THE SHAPE OF THE WORLD

A VIEWER'S GUIDE

Athena

EPISODE 1

HEAVEN AND EARTH

Highlights

- Throughout history, humans have created representations of their landcape and what lies beyond—even into the spiritual realms.
- Extrapolating from his discoveries of the mathematical relationships among musical tones, Pythagoras speculated about the shape of the cosmos and a “harmony of the spheres” in the 6th century BC.
- Eratosthenes calculated the circumference of the Earth with remarkable accuracy in the 3rd century BC.
- In the 2nd century AD, Ptolemy created his *Geographia*, outlining maps of the world, including latitude and longitude, and positing the existence of an undiscovered southern continent.
- Speculation about the location of Biblical sites such as the Garden of Eden continued from medieval times well into the 19th century.

Questions to Consider

1. Why do you think we have a deep-seated need to map our environment? How valuable do you believe the study of geography is?
2. Do you have a particular map that’s important to you for practical, psychological, or sentimental reasons? Discuss its personal significance.
3. Does your sense of geography shape your political thinking? How so?
4. How would you imagine a map of spiritual realms or the afterlife?

EPISODE 2
SECRETS OF THE SEA

Highlights

- More than 700 years ago, maps were crucial to acquiring wealth and power because they contained information about sea lanes and Asian ports vital to trade.
- In the late 13th century, Genoese seafarers proposed sailing to China, a remote, wealthy empire far more advanced than Europe.
- In 1375, Abraham Cresques created the *Catalan Atlas* for King Charles V of France, which showed fantastic faraway lands full of strange peoples and vast wealth.
- Venice used knowledge of geography to consolidate its control of the spice trade in the 15th century.
- By the late 15th century, Portuguese explorers such as Bartolomeu Dias and Vasco da Gama had reached the southern tip of Africa and beyond, establishing Portugal as a major commercial rival to Venice.
- In 1517, the Portuguese captain Ferdinand Magellan arrived in Spain with a plan to sail west to the Spice Islands. His expedition ultimately circumnavigated the globe and revived the competing claims of Spain and Portugal to new territories.

Questions to Consider

1. In the Age of Exploration, maps of the seas contained closely guarded knowledge that held the key to riches. What kinds of maps hold keys to wealth and power today?
2. In retrospect, how would you evaluate the khans' decisions to isolate China and halt foreign ventures?
3. How might Portugal have better protected its cartographic information? How would that have changed history?

EPISODE 3
STAKING A CLAIM

Highlights

- In 1507, mapmaker Martin Waldseemüller christened the New World "America" after Florentine seafarer Amerigo Vespucci, who had visited it at least twice under Portuguese and Spanish flags. Though it mistakenly attributed the land's discovery to Vespucci, the name stuck.
- In the 16th and 17th centuries, Spanish, French, and English expeditions conquered, claimed, and mapped areas of the New World. The Europeans saw land as a source of status and an exploitable commodity—a view that fundamentally conflicted with Native Americans' sense of land as a gift held by the community.

- By the 17th century, the Dutch had acquired Portuguese charts and soon displaced their rivals as masters of the spice trade.
- In the 18th century, John Harrison created seaworthy chronometers to precisely measure distances east or west of a reference point, or prime meridian—essential for standardizing longitude.

Questions to Consider

1. Imagine you're an advisor to Cortés or Montezuma during the tense, eight-month-long Spanish occupation of Tenochtitlán. What reasons would you give your leader for attacking the other side? For peaceful coexistence?
2. What do you think happened to the English settlers who vanished from Roanoke Island?
3. How does the conflict between the ideas of land as a commodity and as a communal right manifest itself today? In your opinion, how are they usually reconciled?

EPISODE 4
EMPIRE!

Highlights

- In 1799, immediately after the British consolidated their power in southern India by putting down the Tippu Sultan's uprising, Capt. Colin Mackenzie—the first surveyor general of India—began a detailed topographical survey of the state Mysore.
- In 1802, William Lambton launched the Great Trigonometric Survey—an ambitious effort to survey and map every square foot of the Indian subcontinent.
- The survey used triangulation, a method known in Europe for about 300 years and applied by Giovanni Cassini to accurately survey Louis XIV's France more than 100 years earlier. It involved precisely measuring a baseline between two points, and then calculating the distances from those spots to a third point using trigonometry.

- After Lambton's death, George Everest took over the Great Trigonometric Survey, eventually establishing a "spine" down the center of the subcontinent.
- Surveyors—often disguised as monks to avoid detection—completed Everest's work by surveying the Himalayas, including the world's tallest peak.

Questions to Consider

1. Lambton's proposal initially met stiff opposition. What arguments would you make to justify the survey's expense?
2. Compare Mackenzie's approach to indigenous Indian culture with Lambton's. Which do you think made more sense?
3. The Great Trigonometric Survey ended up costing hundreds of lives. Do you think it was worth the price? Why or why not?

EPISODE 5
PICTURES OF THE INVISIBLE

Highlights

- In 1858, the French balloonist Nadar (Gaspard-Félix Tournachon) invented aerial photography, ushering in a new mapping tool.
- Today, aerial photography and spectrographic imaging can indicate the presence of oil deposits or minerals such as gold.
- In the 1950s and '60s, sonographic mapping of the ocean floor by Dr. Bruce Heezen of Columbia University provided evidence for the geologic theory of continental drift.
- In the 1960s and '70s, airborne radar mapping of Antarctica revealed

the continent's two geographies: the ice sheet above and the landscape below.

- Started in 1970, Brazil's RADAM Project (Radar in the Amazon) used side-scanning airborne radar to map the vast river basin under cloud cover and tree canopy. Soon after, deforestation efforts began, leading critics to question the project's values.

Questions to Consider

1. Do you believe we should map the ocean floor? Why or why not?
2. How do you explain the remarkable similarities between Orontius Finaeus's 1531 map of a southern continent—drawn with no knowledge of Antarctica whatsoever—and today's radar maps?

3. To what degree do you think RADAM carries the blame for deforestation of the Amazon rain forest? Given what we've learned since the 1960s, do you think the project was worthwhile, or did it simply enable destruction?

EPISODE 6
THE WRITING ON THE SCREEN

Highlights

- Potentially lifesaving applications of computerized mapping include EMS dispatch, air traffic control, weather forecasts, and risk assessment for earthquake response.
- Seismic tomography can reveal three-dimensional images of subterranean features, which might someday lead to earthquake prediction.
- In medicine, magnetic resonance imaging (MRI) gives cross-sectional pictures of internal organs.
- Using techniques pioneered by John Snow during the 19th-century cholera outbreak in London, epidemiologists can map the spread of infectious diseases such as AIDS.
- Satellite mapping can help predict the effects and risks of global warming by giving scientists a better understanding of the complex relationship between ice mass, sea levels, and atmospheric conditions.

Questions to Consider

1. Narrator Patrick Stewart says, "Even at the everyday level, we make compromises between our safety and our convenience." In what ways do you balance risk and convenience in your life? How do maps help you make such decisions?
2. Scientists expect rising sea levels to threaten the Chesapeake Bay, Florida, and other coastal areas around the globe within the next 50 years. In your opinion, should we protect those areas or abandon them?
3. What are your thoughts on global warming? Do you take steps to combat it?
4. Development in places like the Amazon Basin has brought prosperity to the local economy while damaging delicate ecosystems essential to the planet's survival. How do you propose that governments reconcile local needs with global ones? And how can maps help with those policy decisions?

AVENUES FOR FURTHER LEARNING

Companion Book for the Series

Berthon, Simon, and Andrew Robinson. *The Shape of the World: The Mapping and Discovery of the Earth*. New York: Rand McNally, 1991.

General Resources

Akerman, James R., and Robert W. Karrow, Jr. *Maps: Finding Our Place in the World*. Chicago: University of Chicago Press, 2007.

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Kinghoffer, Jay. *The Power of Projections: How Maps Reflect Global Politics and History*. Westport, Conn.: Praeger Publications, 2006.

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Wilford, John Noble. *The Mapmakers*. New York: A.A. Knopf, 2000.

Whitfield, Peter. *New Found Lands: Maps in the History of Exploration*. New York: Routledge, 1998.

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TOOLS OF THE MAPMAKER'S TRADE

Gnomon

A vertical stick used to measure latitude and keep time, gnomon meant "interpreter" or "discerner" in ancient Greek. Scholars date it from about 3500 BC or later and debate whether it was invented by the Babylonians, the Chinese, or by Anaximander of Miletus, the latter of whom introduced it to the Greeks in the 6th century BC. Ancient Greeks used gnomons sometimes as long as 35 ft. to obtain the angle of the shadow caused by the midday sun on particular days of the year. By combining their prior knowledge of the sun's overhead location on those days with the shadow's angle, they could calculate the latitude of a location. In the 3rd century BC, Eratosthenes built on this technique to calculate the circumference of the Earth. As part of a sundial, gnomons also cast the shadows that indicate time of day.

Astrolabe

Dating from the 2nd century BC, astrolabe means "to seize a star" in Greek. An astronomical instrument used to determine the altitude of celestial bodies and to reckon the time, it also had applications in navigation, triangulation, and astrology. Usually from three to 18 inches long, astrolabes consisted of a hollow base plate (the *mater*) with lines for celestial coordinates; *climate* plates with coordinate lines for different latitudes; a *rete* disk with a star chart and ecliptic plane projection that could rotate over the climates and mark the passage of the day; and an *alidade*, a straight rule for sighting objects, which made it helpful in surveying. Widely used in the Middle Ages by both the European and Islamic worlds, the technology was adapted in the mid-15th century into the mariner's astrolabe, with features that accommodated the motion of a ship.

Magnetic Compass

Ancient peoples realized that lodestone, a magnetized iron oxide mineral, aligned itself in a north-south direction, but it is unclear when mariners first took advantage of that fact. Scholars believe the Chinese first used needle compasses on land, taking them to sea around 1100 AD, with either Arab traders spreading the technology to the West in the 12th century or Europeans independently creating their own. Early magnetic compasses suspended the needle in a bowl of water; later they were modified to dry suspension with a center pivot. In the 15th century, users discovered that magnetic north and true north differed in some locations, a phenomenon known as declination, but efforts to correct compasses only caused more confusion. Further difficulties arose when iron and steel entered shipbuilding, as they could deflect the compass needle, but a British committee designed a solution in 1840 that was then adopted by the world's navies.

Cross-staff

Sometimes called a Jacob's staff, the cross-staff is a cruciform instrument that determines latitude by measuring the altitude of the sun or the polestar. Invented by the Chinese and inspired by the crossbow, it replaced the astrolabe as a mariner's tool in the 16th century. It consisted of a three-foot-long staff marked with degrees and a sliding vertical crosspiece. Sailors held the main staff against

their cheek and moved the crosspiece until the top edge aligned with the sun or Polaris, while the bottom end fitted with the horizon. The corresponding degree on the main staff gave them the elevation, which they then converted into latitude. Since it required staring directly at the sun, the cross-staff could be very difficult to use. In 1594, Englishman John Davis created an improved version, the backstaff, which allowed observers to face away from the sun.

Theodolite

This surveying tool obtains vertical and horizontal angle measurements. The name *theodolite* first appeared in a surveying textbook by English mathematician Leonard Digges in 1571, but the instrument provided horizontal angles only. Five years later, the German Joshua Habermel built one fitted with compass and tripod closer to a true theodolite, but it wasn't until the 1620 publication of logarithmic tables that portable theodolites took off. They had pivoted arms for sighting and some also had magnetic compasses. Later advancements improved the theodolite's accuracy and usability, including an auxiliary scale called a vernier (1631), telescopic sights (1669), spirit levels (ca. 1700), and parallel crosshairs (1771, introduced by Scottish inventor James Watt). To use theodolites, surveyors leveled the instrument, aligned the object in the crosshairs of the telescope, and then read the vertical and horizontal scales to find the angles.

Sextant

A wedge-like, highly accurate instrument that determined latitude and longitude at sea, the sextant supplanted the cross-staff and octant (an earlier version of the sextant) as navigational tools by the latter half of the 18th century. With its arc spanning 60° (the name derives from the Latin *sextus*, "one-sixth"), movable radial arm, telescope, and two mirrors—one in line with the telescope, the other mounted on the arm—it could obtain the altitude of celestial bodies. Sailors took a sight by lining up the telescope with the horizon and moving the arm until the star was reflected in both mirrors and appeared to align with the horizon. Using the angle noted on the arc and the precise time of day at which the measurement occurred, sailors could then look up the latitude in tables. Sextants could also obtain longitude via the lunar-distance method, but the process proved quite lengthy with the astronomical tables of the time.

Satellite

Sir Isaac Newton first contemplated the idea of an artificial satellite orbiting the Earth in his 1687 book *Philosophiae Naturalis Principia Mathematica*. However, his vision did not become a reality until October 4, 1957, when the Soviet Union launched Sputnik I. The United States followed on January 31, 1958, with Explorer 1. More than 5,000 satellites have since been sent into space by about 15 countries. They perform a variety of functions, including weather monitoring, communications support, navigation assistance, military applications, and research opportunities. The satellite's function determines at which orbital path it will be positioned: weather ones take a polar orbit, which allows them to cover the full globe, while communications satellites normally have fixed positions above the equator so that they circle the most densely populated areas of the Earth.

THE MATH BEHIND A MAP

Measuring the world with simple triangles

How could William Lambton, George Everest, and their cohorts accurately measure all of India with a 100-foot-long steel chain and a theodolite? The answer involves not magic, but math—specifically geometry and trigonometry.

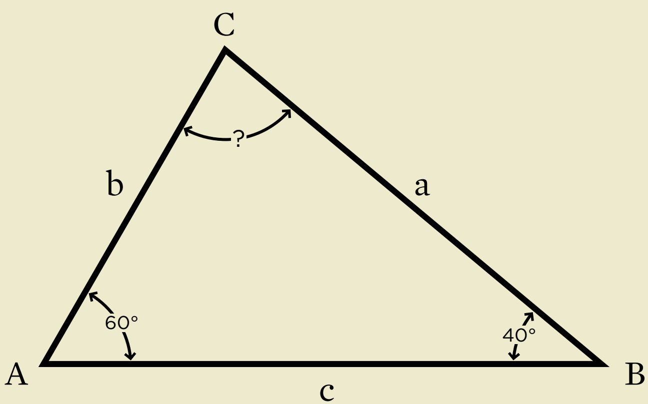
Triangulation boils down to two principles: (1) If you know the measures of two angles in any triangle, you can calculate the measure of the third angle. In any triangle, the measures of all the angles add up to 180°. (2) If you know the measures of three angles and the length of one side in any triangle, you can calculate the lengths of the other two sides.

Unless you're an engineer, you probably don't remember the second principle. It comes from the law of sines:

$$\frac{a}{\text{Sin A}} = \frac{b}{\text{Sin B}} = \frac{c}{\text{Sin C}}$$

where A, B, and C are angles of the triangle, and a, b, and c are the sides opposite those angles. In trigonometry, sine is a value associated with an angle expressing a relationship too complicated to explain here. Suffice it to say that 19th-century surveyors could use a sine table for reference in the field to help them with their calculations.

Let's say Lambton laid down a baseline of 100 feet—the exact length of his team's chain. (Actually, his baselines stretched for miles; otherwise the Great Survey would've taken forever.) From each end of the baseline, he used the theodolite to measure the angle to a fixed object in the distance—a tree, a distinctive rock, or a marker specifically built for the survey—as shown here.



(Baseline = 100 feet)

Then, he started calculating. To begin, he figured out the missing angle of his triangle: in this case, 80°. Next, he plugged values from a sine table into the equation:

$$\frac{a}{0.8660} = \frac{b}{0.6428} = \frac{100}{0.9848}$$

Solving these equations, he found that side *a* was 87.94 feet, and side *b* was 65.27 feet. Once he knew all three sides of the triangle, he could calculate the area.

Measure, calculate, repeat. Measure, calculate, repeat. So went Lambton all over southern India for the last 21 years of his life.

MYTHS ON MAPS

Fabled creatures and kingdoms from old maps

Dragons in Asia. Basilisks in southern Africa. Pygmies in the Arctic. Monsters in Scandinavia's seas. Islands of wealth and plenty impossible to find. Such fabled locations and creatures occur occasionally on medieval maps, bearing testimony to past beliefs and the many detours that cartographers took before arriving at the modern view of the world.

Rarely, these fantastic creatures turned out to be based in truth. Ptolemy's atlas in the *Geographia*, dating from the 2nd century AD and introduced to Europe during the Middle Ages, contains warnings of elephants and hippos. The Waldseemüller maps of 1516 and 1522 place elephant-like creatures in northern Norway and in the Davis Strait between Greenland and present-day Canada. Called a *morsus*, this seemingly monstrous animal had two long teeth projecting outwards; today it is known as a walrus.

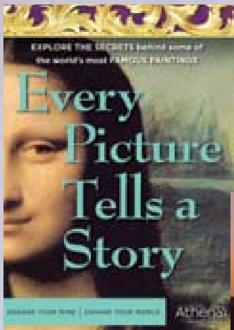
Long before the discovery of the New World, non-existent islands were drawn in the Atlantic to fill the gaps, both literally and figuratively, in cartographers' knowledge. Some islands were swathed in legend. Besides Atlantis, there were Antillia, Saint Brendan's Island, and Hy-Brazil. As early as 1325, Hy-Brazil began appearing on maps and charts. Believed to be located just west of Ireland, the island was thought to be shrouded in fog that lifted only once every seven years. People who claimed they had visited it brought back stories of a wealthy, advanced civilization. Hy-Brazil remained on maps for centuries, appearing even on Toscanelli's chart (1457), which Columbus may have used during his first voyage. It was finally removed from British Admiralty charts in the 1870s.

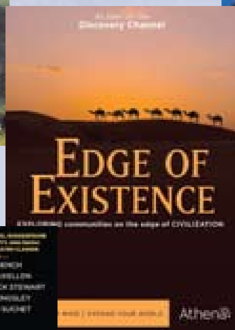
Legendary kingdoms thrived on land, too. The tale of the Christian ruler Prester (or Presbyter) John arose during the Crusades of the 12th and 13th centuries; supposedly an emperor of the Far East, he was highly desired as an ally against the Muslims. Explorers and even popes attempted to seek him out, both for his help and for the wonders of his land, purported to be filled with natural riches. In the mid-14th century, his kingdom was relocated to Africa, where it appears on the 1558 atlas by Diogo Homem and the 1573 map by Abraham Ortelius.

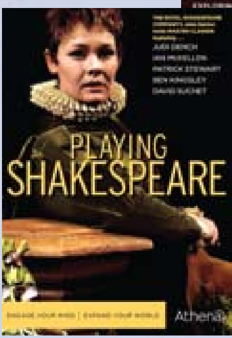
Even some of the navigational tools on maps had roots in myth. On many 15th- and 16th-century charts, the borders are decorated with figureheads symbolizing the winds: Boreas (north), Notos (south), Burus (east), and Zephyrus (west). Their depictions were inspired by a story from Homer's *Odyssey*. Aeolos, ruler of the winds, kept them holed up in a cave but agreed to give them to Odysseus so that the gentle west wind would guide him home. The other winds were stored in leather bags that the crew opened right before landfall, blowing them far off course. The four principal winds became synonymous with the cardinal directions, leading mapmakers to create the wind rose to show the relationship. The earliest wind rose, drawn by Timosthenes of Rhodes and used later by Ptolemy, had 12 winds, but later versions had 32 directional points. Eventually, the compass rose replaced it.

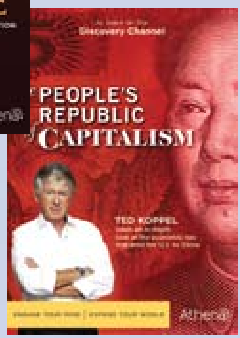
Finally, there is that famous myth of a myth: "here be dragons." Although the evocative phrase, from the Latin *hic sunt dracones*, has come to indicate dangerous, unknown territories, it appeared only once on a medieval map—that of the Lenox Globe (ca. 1503-07). Dragons themselves were depicted on other charts, although oftentimes with religious symbolism attached, such as in the Psalter map (ca. 1250), where dragons resided below the world, while Christ and angels reigned above.

MORE FROM ATHENA









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