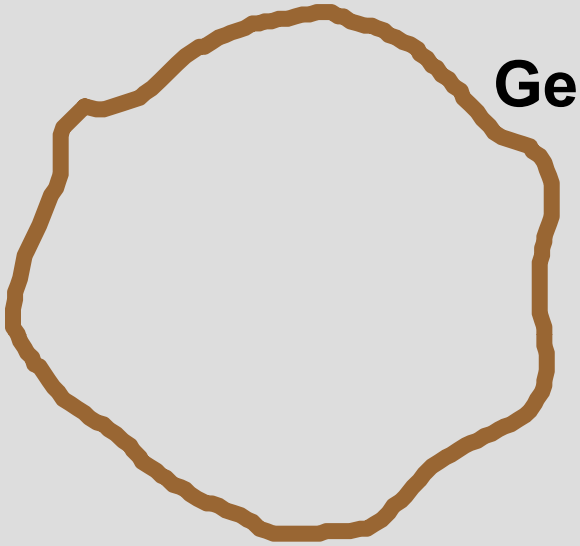
An Astrogeodetic DATUM is an ellipsoid attached to the geoid at a point by celestial observations

- **Used for a specific region or country e.g. North America, Europe, South America etc.**
- **An ellipsoid chosen to minimize the local geoid-ellipsoid separation, using 'Laplace' correction stations. The ellipsoid is oriented so the semi minor axis is aligned with the true polar axis.**
- **Not Earth centered!**
- **Hundreds have been defined for countries all over the planet (often four or more per country)**

Astrogeodetic Datum

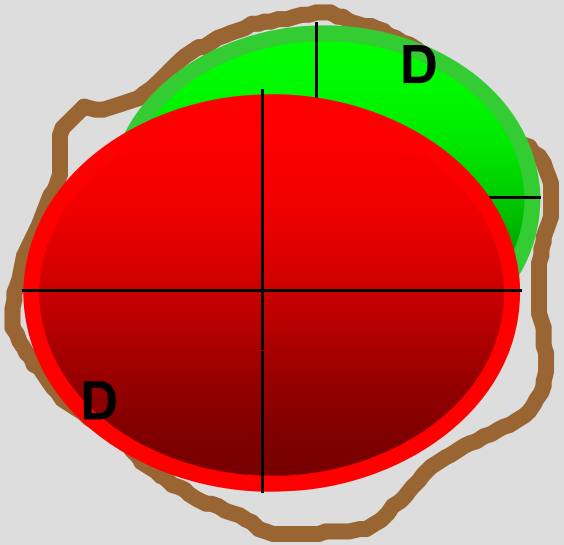


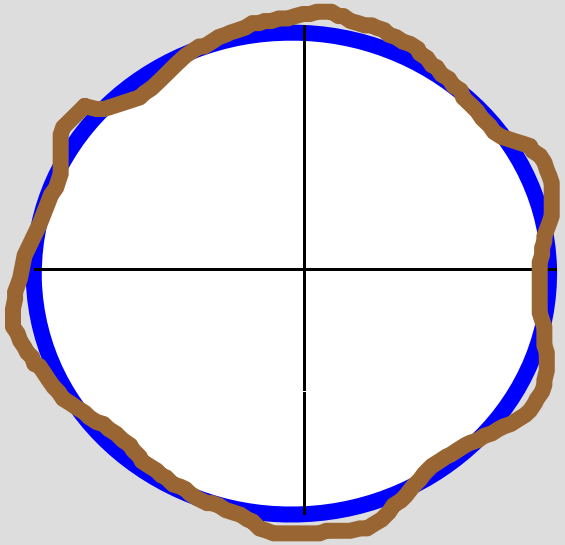
Datum Relationships



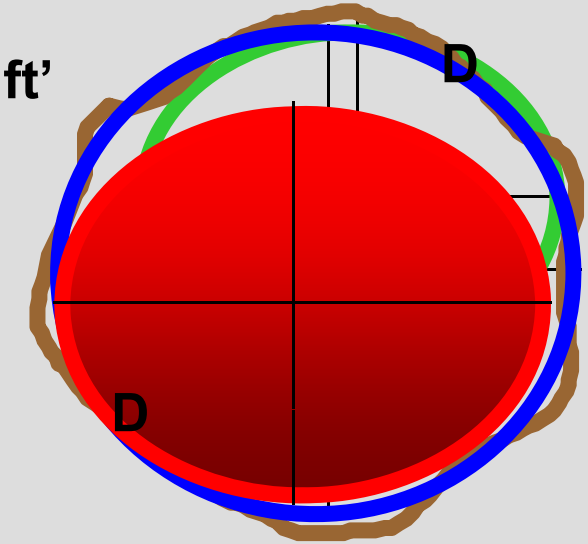
Geoid

Green and Red Ellipsoid Regional Datums





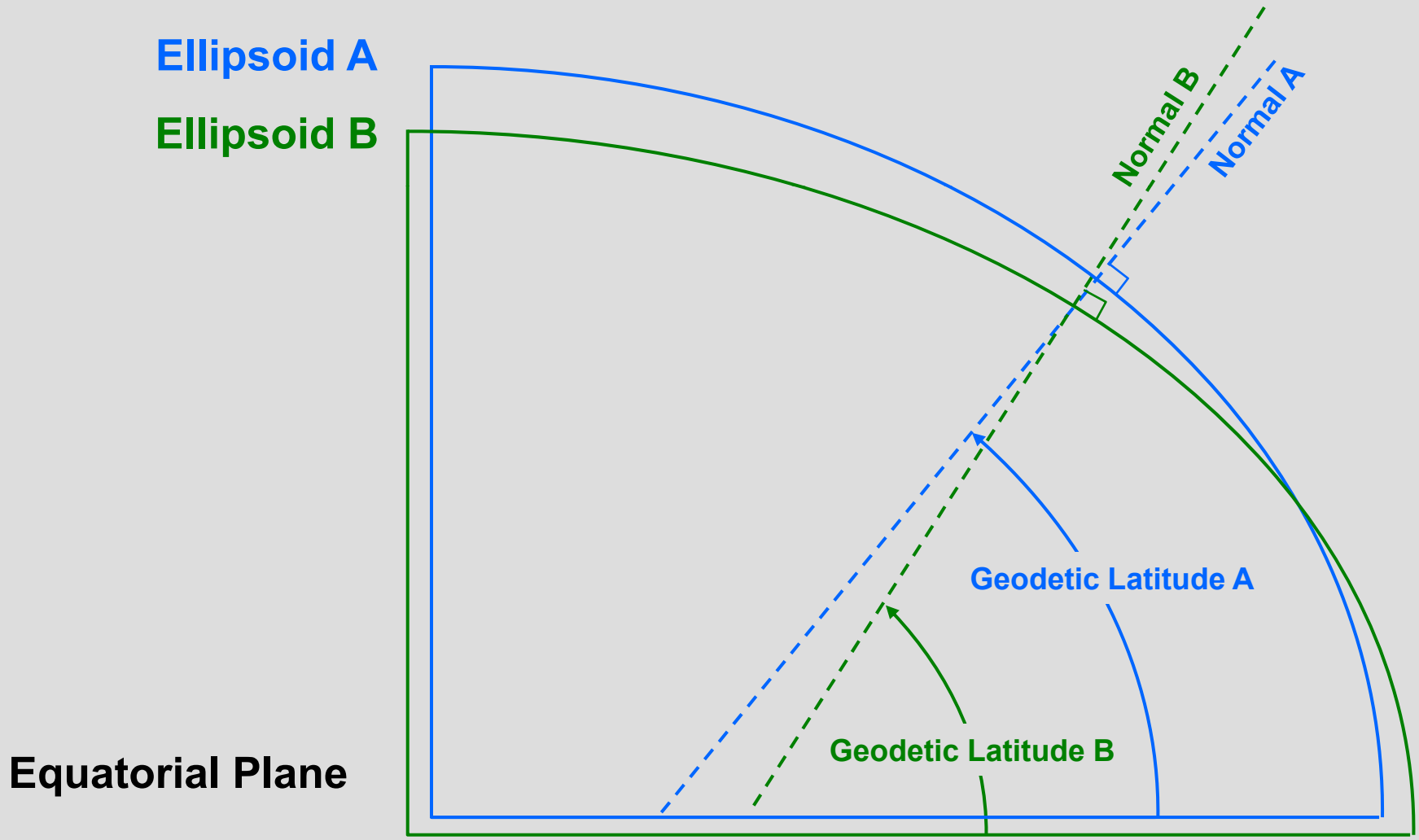
Need 'Datum Shift' to transform between datums



Blue Ellipsoid Global Datum (Satellite)

Geodetic Latitude

LESSON - LATITUDE Is NOT UNIQUE!

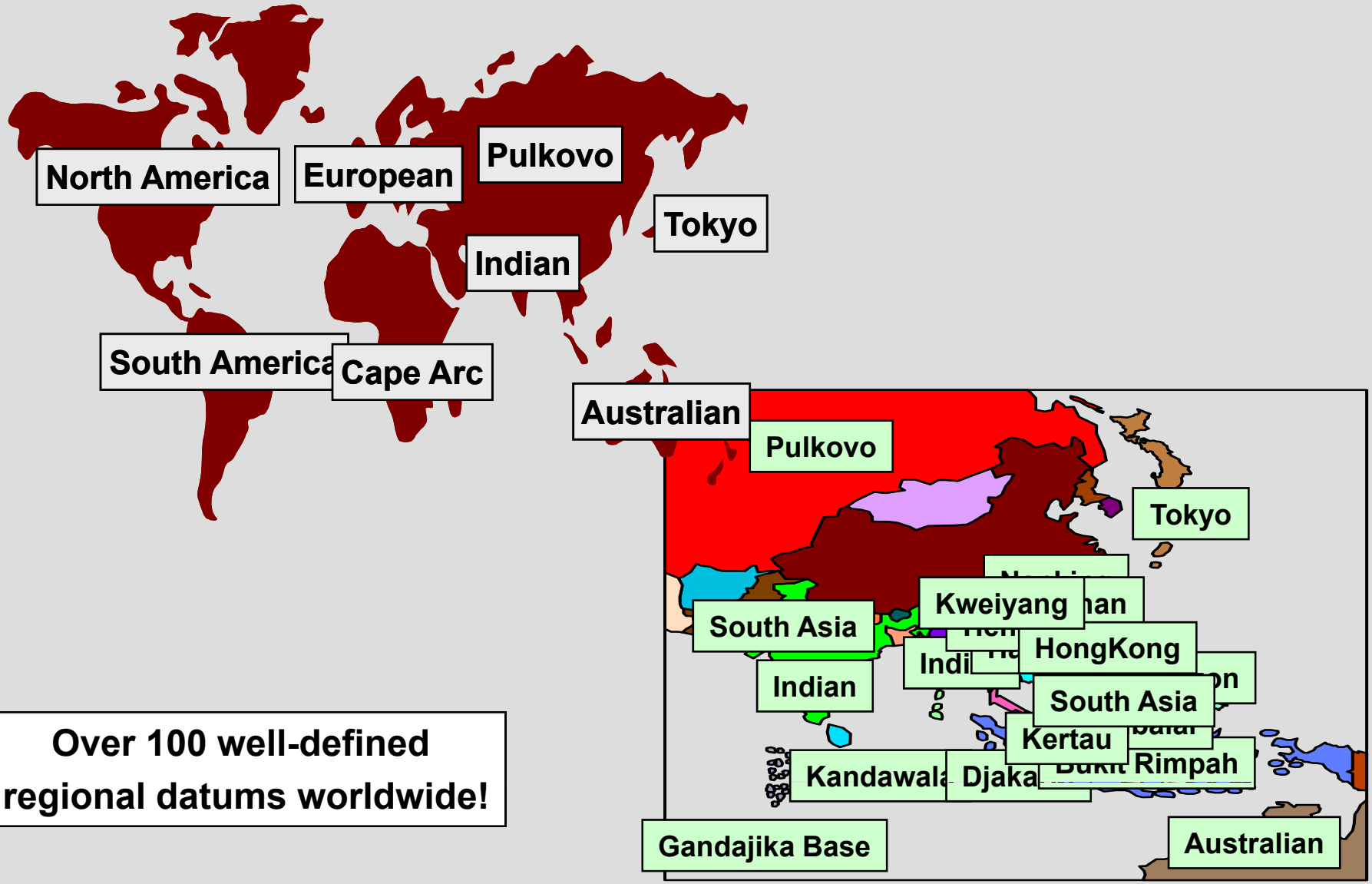


1” of Latitude = 30.0 meters?

- **While working in one GeogCRS (Datum)**
  - **1” latitude = 30.9 meters,**
  - **1” longitude = 30.9 meters * cos (latitude)**
- **This is NOT valid when geographic coordinates are on DIFFERENT datums.**

The example NAD27 and WGS84 latitude on the previous slide differs by only 1.06” , whereas the physical offset is approximately 199.9m (656 feet)

Major World Datum Blocks



Over 100 well-defined regional datums worldwide!

Examples of Datums

Datum	Reference Ellipsoid	Datum Origin
OSGB36	Airy	11 main stns (UK)
WGS72	WGS72 ellipsoid	many pts (global)
WGS84	WGS84 ellipsoid	1591+ pts (global)
ED50	International 1924	Potsdam
PSAD56	International 1924	La Canoa, Venezuela
NAD27	Clarke 1886	Meades Ranch, KS
NAD83	GRS80	Global, numerous pts
OS(SN)70	Airy	Herstmonceux, UK
MANOCA	Clarke 1880 IGN	Manoca Twr, Cameroon
MINNA	Clarke 1880 RGS	Minna, Nigeria
ITRS	GRS80	ITRF yyyy where yyyy = year

Some Reference Ellipsoids

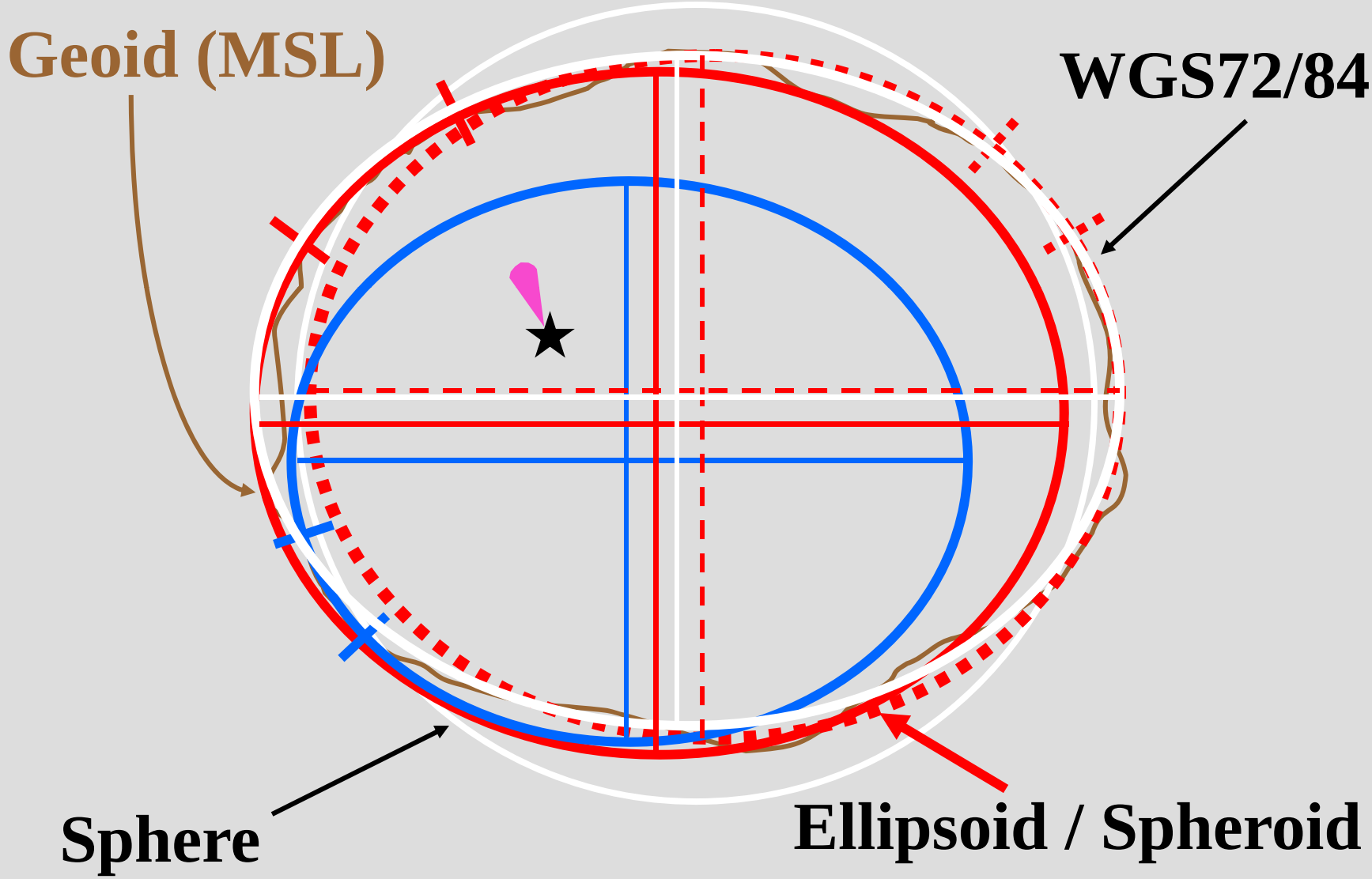
Ellipsoid	Semi Major Axis	Inv. Flattening
Airy 1830	6377563.396	299.3249646
Modified Airy	6377340.189	299.3249646
Australian National	6378160	298.25
Bessel 1841 (Namibia)	6377483.865	299.1528128
Bessel 1841	6377397.155	299.1528128
Clarke 1866	6378206.4	294.9786982
Clarke 1880	6378249.145	293.465
Everest (India 1830)	6377276.345	300.8017
Everest (Sabah)	6377298.556	300.8017
Everest (India 1956)	6377301.243	300.8017
Everest (Malaysia 1969)	6377295.664	300.8017
Everest (Malay. & Sing)	6377304.063	300.8017
Everest (Pakistan)	6377309.613	300.8017
Modified Fischer 1960	6378155	298.3
Helmert 1906	6378200	298.3
Indonesian 1974	6378160	298.247
International 1924 (Hayford)	6378388	297
Krassovsky 1940	6378245	298.3
GRS 80	6378137	298.257222101
South American 1969	6378160	298.25
WGS 72	6378135	298.26
WGS 84	6378137	298.257223563

North American Datums

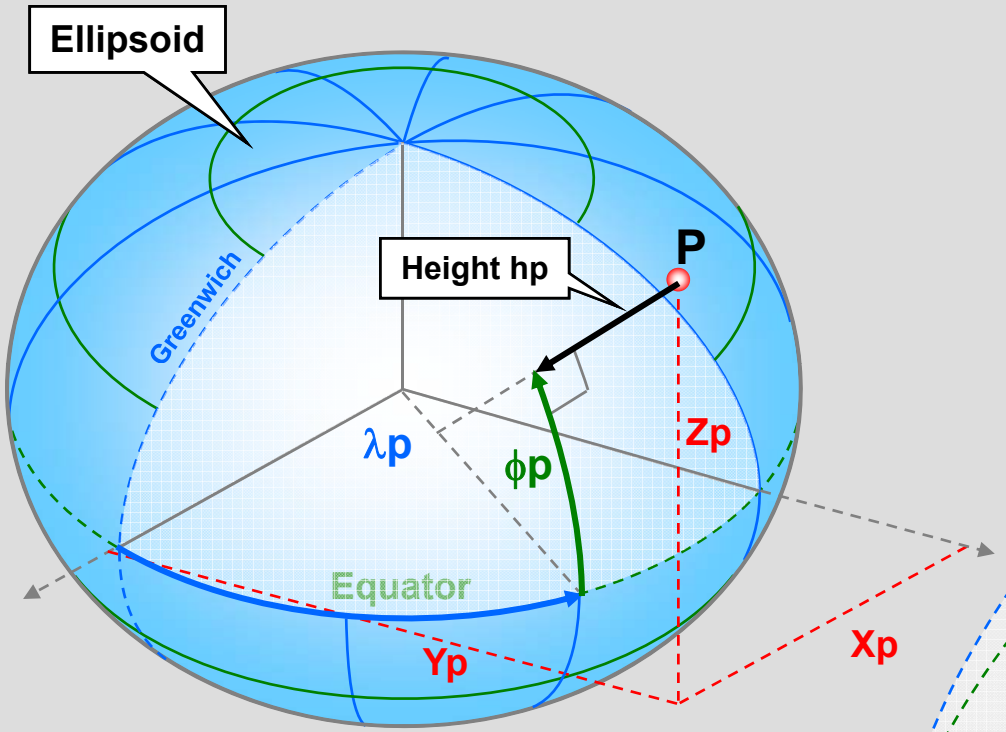
How many datums in U.S.?

- **WGS84**
  - Main GPS Satellite Datum
- **NAD83**
  - US version of WGS84 uses a slightly different ellipsoid
- **WGS72**
  - Datum used by the Transit satellite system
- **NAD27**
  - Primary Regional (Astrogeodetic) Datum for USA

Representations of the Earth's Surface

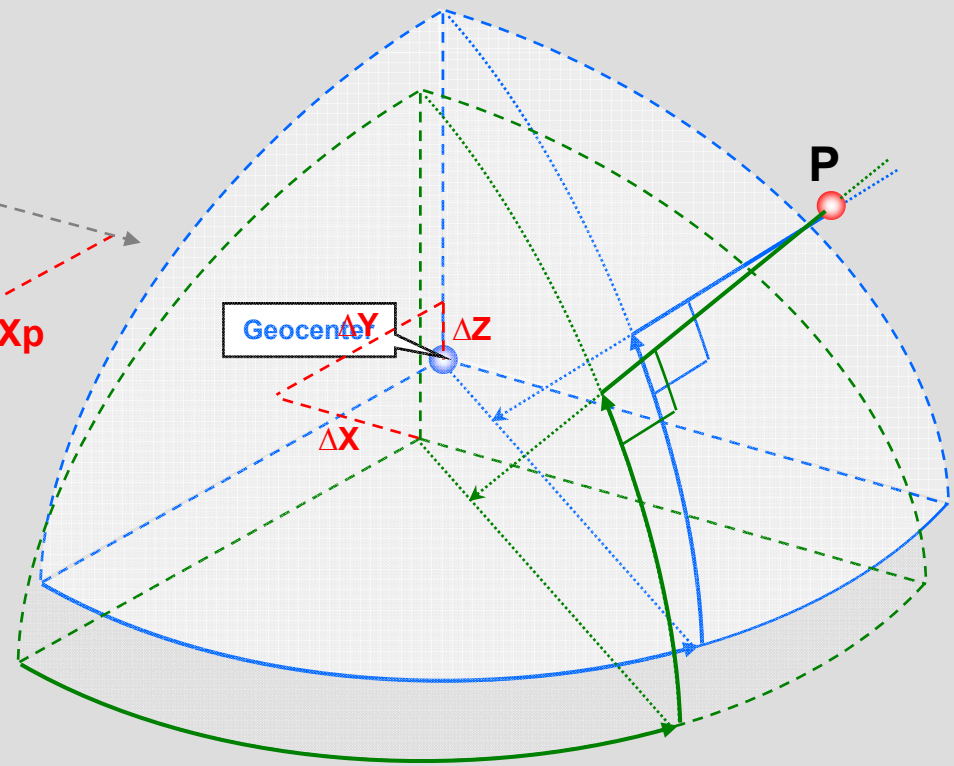


Geodesy Datum Shifts



Ellipsoid A (Global Datum)

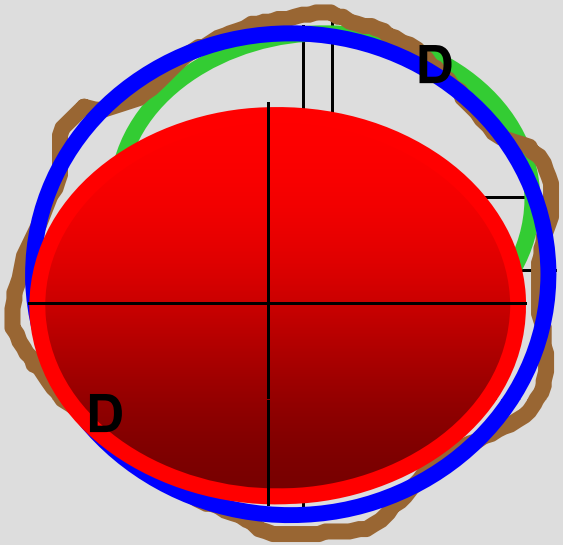
Ellipsoid B (Regional Datum)

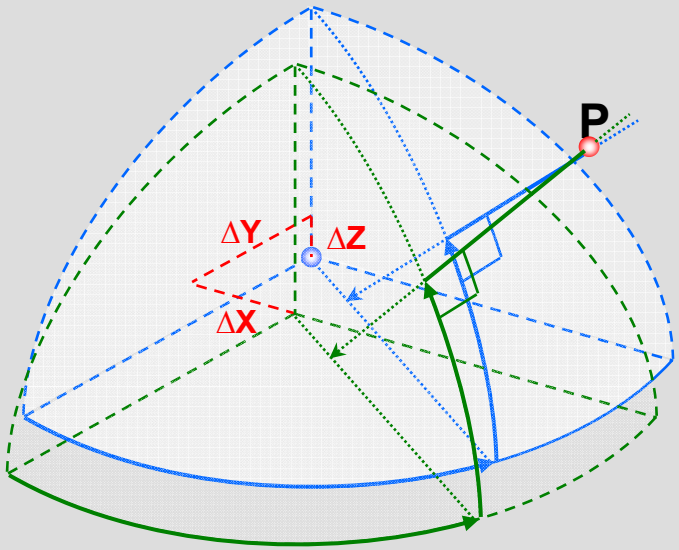


If the geographical area is small, then

$$\begin{bmatrix} X_g \\ Y_g \\ Z_g \end{bmatrix} = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + \begin{bmatrix} X_b \\ Y_b \\ Z_b \end{bmatrix}$$

Don't Guess





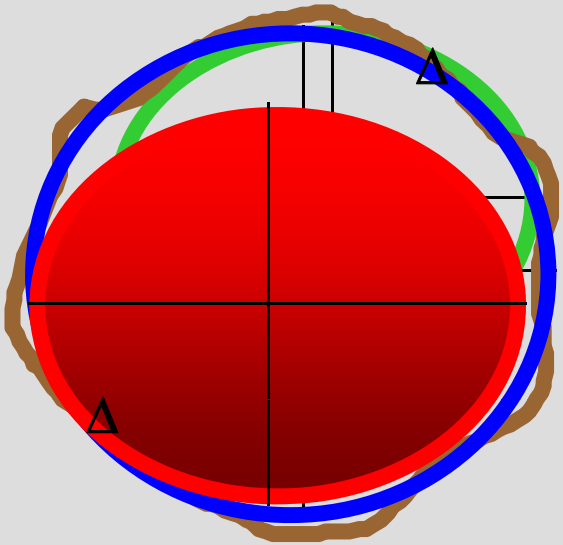
Differences on Datum

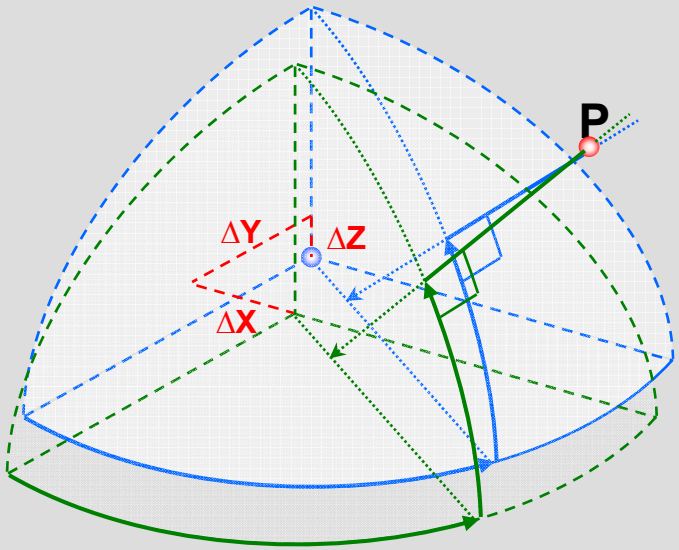
	Nahrwan	WGS84	Ain El Abd
Nahrwan	-	222.8	203.4
WGS 84	222.8	-	68.0
Ain El Abd	203.4	68.0	

Different Datums in the Central Gulf of Mexico

- **GOM 'UTM' ft Zone 15N**
- **NAD 27**
  - **Lat : 27º 00' 36.47" N**
  - **Long : 92º 14' 10.66" N**
- **NAD83**
  - **Lat : 27º 00' 37.53" N**
  - **Long : 92º 14' 11.10" N**
- **Differences**
  - **Δ Latitude = -1.062"**
  - **Δ Longitude = -0.441"**

Mixing Datums - Brazil Example





Datum	Latitude	Longitude	Local to WGS84	Local to Local
Aratu	20º 36’ 13.2757”N	38º 56’ 56.3341”W	236.7 meters	220.56 meters
SAD69	20º 36’ 17.4283”N	38º 56’ 50.1240”W	65.12 meters	
WGS84	20º 36’ 19.2794”N	38º 56’ 51.2166”W		

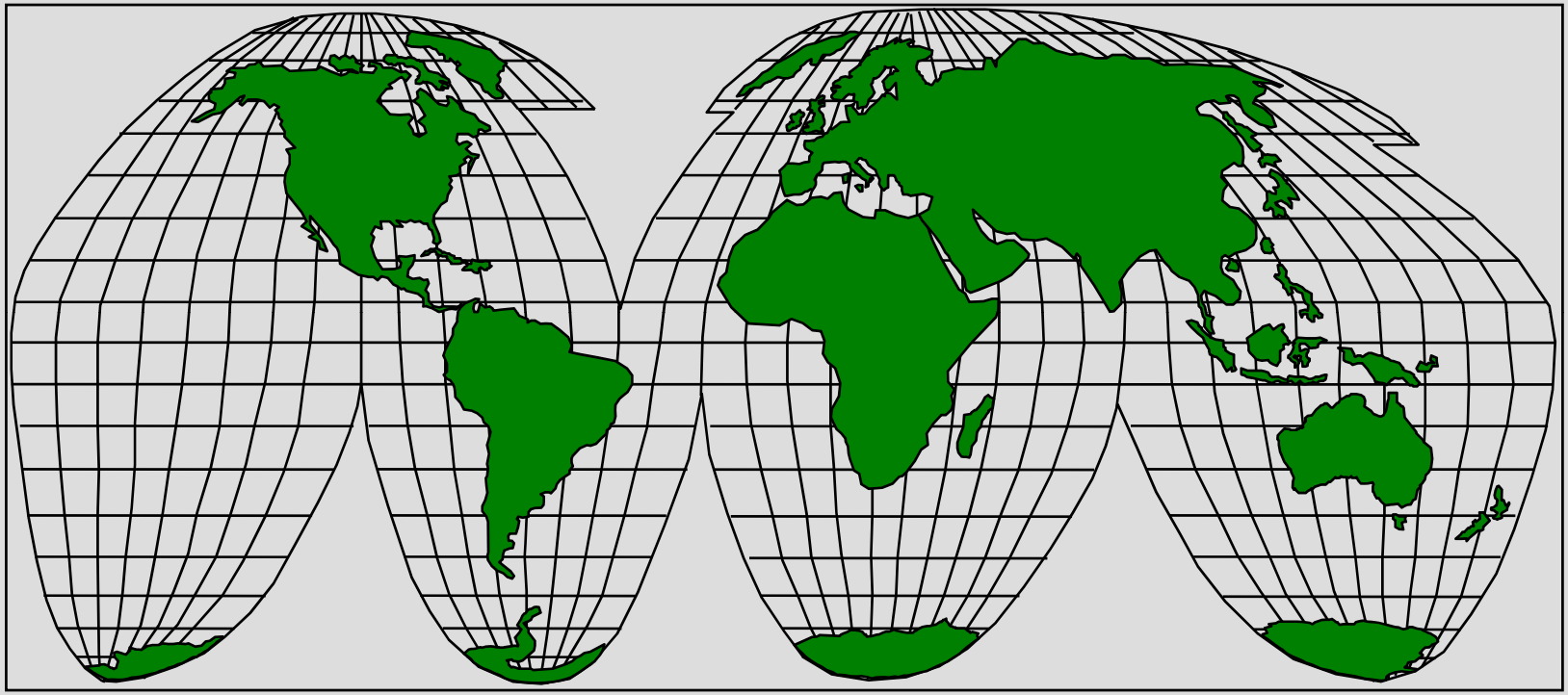
These are coordinates of the SAME physical point

If you remember nothing else…..

Latitudes and Longitudes
are not unique
unless qualified with datum name!

Heights
are not unique
unless qualified with Surface Reference

Part II - Map Projections



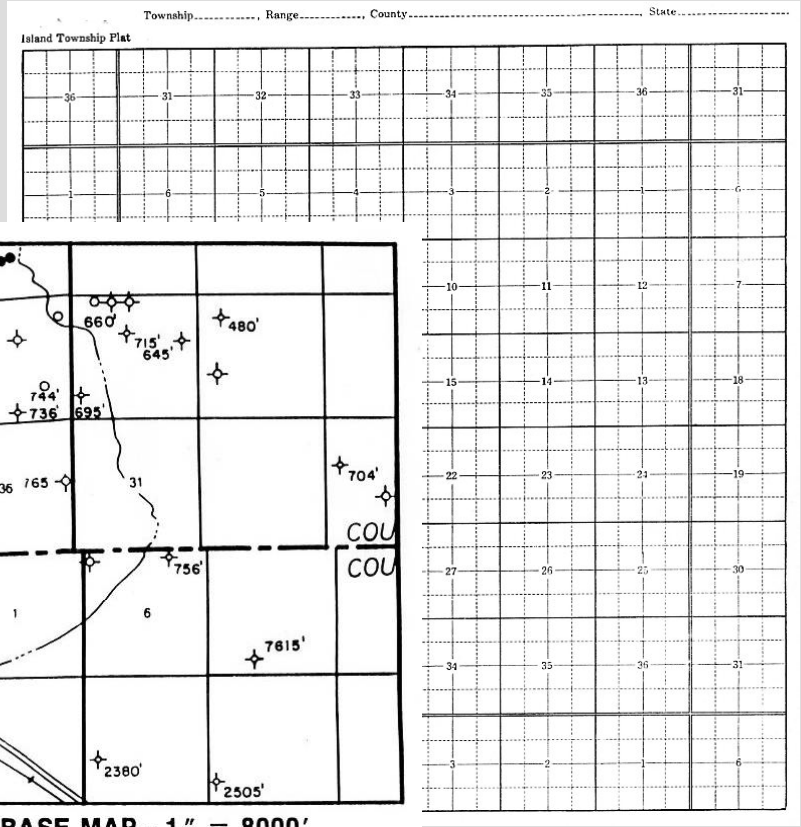
Interrupted Goode Homolosine Projection

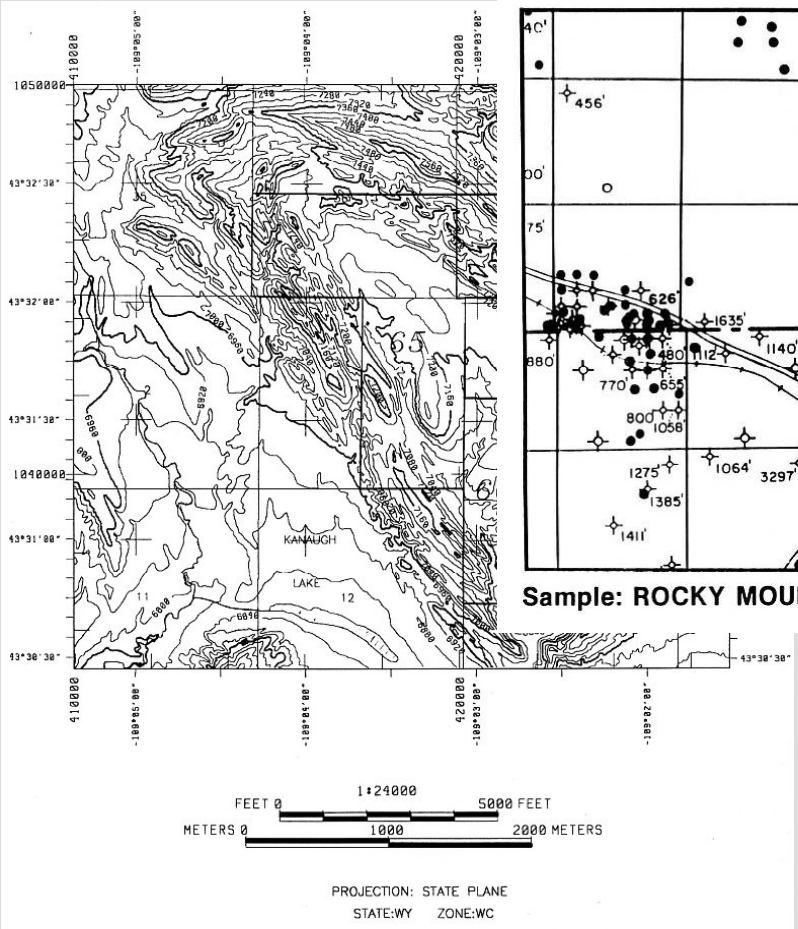
A brief introduction to Map Projections

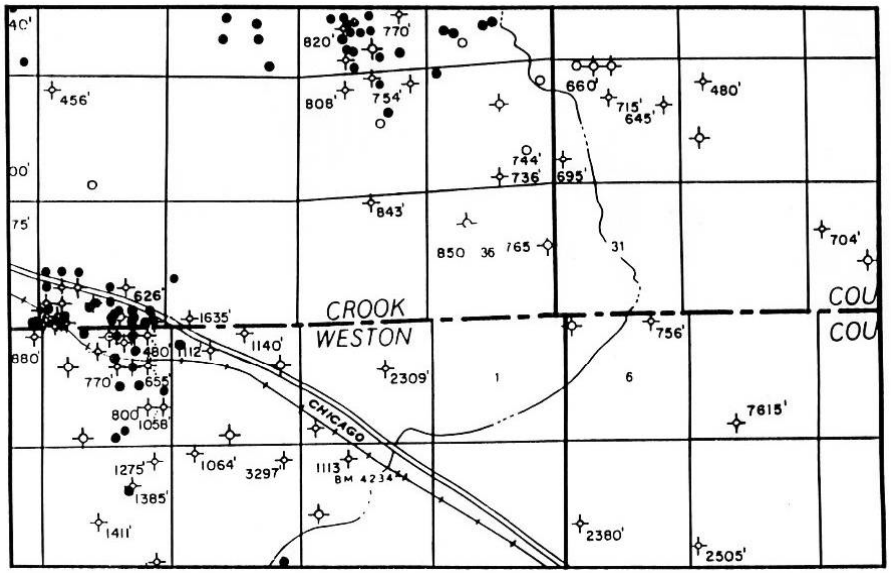
First, What is a True Map?

This is a map:

- True scale depiction of geographic features
- Constructed by projection from the globe to a plane
- Labeled with a graticule and coordinates
- Projection and datum clearly defined







Sample: ROCKY MOUNTAIN REGION BASE MAP - 1″ = 8000′

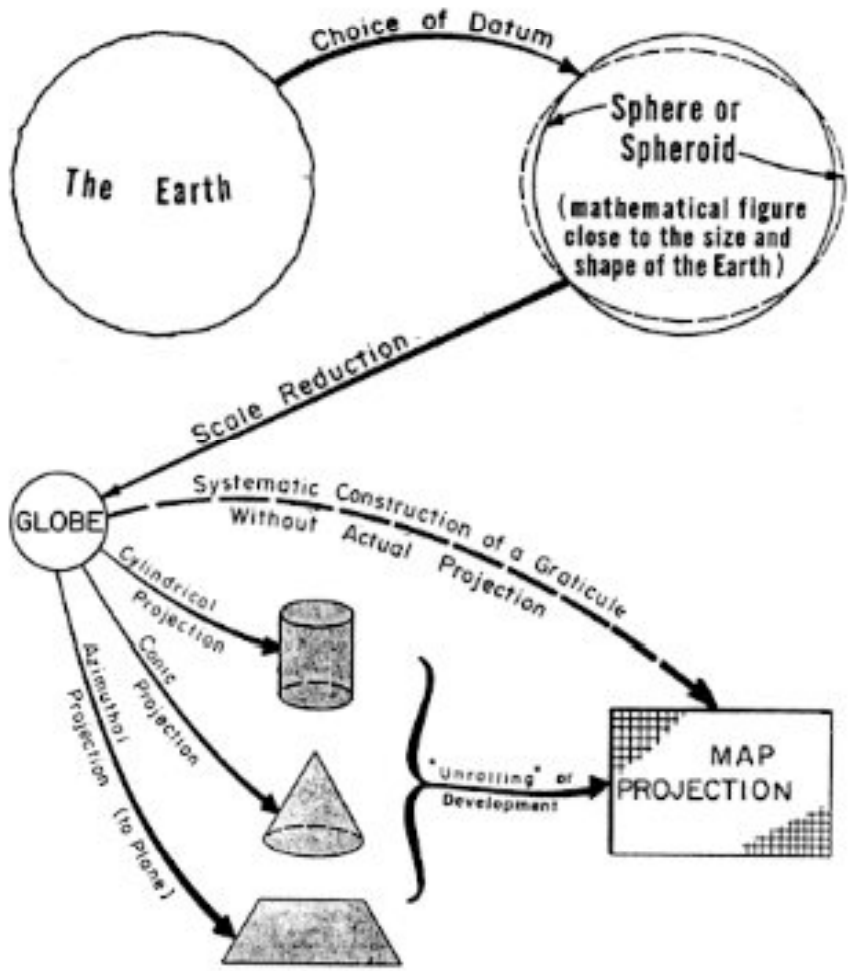
What is this?

This is a plat (or "plan"):

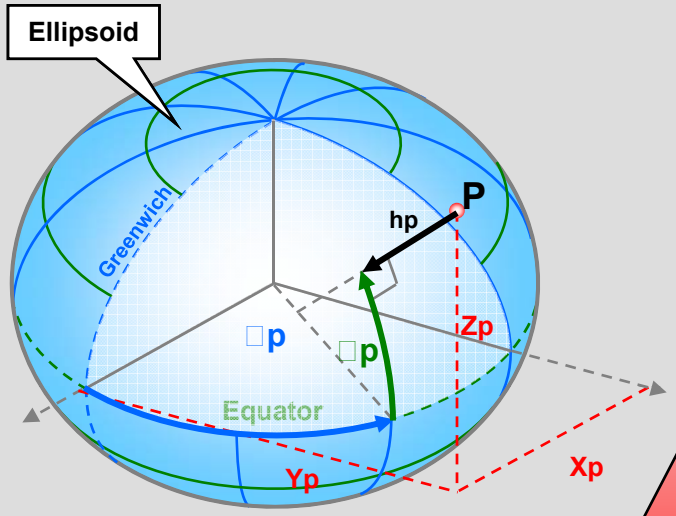
- Pseudo-map showing a representation only
- Usually of a small area
- Simple rectangular grid
- No scale, graticule, or coordinates shown
- No projection information (because it isn't one)

RMOTC

Steps in a Map Projection

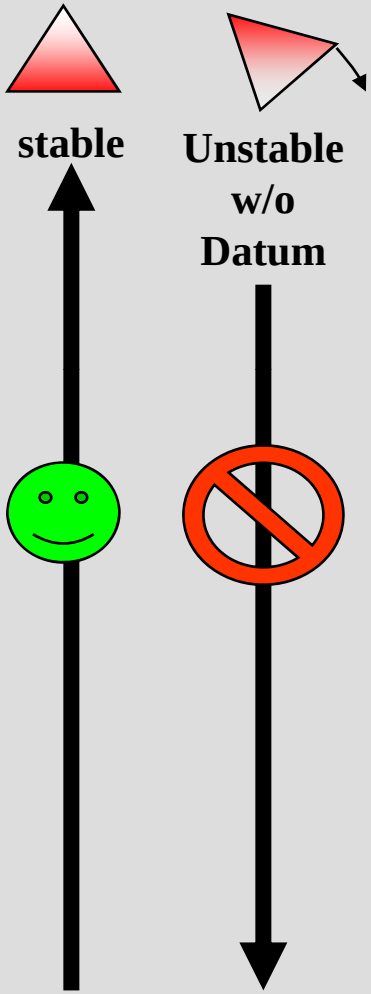


Hierarchy of Mapping



Projected CRS
is derivative
of the Datum
(Geog CRS)
Easting, Northing,
Elevation (above MSL)

Datum (includes ellipsoid)
is the Foundation
X,Y,Z Cartesian and Lat Long, Ht

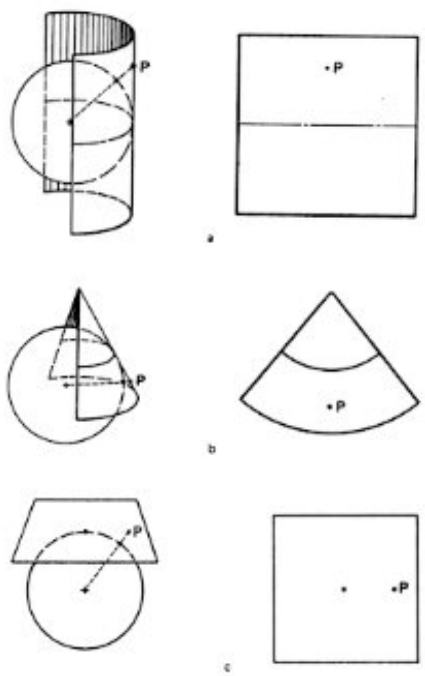


Developable Projection Surfaces

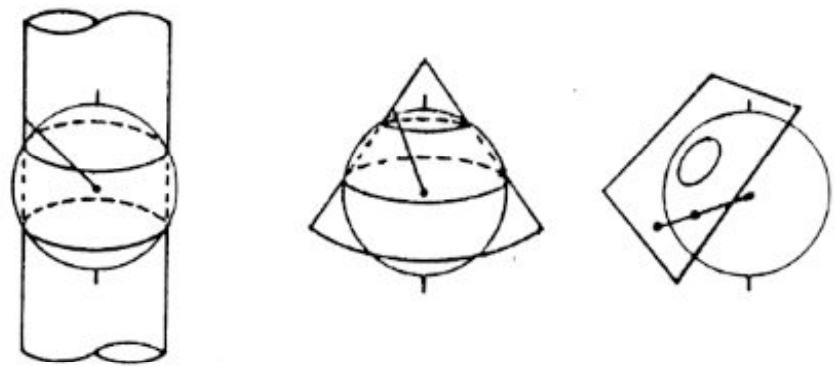
Cylinder

Cone

Plane



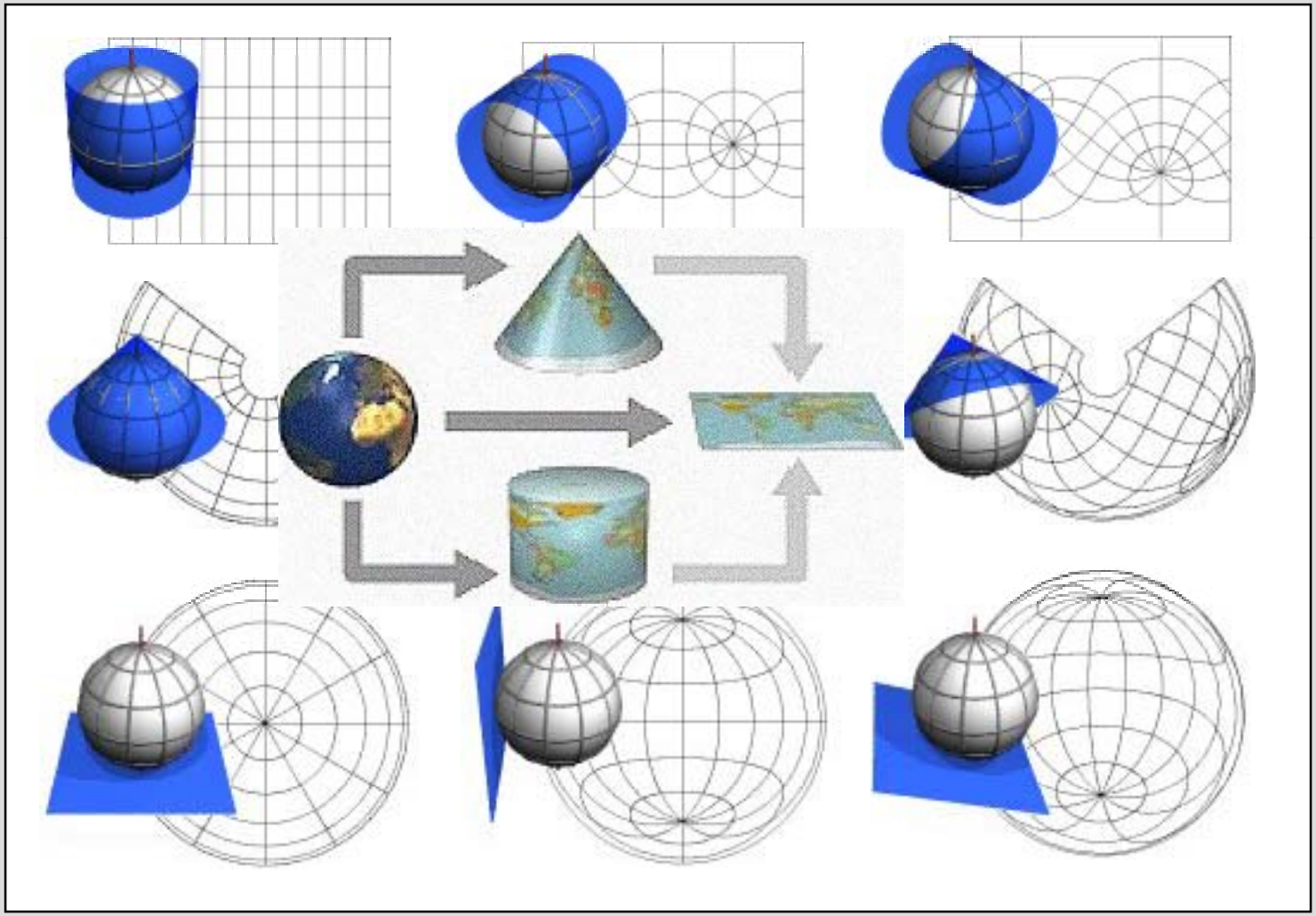
Developable Projection Surfaces



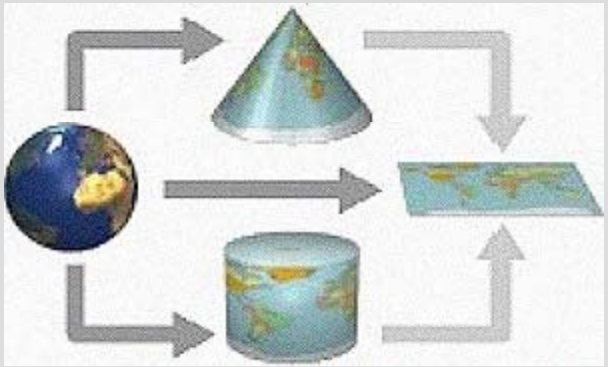
Secant Cylinder Secant Cone Secant Plane

Cartography Secant Surfaces

	Normal (Equatorial Plane)	Transverse (Meridian Plane)	Oblique (Other Plane)
Cylindrical			
Conic			
Planar			

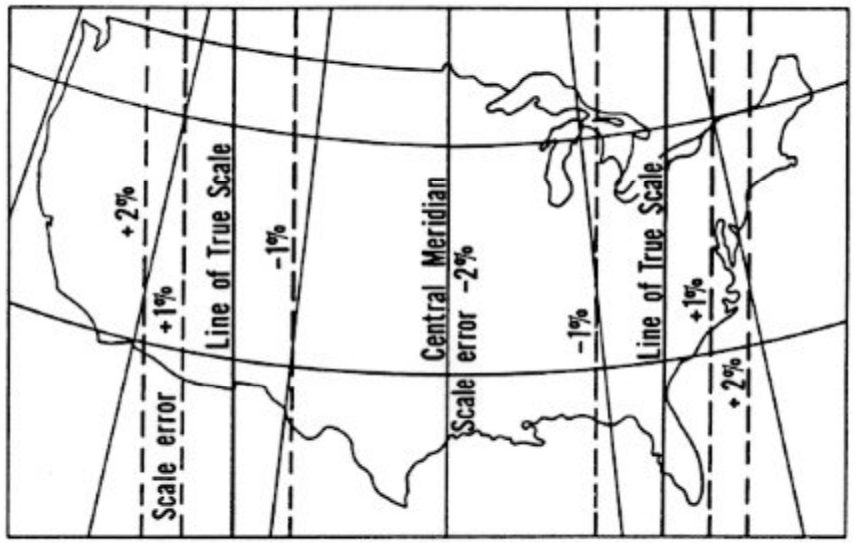


Why not the Globe? Types of Projection

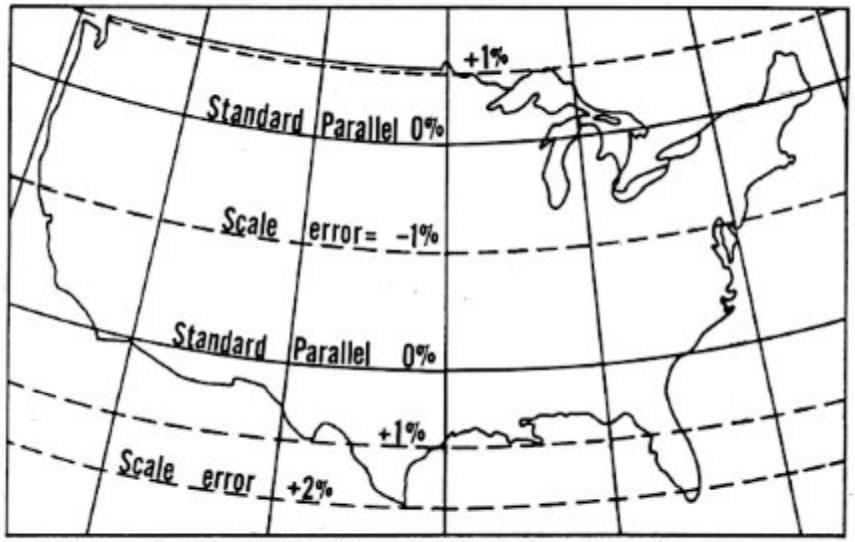


- **Mercator**
- **Transverse Mercator**
- **Universal Transverse Mercator**
- **Lambert Conformal Conic**
- **Other – Oblique Stereographic**

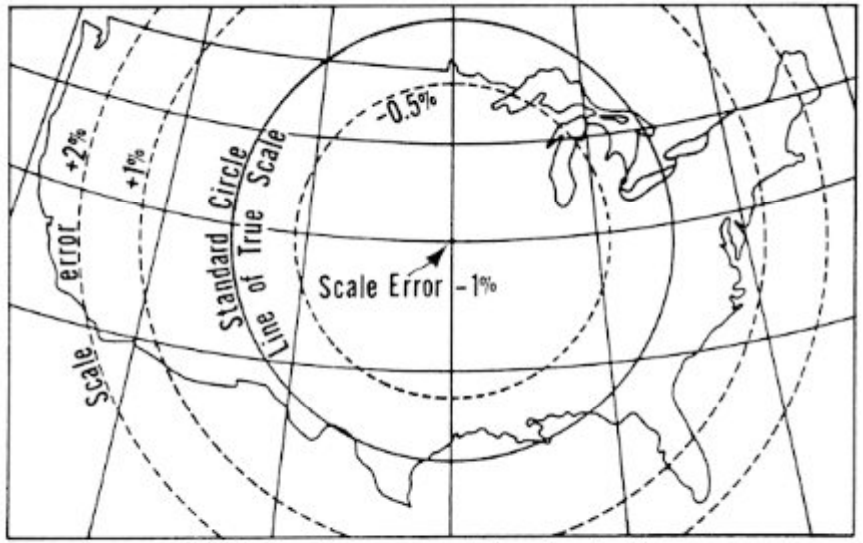
Three Example Projections



Transverse Mercator Projection



Lambert Conformal Conic Projection



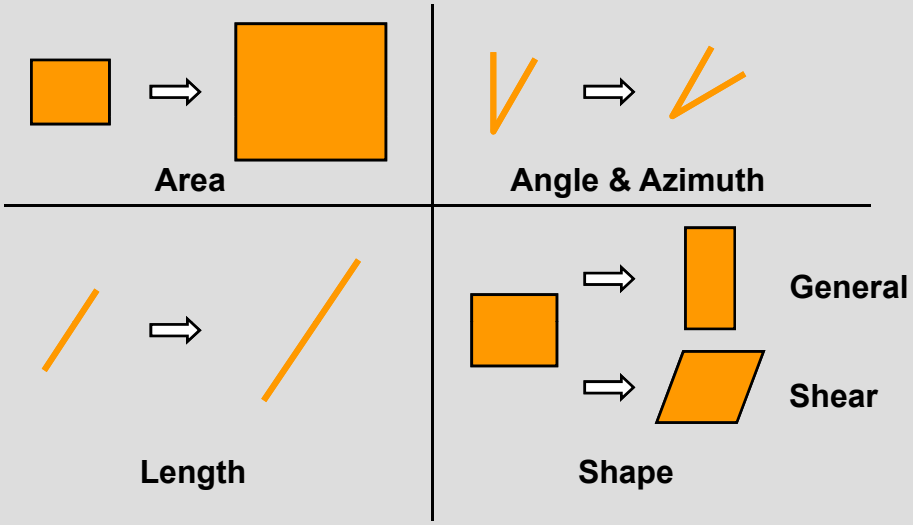
Oblique Stereographic Projection

Map Projections - Shape and Scale

- **Conformality also called Orthomorphism**
  - **Angular integrity between points is retained**
  - **Scale distortion at a point is independent of direction/ is the same in all directions**
  - **Small shapes are honored**
- **Equidistant**
  - **Scale along certain lines is true**
- **Equal Area**
  - **True area is represented**

Cartography Projection Distortion

Distortion is unavoidable in any projection



The distance between 2 points described by projection coordinates is not the same as the distance measured along the ground, by the ratio of the scale factor along the line

The azimuth between 2 points described in projection coordinates will differ from the 'true' azimuth by the convergence angle

Map Projections - Generation

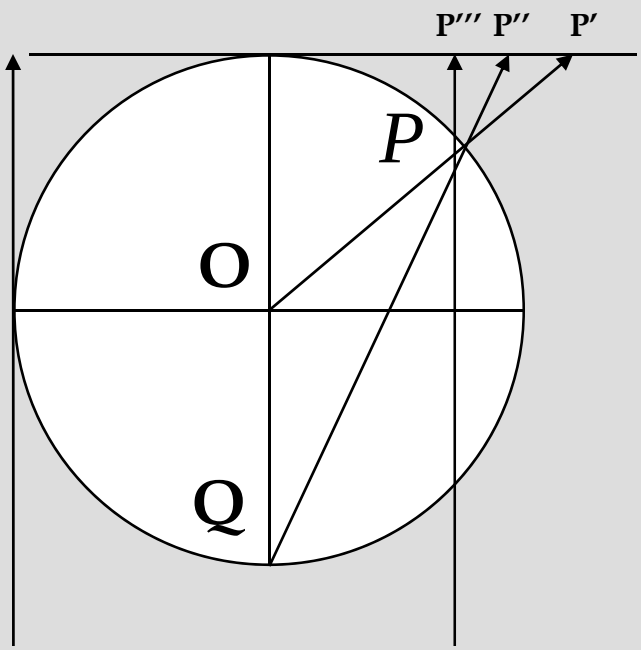
- **Geometric**
  - **Can be constructed geometrically - parallels and meridians usually simple shapes like circles and straight lines**
- **Semi Geometric**
  - **Can be constructed in part or wholly with some computation**
- **Conventional**
  - **Defined and computed mathematically and plotted via computer. Complex shapes to meridians and parallels**

Most of the most commonly used projections are conventional

PERSPECTIVE PROJECTIONS OF A SPHERE

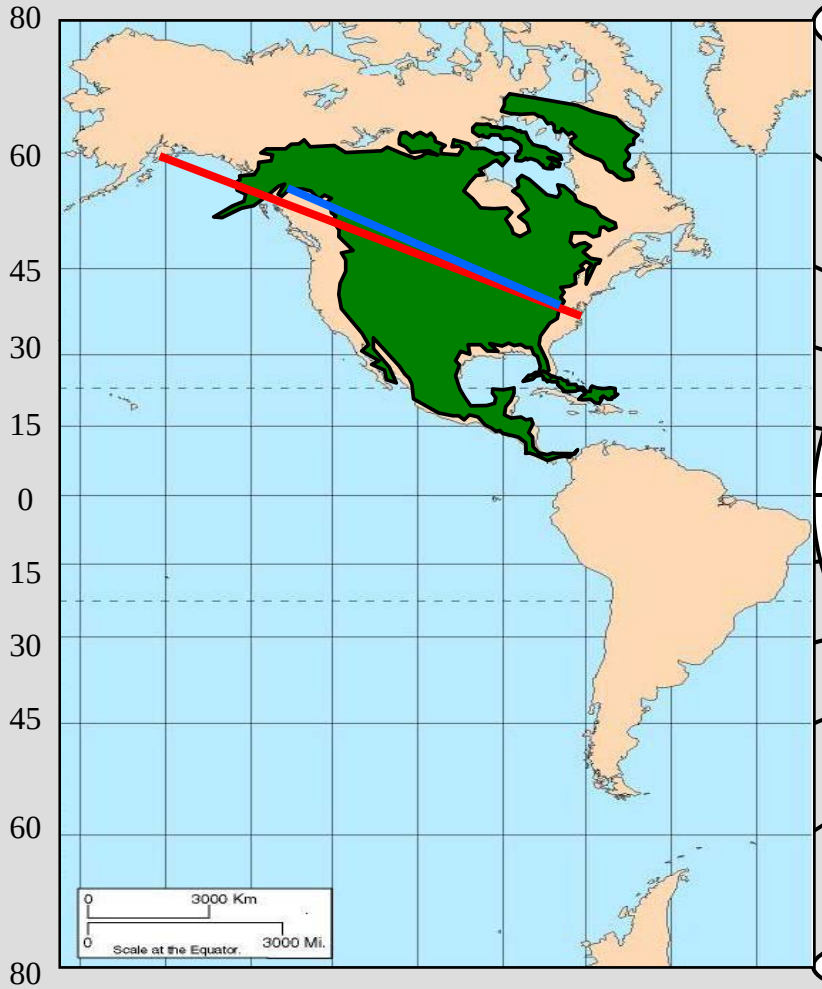
Perspective: Truly perspective projections in a geometrical sense

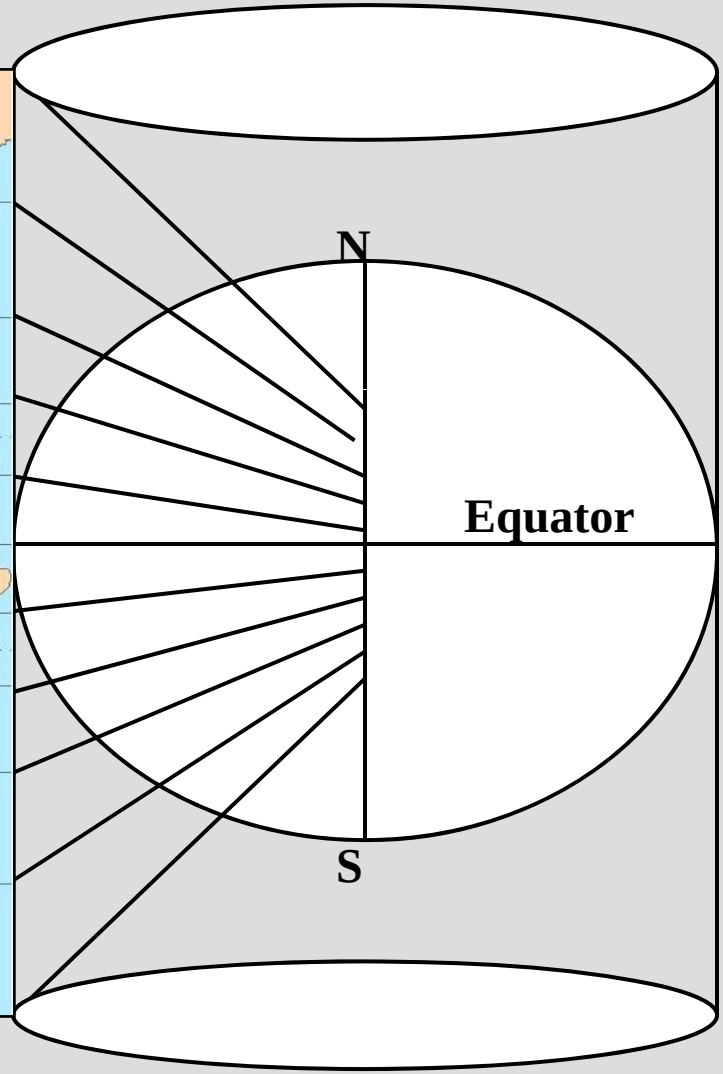
Azimuthal : Perspective projections in which the projection surface is a plane



- **Gnomonic projection, P′**
  Perspective projection from the center of a sphere
- **Stereographic projection, P″**
  Perspective projection from a point placed diametrically opposed to the point of tangency
- **Orthographic projection, P‴**
  Perspective projection from infinity

Mercator Projection - Distortion





Scale Distortion (N:1)

[1/cos(lat)]

0 °	**1**
48 °	**1.5**
60 °	**2**
71 °	**3**
76 °	**4**
80°	**6**

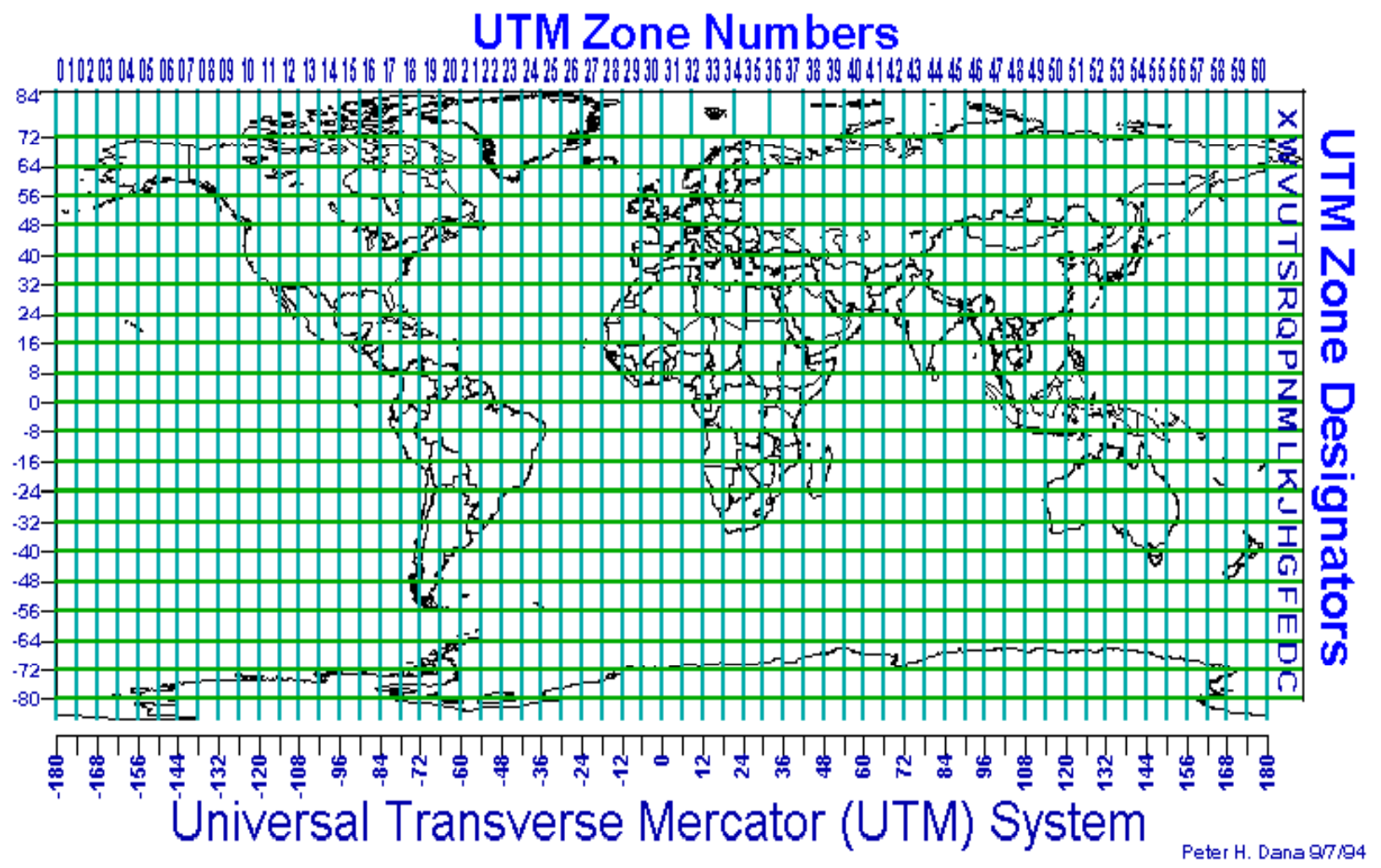
Mercator Class and Use

- **Cylindrical**
- **Usually Tangent**
- **Orientation - Equatorial**
- **Conformal (Shape OK over small area)**
- **Not equal area, Not constant scale, Not perspective**
- **Rhumb Lines become straight lines,**
  Great Circles are curved lines
- **Cannot map above 80° - ie cannot include poles**
- **Used for navigational charts**

TM/UTM Class and Use

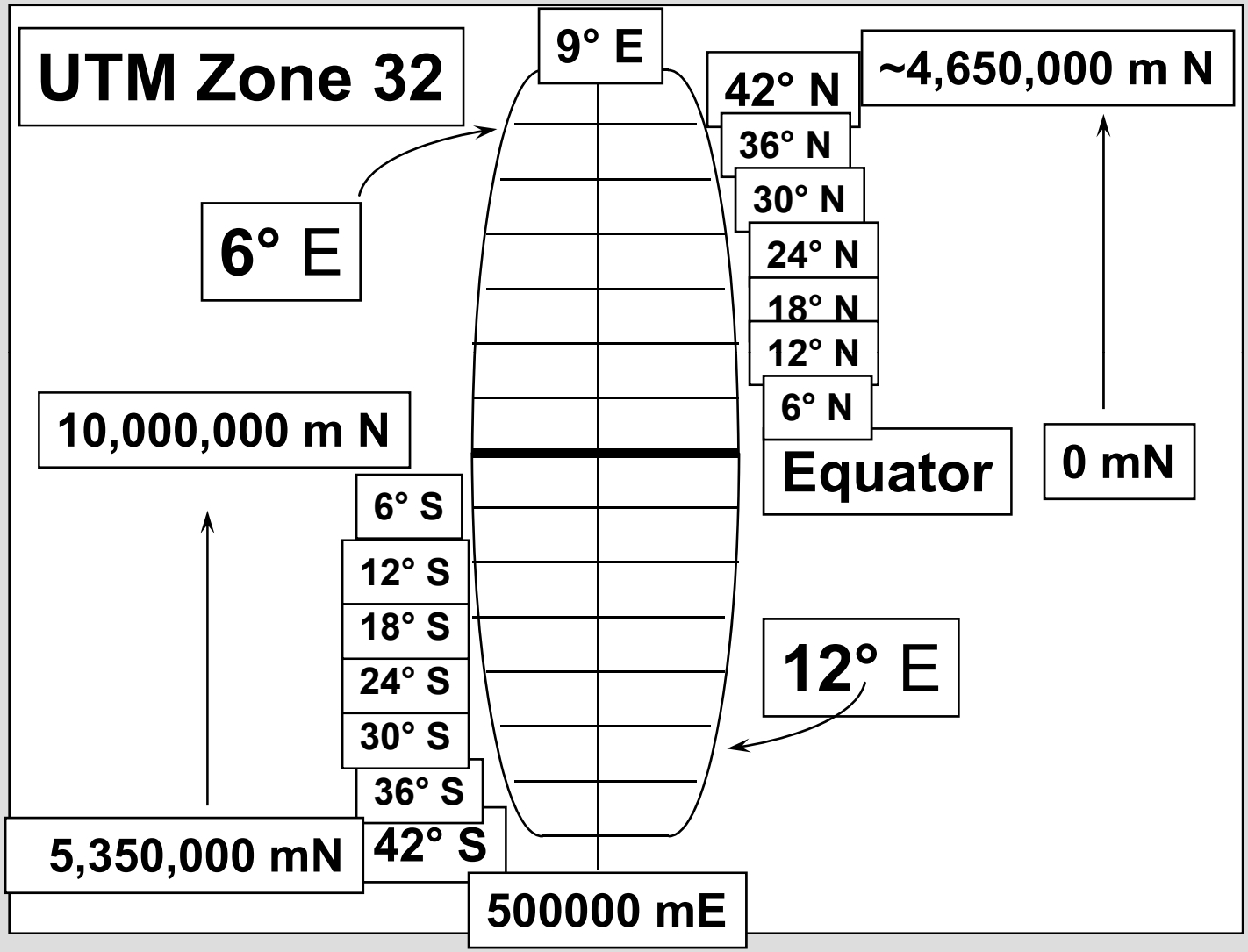
- **Cylindrical**
- **Secant (UTM always, TM Usually)**
- **Transverse (Polar) Orientation**
- **Conformal**
- **Algorithmic (non-geometrical)**
- **TM Used in predominantly N-S geographic areas - many USGS and other national map series including some SPCS**
- **UTM used for large scale charts world wide**
- **Adjoining TM maps in same zone match at E/W edge**
- **UTM SF at CM allows 1:2,500 scale error (.9996)**
- **SPCS SF at CM allows 1:10,000 scale error**

UTM Zones

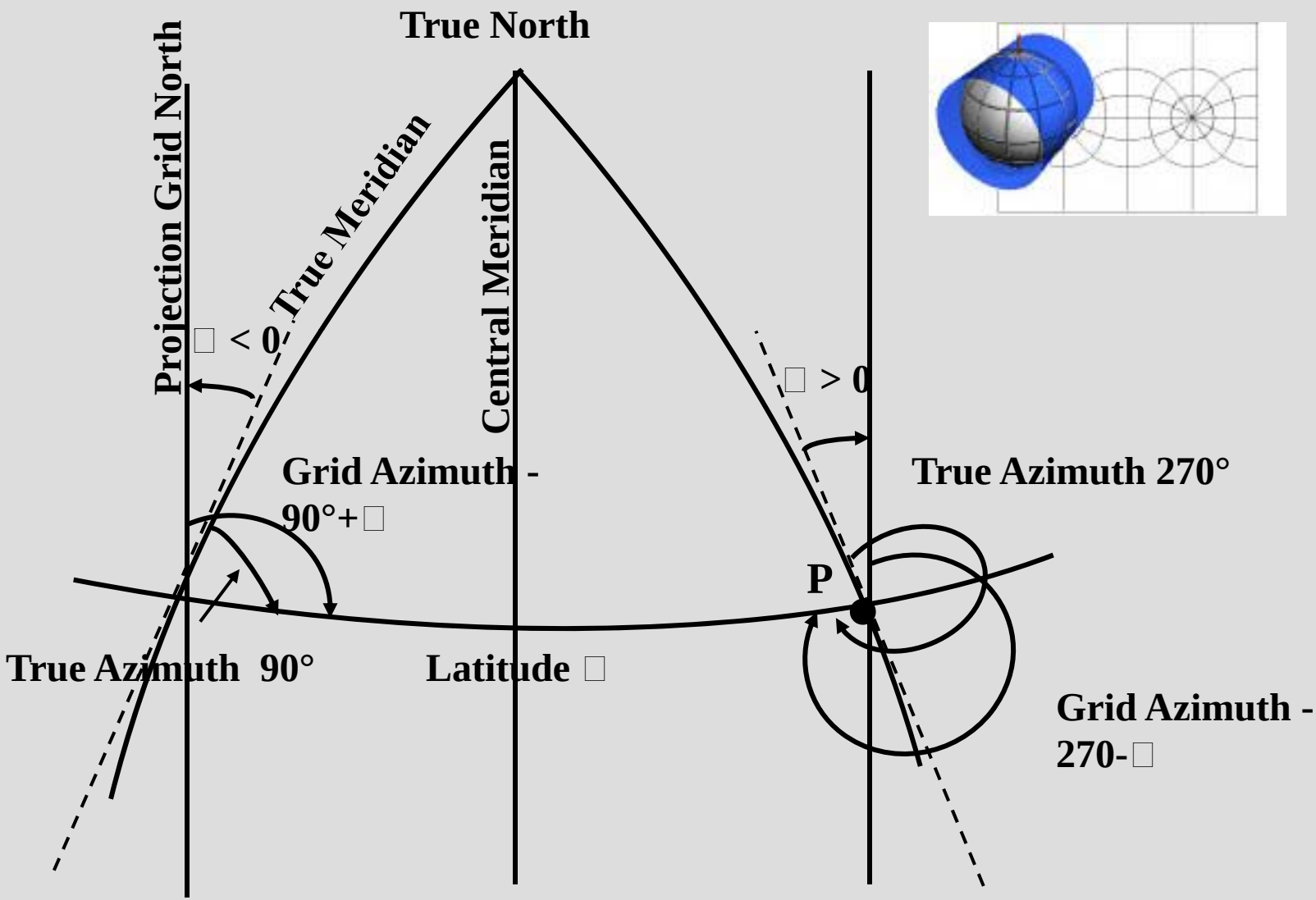

UTM Zone Numbers
0 1 0 2 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 2 1 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 4 1 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
84 72 64 56 48 40 32 24 16 8 0 -8 -16 -24 -32 -40 -48 -56 -64 -72 -80
X W V U T S R Q P N M L K J H G F E D C
UTM Zone Designators
-180 -168 -156 -144 -132 -120 -108 -96 -84 -72 -60 -48 -36 -24 -12 0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180
Universal Transverse Mercator (UTM) System
Peter H. Dana 9/7/94

UTM Example

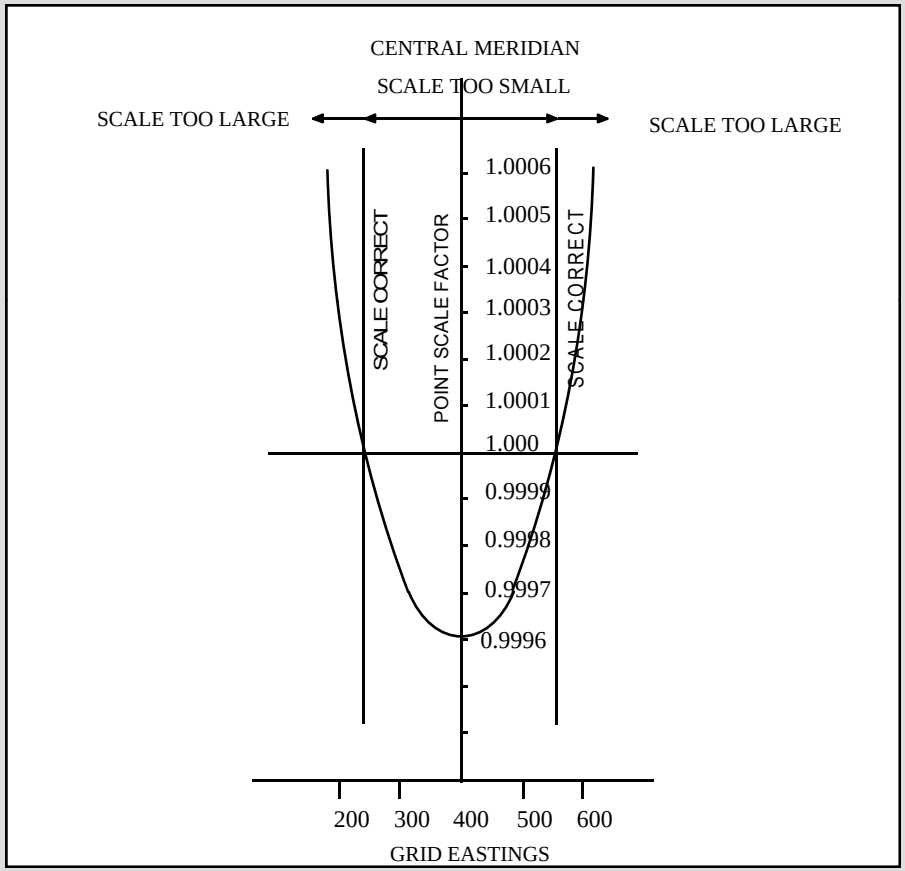
UTM
6° Zones
ev. odd 3°
Zone # 1-60 fm
177° W thru
Greenwich
to 177° E.
Units Meters.
Origin
CM
FE 500,000 mE
FN 0 mN
or
10,000,000 mN
at Equator



TM - Convergence



TM - Scale Factor Distribution



Mixing Projection Coordinates UTM

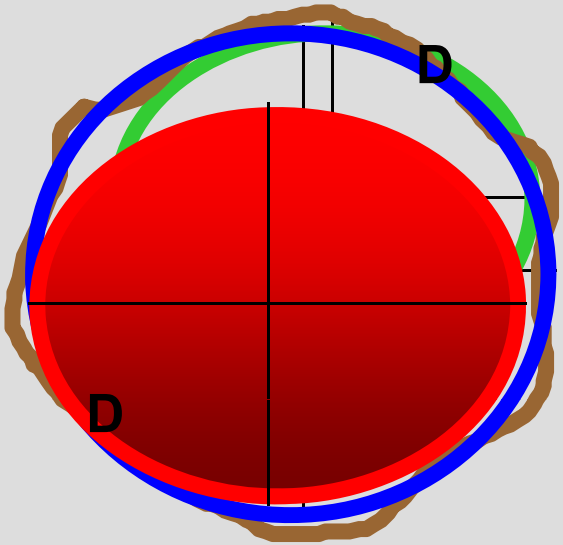
- **West Texas**
- **UTM Zone 13N**
- **NAD27**
  - **Easting: 500,000m**
  - **Northing: 3540248m**
- **NAD83**
  - **Easting: 499951m**
  - **Northing: 3540452m**
- **Differences**
  - **DE 161.1 ft**
  - **DN 669.3 ft**
  - **DR 688.3 ft**

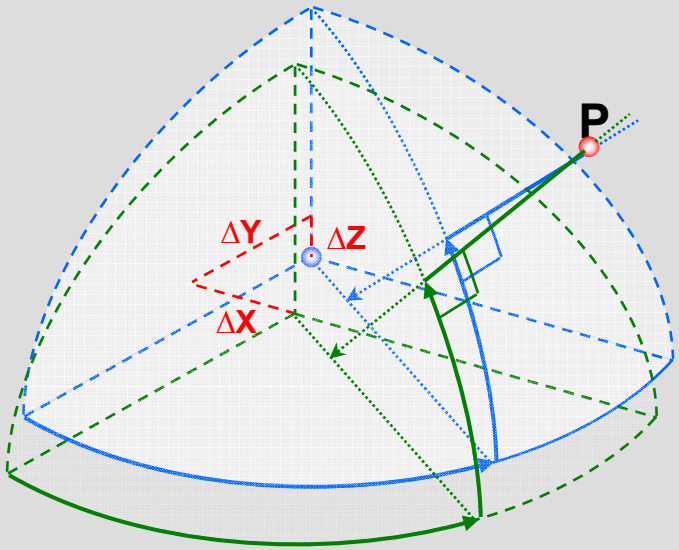
- **Montana**
- **UTM Zone 12N**
- **NAD27**
  - **Easting: 421182m**
  - **Northing: 4983220m**
- **NAD83**
  - **Easting: 421117m**
  - **Northing: 4983427m**
- **Differences**
  - **DE 213.7 ft**
  - **DN 680.1 ft**
  - **DR 712.9 ft**

'UTM' Feet

- **GOM – NAD27**
- **'UTM' Feet is actually a TM projection**
- **Latitude of Origin** **0º**
- **Central Meridian** **93 º W**
- **Central Scale Factor** **0.9996**
- **False Northing** **0**
- **False Easting** **1640416.6665 Ft**
- **Units** **US Survey Ft**

Mixing Projections - Brazil Example





Datum	Latitude	Longitude	Local to WGS84	Local to Local
Aratu	20º 36' 13.2757"N	38º 56' 56.3341"W	236.7 meters	220.56 meters
SAD69	20º 36' 17.4283"N	38º 56' 50.1240"W	65.12 meters	
WGS84	20º 36' 19.2794"N	38º 56' 51.2166"W		

Datum	Easting UTM 24S	Northing UTM 24S	Local to WGS84	Local to Local
Aratu	505,316.4	2,278,317.4	214.7 meters	208.8 meters
SAD69	505,495.9	2,278,424.1	58.4 meters	
WGS84	505,464.2	2,278,473.1		

Example shows coordinates of the SAME physical point

Multiple Options - Domestic

Mississippi State Plane Projection Options

	USA NAD27	USA NAD83	USA NAD83 (HARNS)
Latitude of Origin	30º 30’ N	29º 30’ N	29º 30’ N
Central Meridian	90º 20’ W	90º 20’ W	90º 20’ W
Central Scale Factor	.999941177	.99975	.99995
False Northing	0	0	0
False Easting	500,000	2296583.333	700,000
Units	US Survey Feet	US Survey Feet	Meters

Not difficult to imagine parameters being confused by the inexperienced surveyor or data loader

Multiple Options – International

Datum	Ellipsoid	Projections
Aratu	International 1924	UTM 22, 23, 24
Corrego Allegre	International 1924	UTM 23, 24
PSAD56	International 1924	UTM 22
SAD69	GRS 1967 or International 1967	UTM 18-22, 24
Sirgas	GRS80	UTM 18S, 19-22 N&S, 23-25 S
WGS84	WGS84	Same as Sirgas

Total of 28 projections – ALL UTM!

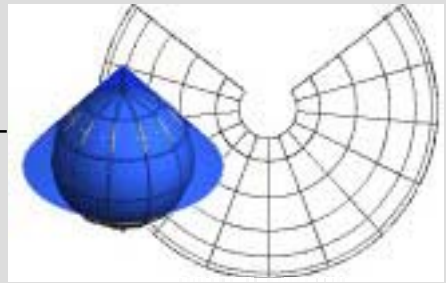
Lambert Class and Uses

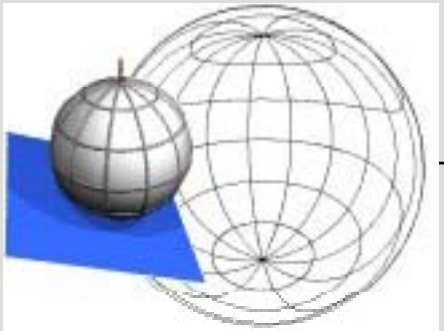
- **Conic**
- **Secant**
- **Polar**
- **Conformal (Shape distortion is small)**
- **Algorithmic**
- **Great Circles (approximately) straight lines**
- **Parallels are arcs of concentric circles expanding in distance at edges, contracted between standard parallels**
- **Meridians are straight lines**
- **Used for mapping areas of large E/W extent including some US States (SPCS) and world series aeronautical charts, hurricane tracking charts**

Example Lambert and Oblique Stereographic

Syria – Levant Datum

- Projection: Lambert Conformal Conic
- Grid: Syria North Lambert
- Central Meridian: 37º 21’ E
- Latitude of Origin: 34º 39’ N
- Central Scale Factor: 0.9996256
- False Easting: 300,000 meters
- False Northing: 300,000 meters
- Units: Meters





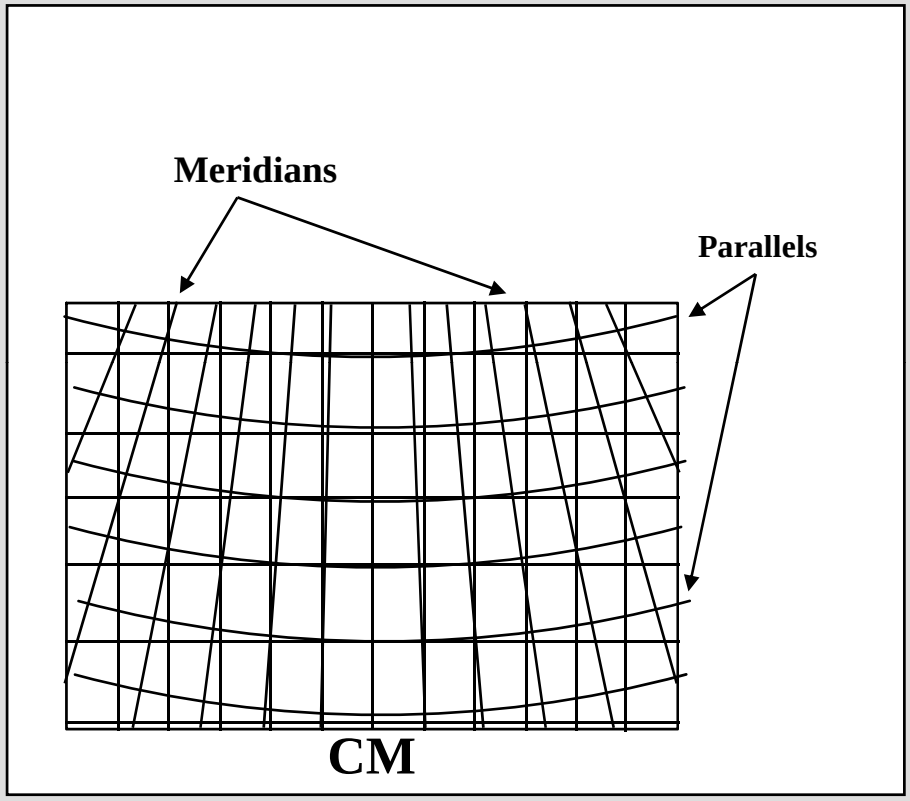
Syria – Levant Datum

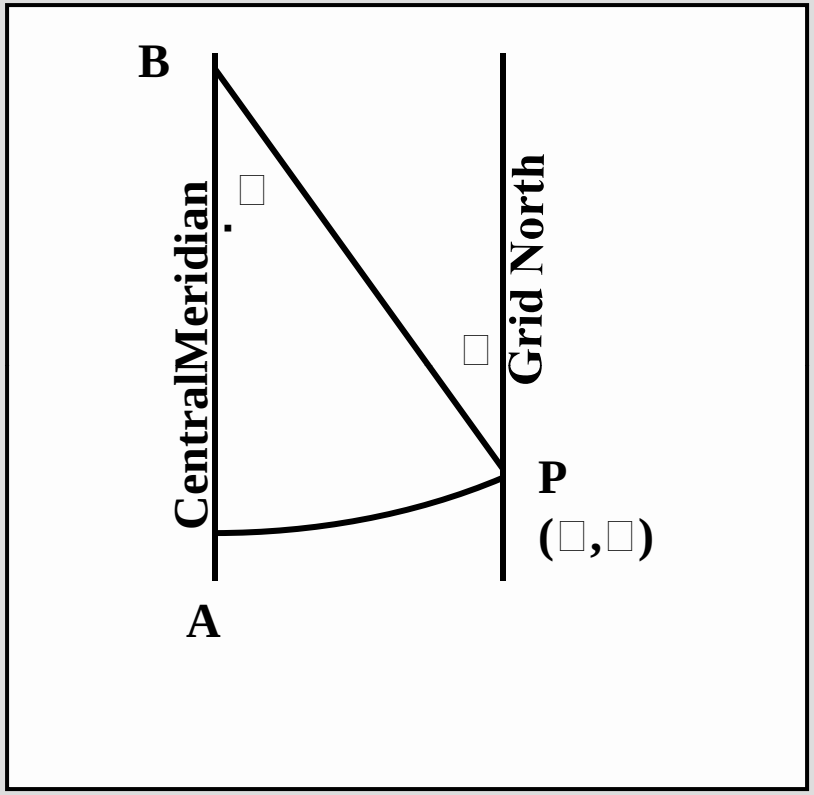
- Projection: Oblique Stereographic
- Grid: Syria
- Central Meridian: 39º 09’ E
- Latitude of Origin: 34º 12’ N
- Central Scale Factor: 0.9995341
- False Easting: 0 meters
- False Northing: 0 meters
- Units: Meters

Example Lambert - Domestic

- **USA – NAD27 (Geog. CRS)**
  - **Projection** **Lambert Conformal Conic**
  - **Proj. CRS** **Louisiana South Zone**
  - **Central Meridian:** **91º 20’ E**
  - **Latitude of Origin:** **28º 40’ N**
  - **Latitude 1st Standard:** **29º 18’ N**
  - **Latitude 1st Standard:** **30º 42’ N**
  - **False Easting:** **2000,000**
  - **False Northing:** **0**
  - **Units:** **US Survey Feet**

Lambert Convergence

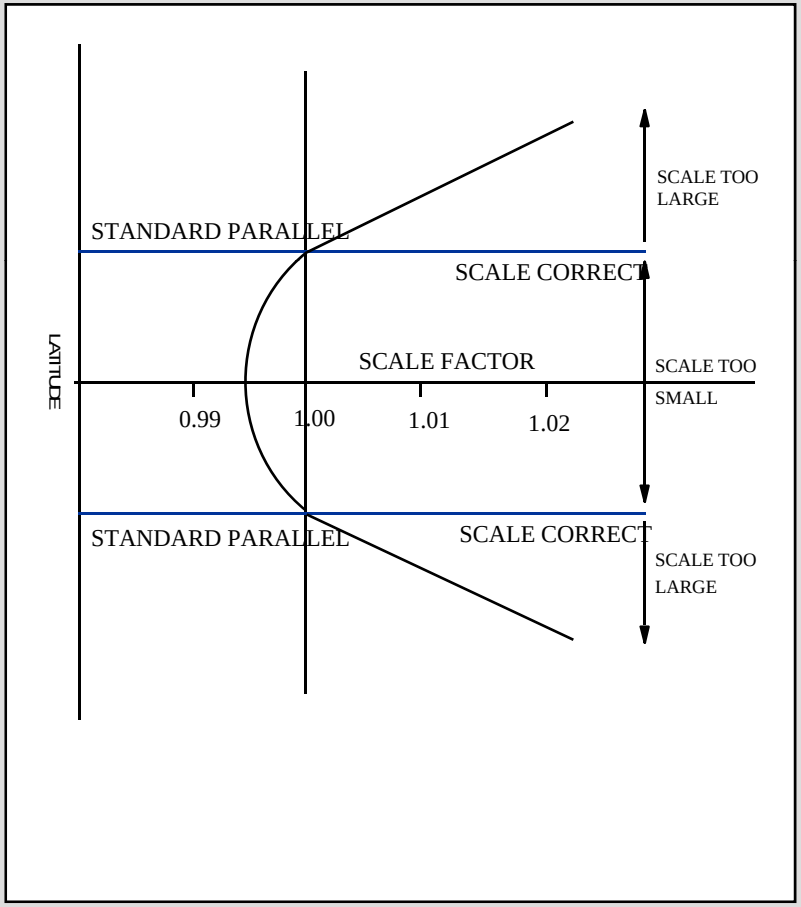




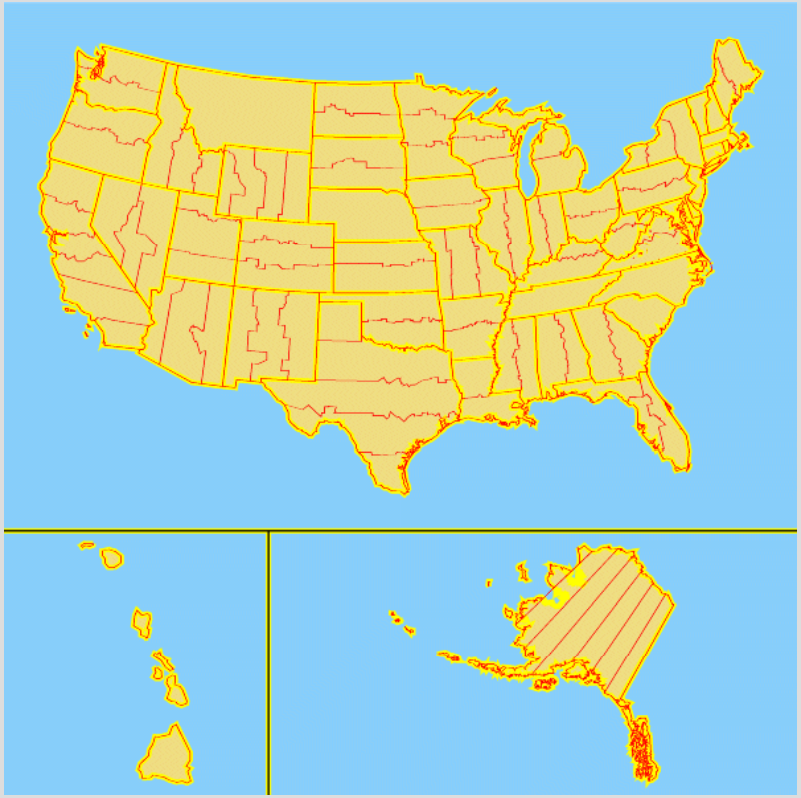
Parallels project as circular arcs concave to the nearest pole. Meridians are straight lines converging towards the nearest pole. Meridians and Parallels orthogonal

Lambert Scale Distortion

- Scale is constant in the E-W direction but varies in the N-S direction
- Scale is correct along the standard parallels. Too large outside them and too small inside them
- Variation in scale in N-S direction is shown opposite
- The projection is limited in N-S extent by the amount of distortion allow



State Plane Coordinate System



- **Designed to be accurate to 1:10,000**
- **Different projections used:**
  - **Transverse Mercator for States with large N/S extent**
  - **Lambert conformal conic for States with large E/W extent***
  - **Some states use both projections (NY, FL, AK)**
  - **Oblique mercator used for Alaska panhandle**

Note: Wyoming is an exception to this

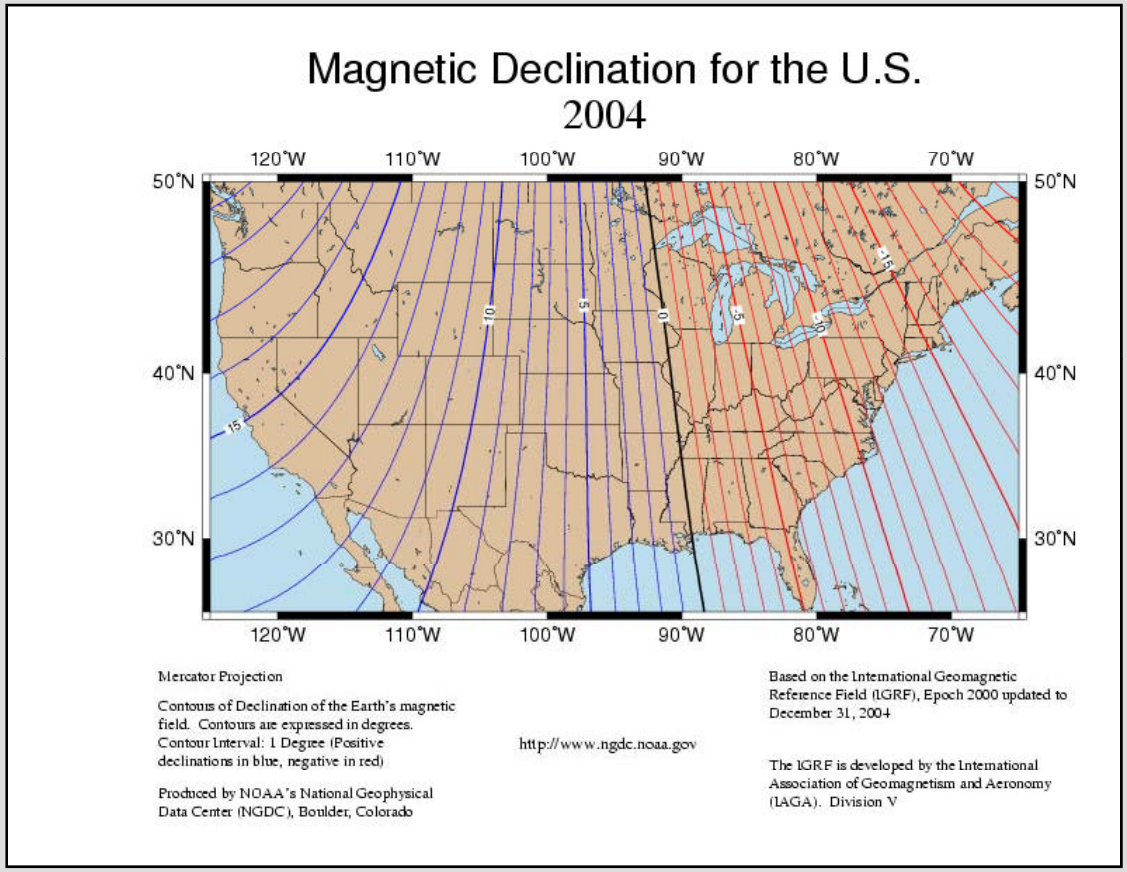
Over One Hundred Different Projections in each of Two Datums

Reference Orientations

Multiple Norths

- **True North**
  Direction of the meridian through a point
- **Grid North**
  Differs from True North by the convergence
- **Magnetic North**
  Differs from True North by Declination

Magnetic Declination



GOM varies ± 5º from Brownsville to Tampa. There is also a temporal variation (so many seconds per year.

Magnetic North to Grid North - Required Corrections

- **Magnetic North to True North**
  - **Add magnetic declination to magnetic north to get true north.**
- **True North to Grid North**
  - **Subtract Meridian Convergence from true north to get grid north**

On the other foot! Reference Lengths

Name	International Meter per Unit	Units/International Meter
British Foot (Sears)	0.304799472	3.280845578367668563415359197210 2
US Survey Foot	0.304800610	3.280833333
Modified American Foot	0.304812253	3.280708010
Canadian Standard Foot	0.304800000	3.280839895
Clarke's Foot	0.304797265	3.280869335
British Foot (Benoit 1895 A)	0.304799733	3.280842765
British Foot (Benoit 1895 B)	0.304799735	3.280842750
British Foot (1865)	0.304800833	3.280830925
Indian Foot	0.304799510	3.280845167
Indian Foot (1937)	0.304798410	3.280857010
Indian Foot (1962)	0.304799600	3.280844201
Indian Foot (1975)	0.304799500	3.280845277
Gold Coast Foot	0.304799710	3.280843015
Fathom (6 International ft)	1.8288	0.546806649
International Nautical Mile	1852	0.000539957
Statute Mile	1609.344	0.000621371
US Survey Mile	1609.347218694	0.000621370
German Legal Meter	1.000013597	0.999986404

Non-Coordinate Reference - PLSS

Public Land Survey System

- **Section Corners/Lines**
- **Used to determine location in relation to mapped lines**
  - **Concerns:**
    - **Digitizing of maps**
    - **Corner/Line ID**

Features of Common Map Projections

Cylindrical

- **Equidistant**
  - Neither equal-area nor conformal
  - Graticule consists of straight lines at 90 degrees
  - Same as plotting Lat/Long as scaled X/Y
- **Mercator**
  - Conformal, but great distortion in polar areas
  - Parallels unequal, meridians equal spacing
  - Loxodromes straight for navigational usage
- **Transverse Mercator**
  - Conformal with distortion <0.1% in UTM Zone
  - Used for predominantly north-south regions
  - UTM has standard parameters and zones
- **Oblique Mercator**
  - Conformal, similar to Transverse Mercator
  - Used in Alaska Panhandle, State Plane
  - Also used for satellite tracking charts
- **Miller**
  - Neither equal-area nor conformal
  - Resembles Mercator but with less distortion
  - Compromise used for world maps

Conic

- **Equidistant**
  - Neither equal-area nor conformal
  - Constant scale along all meridians
  - Adequate for mid-latitude areas
- **Lambert Conformal**
  - Conformal
  - True scale along two standard parallels
  - Used for predominantly east-west regions
- **Albers Equal-Area**
  - Equal-area
  - True scale along two standard parallels
  - Used for predominantly east-west regions
- **Polyconic**
  - Neither equal-area nor conformal
  - True scale along all parallels
  - Extensive historic usage in U.S.
- **Bonne**
  - Actually a pseudoconic
  - Meridians are complex curves
  - Conic version of the sinusoidal projection

Features of Common Map Projections

Azimuthal

- **Equidistant**
  - Neither equal-area nor conformal
  - Distances and directions from center are true
  - Used mostly in polar aspect
- **Orthographic**
  - Neither equal-area nor conformal
  - Appearance of globe from space
  - Used for pictorial views, distortion
- **Stereographic**
  - Conformal
  - Directions from center are true
  - Commonly used in polar regions
- **Lambert Equal-Area**
  - Equal-area
  - Directions from center are true
  - Used for maps of continents
- **Gnomonic**
  - Neither equal-area nor conformal
  - All straight lines are great circles
  - Used in seismic wave propagation charts

Miscellaneous

- **Sinusoidal**
  - Equal-area, pseudo-cylindrical
  - True scale along all parallels
  - Interrupted form: multiple central meridians
- **Van Der Grinten**
  - Neither equal-area nor conformal
  - Curved modification of Mercator
  - Entire globe in a circle, used for world maps
- **Eckert**
  - Equal-area, pseudo-cylindrical
  - Like sinusoidal, but poles = ½ equator
  - Distortion high in polar regions
- **Mollweide**
  - Equal-area, pseudo-cylindrical
  - Entire globe in an oval, or interrupted
  - Used for world maps
- **Goode's Homolosine**
  - Equal-area hybrid
  - Same as sinusoidal from equator to 40th parallel
  - Same as Mollweide from 40th parallel to pole

Random Selection

- M Datums per country, N Datasets per Project gives Random Chance 1:M*N
- 4 Datums, 5 Datasets
- Chances of getting Datum 100% right

1:20 (5%)

- Add P Projections gives Random Chance 1:M*N*P
- 4 Projections
- Chances of getting Datum *and* Projection right

1:80 (1.25%)

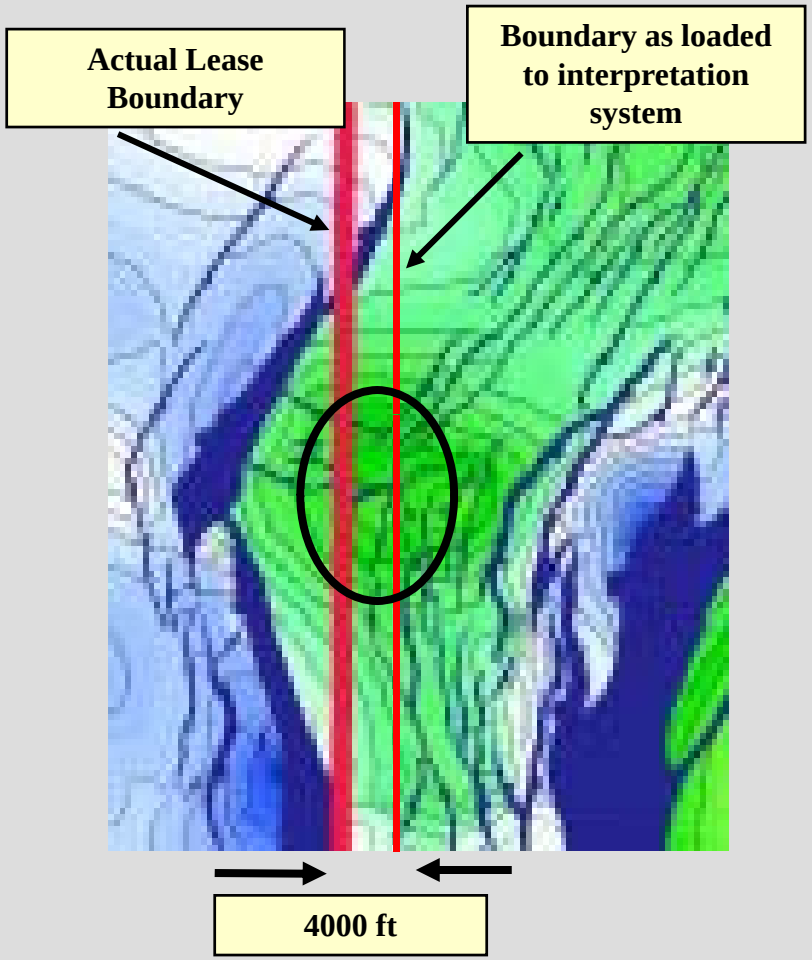
With some prior knowledge/input

Fairly realistic chances are 2 datums, 2 projections and 5 datasets giving a chance of

1:20 (5%)

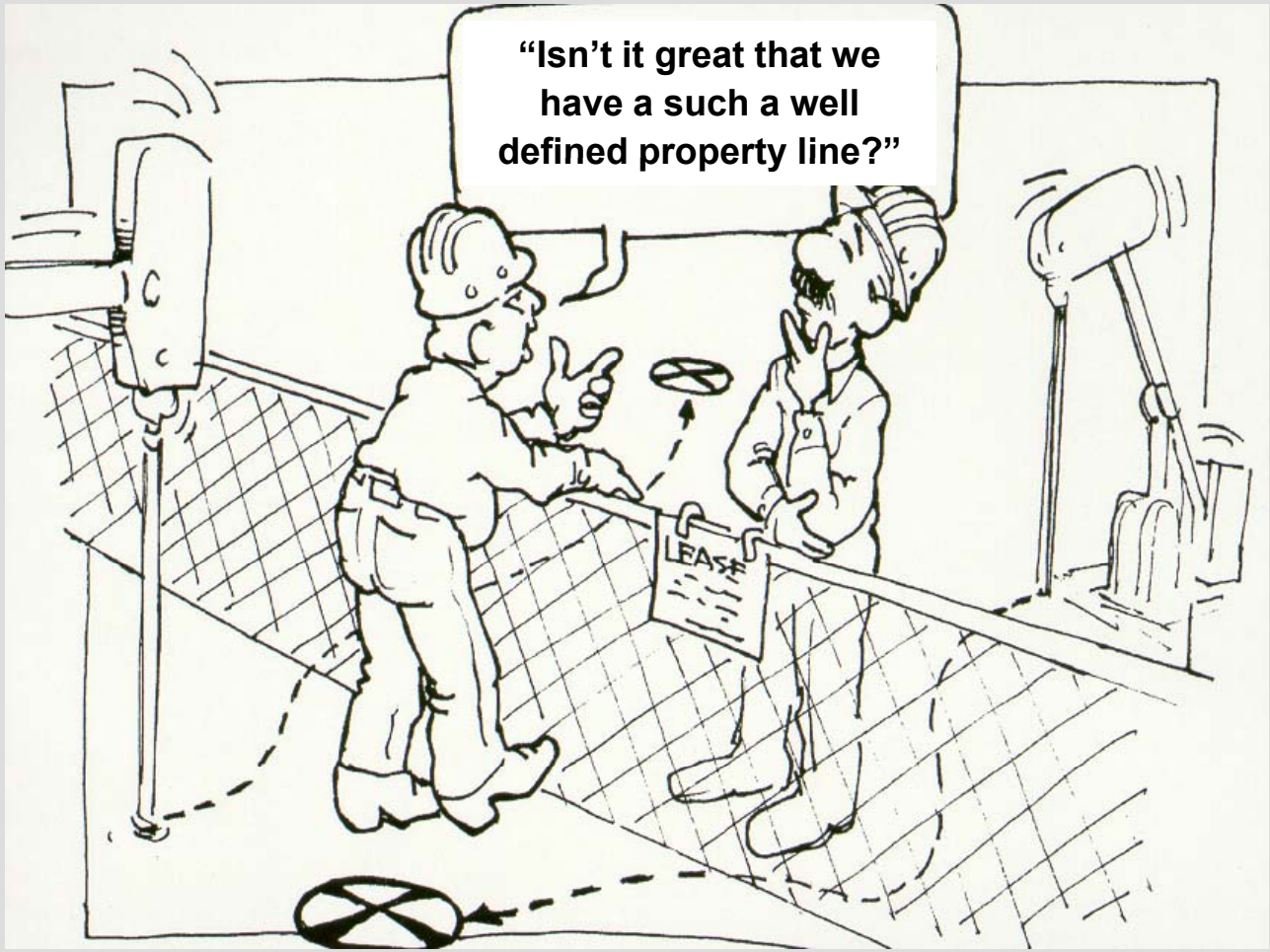
of getting all 5 datasets properly mapped.

Who Owns it?



At ~300 barrels per acre foot, this represent about 49 MM barrels per 100 ft of pay in the next door block!

RMOTC


"Isn't it great that we have a such a well defined property line?"
LEASE

Software Uncertainty!

- Openworks/Landmark
- Finder/Geoframe
- Geographix
- Kingdom
- Trango
- Probe
- Petrel

- Blue Marble Geographic Calculator
- Mentor
- ArcView
- ERMapper
- AutoCAD
- Atlas Seismic
- Excel
- NADCON
- Other Web-Based applications

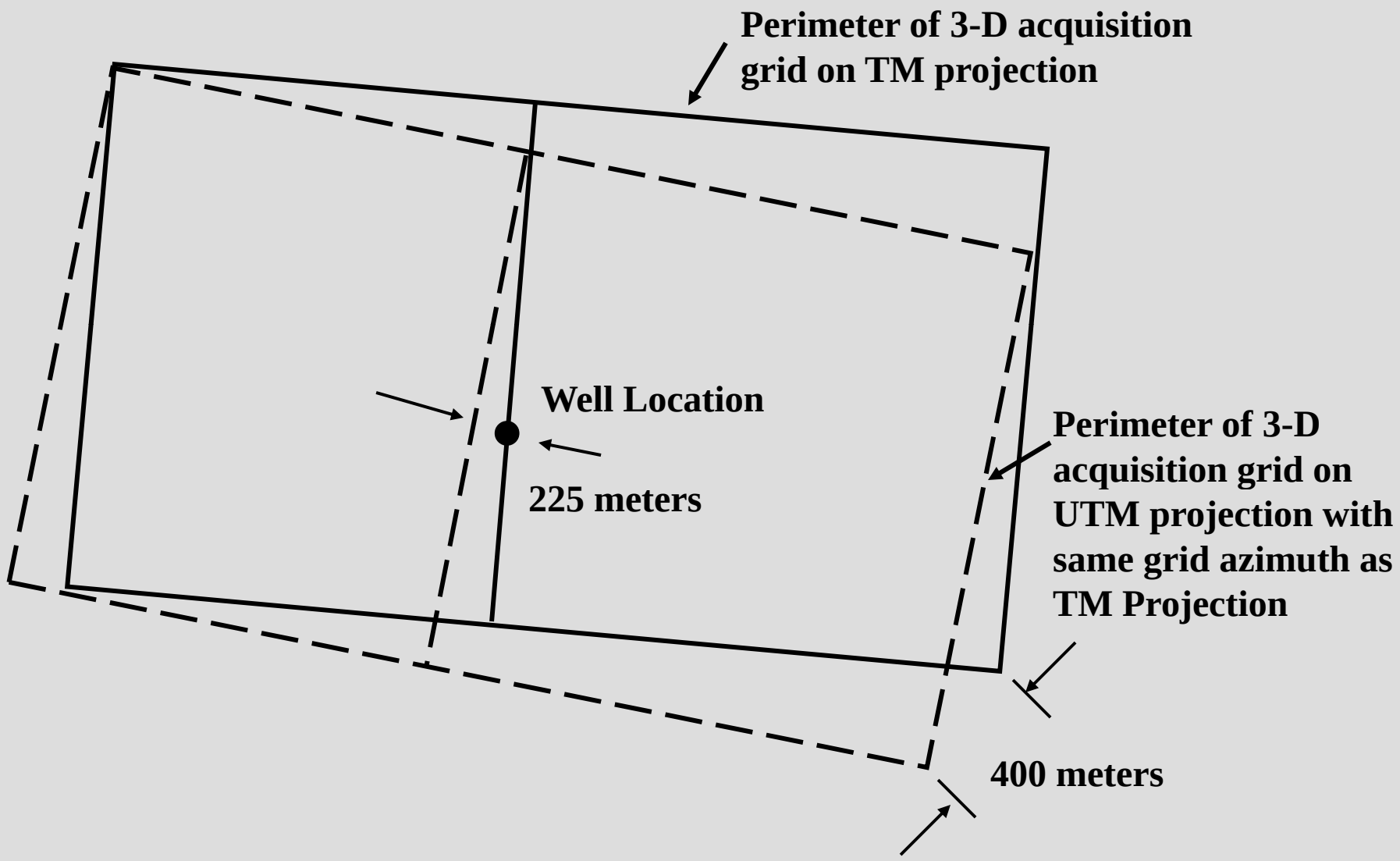
- Satellite/Aerial Image
- ASCII
- Shapefile
- DEM
- Bathymetry
- DWG/DRG
- Digitized data (Accuracy 0.06" at Scale)

Do you know the references?

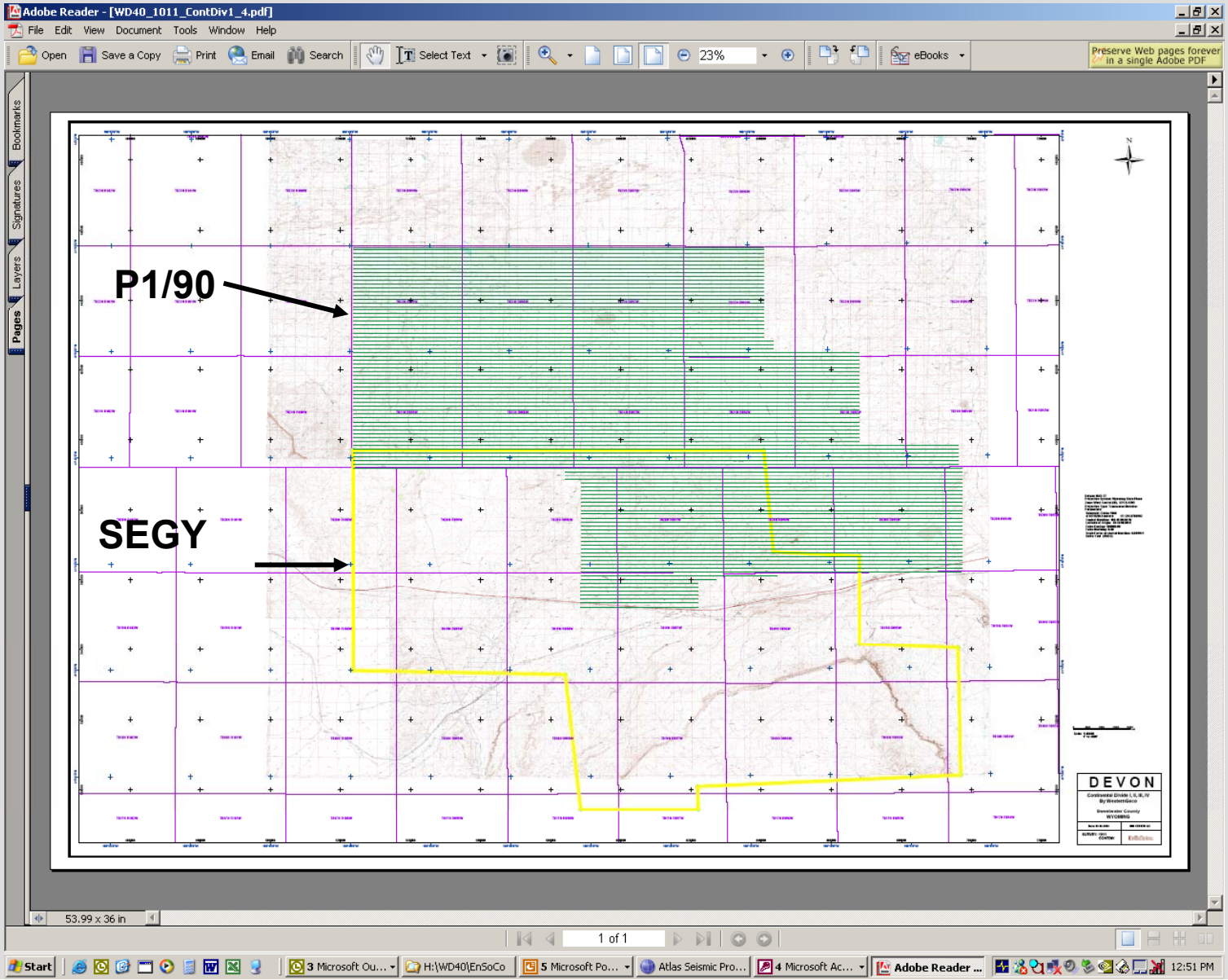
Datum, Projection, Height, Orientation!

Do these databases and programs all produce the same result when transforming or converting coordinates? Did anyone check?

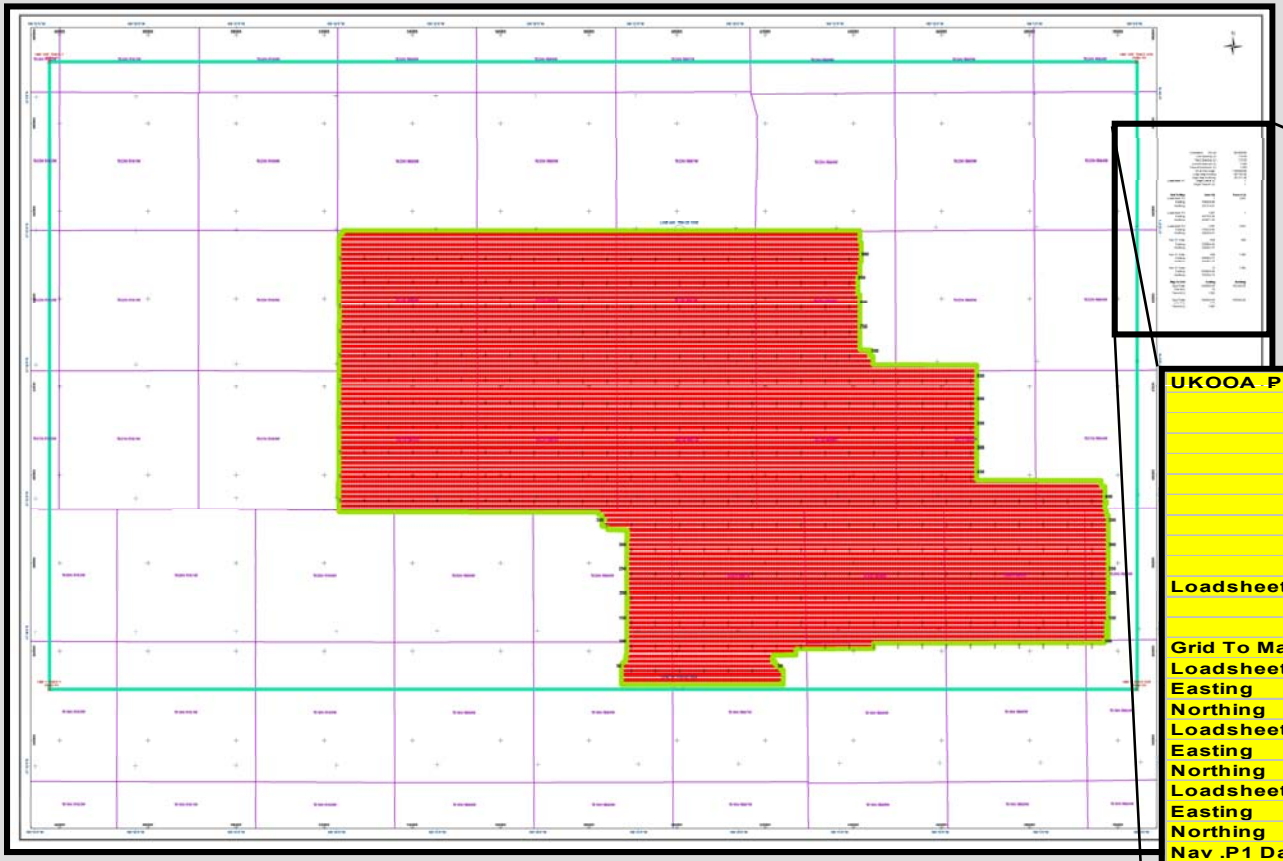
Wrong handling of heading references



Loading Sheet Lament!

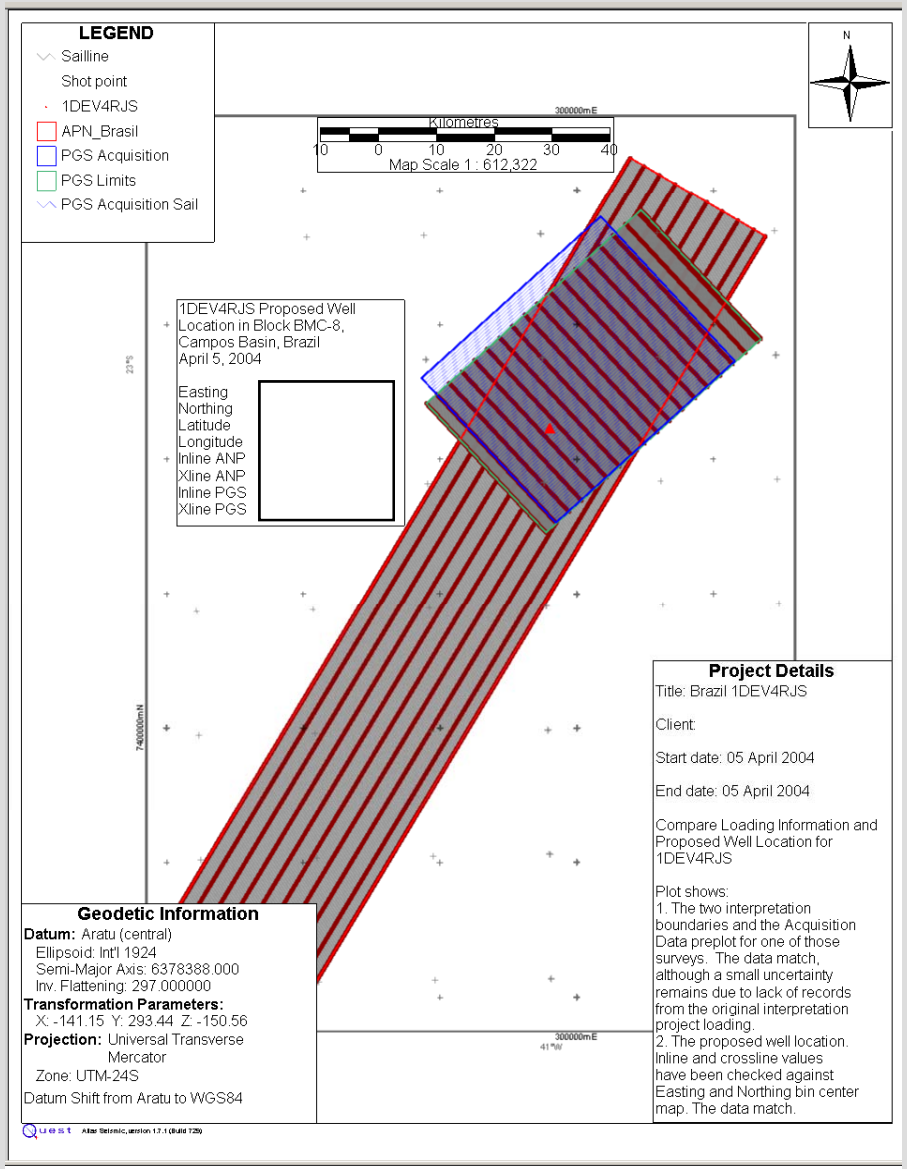


After QC



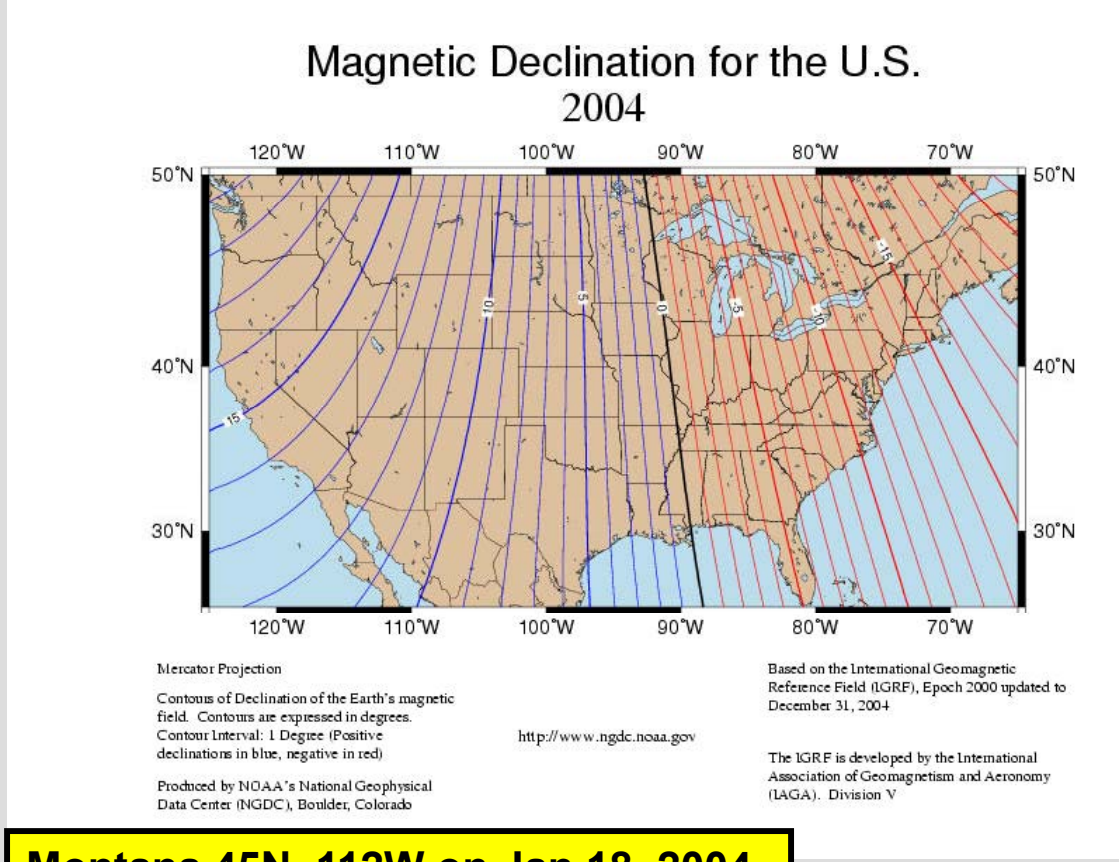
UKOOA P6/98 Grid	Coordinate Conversions	on Projection
		Parameters
	Orientation DD.dd	89.999300
	Line Spacing (I)	110.00
	Trace Spacing (J)	110.00
	Line # Increment (I)	1.000
	Trace # Increment (J)	1.000
	SF at Grid Origin	1.00000000
	Origin Map Easting	457705.00
	Origin Map Northing	351311.00
Loadsheet P1	Origin Line # (I)	1
	Origin Trace # (J)	1
		Coefficients
Grid To Map	Line # (I)	Trace # (J)
Loadsheet P2	1	2243
Easting	704325.00	
Northing	351314.01	
Loadsheet P3	1297	1
Easting	457703.26	
Northing	493871.00	
Loadsheet P4	1297	2243
Easting	704324.46	
Northing	395204.01	
Nav .P1 Data	400	650
Easting	529094.46	
Northing	395201.87	
Nav .P1 Data	948	1300
Easting	600593.73	
Northing	455482.75	
Nav .P1 Data	10	1300
Easting	600594.99	
Northing	352302.75	
Map To Grid	Easting	Northing
SegY Data	600595.00	352303.00
Line # (I)	10	
Trace # (J)	1300	
SegY Data	600594.00	455483.00
Line # (I)	948	
Trace # (J)	1300	

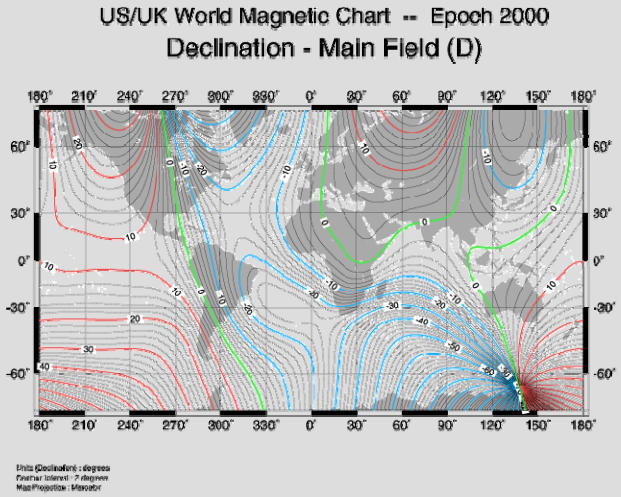
Brasil BMC-8 Well Proposal

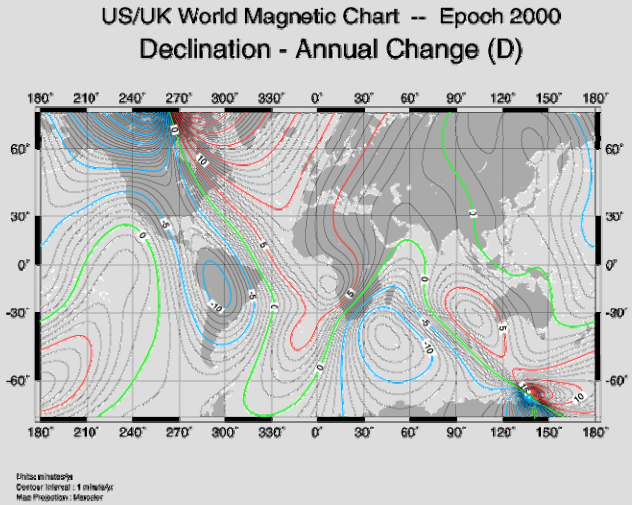


Procedure is to enter workstation coordinates and line reference and check against an independently generated bin center map, as well as against the acquisition P1 data, to ensure that datum and projection or line information has not changed during processing and interpretation.

Magnetic Declination





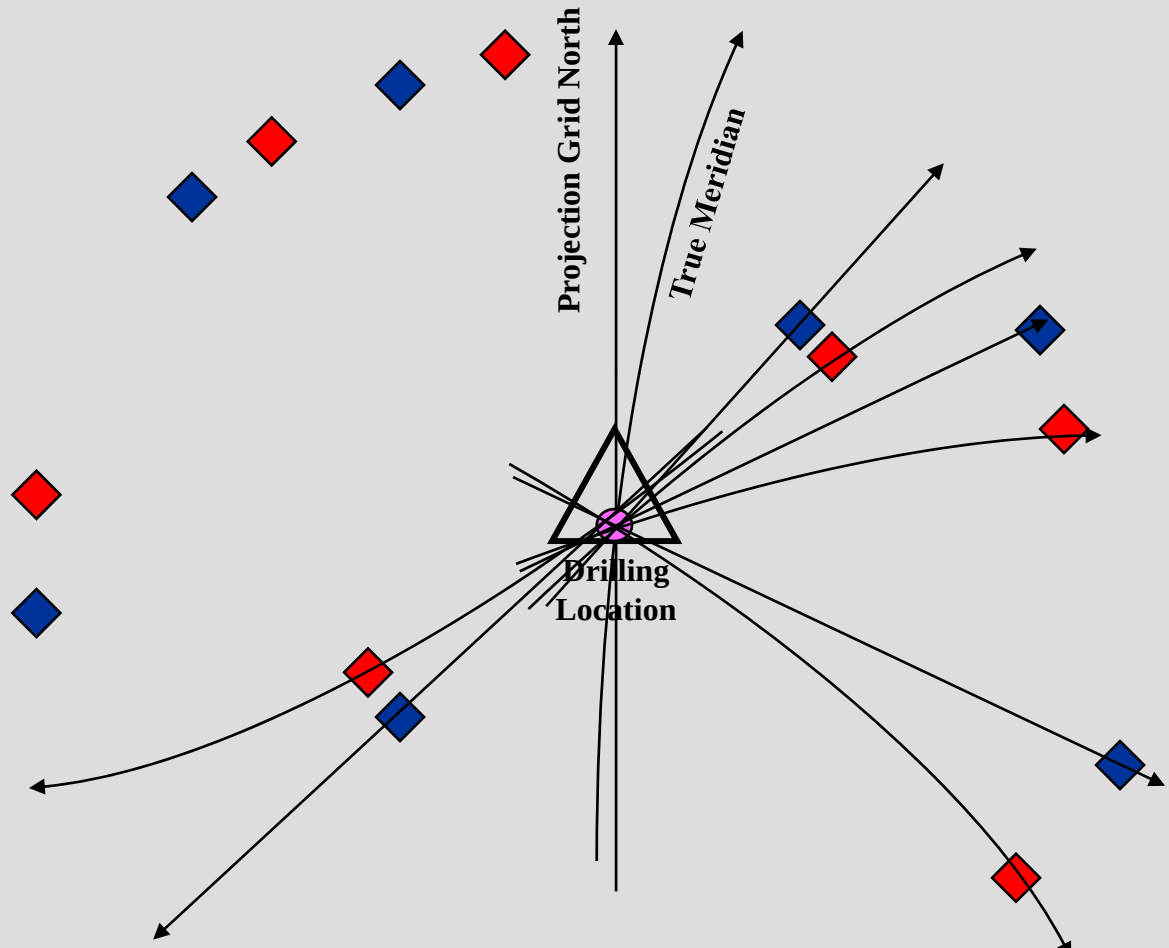


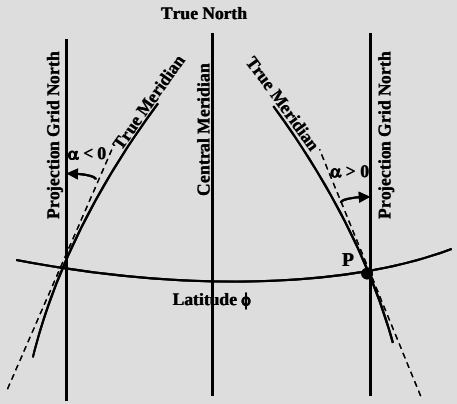
Montana 45N, 112W on Jan 18, 2004 14.35º E changing by 6' W/year

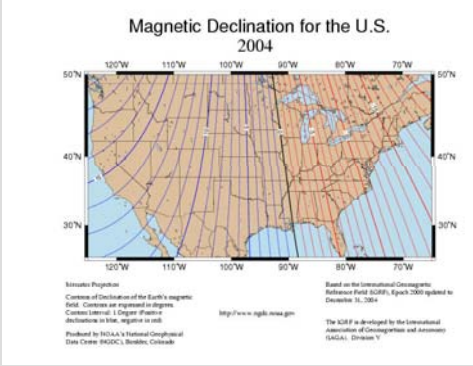
W Texas/NM 32N, 105W on Jan 18, 2004 9.25º E changing by 3' W/year

Brasil 32N, 105W on Jan 18, 2004 22.3º E changing by 7' E/year

Drilling Disorientation







Mishandling/Ignoring Convergence
W. Texas 3.9' error per 100' offset
GOM 1.3' error per 100' offset
Brasil Campos 0.8' per 100' offset

Mishandling/Ignoring Declination
GOM 9' error per 100' offset
W Texas 16' error per 100' offset
Brasil Campos 40' per 100' offset

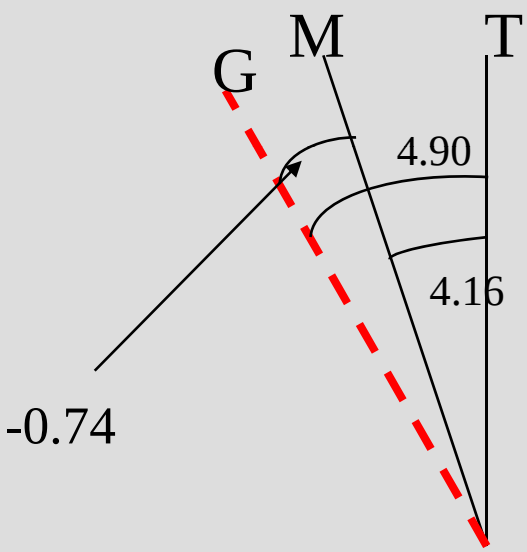
•Remember the 4 Norths!!!

Directional Survey Disconnect

- **EB 642 #2 well, API num 60804 40208 00**
- **Two Directional Surveys,**
  - **one from Anadrill (Schlumberger)**
  - **one from Energy Graphics (DDI)**
- **Azimuths differed by about 5.5 degrees, otherwise identical surveys**
- **Horizontal reach about 5300 feet,**
- **Bottom Hole locations differed by 550 ft +/-**

Directional Survey Disconnect

SLB Processing

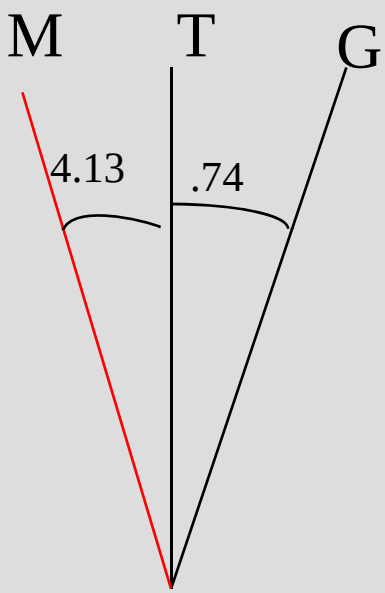


Magnetic Dec (MD) : 4.16

TN to Grid (GC): -4.90

Totl AZ Corr MD+GC : -0.74

Valid Correction

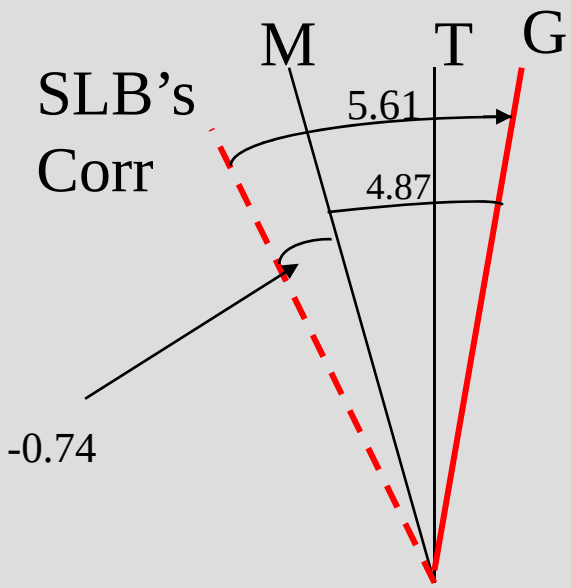


MN to TN : 4.13

TN to Grid : 0.74

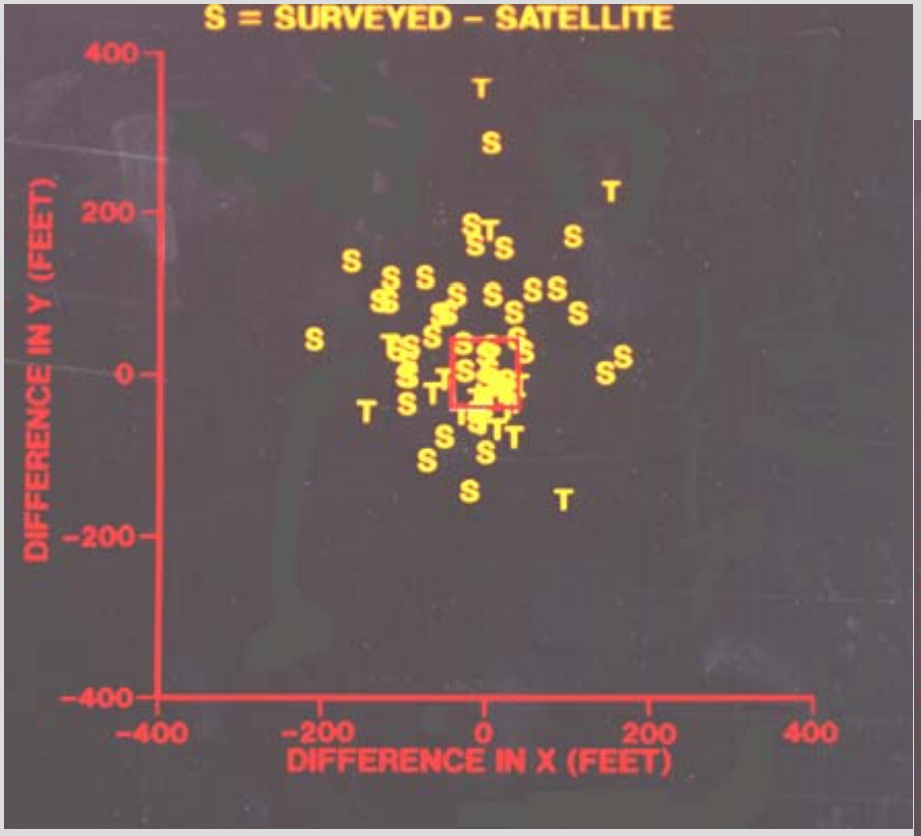
Totl Corr : **4.87**

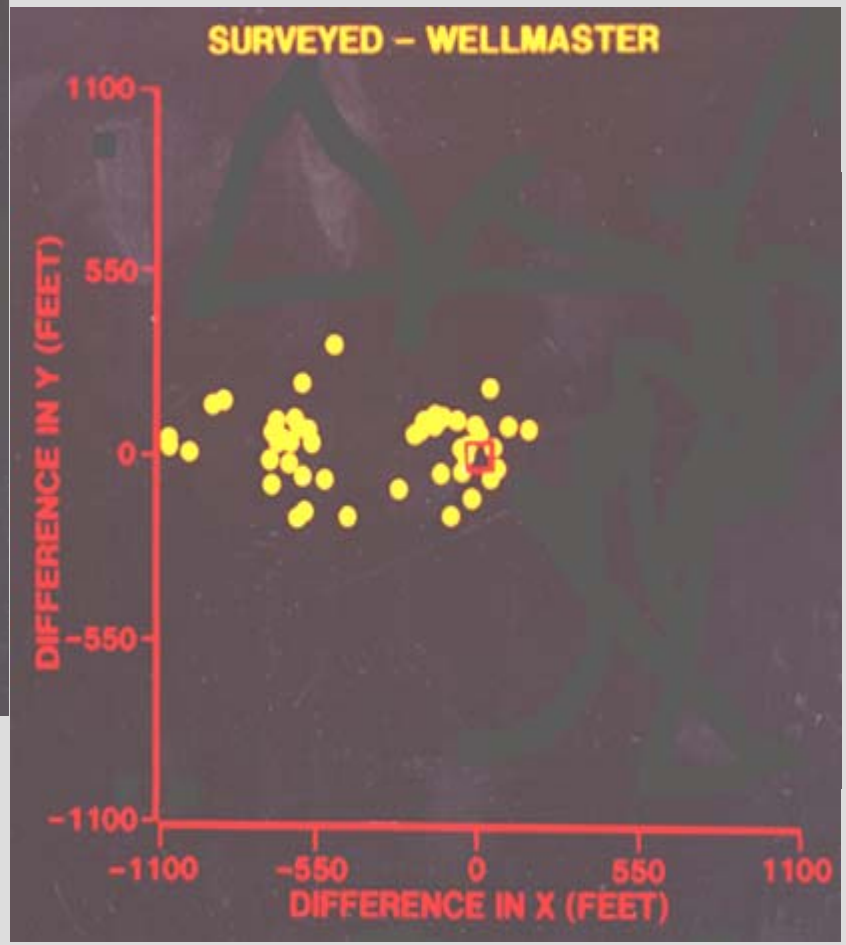
•EG's solution



- Valid Corr : 4.87
- SLB's corr : -0.74
- Correction Applied to SLB : 5.61

Well Walkabout!





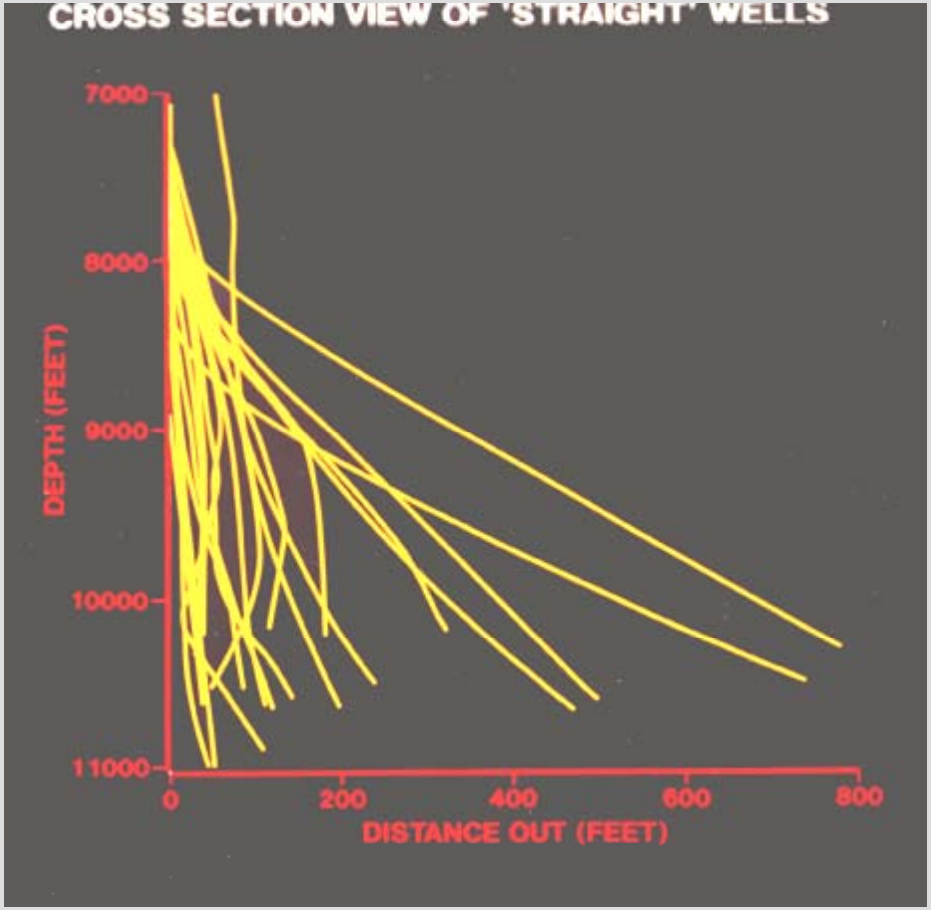
An Industry database

Downhole - The case of the missing data

Downhole Surveys

- **From own wells or databases**
  - **Casing MWD – Magnetic**
  - **Below Casing – Inertial**
  - **Do you have both?**
  - **Did the orientation of the rig get recorded correctly?**
  - **Was the magnetic data adjusted to grid or true? Does the person who received it, know?**
- **Were there any specifications?**
- **Did anyone QC the methods and data onsite?**
- **Is there a meaningful report?**

Angle of Dangle!!



Summary

- **Know the references – Always ask!**
  - **Datum**
  - **Projection**
  - **Elevation/Ht**
  - **Orientation**
  - **Units of measurement**

- **QC/Audit and record references in detail especially when transferring data between functions**
  - **In Field**
  - **From field to office**
  - **When downloading data from DB or web**
  - **When converting data before or during loading**
  - **From function to function**
    - **Field/DB to Processing**
    - **Processing to Interpretation**
    - **Interpretation to Drilling**
    - **Drilling to Construction**

Ensuring that all staff are aware of these issues and follow the procedures is the responsibility of the project lead G&G person.