Chapter 2: Portraying Earth

The purpose of Chapter Two is twofold:
- To describe the basic characteristics of maps, including their capabilities and limitations as tools for geographic study;
- To describe the various ways a landscape can be portrayed—through map projections, globes, photographs, and remotely sensed imagery.

Maps are the most important and universal of the various tools used in geographic studies. Mapping of any geographic feature is normally essential to understand the spatial distributions and relationships of that feature.

TOPICS

The Nature of Maps
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CHAPTER OUTLINE

I. The Nature of Maps
   A. Map—a two-dimensional representation of the spatial distribution of selected phenomena.
   B. Basic attributes of maps, making them indispensable:
      1. Their ability to show distance, direction, size, and shape in horizontal (two-dimensional) spatial relationships.
      2. They depict graphically what is where and they are often helpful in providing clues as to why such a distribution occurs.
   C. Basic fault of maps:
      1. No map can be perfectly accurate:
         a) Maps are trying to portray the impossible—taking a curved surface and drawing it on a flat piece of paper.

II. Map Scale
   1. Map scale—gives the relationship between length measured on the map and corresponding distance on the ground. Essential for being able to measure distance, determine area, and compare sizes.
   2. Scale can never be perfectly accurate, again because of the curve of Earth’s surface.
      a) The smaller the area being mapped, the more accurate the scale can be.
   B. Scale Types
      1. Several ways to portray scale, but only three are widely used:
         a) Graphic Map Scales
            (1) Uses a line marked off in graduated distances; remains correct when map is reproduced in another size, because both the graphic scale line and the map size change in same dimension.
         b) Fractional Map Scales
            (1) Uses a ratio or fraction, called a representative fraction, to express the comparison of map distance with ground distance on Earth’s surface.
            (1) 1/63,360 is commonly used because the number in denominator equals the number of inches in one mile.
(2) Often, no units are given in a fractional scale, so the dimensions translate whether one is using inches, millimeters, or some other unit of measurement.

c) **Verbal Map Scales**
(1) Also called **word scale**; uses words to give the ratio of the map scale length to the distance on Earth’s surface.

C. **Large and Small Scale**
1. The concepts of “large” and “small” are comparative, not absolute; it all depends on the frame of reference whether one considers something large or small.
2. **Large-scale map**—has a relatively large representative fraction, which means the denominator is “small”—1/10,000 is large-scale as compared to 1/1,000,000.
   a) Portrays only a small portion of Earth’s surface, providing considerable detail.
3. **Small-scale map**—has a small representation fraction, which means the denominator is “large.”
   a) Portrays a larger portion of Earth’s surface, but gives only limited detail.

III. **Map Essentials**
A. Maps should include a few essential components; omitting any of these components will decrease the clarity of the map and make it more difficult to read.
1. The eight essential components are Title, Date, Legend, Scale, Direction, Location, Data Source, and Projection Type.
   a) Title—should provide a brief summary of the map’s content or purpose and identify the area it covers.
   b) Date—should indicate the time span in which the map’s data were collected.
   c) Legend—should explain any symbols used in the map to represent features and any quantities.
   d) Scale—should provide a graphic, verbal, or fractional scale to indicate the relationship between length measured on the map and corresponding distance on the ground.
   e) Direction—should show direction either through geographic grid or a north arrow.
   f) Location—should have a grid system, either a geographic grid using latitude and longitude, or an alternative system that is expressed like the x and y coordinates of a graph.
   g) Data Source—should indicate the data source for thematic maps.
   h) Projection type—should indicate the type of projection, particularly for small-scale maps.

IV. **The Role of Globes**
A. Globes have several advantages:
1. Can maintain the correct geometric relationships of meridian to parallel, of equator to pole, of continents to oceans.
2. Can show comparative distances, comparative sizes, and accurate directions.
3. Can represent, essentially without distortion, the spatial relationships of features on Earth’s surface.
V. Map Projections
A. Map projection—the system used to transform the rounded surface of Earth to a flat display.
B. The fundamental problem with mapping is how to minimize distortion while transferring data from a spherical surface to a flat piece of paper.
C. The Major Dilemma: Equivalence versus Conformality
   1. Central problem in constructing and choosing a map projection:
      a) Impossible to perfectly portray both size and shape, so must strike a compromise between equivalence and conformality.
         (1) Equivalence—the property of a map projection that maintains equal areal relationships in all parts of the map.
         (2) Conformality—the property of a map projection that maintains proper angular relationships of surface features.
      b) Can only closely approximate both equivalence and conformality in maps of very small areas (e.g., large-scale maps).
         (1) Mapmaking must be an art of compromise.
         (a) Robinson projection in Figure 2–11 is one of the most popular methods for compromising between equivalence and conformality.
   2. Equivalent projection—portrays equal areal relationships throughout, avoiding misleading impressions of size.
      a) Disadvantages:
         (1) Difficult to achieve on small-scale maps because they must display disfigured shapes:
            (a) Greenland and Alaska usually appear squattier than they actually are on equivalent projections.
         (2) Even so, most equivalent world maps are small-scale maps.
   3. Conformal projection—maintains proper angular relationships in maps so the shape stays accurate (e.g., Mercator projection).
      a) Disadvantages:
         (1) Impossible to depict true shapes for large areas like continents.
         (2) Biggest problem is that they must distort size (e.g., usually greatly enlarges sizes in the higher latitudes).

VI. Families of Map Projections
A. Cylindrical Projections
   1. Cylindrical projections are created by mathematically “wrapping” a globe in a cylinder.
   2. The paper touches, or is tangent to, the globe only along the equator. This forms a circle of tangency.
   3. The resulting map is a rectangular surface possessing a grid of lines of latitude and longitude.
   4. Mercator: The Most Famous Projection
      a) The Mercator projection—a special-purpose projection that was created more than 400 years ago as a tool for straight-line navigation.
      b) Prime advantage: shows loxodromes as straight lines.
(1) **Loxodrome**—also called **rhumb line**, is a curve on the surface of a sphere that crosses all meridians at the same angle. They approximate the arcs of a great circle but consist of constant compass headings.

c) How do navigators use Mercator projection?

(1) First, navigators must use another type of projection that shows great circles as straight lines; they draw a straight line between their starting point and destination.

(2) They then transfer that straight-line route to a Mercator projection by marking spots on the meridians where the straight-line route crossed them.

(3) They then draw straight lines between the meridian points, which are loxodromes or rhumb lines.

(4) The navigator can use these loxodromes to chart when periodic changes in compass course are necessary to approximate the shortest distance between two points.

d) Why does the Mercator projection distort size?

(1) It is a conformal projection. Although it is accurate in its portrayal of the equator and relatively undistorted in the low latitudes, it must distort size in the middle and high latitudes in order to maintain conformality, that is, approximate the shapes of landmasses.

(2) It shows the meridians as straight, parallel lines instead of having them converge at the poles as they actually do. This causes east–west stretching. To compensate for this stretching and keep shapes intact, the Mercator projection must also stretch north–south, so it increases the spacing between parallels of latitude as one goes further from the equator. Thus landmasses further away from the equator appear larger than they actually are.

e) The Mercator projection has been misused and so creates many misconceptions about the size of landmasses, as it makes those landmasses in the high latitudes appear much larger than they actually are.

(1) For example, Greenland appears much larger than Africa, South America, and Australia, although Greenland is actually smaller than them.

(2) Indeed, Africa is 14 times larger than Greenland.

B. **Plane Projections**

1. Planar projections (AKA azimuthal projections or zenithal projections) are created by projecting the markings of a center-lit globe on a flat piece of paper.

2. There is only a point of tangency that is usually located on one of the poles, and distortion increases as distance increases from this point.

3. The disadvantage of this projection is that no more than one hemisphere can be displayed.

C. **Conic Projections**

1. A conic projection is created by projecting the markings of a center-lit globe onto a cone wrapped tangent to, or intersecting, a portion of the globe.

2. The apex of the cone is usually positioned above a pole, resulting in the circle of tangency coinciding with a parallel.

3. Distortion increases with distance from this circle. As such, conic projections are best used with landmasses possessing great east–west orientations.
4. Because of the distortion associated with them, they are better suited for mapping smaller regions (i.e., a single country).

D. Pseudocylindrical Projections
1. Pseudocylindrical projections (AKA elliptical projections of oval projections) are generally designed to show the entire globe.
2. These projections usually employ a central parallel and a central meridian that cross at right angles in the middle of the map.
3. Distortion usually increases in all directions away from the point where these lines cross.

E. Interrupted Projections
1. The interruption of a projection is a technique used to minimize distortion.
2. Ocean regions are usually split apart or interrupted so that the distortion over landmasses is minimized.
3. The result is a map with very little distortion over land and great gaps over the oceans.

VII. Isolines
A. Isoline—commonly used cartographic device for portraying the spatial distribution of some phenomenon. Also called isarithm, isogram, isopleth, and isometric line.
1. Refers to any line that joins points of equal value.
B. Isolines help to reveal spatial relationships that otherwise might go undetected.
1. They can significantly clarify patterns that are too large, too abstract, or too detailed for ordinary comprehension.
C. Types of isolines that are most relevant to this course:
1. Elevation contour line—joins points of equal elevation.
2. Isotherm—joins points of equal temperature.
3. Isobar—joins points of equal atmospheric pressure.
4. Isohyet—joins points of equal quantities of precipitation.
5. Isogonic line—joins points of equal magnetic declination.
D. Basic characteristics of isolines:
1. Conceptually, they are always closed lines, having no ends.
2. They represent gradations in quantities, so only touch or cross one another in very rare and unusual circumstances.
3. Interval—the numerical difference between one isoline and the next.
   a) Size of interval is up to the cartographer’s discretion, but it is best to maintain a constant interval thorough a map.
4. Their proximity depends on the gradient (that is, the change in the interval).
   a) The closer they lie together, the steeper the gradient; the further apart they lie, the more gentle the gradient.

VIII. GPS—The Global Positioning System
A. Global Positioning System (GPS)—a satellite-based system for determining accurate positions on or near Earth’s surface. Formally called NAVSTAR GPS [Navigation Signal Timing and Ranging Global Positioning System], the system is based on high-altitude satellites (24) continuously transmitting both identification and position information that can be picked up by receivers on Earth. Clocks stored in both units help in calculating the
distance between the receiver and each member of a group of four (or more) satellites, so one can then determine the three-dimensional coordinates of the receiver’s position.
1. Even the simplest units allow a position calculation within about 15 meters (49 feet).
2. The greater number of satellites that can be tracked, the greater the accuracy.

B. **Wide Angle Augmentation System (WAAS)**
1. Increases GPS accuracy through the use of ground-based stations that monitor GPS satellite signals and then generate a correction message that is transmitted to GPS units.
2. Was originally developed by the Federal Aviation Administration (FAA).
3. With WAAS, GPS units can achieve a position accuracy of 3 meters (10 feet) about 95 percent of the time.

C. **Continuously Operating GPS Reference Stations (CORS)**
1. CORS are a system of permanently installed GPS receiving stations managed by NOAA (National Oceanic and Atmospheric Administration)
2. They are capable of detecting location differences of less than 1 centimeter of latitude, longitude, and elevation.
3. They can be used for monitoring lithospheric plate movement or the bulging of magma under a volcano.

D. GPS Applications
1. Also used in earthquake prediction, ocean floor mapping, volcano monitoring, mapping projects, and damage assessment after natural disasters.
2. Commercial applications now far outnumber military applications.
3. Given GPS’s increasing importance, other global navigation satellite systems are being implemented around the world such as Russia’s GLONASS.
4. Because of accuracy of GPS units, latitude and longitude are increasingly being reported in decimal form.

IX. **Remote Sensing**
A. **Remote sensing**—study of an object or surface from a distance by using various instruments.
1. Sophisticated technology now provides remarkable set of tools to study Earth, through precision recording instruments operating from high-altitude vantage points.
   a) Different kinds of remote sensing:
      (1) Aerial photographs, color and color infrared sensing, thermal infrared sensing, microwave sensing, radar, sonar, multispectral, and SPOT imagery.
(a) **Photogrammetry**—science of obtaining reliable measurements from photographs and, by extension, the science of mapping from aerial photographs.

(b) Color photogrammetry was developed in the 1940s and 1950s with many improvements as a result of their application during the Second World War.

C. **Orthophoto Maps**

1. **Orthophoto maps**—multicolored, distortion-free photographic maps produced from computerized rectification of aerial imagery.
   a) Show the landscape in much greater detail than a conventional map, but are like a map in that they provide a common scale that allows precise measurement of distances.
   b) Particularly useful in flat-lying coastal areas because they can show subtle topographic detail.

D. **Visible Light and Infrared Sensing**

1. Color—refers to the visible-light region of the electromagnetic spectrum.
2. **Color infrared (color IR)**—refers to the infrared region of the spectrum.
   a) Color infrared uses film or sensors to detect the near infrared portion of the electromagnetic spectrum.
   b) Color IR film is more versatile; uses include evaluating health of crops and trees.

E. **Thermal Infrared Sensing**

1. **Thermal infrared sensing (thermal IR)**—middle or far infrared part of electromagnetic spectrum; can’t be sensed with film.
   a) Thermal scanning is used for showing diurnal temperature differences between land and water and between bedrock and alluvium, for studying thermal water pollution, for detecting forest fires, and, its greatest use, for weather forecasting.

F. **Microwave Sensing**

1. Microwave radiometry—senses radiation in the 100-micrometer to 1-meter range.
   a) Useful for showing subsurface characteristics such as moisture.

G. **Multispectral Remote Sensing**

1. These systems image more than one region of the electromagnetic spectrum simultaneously from the same location.
2. The image is digital, conveyed through a matrix of numbers with each number representing a single value for a specific pixel and band.
3. **Landsat**
   a) **The early Landsat was the multispectral scanning system (MSS)**—a system that images Earth’s surface in several spectrum regions.
   b) Landsat Sensory Systems use an MSS; can gather more than 30 million pieces of data for one image 183 by 170 kilometers (115 by 106 miles).
   c) Although originally designed to possess a 10-year life span, both Landsat 5 and Landsat remain in active operation, but have been limited by some equipment malfunctions.
   d) Landsat Data Continuity Mission is scheduled for launch in 2012.

H. **Earth Observing System Satellites**

1. NASA’s **Earth Observing System (EOS)** satellite *Terra* was launched in 1999.
2. The satellite contains a moderate resolution imagery spectroradiometer (MODIS) that gathers 36 spectral bands.
3. The latest device is a multiangle image spectroradiometer (MIS) that is capable of distinguishing various types of atmospheric particulates, land surfaces, and cloud forms.
4. The most recent EOS satellite *Aqua* monitors water vapor, precipitation, clouds, glaciers, and soil wetness.
   a) *Aqua* also includes the Atmospheric Infrared Sounder (AIRS), which permits accurate atmospheric temperature measurements.
   b) Many satellite images are now easily available for online viewing at [http://earthobservatory.nasa.gov](http://earthobservatory.nasa.gov) and [http://www.goes.noaa.gov](http://www.goes.noaa.gov)

I. Commercial High Resolution Satellites
1. A number of commercial satellites also provide high-resolution imagery (50–70 centimeter [20 to 24 inch]).
2. These include SPOT, GeoEye-1, QuickBird, and WorldView.

J. Radar and Sonar Sensing
1. **Radar**—(radio detection and ranging) senses wavelengths longer than 1 millimeter and now provides images in photo-like form.
   a) Radar is unique in its ability to penetrate atmospheric moisture, so it can analyze wet tropical areas that can’t be sensed by other systems.
   (1) Radar is particularly useful for terrain analysis.
2. **Sonar**—(sound navigation ranging) permits underwater imaging.

X. Geographic Information Systems
A. **Geographic information systems (GIS)**—computer systems for the capture, storage, retrieval, analysis, and display of spatial data.
1. Uses both computer hardware and software to analyze geographic location and handle spatial data.
2. Virtually, libraries of information that use maps instead of alphabet to organize and store data.
   a) Allows data management by linking tabular data and map.
   b) Map and data are encoded with geographic coordinates so that users can search data using the map or search the map using the data.
   c) The map data then can be cross referenced for a variety of uses.
   d) Mainly used in overlay analysis, where two or more data layers, such as soils and vegetation, are superimposed or integrated and then can be analyzed together.
   e) GIS data can be used in conjunction with remotely sensed images and provide digital elevation models.
   f) First uses were in surveying, photogrammetry, computer cartography, spatial statistics, and remote sensing; now being used in all forms of geographic analysis, and bringing a new and more complete perspective to resource management, environmental monitoring, and environmental site assessment.
XI. Tools of the Geographer
   A. In using remote sensing and its images, the geographer works as an interpreter.
      1. The wide variety of tools available are only as useful as one’s ability to assess their veracity.
      2. Certain types of imagery may be useful for one purpose (i.e., studying major features of the lithosphere) while the same imagery may be quite limited for other applications (detailed terrain analysis).
      3. The new technologies provide new tools for the geographer, but they do not function as substitutes for field study, geographic description, and maps.
      4. No single sensing system works for all problems; each has its own use for particular purposes, so geographers must be careful in selecting and obtaining the best type of imagery for their individual needs.

XII. Focus: Portraying the Three-Dimensional Landscape
   A. Most maps are two-dimensional representations of Earth
   B. Vertical landscape development is essential for geography
   C. Many methods to depict the three-dimensional nature of Earth include
      1. Contour lines on topographic maps
      2. Air photo stereopairs (AKA stereograms)
         a) The photos are usually taken at regular spatial intervals and this gives them about a 60 percent overlap.
         b) When the two vertical aerial photographs are properly aligned and overlapping, they can produce three-dimensional appearance when viewed through a stereoscope.
      3. Digital elevation models
         a) Precise base elevations are used as reference point for grid (usually 30 meters).
         b) Computer then generates a shaded relief image of landscape being portrayed.
         c) The entire image can also be digitally manipulated to alter orientation, scale, vertical exaggeration of the topography, etc.

XIII. Focus: Geographic Research Using Google Earth and the National Map
   A. These two online programs have transformed how geographers approach research using maps.
      1. Google Earth is a three-dimensional geographic data viewer.
         a) Uses aerial photos and terrain models to provide lifelike views of cultural and physical landscapes.
      2. The National Map, developed by the USGS, gives users access to a wide array of federal geographic data.
         a) E.g., aerial photos, elevation, transportation, and land cover.
      3. Both Google Earth and the National Map provide map layers which allow users to toggle through various map layers and to change the map scales.
         a) This allows users to customize maps.
         b) The National Map provides the additional benefit of downloadable KML files that can be displayed in Google Earth.
      4. The utility of these tools is nearly boundless.
         a) They have been used to
(1) Examine rangeland to cropland conversion in Nebraska.
(2) Examine farmland lost to urbanization on Chicago’s edge.

Chapter 2 Learning Review
After studying this chapter, you should be able to answer the following questions:

The Nature of Maps (p. 27)
1. Why is it impossible for a map of the world to portray Earth as accurately as can be done with a globe?

Map Scale (p. 27)
2. Describe and explain the concept of **map scale**.
3. Contrast **graphic scales**, **fractional scales**, and **verbal scales**.
4. What is meant by a map with a **representative fraction** of 1/10,000 (also written 1:10,000)?
5. Explain the difference between **large-scale maps** and **small-scale maps**.

Map Projections (p. 31)
6. What is meant by a map projection?
7. Explain the differences between an **equivalent map projection** and a **conformal map projection**.
8. Is it possible for a map to be both conformal and equivalent? Neither conformal nor equivalent?

Families of Map Projections (p. 33)
10. Why is a **Mercator projection** useful as a navigation map? Why is it not ideal for use as a general purpose classroom map?
11. What is a **loxodrome (rhumb line)**?
12. Why are there so many types of map projections?

Isolines (p. 35)
13. Explain the concept of an **isoline**.
14. What characteristics on maps are shown by **isotherms**, **isobars**, and **elevation contour lines**?

GPS—The Global Positioning System (p. 38)
15. Briefly explain how the **Global Positioning System (GPS)** works.

Remote Sensing (p. 40)
16. What is **remote sensing**?
17. Briefly define the following terms: **aerial photography**, **photogrammetry**, **orthophoto map**.
18. What are some of the applications of color infrared imagery?
19. What are some of the applications of thermal infrared imagery?
20. Describe **multispectral** remote sensing.
21. Compare and contrast radar and sonar.

**Geographic Information Systems (p. 45)**
22. Distinguish between GPS and GIS (**geographic information systems**).