

HISTORY OF GEODESY

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EARLY IDEAS OF EARTH

- Earth stood still
 - Otherwise, we would feel ourselves moving
- Must be flat
 - Otherwise we would fall off
- Immense - stretching into unknown oceans and lands
- World center of universe
 - Looking up one saw the moon and stars revolving about earth
- Each society thought itself as the center of universe
 - called *ompalos syndrome* - Greek for navel

FLAT DISK EARTH

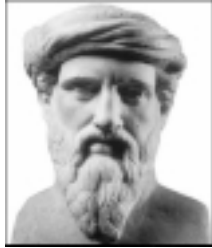
- Homer (9th Century BC) - flat earth supporting the sky over hemisphere
- Thales of Miletus - earth disk resting on water
- Anaximenes - earth held fixed over air of infinite thickness which could not escape upward due to the large extent of the disk

CYLINDRICAL EARTH

- Anaximander
 - first to hold that the earth was held at the center of a celestial sphere
 - Being in the center, earth needed no support because it was equidistant to the sphere at all points
 - No preference between directions to fall toward one end and no up and down
 - Earth cylinder - 3:1 ratio of diameter to height
 - Top location of inhabited world
 - Axis oblique to path of sun

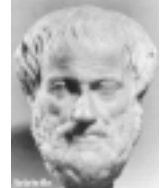
SPHERICAL EARTH

- Pythagoras (6th Century BC)
 - From aesthetically speculative considerations, suggested earth as sphere
 - Sphere and number 10 considered perfect therefore, a perfect world would consist of 10 planetary bodies of spherical form
 - First to suggest the earth rotated in a circular motion around the sun



ARISTOTLE (4th CENT. BC)

- Spherical earth based on gravity
 - All heavy bodies tend to fall towards the center and seek the lowest place in this process thus they are eventually pressed into spherical ball
- Observational experience
 - Ships at sea, superstructure is last seen going away from land
 - Changes in observable stars going north/south
 - Earth cast round shadows during lunar eclipses

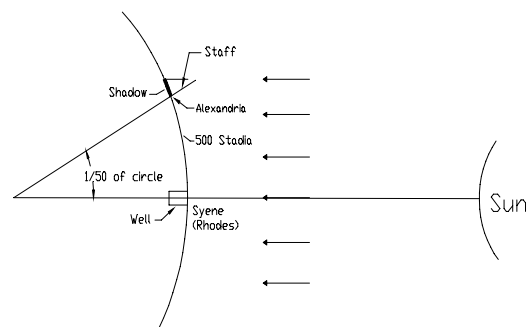


ERATOSTHENES (276-195 BC)



- "Father of Geodesy"
- First to make measurement of size of earth
- Measured length of shadow from a gnomon at noon in Alexandria at the summer solstice
- In Syene, which was assumed to be on same meridian and known to lie under the Tropic of Cancer, sun's rays reached the bottom of a well

ERATOSTHENES



ERATOSTHENES

- How was distance measured?
 - Camel caravan traveled 100 stadia/day and took about 50 days to travel distance
 - Probably determined by Egyptian cadastral maps made by 'bematists' (clerks who measured distances by walking evenly and counting their steps)
- Calculated distance 5000 stadia therefore circumference of earth 250,000 stadia

ERATOSTHENES

- Difficulty in converting stadia into meters therefore one estimate is the circumference is too large by 16% and another 0.6% too small
- Errors
 - Sun could not be directly overhead at time of measurement -- off by about 22'
 - Alexandria and Syene not on same meridian
 - Unit conversion problem

POSIDONIUS & AL-MAMUM

- Posidonius (135-50 BC)
 - Used star Canopus to determine size of earth
 - Found star grazed horizon at Rhodes but came up 1/4 of zodiacal sign over Alexandria (1/48 of circle)
 - Reduced size to 180,000 stadia which was used by Columbus in voyage
- Caliph al-Mamum (9th century)
 - Measured size of earth but measured length using wooden rods over a degree of latitude (56 2/3 Arabic miles) near Bagdad



WILLEBRORD SNELLIUS

- 1580 - 1626
- One of first to use triangulation
- Measured 33 triangles along nearly meridional arc between Alkmaar and Bergen op Zoom in Netherlands with 1' angular precision and astronomic latitudes at ends
- about 0.1% different from current average

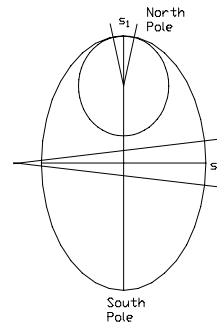


CASSINIS



- Jean Picard, 1669, measured meridional arc from Malvoisine north to Amiens using triangulation and astronomic latitude at ends
- Continued north to Dunkerque & south to Collioure by Philippe de Lahire & Dominique and Jaques Cassini between 1683 and 1716

CASSINIS



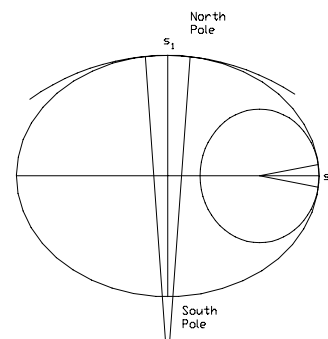
- Found 1° meridional arc decreased northward
- Earth was pointed at poles, or egg-shaped
- Called prolate spheroid
- $s_2 > s_1$
- First evidence earth not sphere

NEWTON



- Suggested earth should be flattened at poles from study of gravity
- Used model of a liquid in rotation about an axis would flatten
- Purely theoretical
- $s_1 > s_2$ oblate spheroid

ISSAC NEWTON



OBLATE SPHEROID

- Pendulum clock provided practical evidence
 - Jean Richer experienced trouble adjusting his clock on his expedition to Cayenne, Guiana, in South America
 - Clock lost 2 1/2 minutes/day and pendulum had to be shortened
 - Period of clock depends on length of pendulum and value of gravity -- farther from center of gravity, slower the clock

ACADEMIE ROYALE DES SCIENCES

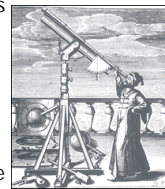
- Two expeditions commissioned to determine size
- Peru (now Equador) in 1735 led by Charles Marie de la Condamine
- Lapland in 1736 by Pierre L. M. de Maupertuis
- Found 1° meridional arc in Lapland was longer than 1° meridional arc in Peru
- Newton's concept correct
- Beginning of ellipsoidal era in geodesy

DETERMINING LONGITUDE

- Early explorers used "dead reckoning"
 - Never agreed with one another because estimates of distance and direction varied hour-by-hour and day-to-day
- Not knowing precise longitude was costly
 - Shipwrecks common because sailors did not know where they were accurately enough
 - Caused death and loss of ships and goods

DETERMINING LONGITUDE

- Galileo discovered "celestial timekeeper"
 - Jupiter had 4 satellites and their passages in front and behind the plane could be predicted for some months in advance
 - Because Jupiter is so far away, astronomic parallax no problem – motion would appear the same everywhere
 - If observed at 2 points, and if local time were determined when observations were made, one could subtract to obtain the difference & at a rate of 4 min/degree, one would have the longitude
 - Still not possible at sea





DETERMINING LONGITUDE

- John Harrison developed a clock that could accurately keep time during ocean voyages and help determine longitude

- Constructed of compensating pendulum and a box to control the motion of the ship
- First clock completed in 1735



John Harrison



- 4th chronometer was smaller design and had an error rate of less than 2 minutes over a 5 month voyage

JOHANN CARL FRIEDRICH GAUSS (1777-1855)



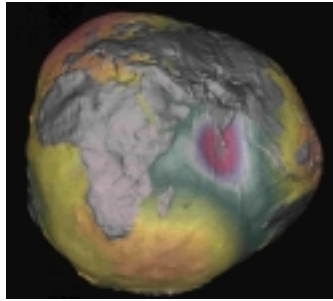
- Worked in a variety of areas including mathematics, physics, and geodesy
- Served as director of the Göttingen astronomic observatory
 - Worked on planet orbital theory
- Developed the theory of least squares and was first to use this to adjust a triangulation network

JOHANN CARL FRIEDRICH GAUSS

- Developed theories in statistical estimators and potential theory
- 1818 carried out geodetic survey of the state of Hannover
- Wrote: "What we call the surface of the earth in a mathematical sense, is nothing else but that surface, which everywhere intersects the direction of gravity at right angles, and of which the surface of the oceans is a part. The direction of gravity at every point is determined by the shape of the rigid part of the Earth and its uneven density"

LISTING

- In 1872, suggested that figure of the earth should be thought of as irregular, coinciding with the oceans
- Later called geoid



HELMERT



Helmert

- In 1884, defined the geoid as the figure of the earth
- Coined the term geoid
- Related geoid to potential theory - equipotential surface, gravity potential constant
- Surface should be thought of as the average that corresponds to the undisturbed mean sea level (no winds, currents, tides, etc.)

COAST & GEODETIC SURVEY

- First technical bureau of Federal Government
- Performs surveys and published nautical and aeronautical charts
- In early 19th century, coastal shipping primary means of commerce
- Shipwrecks common
 - high cost of products
 - high insurance rates
 - wrecks were affecting commerce and industry
- Lack of adequate charts contributed to wrecks

COAST & GEODETIC SURVEY

- Act of February 10, 1807 gave the president the ability "... to cause a survey to be taken of coasts of the United States, in which shall be designated the islands and shoals and places of anchorage ..."
- President Thomas Jefferson asked the American Philosophical Society for list of individuals who were asked for proposals

FERDINAND HASSLER



- Named first Superintendent of the Survey of the Coast
- Suggested determining the true geographical position of points on the coast and tying them together with triangulation. Also perform topographic survey of coast & hydrographic survey of coastal waters

COAST & GEODETIC SURVEY

- Nothing happened during first 4 years
 - Dissension in US led to withholding the appropriated funds
 - Problems in Europe delayed purchase of equipment and instruments
- Hassler became acting professor of math at the Military Academy at West Point, 1807-1810
 - Went to Union College of Schenectady, NY, in 1810 until July 1811

COAST & GEODETIC SURVEY

- April 1811, the appropriation of \$25,000 released
- Hassler left for Europe to purchase equipment and instruments
- War of 1812 delayed return until 1815
- Geodetic work started in 1816
 - Reports indicated that not all government officials cooperated
 - Measured 2 baselines
 - Congress unhappy with work progress
 - April 1818, survey placed under Navy, excluding civilian workers

SPUTNIK



- USSR - Began satellite geodesy era with launch of Sputnik 1 on Oct. 4, 1957
- Geodesist's one of first to see the practical applications of space

VANGUARD



The Vanguard 1 satellite
(NASA)

- USA launched Vanguard in 1958
- Geodetic measurement systems in space geodesy include:
 - Baker-Nunn camera station
 - BC-4 Camera
 - Doppler
 - GPS