GEOMETRY OF MAPMAKING

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Title Slide
ACTIVITY

Using the map projection that your group was given, please list the 7 continents in order of largest to smallest area

Continents: North America, South America, Antarctica, Europe, Asia, Africa, Australia

Reference Activity Handout Sheet. Four projections handed out – Mercator, Peters, Azimuthal, Goode Homolosine

All groups will list the continents in different order as they are portrayed “incorrectly” on each map
Correct, actual areas for each continent

<table>
<thead>
<tr>
<th>Continent</th>
<th>Area in Sq Mi</th>
<th>% of Land on Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td>17,212,000</td>
<td>30</td>
</tr>
<tr>
<td>Africa</td>
<td>11,608,000</td>
<td>20.3</td>
</tr>
<tr>
<td>North America</td>
<td>9,365,000</td>
<td>16.3</td>
</tr>
<tr>
<td>South America</td>
<td>6,880,000</td>
<td>12</td>
</tr>
<tr>
<td>Antarctica</td>
<td>5,100,000</td>
<td>8.9</td>
</tr>
<tr>
<td>Europe</td>
<td>3,837,000</td>
<td>6.7</td>
</tr>
<tr>
<td>Australia</td>
<td>2,968,000</td>
<td>5.2</td>
</tr>
</tbody>
</table>
Longitude covers 360 degrees (+/-180 degrees; E, W respectively)
Latitude covers 180 degrees (+/- 90 degrees; N, S respectively)
Marshall Islanders created stick charts as shown on the right hand side of the slide.

They used these to map ocean swells because they had to canoe around the islands that they inhabited in the Pacific Ocean.

Fun fact: Only the creator of the stick chart could actually 100% understand it.
Also a theory that the oldest known map (Babylon) was represented mythological ideas – not actually Babylon – Babylon theory much more popular

Ptolemy was a Greek astronomer and geographer. He set the stage for future cartographers in regard to the idea of using a universal coordinate system as well as latitude and longitude lines

Medieval maps became more advanced. During this timeframe, maps were usually centered around Jerusalem, but when the Vikings started to explore the North Atlantic that started to change
Orange peel experiment – draw all of the continents on an orange peel and peel it off of the actual orange. Try to flatten it on a table. The continents that you drew are going to be distorted as you attempt to flatten out the orange.
Azimuth - these measurements can be used to navigate and map astronomical bodies, but in our case they are used to plot points on an azimuthal map projection by converting a point on a 3D sphere to a point on a 2D map.

Conic - creates heavy shape and area distortion further from the vertex point (in the case of this picture example, the north pole); notice when you unroll the map there is a small triangular section missing, demonstrating the difficulty of transforming a 3D object into a 2D object.

Cylindrical - creates heavy area distortion further from the equator and as a result, land masses in both polar regions appear much larger than they really are.
A perfect map does not exist because if it did, it would preserve all map properties. Because we are transforming from the third dimension to the second dimension, some of these properties will have to be compromised. There is no such map projection which always preserves distance because if it did, it would just be an accurate globe; although some projections do preserve distance along lines of latitude OR longitude (never both).
DIFFERENT PROJECTIONS

- Azimuthal Projection
- Mercator Projection
  - By Gerardus Mercator – 1569
  - Preserves angles
  - Distorts Area
- Gall-Peters Projection
  - By James Gall (1855) and Arno Peters (1973)
  - Preserves area

No additional notes; everything to be presented on slide
To create this projection from a physical standpoint, concentric tangent planes are used starting from a given point on the globe and swept towards the opposite point on the other side; in this example we go from the north pole to the south pole, but you can also start from a point on the equator or anywhere else. Distortion is heavier further from the starting point; in this example you can see Antarctica wraps all the way around the globe and appears to have a much larger area than it does in real life. Due to this distortion, these maps are not useful for displaying all land masses, rather certain sections of the globe, perhaps one hemisphere.
There are different types of azimuthal projections, as this is a more broad classification (e.g. how Mercator is a type of cylindrical projection); two types include the equidistant projection and the Lambert projection.

Equidistant projection preserves distance along lines of longitude.

Lambert projection preserves area but heavily distorts shape, it’s an example of an azimuthal projection where the starting point is along the equator.
Gerardus Mercator

- Gerardus Mercator was born as Gerhard Kremer in the Netherlands in 1512.
- Mercator studied theology along with mathematics, astronomy, and geography.
- When he was 25 he published a map of Palestine.
- He was also really interested in reformation theology. When authorities rounded up suspected Lutherans, they took in Mercator. Some were beheaded or maybe buried alive. The rest were to be burned at the stake. Mercator's priest saved his life by taking him out of the prison. After that Mercator mainly focused on religion and worked as a cosmographer in Germany.
- (Cosmography is the science of mapping the general features of the cosmos or universe, describing both heaven and Earth.)
- Mercator made the lines of longitude run straight up and down.
- He stretched the map more and more toward each pole, and he published this remarkable map, Mercator, in 1569.
- It was simple, clear, and wonderfully useful to sailors who had to keep track of longitude.

No additional notes; everything to be presented on slide.
The cylindrical projection is explained on the next slide. The heavy area distortion far from the equator can be seen with Antarctica, which the second group who had the Mercator map did a great job of putting Antarctica as the biggest continent, however it is actually fifth largest continent all together. Also, comparing Africa that is closer to the equator than Greenland, even though Africa is 11 times bigger than Greenland, Greenland looks a lot larger than Africa.
The P on the globe is projected on to the cylinder as P'. The angle theta (or phi in the picture) is the angle of P from the equator, and the lambda is the angle (or how far it would be) from the prime meridian to where P on the equator.
North and East represented the positive numbers and the South and West represented the negative numbers.
PLOTTING THE EQUATOR

- Equator:
  - $y = R \ln \tan(45^\circ + \theta^\circ / 2)$
  - $y = R \ln \tan(45^\circ + \theta^\circ / 2)$
  - $y = R \ln \tan(45^\circ)$
  - $y = R \ln(1)$
  - $y = 0$

- So, the equator will be our x-axis (where $y=0$)

No additional notes; everything to be presented on slide
PLOTTING THE PRIME MERIDIAN

- Prime meridian:
  - $x = \frac{\pi R (\lambda - \lambda_0)}{180^\circ}$
  - $x = \frac{\pi R(0)}{180^\circ}$
  - $x = 0$

- So, the prime meridian
  Will be our $y$-axis
  (where $x=0$)

No additional notes; everything to be presented on slide
Mercator was a cosmographer who wanted to plan the universe including heaven and hell, and he did this by using the positive infinity (or the north pole) as heaven, and the negative infinity (or the south pole) as hell.
This is an example of how one would plot Amherst Ma using the Mercator Projection – Note that we are working in miles (there would have to be some scale factor if we were actually going to produce a paper map) – the equator ranges from about 12,500 miles to -12,500; this is simply the radius of the earth. The N and S poles go to infinity, as explained earlier.
This projection is used for aviation – accurate with 15 degrees of meridians

Note how the earth is placed inside the cylinder differently – the equator will now extend to infinity, with the y axis being defined
They were not even alive during the same period: Gall (1800s), Peters (1900s)
Gall created his map in 1855 and Peters created his in 1973
Although Gall invented it, their map is more often referred to as the Peters projection due to its recency
Peters recognized the distortion of the widely-used Mercator map and wanted to create a more accurate one himself, so he presented his map as a “new invention” although Gall had previously published it as his own
The map appears to be stretched vertically, and while this projection does distort shape, this appearance might also be interpreted the way it is simply because we are more used to the Mercator projection which merely distorts area. This projection gives us a much more accurate sense of the proper size of the continents in relation to each other.
The x-coordinate is calculating using the same formula as the Mercator projection, however the y-coordinate is found differently. You might recognize the y-coordinate formula because it is the same one we use to convert polar coordinates into cartesian coordinates.
Unlike the Mercator projection where its $y$-coordinate formula results in +/- infinity when attempting to plot the poles, this formula returns real values.
This is an example of how one would plot Amherst Ma using the Peters Projection – Note that we are working in miles (there would have to be some scale factor if we were actually going to produce a paper map) – the equator ranges from about 12,500 miles to -12,500; this is simply the radius of the earth. The N and S poles are represented by the radius of the earth, as calculated earlier.
MOVING FORWARD WITH THIS TOPIC

- In March, the Boston Public Schools switched to using the Peters map instead of the Mercator map (which had been used in the world for about 500 years).
- It would be helpful for the students to understand the sizes of the continents.

No additional notes; everything to be presented on slide
MODERN CARTOGRAPHY

- We live in the era of technology
- Computers, plotters other tech advances
- Google earth...
  - You can carry the globe around with you...
- Geographical Information System Software
  - Open source software, create maps from excel files, within programs

No additional notes; everything to be presented on slide
CONCLUSION

• Maps used / evolved in many different time periods

• Many different map projections used for different reasons

• A 100% accurate map projection does not exist…

No additional notes; everything to be presented on slide
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WORKS CITED

• http://math.stanford.edu/~conrad/diffgeomPage/handouts/mapmaking.pdf
• http://www.jstor.org/stable/40573938?Search=yes&resultItemClick=true&searchText=peters&searchText=projection&searchUri=%2Faction%2FdoBasicSearch%3Faroup%3Dnone%2FQuery%3Dpeters%2Bprojection%26wc%3Don%26tc%3Dotf%26acc%3Don%26amp%3D%26amp%3D%26amp%3D%26amp%3D&seq=1#page_scan_tab_contents
• http://academic.emporia.edu/abergame/map/h_map/h_map.htm
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