Introduction to Cartography

Overview

- What is a map?
- Map scale
- Components of a map
- Map types
- Basic issues of map design

What is a map?

- “A graphic depiction of all or part of a geographic realm in which the real-world features have been replaced by symbols in their correct spatial location at a reduced scale.” (Clarke, 2001)

What is a map?

- “a symbolized image of geographic reality, representing selected features or characteristics resulting from the creative efforts of cartographers and designed for use when spatial relationships are of special relevance.” (ICA, 1995)

Cartographic Basics

- Maps perform two important functions:
  - Storage medium for information
  - Provides a picture of the world to help understand:
    - *Spatial patterns*
    - *Spatial relationships*
    - *Environmental complexity*

Cartographic Basics

- **Maps tell us:**
  - Where it is
  - What it is
  - When it is (often but not always)
  - What is nearby
    - *How far away*
    - *In which direction*
    - *How do I get there*
  - How might they be related

Cartographic Basics

- All maps have the same goal:
  - Communicating spatial relationships
  - Communicating the “form” of the landscape

Cartographic Basics

- Basic characteristics of all maps:
  - *Location*
  - *Attribution*
  - *Reduction of reality*
  - *Scale*
  - *Geometrical transformation/projection*
  - *Abstractions of reality*
  - *Symbolism*

Cartographic Basics

- Mapping involves information transformations:
  - Selection
  - Classification
  - Simplification
  - Exaggeration
  - Symbolization

Scale

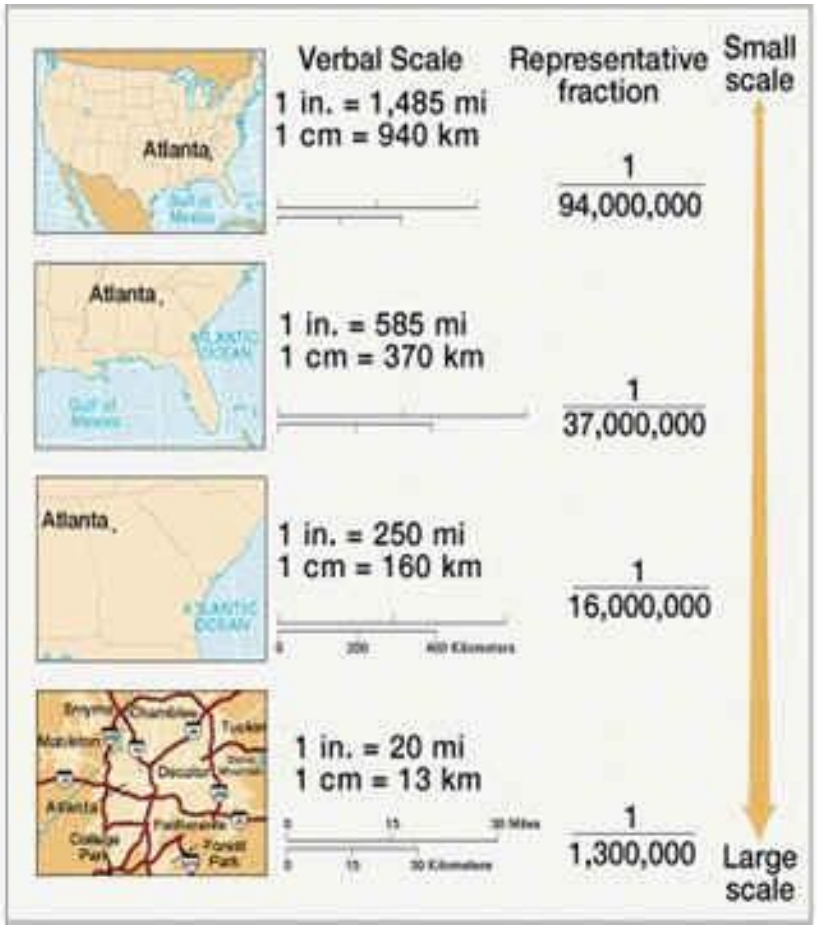
- Types of scale:
  - *Graphical:* 

  - *Verbal : **One inch represents one mile***
  - *Representative Fraction: **1:24,000***

Large Scale vs. Small Scale

- Small scale = large area
- Small scale = large denominator
  - *1:1,000,000*
- Large scale = small area
- Large scale = small denominator
  - *1:24,000*

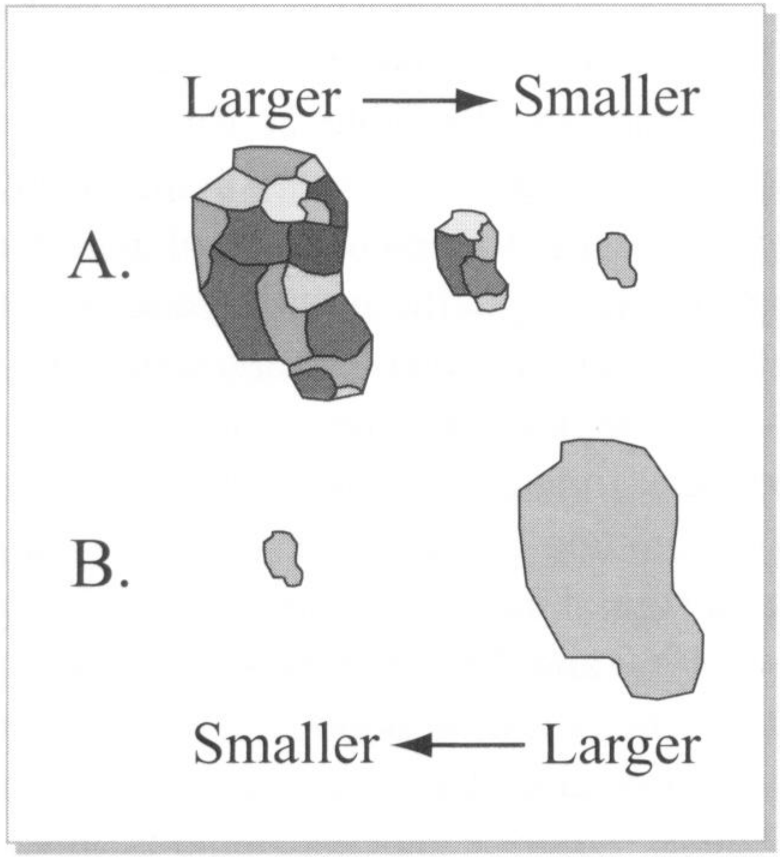
Large Scale Vs. Small Scale



Scale & Generalization

- Smaller scale means fewer features
- Smaller scale means smoother features
- Smaller scale means combining features
- Smaller scale means displacing features

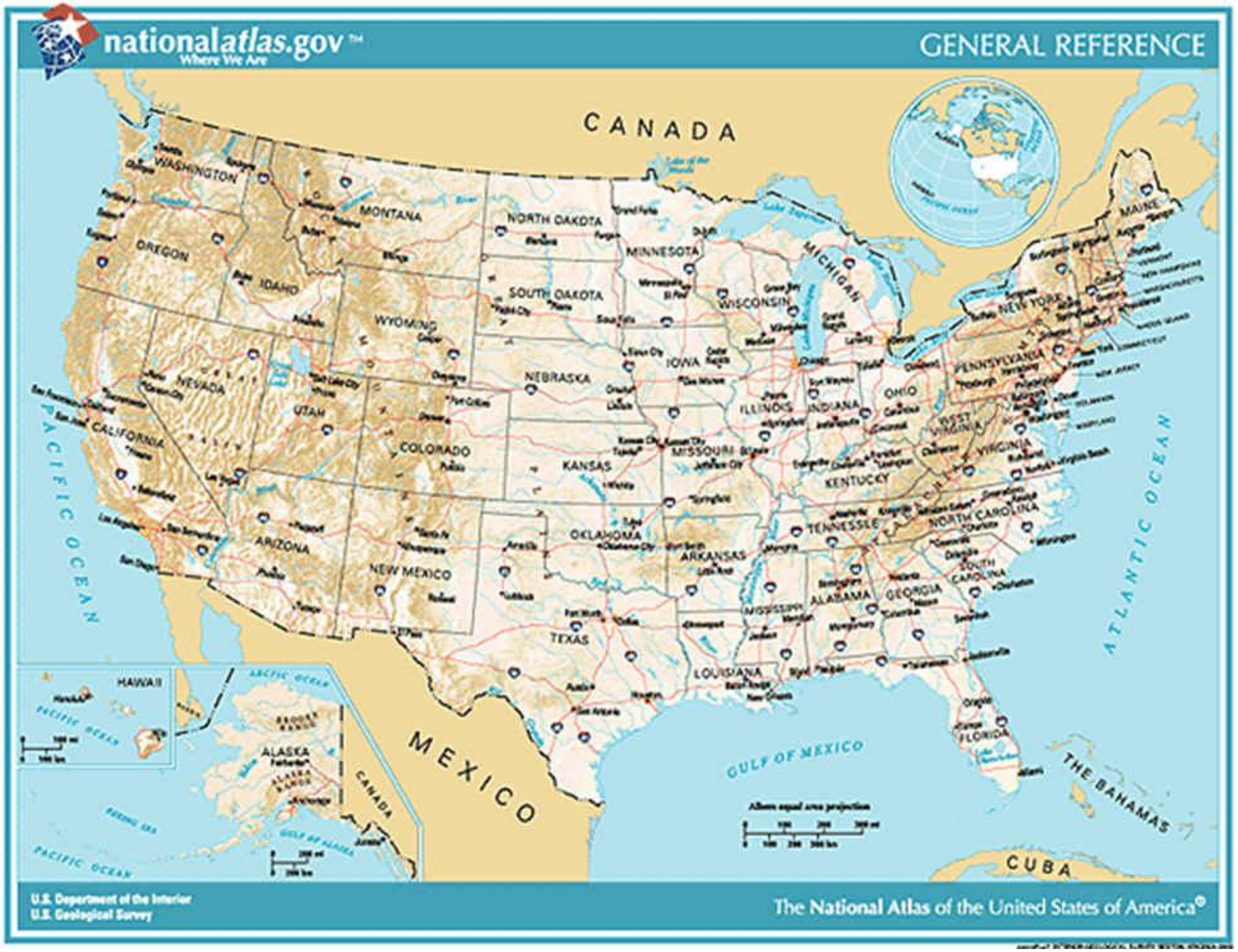
Data Aggregation



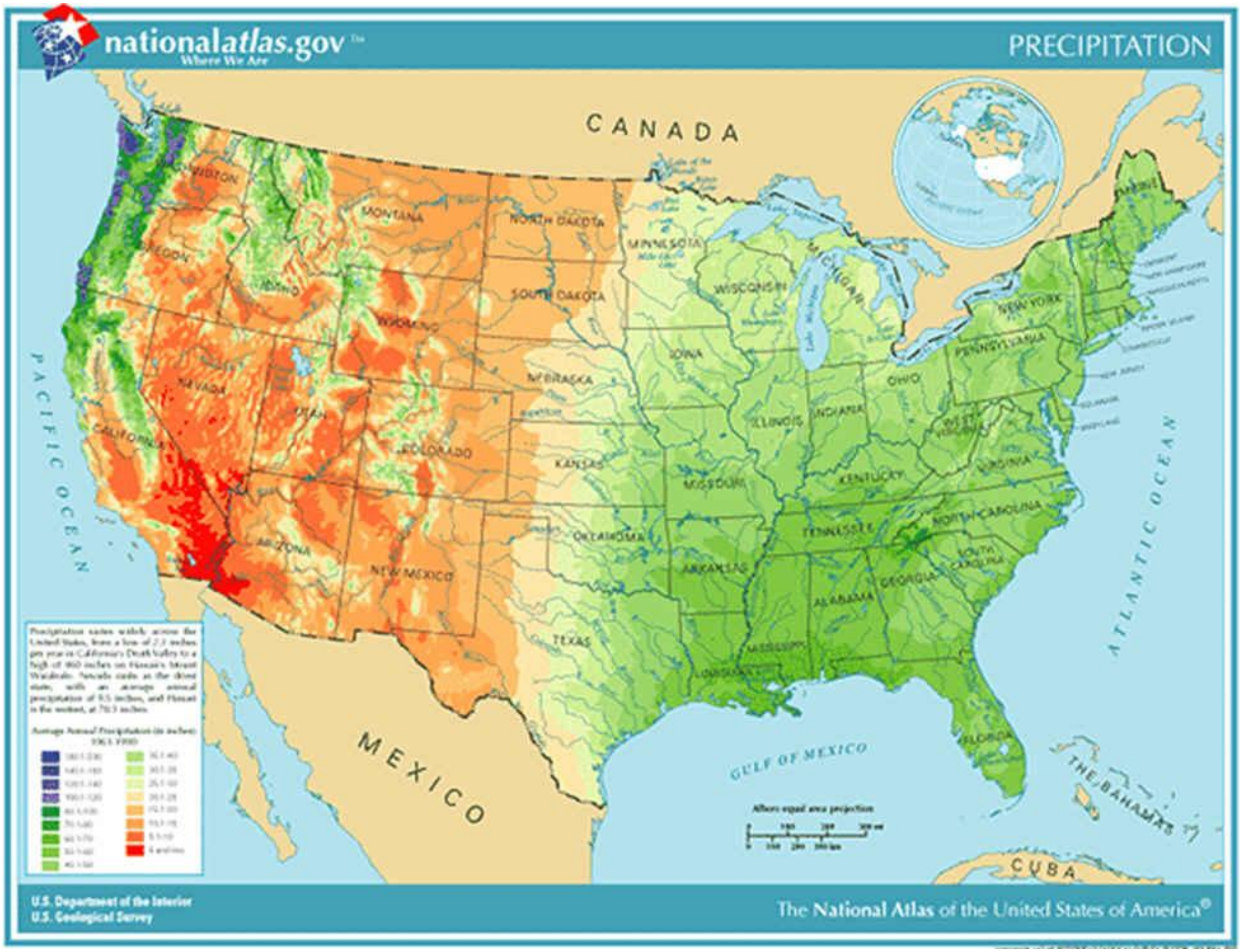
Map Categories

- Reference maps
  - *Are multipurpose*
- Thematic maps
  - *Qualitative*
  - *Quantitative*

Reference Maps



Thematic Maps



Choosing a Thematic Map Type

- There are many different map types or methods of cartographic representation
- Not all GISs allow all types
- Most have a set of basic types
- Depend heavily of the dimension of the data to be shown

Choosing a Thematic Map Type

- Is the data:
  - Continuous?
  - Discrete?
  - What is the accuracy and precision?
  - Reliability of the data?
- Data dimension (point, line, area, volume?)
- Scale of measurement (nominal, etc)

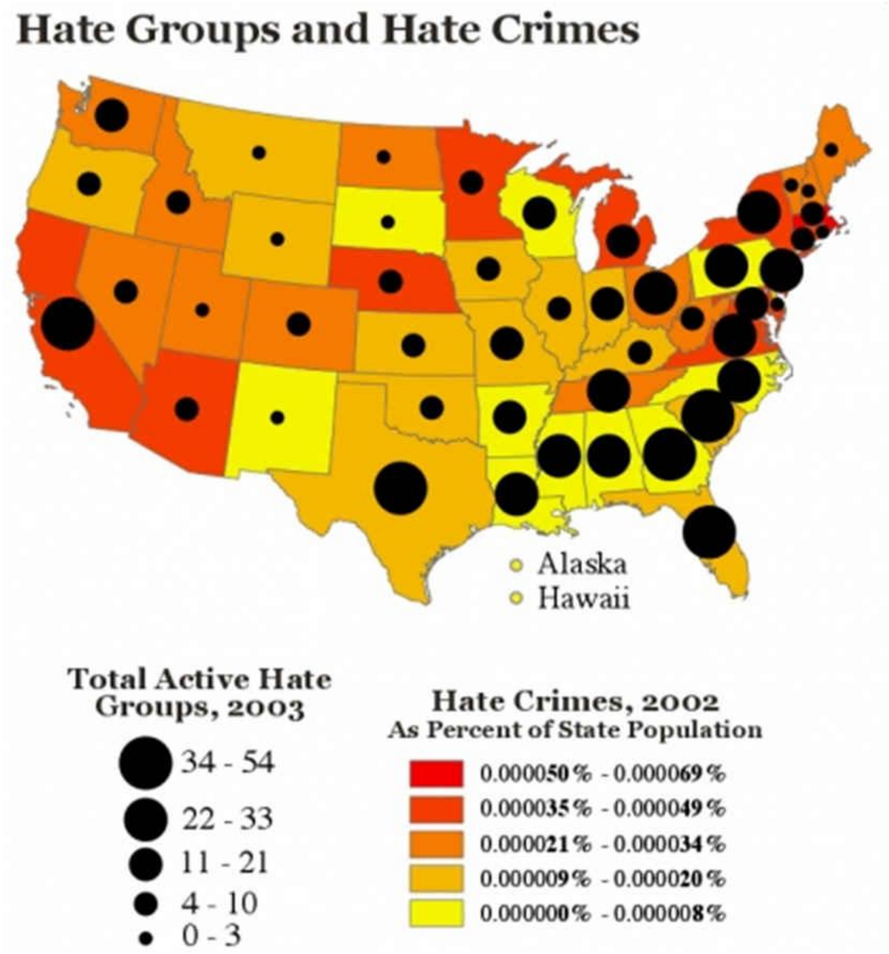
Choosing the Wrong Type of Map

- Common GIS error
- Due to lack of knowledge about cartographic options
- Can have perfect symbolization and have errors
- Possibility of misinformation
- Reduction in communication effectiveness

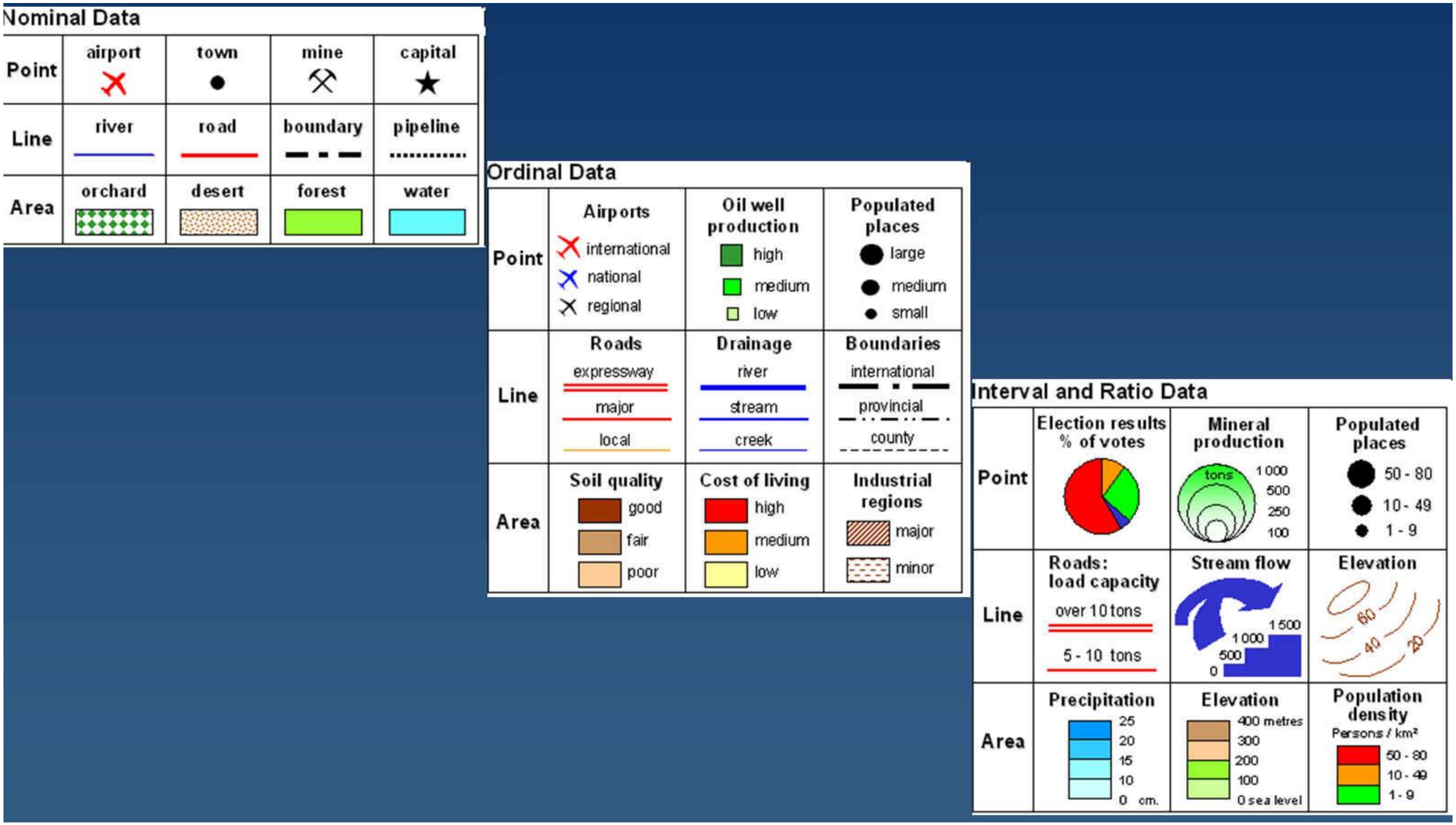
Measurement Scale

- **Nominal** (name of a place)
- **Ordinal** (small, medium, large town)
- **Interval** (arbitrary zero point, e.g. sea level)
- **Ratio** (absolute zero, e.g. dollars)

Effective Symbolization



Symbology



Nominal Data
Point
airport
town
mine
capital
Line
river
road
boundary
pipeline
Area
orchard
desert
forest
water
Ordinal Data
Point
Airports
international
national
regional
Oil well production
high
medium
low
Populated places
large
medium
small
Line
Roads
expressway
major
local
Drainage
river
stream
creek
Boundaries
international
provincial
county
Area
Soil quality
good
fair
poor
Cost of living
high
medium
low
Industrial regions
major
minor
Interval and Ratio Data
Point
Election results % of votes
Mineral production
tons
1 000
500
250
100
Populated places
50 - 80
10 - 49
1 - 9
Line
Roads: load capacity
over 10 tons
5 - 10 tons
Stream flow
1 500
1 000
500
0
Elevation
60
40
20
Area
Precipitation
25
20
15
10
0 cm.
Elevation
400 metres
300
200
100
0 sea level
Population density
Persons / km²
50 - 80
10 - 49
1 - 9

Selection of Thematic Map Symbols

Homogeneity

- The *qualitative feature data* may give the mapmaker information about the actual *degree of homogeneity* within each feature.
- For example, a stand of trees might prove to be entirely of the same species.
- The stand is a completely homogeneous qualitative area feature since all of its **defining objects (trees)** are of the same **category (species)** within the **homogeneous area (stand)**

Homogeneity

- **Mapmakers deal with this in several ways**
- They could decide to **define the boundary** between the two single species stands as the middle of the transition zone
- They may **add a transition zone** to the classification so that the map now includes a mixed class as well as the two single species classes

Homogeneity

- *An example of homogeneity within line features…..*
- **For example**…… many roads are probably completely asphalt or totally concrete
- When these homogeneous features are shown on a map as asphalt or concrete roads, the maps agree with what's on the ground

Homogeneity

- **An alternative** is to segment the features by breaking them at locations where the road surface type changes
- The feasibility of this approach relates to the map scale

Single Theme Maps

- To read these **single theme maps**, you must first determine what features have been shown with **point, line or area symbols**
- The graphic marks are symbolized using what mapmakers call **visual variables**
- Certain **visual variables** work well for qualitative data because they *do not impart a magnitude message*; others work well for quantitative data because they do

Feature type	Graphic element		
	Shape	Orientation	Color hue
Point	Spring House Mine	Live tree Dead tree	Live tree Dead tree
Line	National border Trail Section line	Asphalt road Concrete road	National border State border
Area	Gravel Sand	Orchard Field crop	Land Water

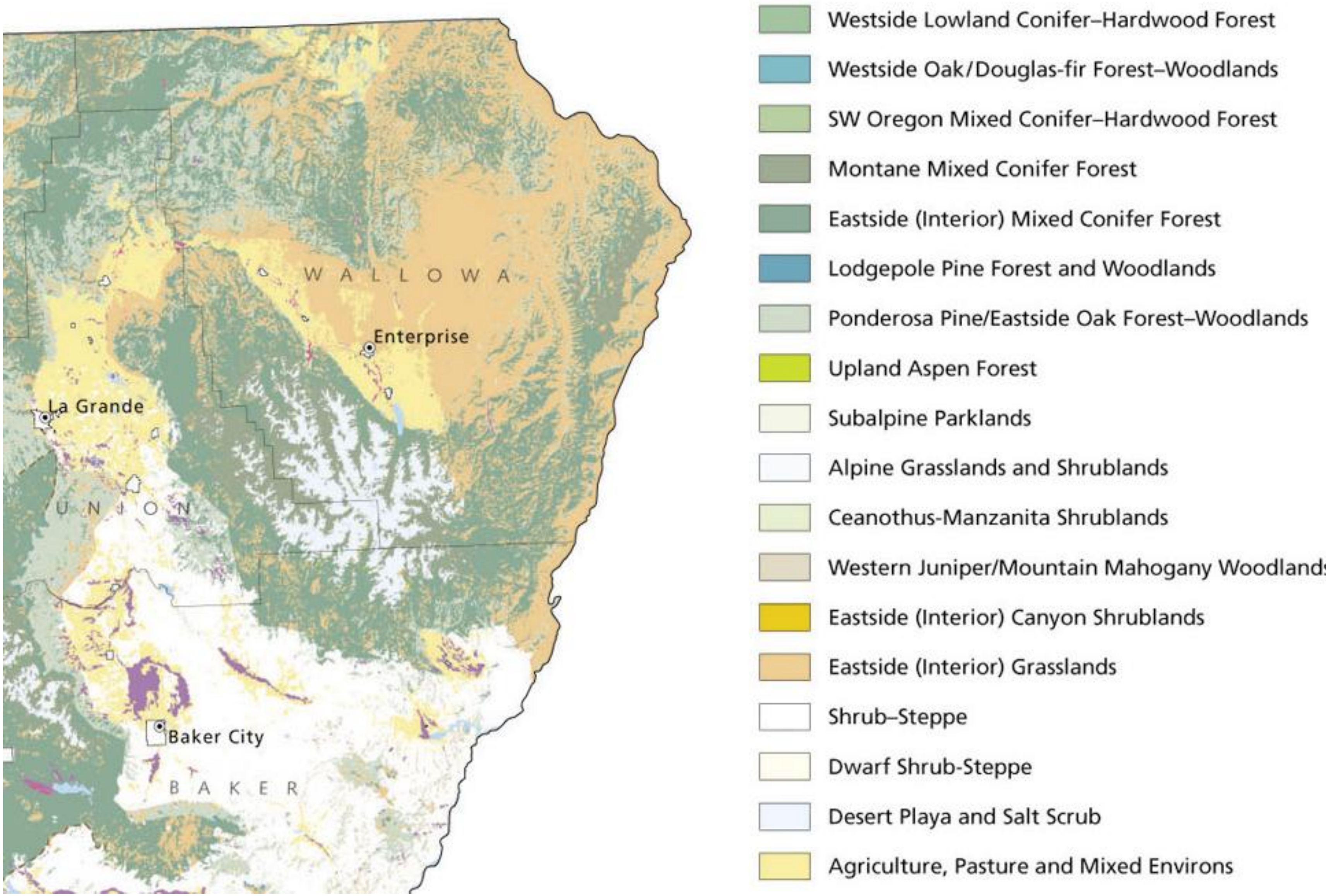
Figure 7.2

Single Theme Maps

- **For example**, a set of point symbols might be designed as circles with lines in them that are oriented in different directions
- Each of these visual variables gives the impression that features are different in type or kind but not more or less in magnitude

Single Theme Maps

- Thus, some other visual variable (**size, texture, color value or color intensity**) may be used that is really most appropriate for showing quantitative differences



WALLOWA
Enterprise
La Grande
UNION
Baker City
BAKER
Westside Lowland Conifer–Hardwood Forest
Westside Oak/Douglas-fir Forest–Woodlands
SW Oregon Mixed Conifer–Hardwood Forest
Montane Mixed Conifer Forest
Eastside (Interior) Mixed Conifer Forest
Lodgepole Pine Forest and Woodlands
Ponderosa Pine/Eastside Oak Forest–Woodlands
Upland Aspen Forest
Subalpine Parklands
Alpine Grasslands and Shrublands
Ceanothus-Manzanita Shrublands
Western Juniper/Mountain Mahogany Woodlands
Eastside (Interior) Canyon Shrublands
Eastside (Interior) Grasslands
Shrub–Steppe
Dwarf Shrub-Steppe
Desert Playa and Salt Scrub
Agriculture, Pasture and Mixed Environs

Figure 7.3

Point Feature Maps

- It isn't being used in the strict mathematical sense of a one-dimensional figure but, rather, as the center of a circle, square or some other map symbol representing a point feature found at this location or as we saw earlier, representing a feature conceived of as a point for mapping purposes

Point Feature Maps

- **Geometric symbols** are simple shapes, such as squares, circles and triangles to represent features

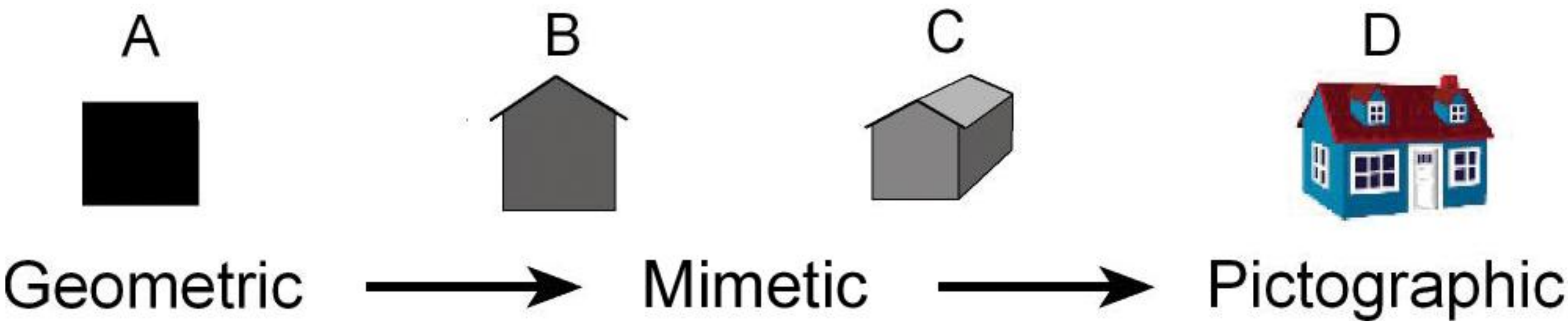


Figure 7.4

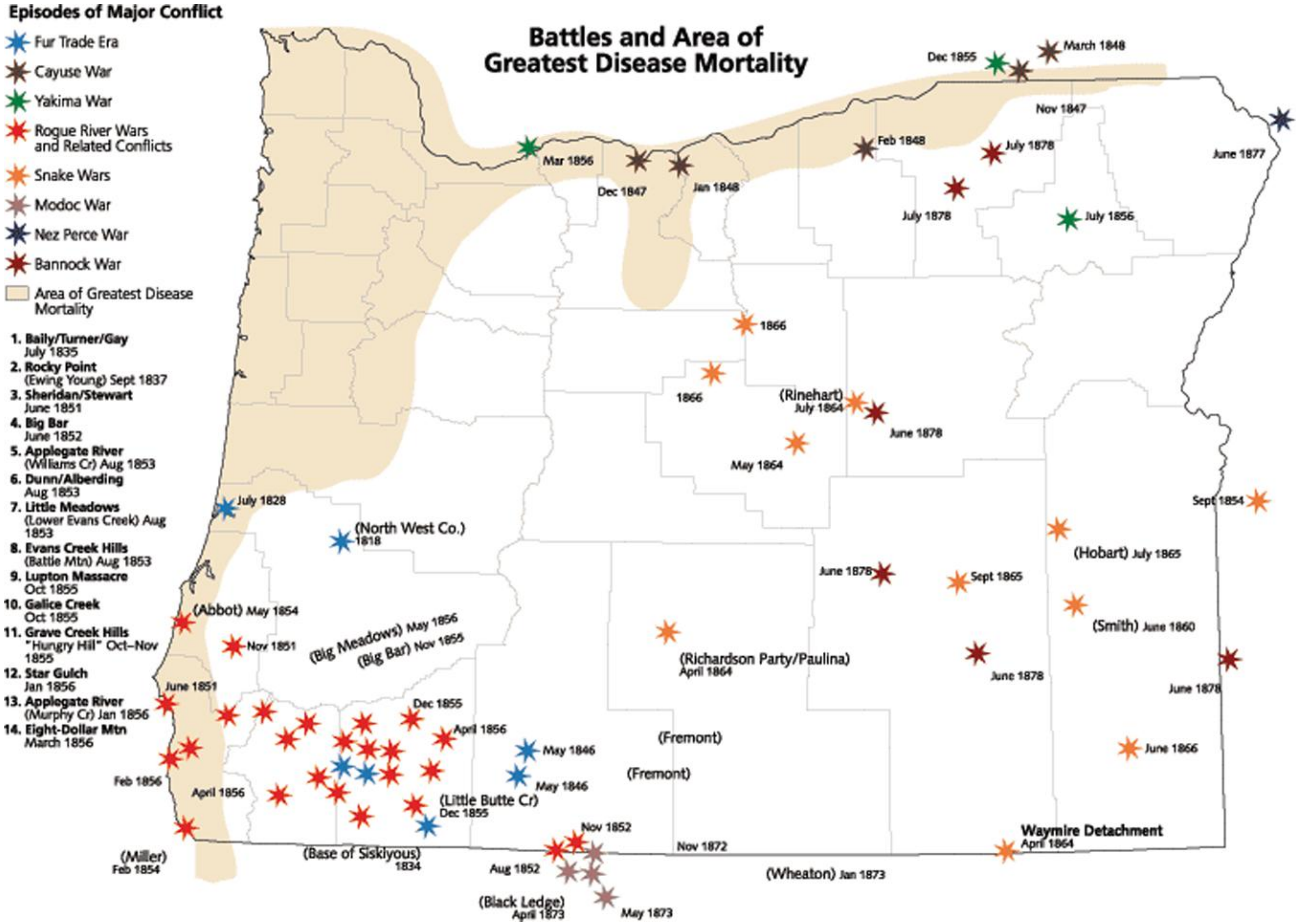

Battles and Area of Greatest Disease Mortality
Episodes of Major Conflict
Fur Trade Era
Cayuse War
Yakima War
Rogue River Wars and Related Conflicts
Snake Wars
Modoc War
Nez Perce War
Bannock War
Area of Greatest Disease Mortality
1. Baily/Turner/Gay July 1835
2. Rocky Point (Ewing Young) Sept 1837
3. Sheridan/Stewart June 1851
4. Big Bar June 1852
5. Applegate River (Williams Cr) Aug 1853
6. Dunn/Alberding Aug 1853
7. Little Meadows (Lower Evans Creek) Aug 1853
8. Evans Creek Hills (Battle Mtn) Aug 1853
9. Lupton Massacre Oct 1855
10. Galice Creek Oct 1855
11. Grave Creek Hills "Hungry Hill" Oct–Nov 1855
12. Star Gulch Jan 1856
13. Applegate River (Murphy Cr) Jan 1856
14. Eight-Dollar Mtn March 1856
Dec 1855
March 1848
Nov 1847
Feb 1848
July 1878
June 1877
Mar 1856
Dec 1847
Jan 1848
July 1878
July 1856
1866
1866
(Rinehart) July 1864
June 1878
May 1864
July 1828
(North West Co.) 1818
Sept 1854
(Hobart) July 1865
June 1878
Sept 1865
(Abbot) May 1854
(Big Meadows) May 1856
(Big Bar) Nov 1855
Nov 1851
(Smith) June 1860
(Richardson Party/Paulina) April 1864
June 1878
June 1878
June 1851
Dec 1855
April 1856
(Fremont)
May 1846
(Fremont)
May 1846
June 1866
Feb 1856
April 1856
(Little Butte Cr) Dec 1855
Nov 1852
Waymire Detachment April 1864
Nov 1872
(Miller) Feb 1854
(Base of Siskiyous) 1834
Aug 1852
(Wheaton) Jan 1873
(Black Ledge) April 1873
May 1873

Figure 7.5

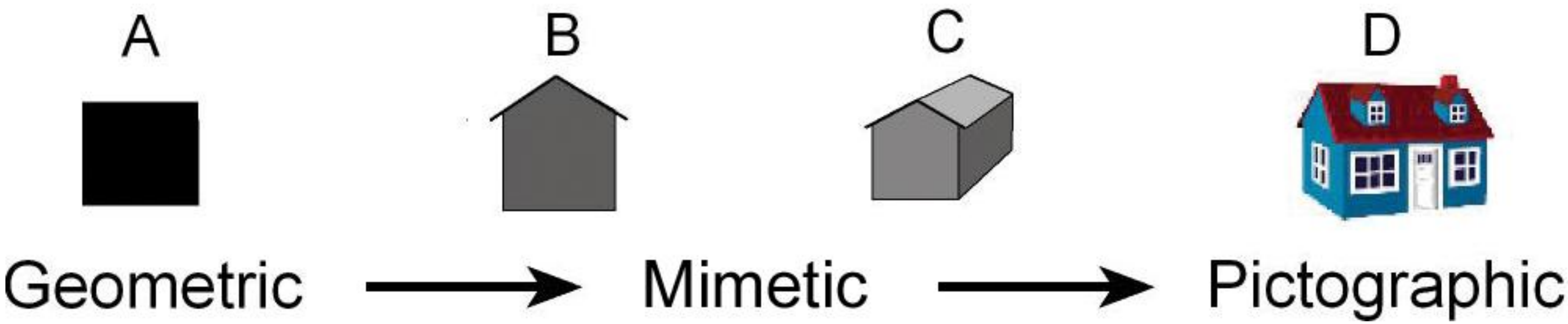


Figure 7.4

Point Feature Maps

- **Mimetic symbols** are often created as a combination of geometric shapes such as a square with a triangle on top to represent a house, or they can be more complex, like a small cartoon of a particular type of building like a **ranger station** or a **museum**

Point Feature Maps

- A **special type of mimetic symbol** is the **standard symbol**, which is a symbol that is used as a standard in some mapping practice or for some mapping product
- **Sets of standard symbols** have been created to show different categories of:
  - transportation,
  - recreation and
  - other activities

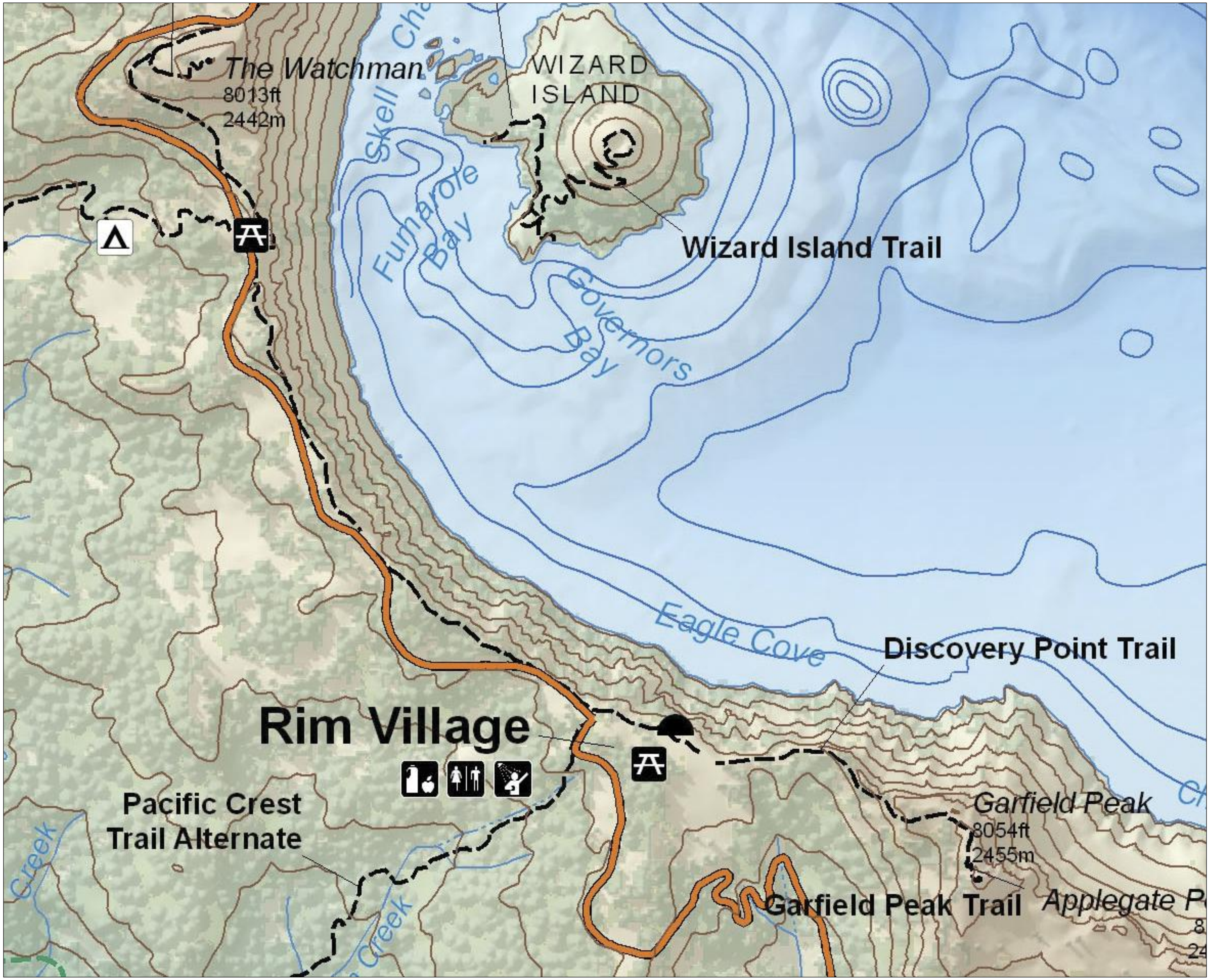

The Watchman
8013ft
2442m
WIZARD
ISLAND
Skell Ch
Fumarole
Bay
Wizard Island Trail
Governors
Bay
Eagle Cove
Discovery Point Trail
Rim Village
Pacific Crest
Trail Alternate
Garfield Peak
8054ft
2455m
Garfield Peak Trail
Creek
Creek

Figure 7.6

Point Feature Maps

- **Standard symbols** have a more professional look but they still **suffer problems** associated with more pictographic symbols in general

Point Feature Maps

- *What, for example, is an obvious icon for a vista or an overlook?*
- *And what if there are 10 such cryptic symbols on a map?*

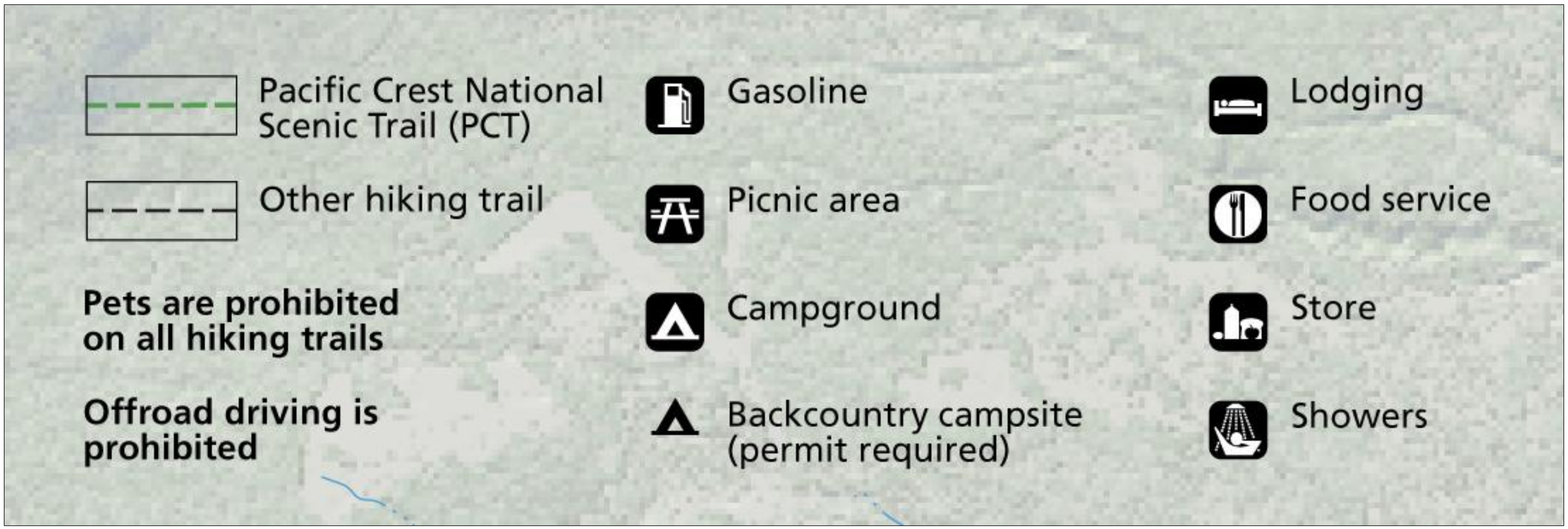

Pacific Crest National Scenic Trail (PCT)
Other hiking trail
Pets are prohibited on all hiking trails
Offroad driving is prohibited
Gasoline
Picnic area
Campground
Backcountry campsite (permit required)
Lodging
Food service
Store
Showers

Figure 7.7

Point Feature Maps

- **Notice in figure 7.2** that the orientation or hue of the mimetic symbol for a coniferous tree can be changed to show the tree is **alive (vertical or green)** or **dead (horizontal or brown)**

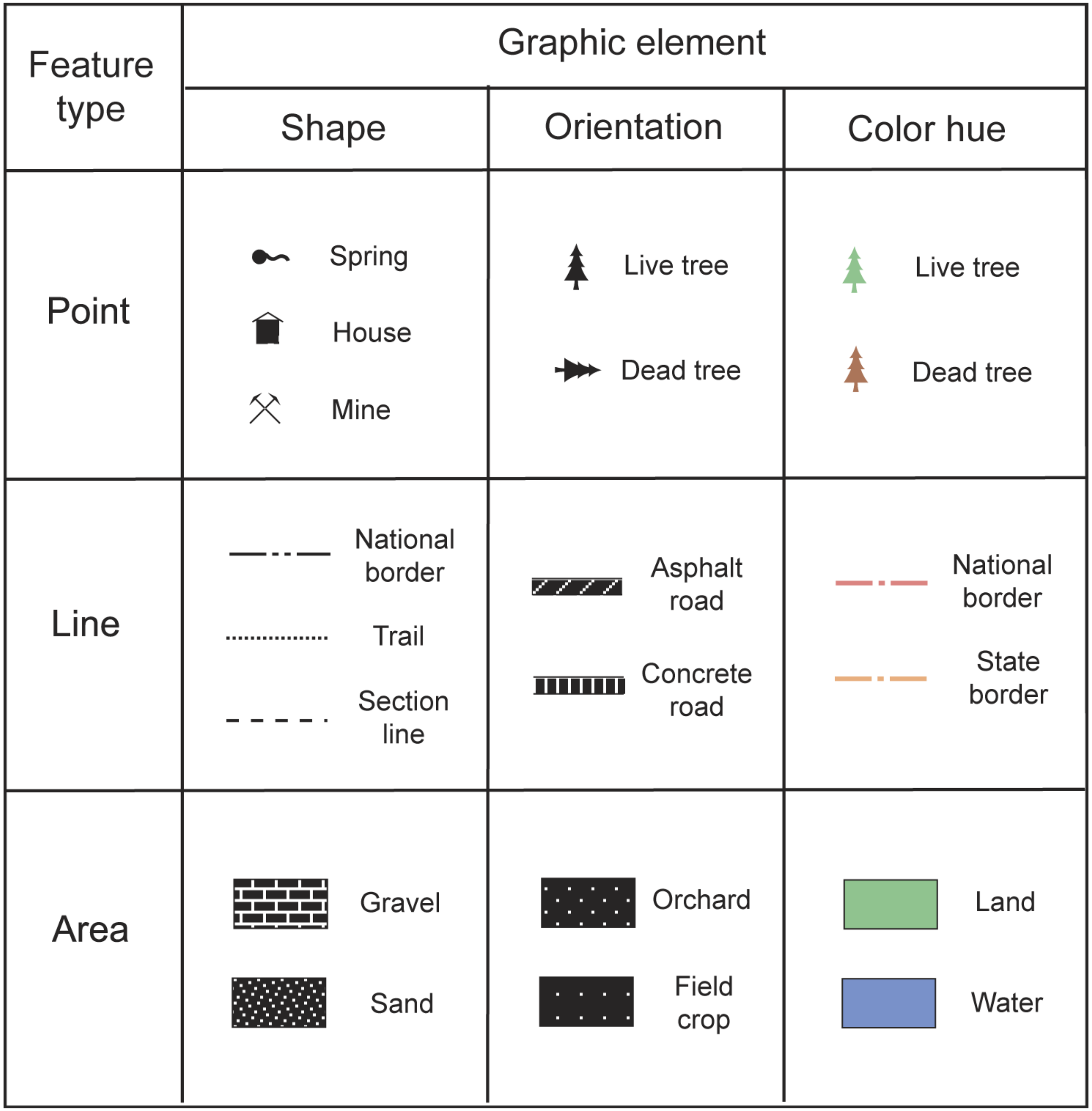

Feature type
Graphic element
Shape
Orientation
Color hue
Point
Spring
House
Mine
Live tree
Dead tree
Live tree
Dead tree
Line
National border
Trail
Section line
Asphalt road
Concrete road
National border
State border
Area
Gravel
Sand
Orchard
Field crop
Land
Water

Figure 7.2

Point Feature Maps

- Although these symbols may look very abstract, they can be read correctly even when very small
- They can also be used for larger categories having hundreds of individual features
- This lets mapmakers pack more information into the map that they can with larger mimetic or pictographic symbols

Line Feature Maps

- Mapmakers make **line feature maps** with **qualitative line symbols** showing different categories of linear features, such as roads, streams or boundaries

Line Feature Maps

- The lines used to **symbolize linear features** on maps have width as well as length, and the symbol width rarely corresponds directly with the feature width on the ground

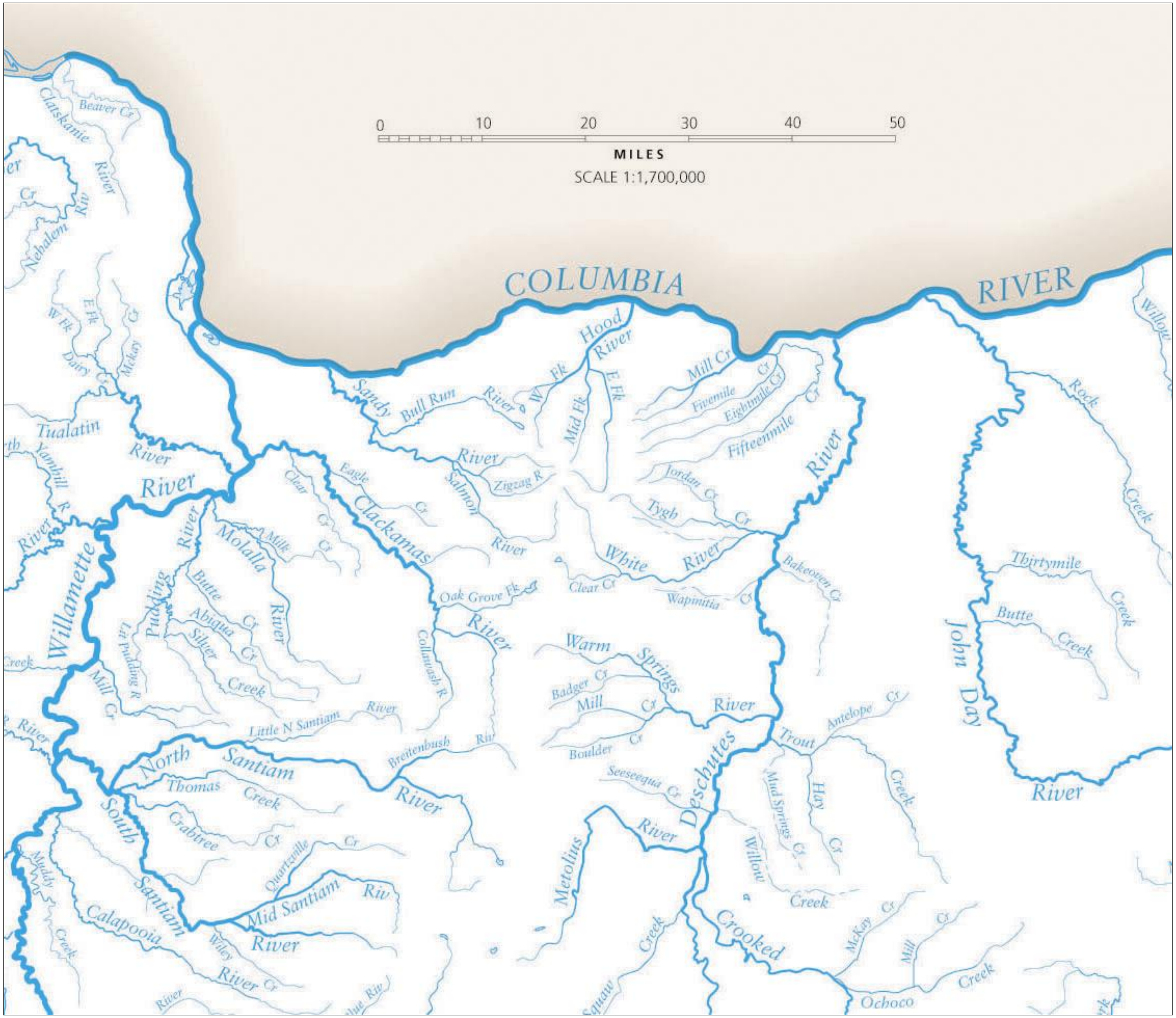

0 10 20 30 40 50
MILES
SCALE 1:1,700,000
COLUMBIA RIVER
Hood River
Sandy
Bull Run
Clackamas
Molalla
Willamette
Tualatin
Deschutes
John Day
White River
Warm Springs
North Santiam
Mid Santiam
South Santiam
Calapooia
Metolius
Crooked
Ochoco
Trout Creek

Figure 7.8

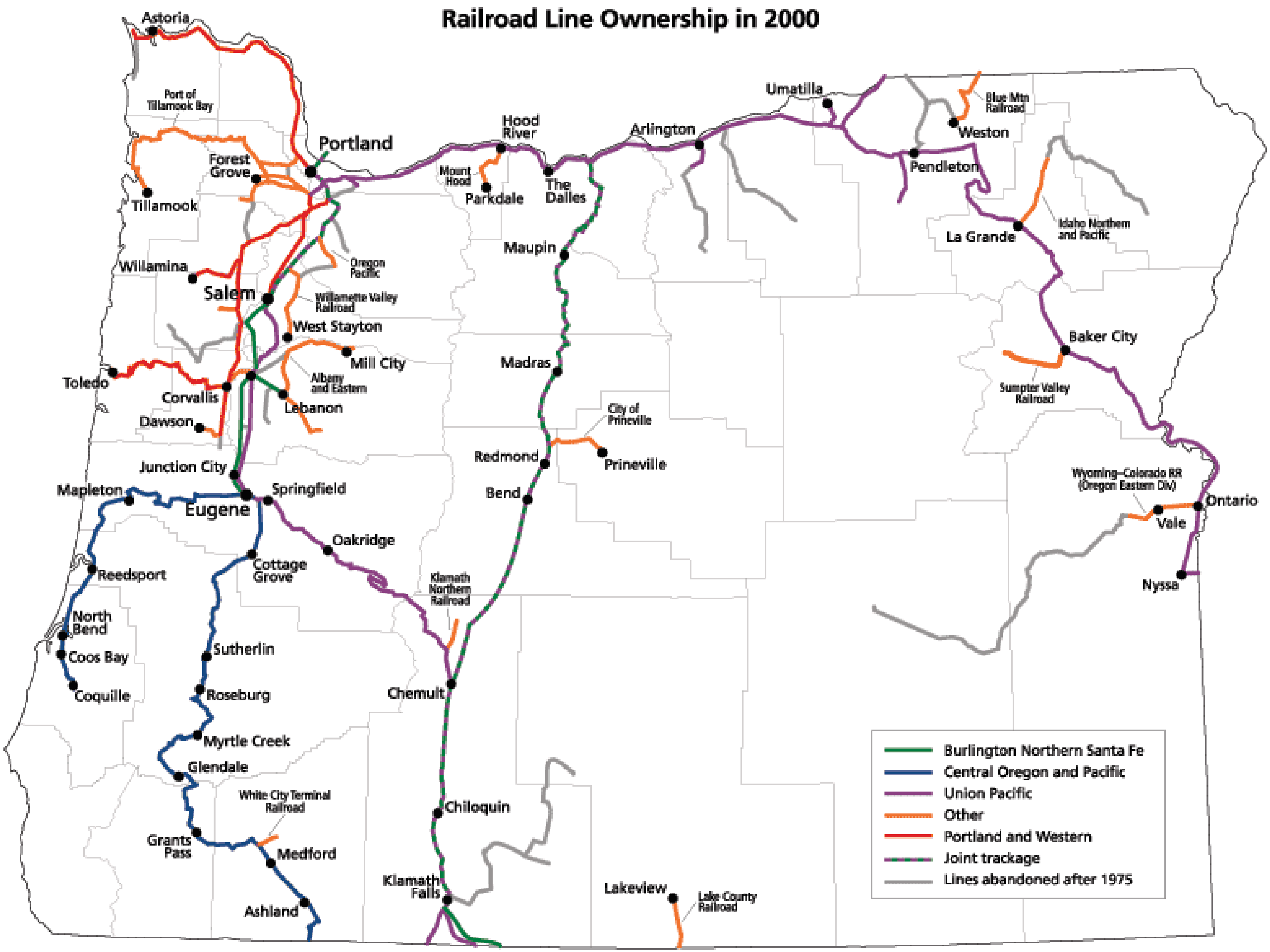

Railroad Line Ownership in 2000
Astoria
Port of Tillamook Bay
Portland
Forest Grove
Tillamook
Willamina
Salem
Oregon Pacific
Willamette Valley Railroad
West Stayton
Mill City
Albany and Eastern
Toledo
Corvallis
Lebanon
Dawson
Junction City
Mapleton
Springfield
Eugene
Oakridge
Reedsport
Cottage Grove
North Bend
Coos Bay
Coquille
Sutherlin
Roseburg
Myrtle Creek
Glendale
White City Terminal Railroad
Grants Pass
Medford
Ashland
Hood River
Mount Hood
Parkdale
The Dalles
Maupin
Madras
City of Prineville
Prineville
Redmond
Bend
Klamath Northern Railroad
Chemult
Chiloquin
Klamath Falls
Lakeview
Lake County Railroad
Arlington
Umatilla
Blue Mtn Railroad
Weston
Pendleton
La Grande
Idaho Northern and Pacific
Baker City
Sumpter Valley Railroad
Wyoming-Colorado RR (Oregon Eastern Div)
Ontario
Vale
Nyssa
Burlington Northern Santa Fe
Central Oregon and Pacific
Union Pacific
Other
Portland and Western
Joint trackage
Lines abandoned after 1975

Figure 7.9

Line Feature Maps

- Some **hues** have been **standardized** for certain features
- **For example**, water features are usually shown with **blue lines**
- Boundaries are depicted with **red lines**
- Roads are drawn in **black** and
- contour lines are drawn in **brown**

Feature type	Graphic element		
	Shape	Orientation	Color hue
Point	Spring House Mine	Live tree Dead tree	Live tree Dead tree
Line	National border Trail Section line	Asphalt road Concrete road	National border State border
Area	Gravel Sand	Orchard Field crop	Land Water

Figure 7.2

Line Feature Maps

- The **individual marks** repeated along the line usually are **geometric**, but they can also be **mimetic**
- **Mimetic shapes** may be easier to discern than abstract geometric shapes, but they're more difficult to miniaturize and repeat along a line

Line Feature Maps

- **For example**, the lines on a map can be used to represent features that are **linear** (**fences or walls**), as well as **networks** (**roads and railroads**), the **edges of area features** (**administrative boundaries**), and the **land surface form** (**contours**)

Area Feature Maps

- **Qualitative area feature maps** use **area symbols** to portray features that are homogeneous within regions

Area Feature Maps

- These include:
  - **Color hue**
  - **Pattern shape**
  - **Pattern orientation**

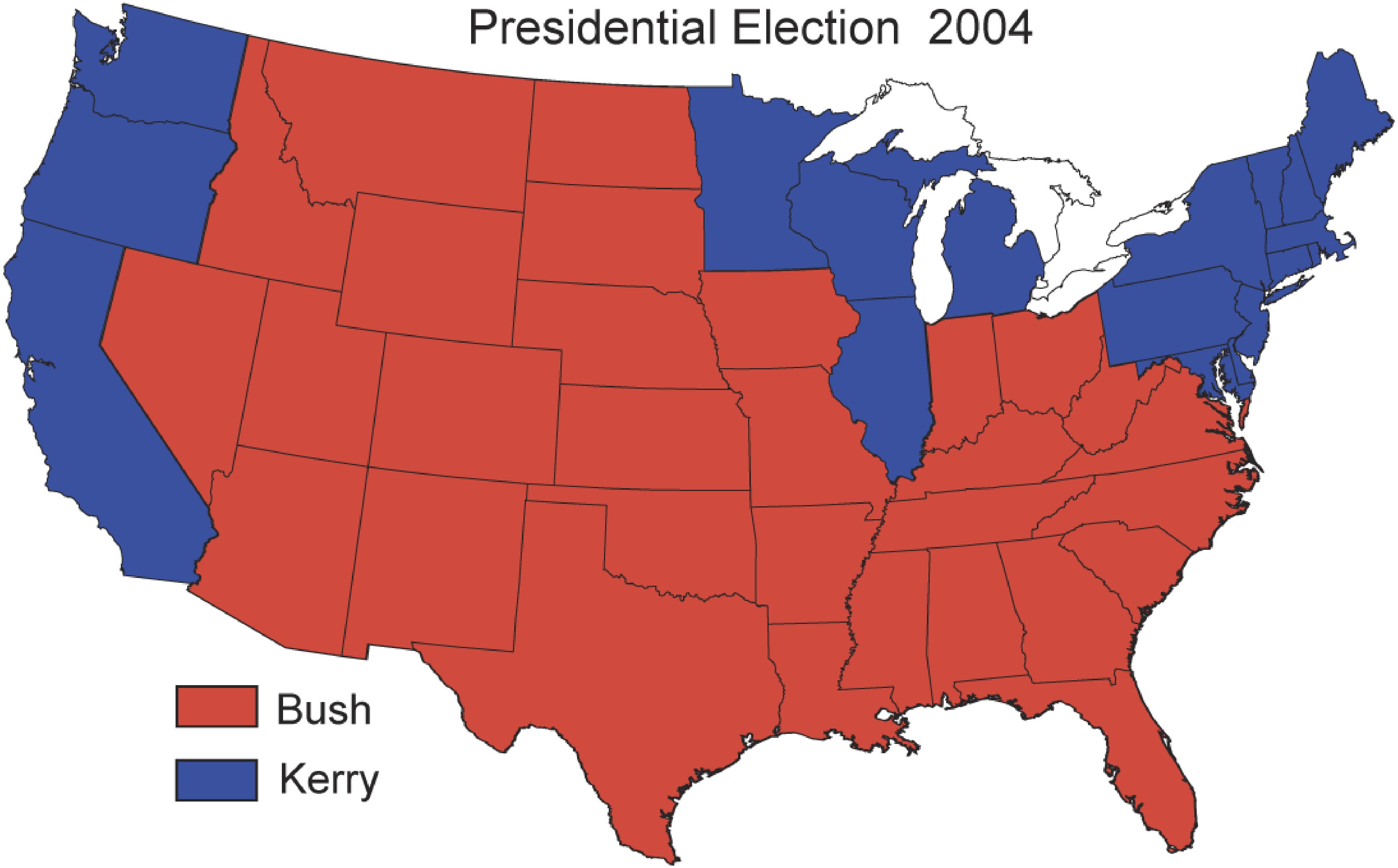


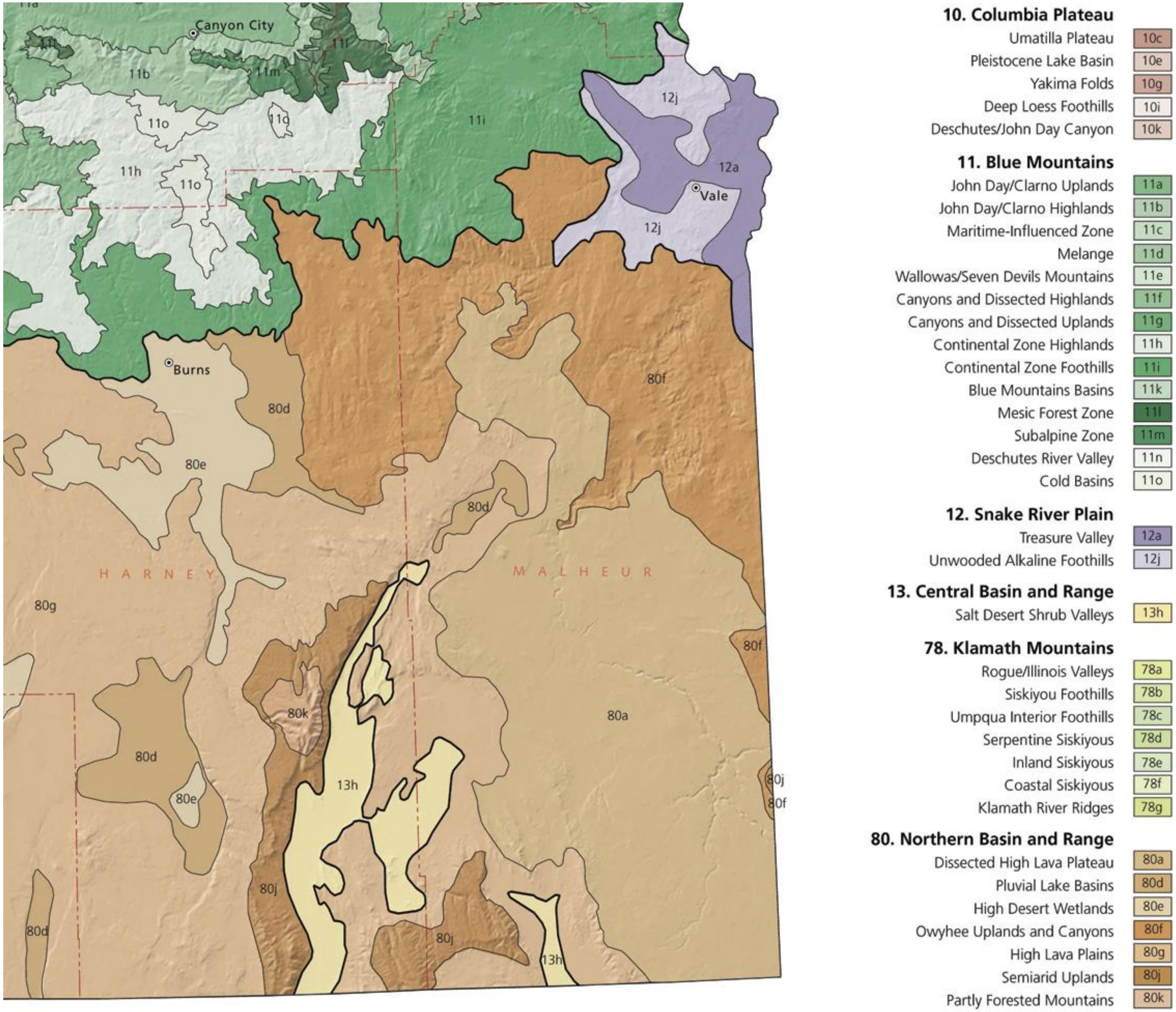
Figure 7.10

Area Feature Maps

- Or she could use a **combination of pattern shape and hue** (**red elephants and blue donkeys**) to make sure you correctly see the category for each region

Area Feature Maps

- If mapmakers instead use **visual variables** that give a **magnitude impression**, such as:
  - color lightness,
  - color intensity,
  - pattern texture or
  - size,
- you’ll likely see quantitative rather than qualitative differences in the data

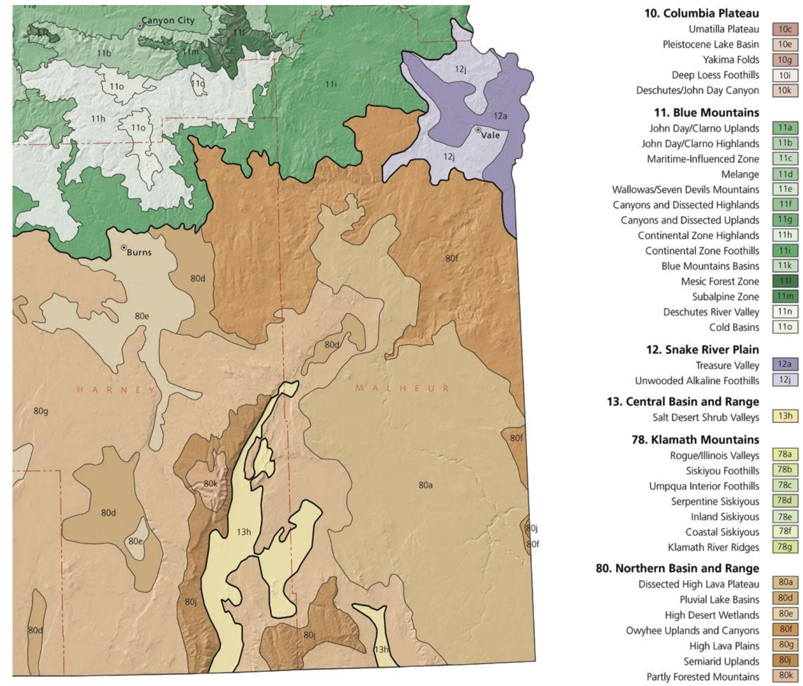


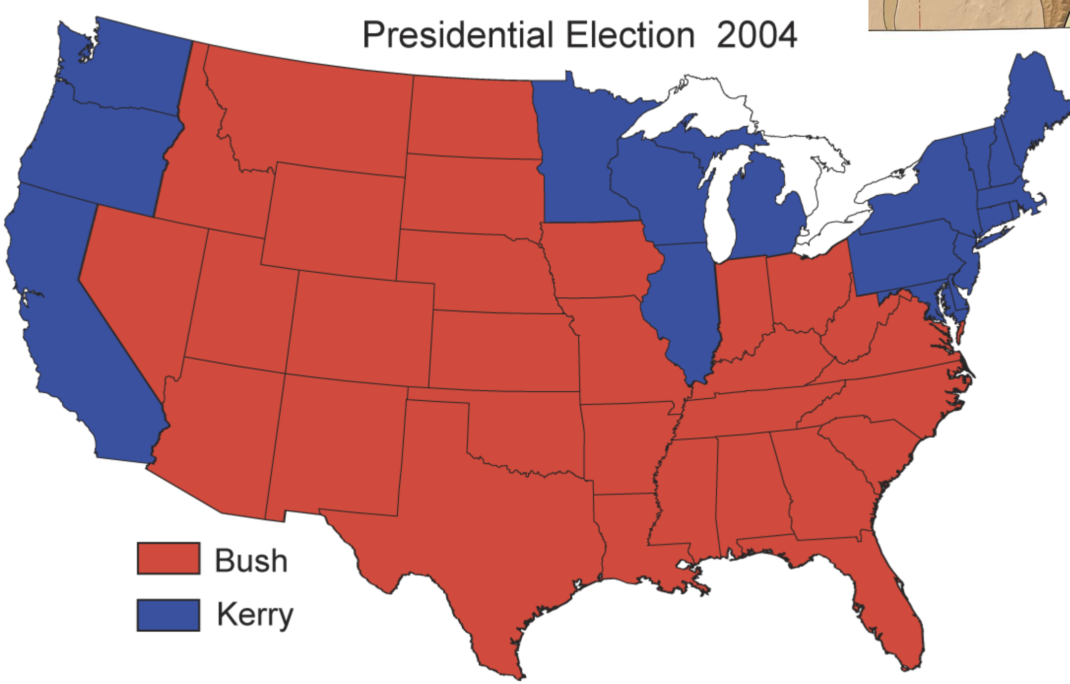
Canyon City
11b
11m
11l
11o
11i
11h
12j
12a
Vale
Burns
80d
80e
80f
H A R N E Y
M A L H E U R
80g
80k
80a
13h
80j
10. Columbia Plateau
Umatilla Plateau 10c
Pleistocene Lake Basin 10e
Yakima Folds 10g
Deep Loess Foothills 10i
Deschutes/John Day Canyon 10k
11. Blue Mountains
John Day/Clarno Uplands 11a
John Day/Clarno Highlands 11b
Maritime-Influenced Zone 11c
Melange 11d
Wallowas/Seven Devils Mountains 11e
Canyons and Dissected Highlands 11f
Canyons and Dissected Uplands 11g
Continental Zone Highlands 11h
Continental Zone Foothills 11i
Blue Mountains Basins 11k
Mesic Forest Zone 11l
Subalpine Zone 11m
Deschutes River Valley 11n
Cold Basins 11o
12. Snake River Plain
Treasure Valley 12a
Unwooded Alkaline Foothills 12j
13. Central Basin and Range
Salt Desert Shrub Valleys 13h
78. Klamath Mountains
Rogue/Illinois Valleys 78a
Siskiyou Foothills 78b
Umpqua Interior Foothills 78c
Serpentine Siskiyous 78d
Inland Siskiyous 78e
Coastal Siskiyous 78f
Klamath River Ridges 78g
80. Northern Basin and Range
Dissected High Lava Plateau 80a
Pluvial Lake Basins 80d
High Desert Wetlands 80e
Owyhee Uplands and Canyons 80f
High Lava Plains 80g
Semiarid Uplands 80j
Partly Forested Mountains 80k

Figure 7.11

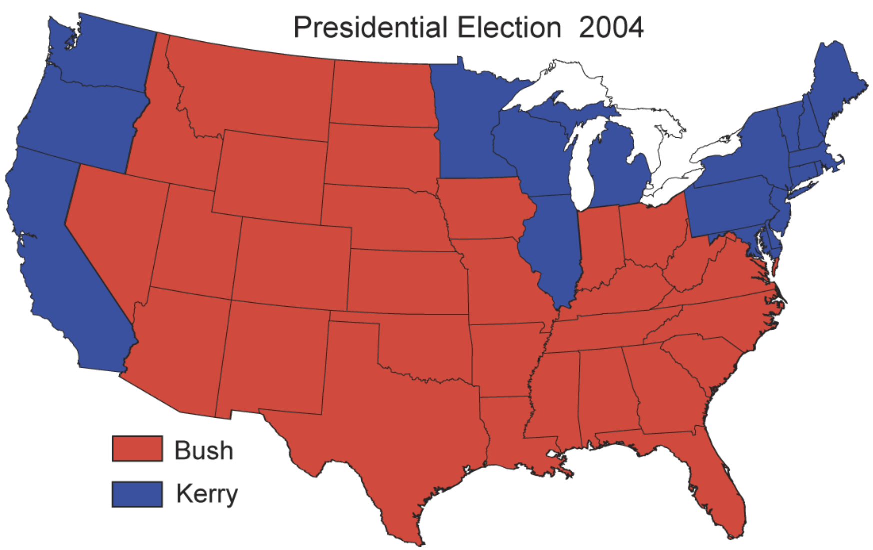
Ecoregions

- **Figures 7.10 and 7.11 exemplify two basic types of qualitative thematic maps** that differ in the kind of data collection areas being mapped, though both use color hue as the primary visual variable

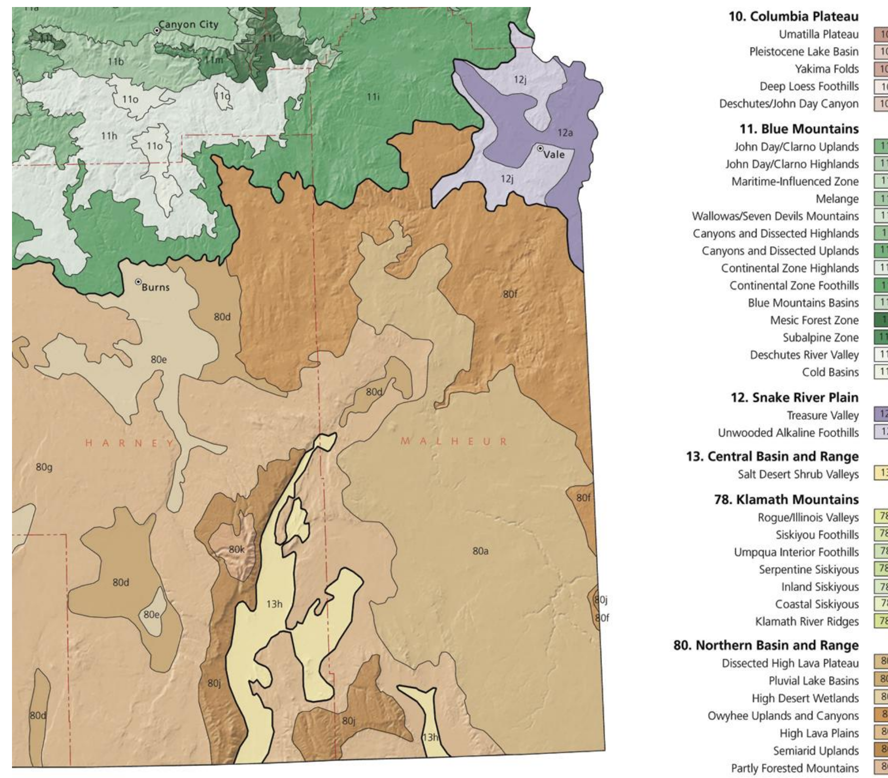

Canyon City
Burns
Vale
HARNEY
MALHEUR
10. Columbia Plateau
Umatilla Plateau
Pleistocene Lake Basin
Yakima Folds
Deep Loess Foothills
Deschutes/John Day Canyon
11. Blue Mountains
John Day/Clarno Uplands
John Day/Clarno Highlands
Maritime-Influenced Zone
Melange
Wallowas/Seven Devils Mountains
Canyons and Dissected Highlands
Canyons and Dissected Uplands
Continental Zone Highlands
Continental Zone Foothills
Blue Mountains Basins
Mesic Forest Zone
Subalpine Zone
Deschutes River Valley
Cold Basins
12. Snake River Plain
Treasure Valley
Unwooded Alkaline Foothills
13. Central Basin and Range
Salt Desert Shrub Valleys
78. Klamath Mountains
Rogue/Illinois Valleys
Siskiyou Foothills
Umpqua Interior Foothills
Serpentine Siskiyous
Inland Siskiyous
Coastal Siskiyous
Klamath River Ridges
80. Northern Basin and Range
Dissected High Lava Plateau
Pluvial Lake Basins
High Desert Wetlands
Owyhee Uplands and Canyons
High Lava Plains
Semiarid Uplands
Partly Forested Mountains


Presidential Election 2004
Bush
Kerry

- This type of map is often called a **categorical map** – a map that has polygons enclosing areas assumed to be uniform or areas to which a single description can apply



The **ecoregion map in figure 7.11** is an example of **mapping area features** that are inherently **homogeneous** in some way, such as having the same bedrock geology, soils or vegetation



Multivariate Maps

- Most qualitative thematic maps use a separate symbol to represent each category
- But sometimes mapmakers show several attributes of the feature within the same symbol on a multivariate map

Multivariate Maps

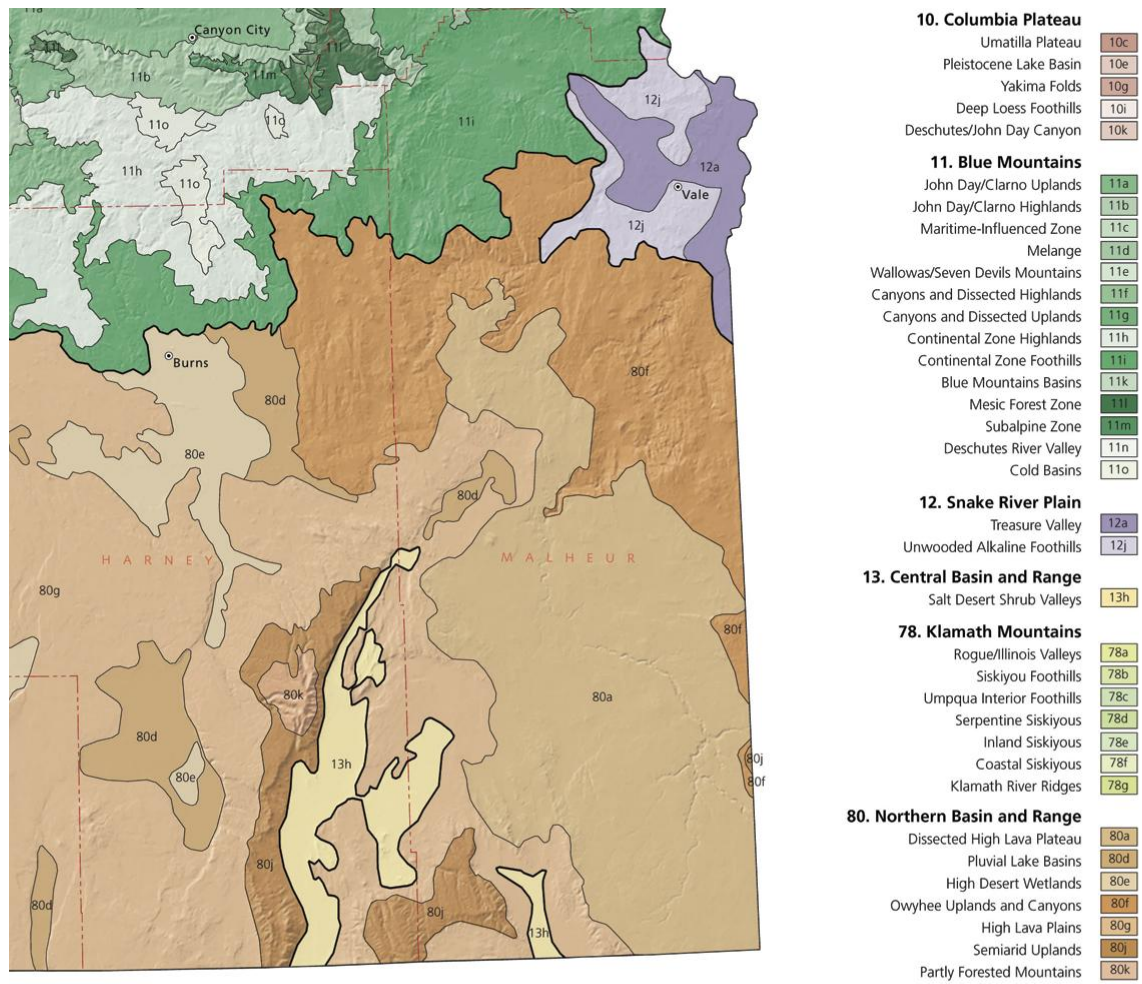
- In theory, mapmakers could show **four different qualitative attributes** at once by varying the symbol's shape, hue, pattern and orientation
- **In practice**, symbols showing even two or three feature attributes can be very difficult to read if they are not created carefully

Multivariate Maps

- **With the second method** of symbolizing multivariate information, mapmakers show a concept defined by a **composite of attributes** rather than raw data for a single theme

Multivariate Maps

- This is the case with the ecoregion map in figure 7.11

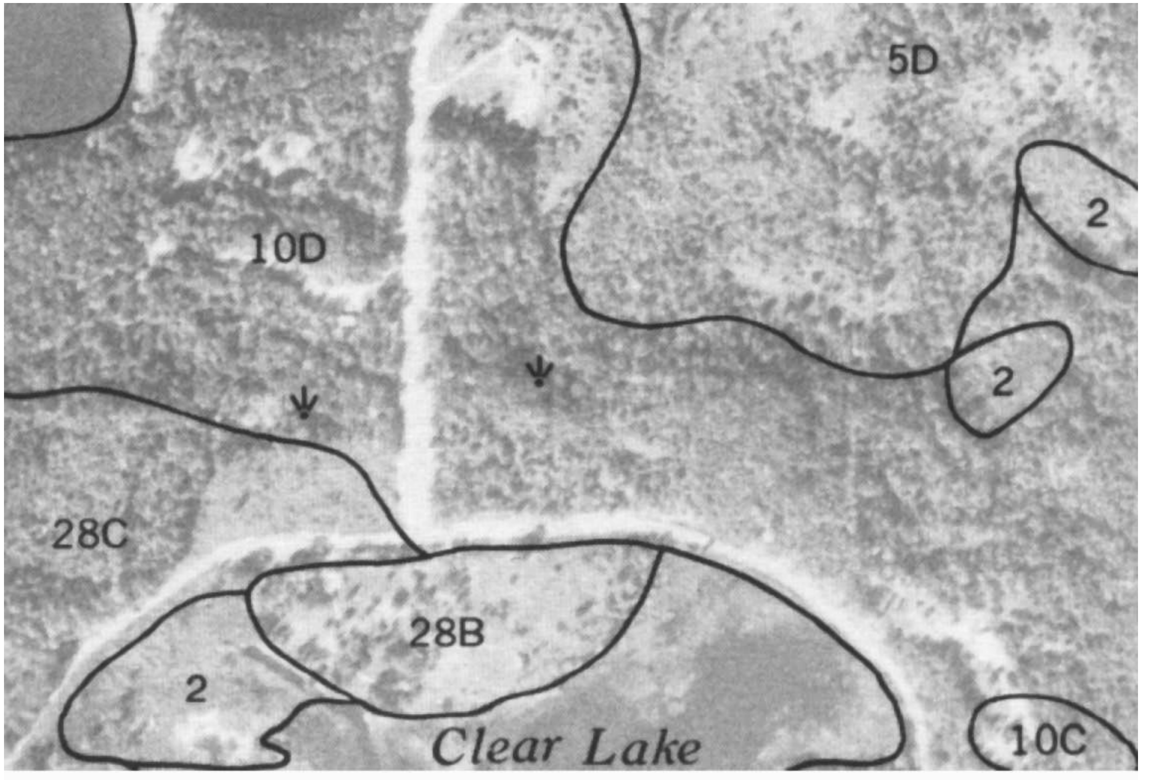


Ecoregion

- The concept of an ecoregion is defined by:
  - **Temperature**
  - **Precipitation**
  - **Vegetation**
  - **Soils geology**
  - **Human influences on the landcape**

Ecoregion

- Similarly, the concept of a soil class is defined by a set of soil attributes, including:
  - **Slope**
  - **Depth**
  - **Drainage**
  - **Color**
  - **Texture**



Soil Types

2 -- Ponded histosols & aquents
5D-- Spinks loamy sand; 12-18% slope
10C-- Hillsdale sandy loam; 6-12% slope
10D-- Hillsdale sandy loam; 12-18% slope
28B-- Riddle sandy loam; 2-6% slope
28C-- Riddle sandy loam; 6-18% slope

Figure 7.12

Multivariate Point Symbols

- Mapmakers like to use **point symbols** to show **multivariate qualitative information** because they can pack information into each symbol by **combining several visual variables**
- The resulting symbol is sometimes referred to as a **glyph**

Multivariate Point Symbols

- Some multivariate point symbols are **pictographic**, but most are **geometric**
- **For example**, the symbols for landfills and dumps shown in figure 7.13 are circles and squares

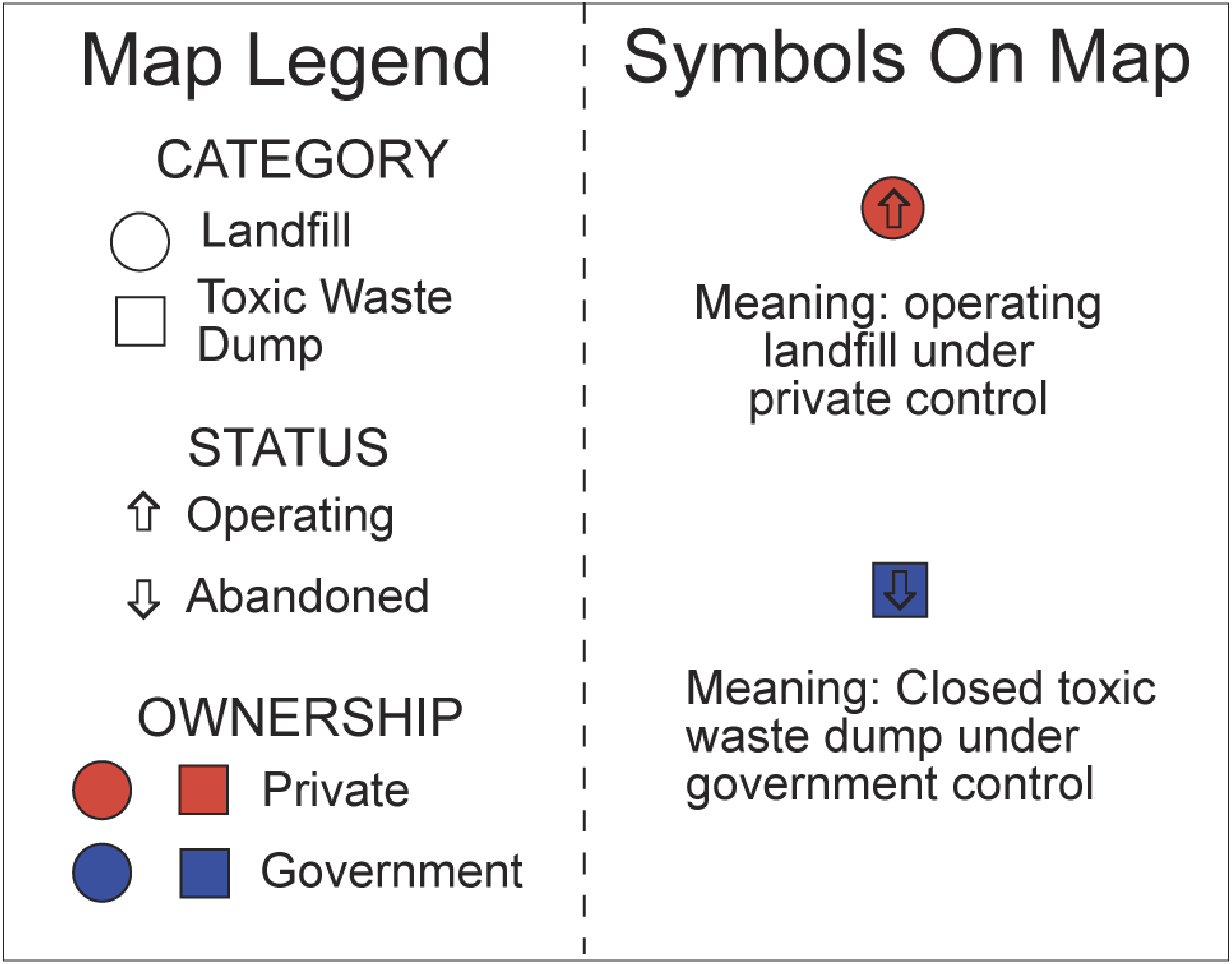

Map Legend
CATEGORY
Landfill
Toxic Waste Dump
STATUS
Operating
Abandoned
OWNERSHIP
Private
Government
Symbols On Map
Meaning: operating landfill under private control
Meaning: Closed toxic waste dump under government control

Figure 7.13

Multivariate Point Symbols

- **For instance**, they may use two shapes, such as a **star within a circle**, which is a common way to show capitol cities
- *More often they will show two different attributes of a feature with two different qualitative visual variables as in figure 7.13*

Multivariate Line Symbols

- **For example**, road maps may be enhanced with multivariate data
- It’s common to see highway maps with **red lines for freeways**, **black lines for state highways** and **gray lines for US or state highways**
- Sometimes these single variable line symbols are augmented to show a **second variable**

Multivariate Line Symbols

- These are called **cased line symbols** as the interior line is bounded by a casing that is shown in a different color
- **For example**, **road categories** might be shown by different hues, and the casing lines could be patterned as solid, dashed, or dotted lines to show where the roads are in tunnels or on bridges

Multivariate Area Symbols

- Mapmakers can make **qualitative multivariate maps** for **area features** in a number of ways
- One **common method** is to **overlap two types** of area symbols that are appropriate for nominal data

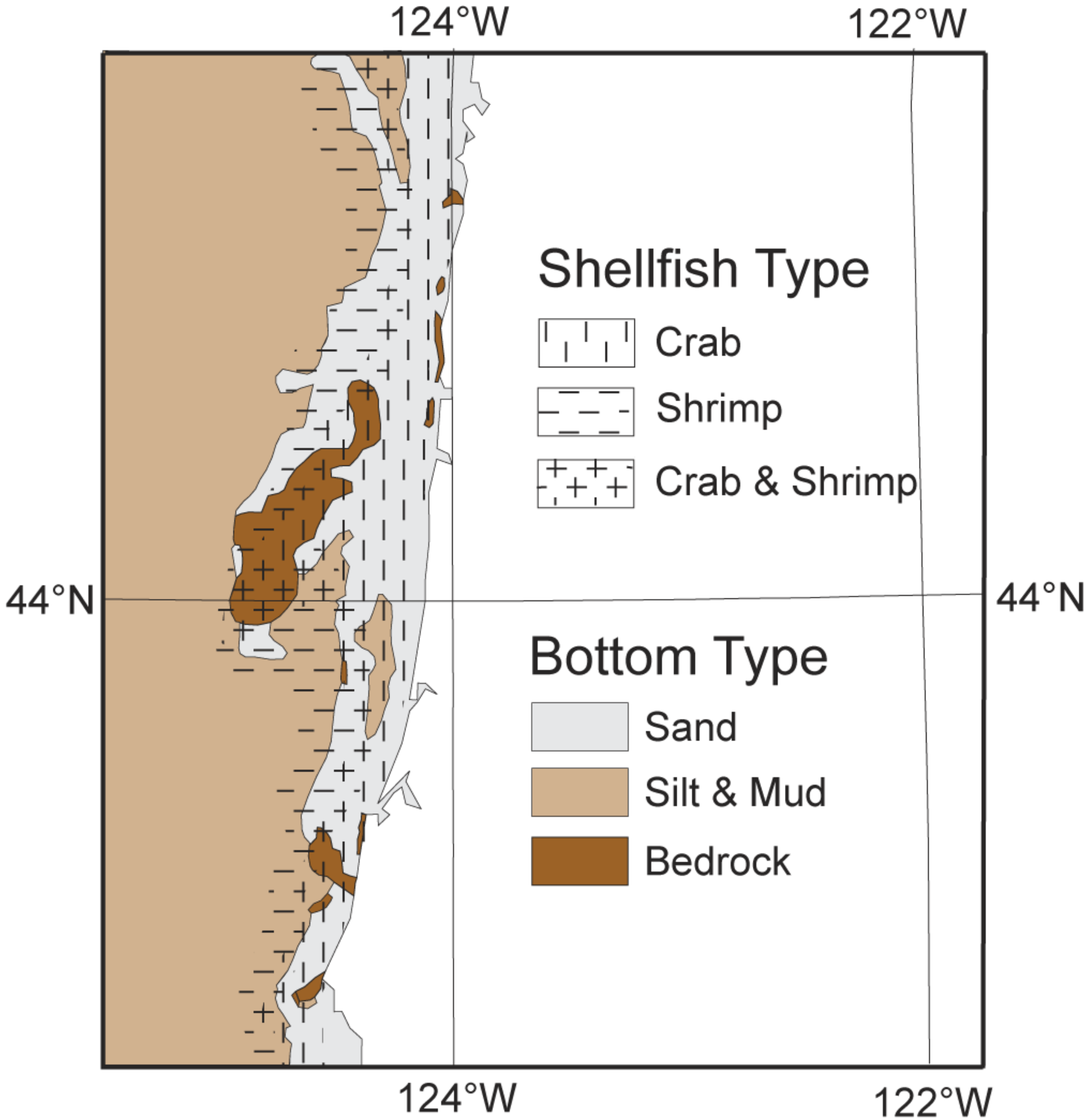

124°W
122°W
Shellfish Type
Crab
Shrimp
Crab & Shrimp
44°N
44°N
Bottom Type
Sand
Silt & Mud
Bedrock
124°W
122°W

Figure 7.14

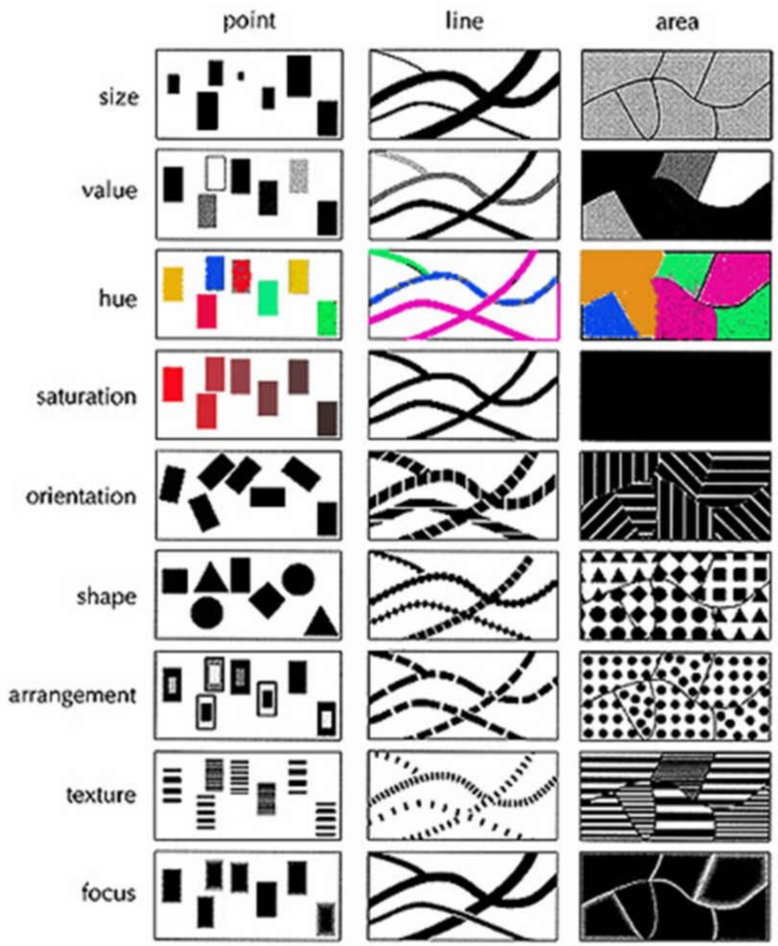
Multivariate Area Symbols

- On other maps, **two different hues**, such as yellow and blue are used for two different categories so that their **area of overlap** is seen as the hue combination – in this case green

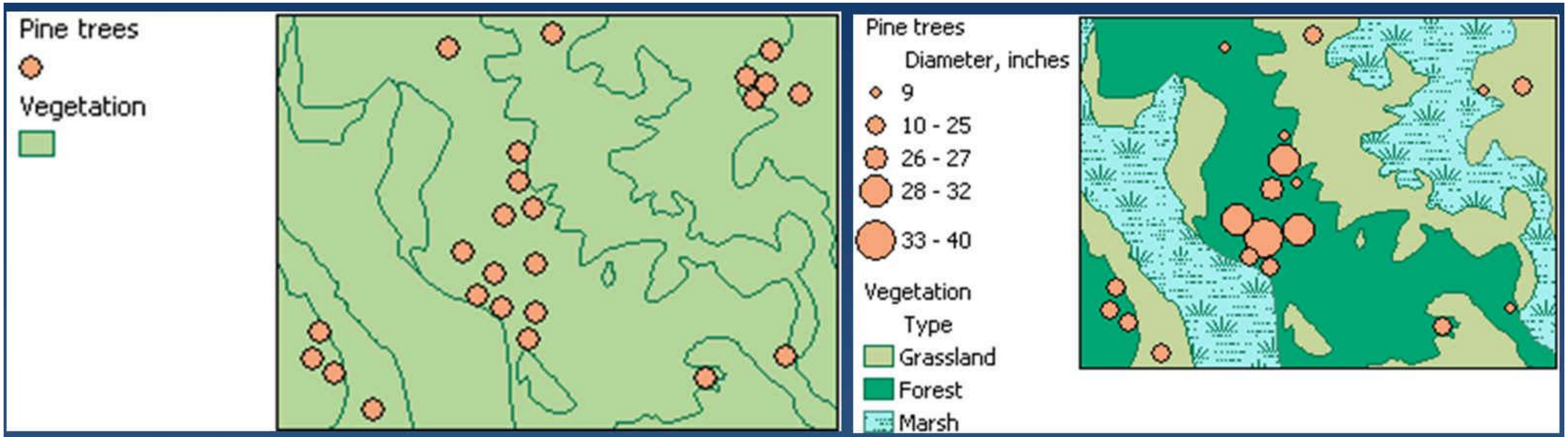
Multivariate Area Symbols

- Could you predict what hue should be used to show the overlap between an area symbolized with purple and another shown in green?
- **In such cases**, it’s necessary to refer to the map legend to see what each hue represents

Visual Variables



Representing Attribute Values



- All features of a layer are the same
- Differentiation according to feature's attribute value

Representing Categories