First Edition

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Mastering ArcGIS Pro

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MASTERING ArcGIS PRO

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Preface

Welcome to *Mastering ArcGIS Pro*, a detailed primer on learning the latest ArcGIS™ software by Esri®, Inc. This book is designed to offer everything you need to master the basic elements of GIS.

A new text for a new GIS experience

Although the concepts of GIS have remained fairly constant over time, the software is continually evolving. With the release of ArcGIS Pro, the latest software in the Esri GIS family, a new generation of GIS has arrived. ArcGIS Pro has a 64-bit, multithreaded architecture, uses ribbon-style menus, integrates 2D and 3D applications, and is closely tied to ArcGIS Online.

This text constitutes a major rewrite of *Mastering ArcGIS*, a book that covered GIS concepts and skills using the ArcGIS Desktop programs of ArcMap and ArcCatalog. Although the GIS concepts largely remain the same in both texts, the implementation, and in some cases the terminology, has changed. The new software has also prompted a reorganization of the book in several important ways.

First, the book has been refocused on the basics of GIS. The ArcGIS Pro software capabilities are improving with each new version but have not yet completely matched the capabilities of ArcMap. Partly for this reason, and partly to better match the rhythm of a semester, the book is now presented in 12 chapters, leaving time for instructors to better incorporate exams and projects within the semester. Some of the more advanced and less frequently used skills, such as planar topology and standards-based metadata, have been left for students to explore on their own.

Second, the book includes some new topics. Raster data management has been discussed in a new chapter to acquaint students with compiling and processing raster data sets, supplementing a similar chapter on vector data management. ArcGIS Pro was designed to foster the sharing of GIS data and workflows, and these enhanced capabilities are explored in another new chapter, including how to prepare a database for collecting data using mobile devices.

Third, the chapters and topics have been reorganized to eliminate some repetition and to present the information more logically. The text still roughly follows the project model with data management presented first and analysis second.

The tutorials, questions, and exercises have been rewritten. I have tried to incorporate more open-ended and creative questions in the exercises, rather than relying on cut-and-dried questions and answers. Although this approach makes grading a little harder for instructors, I believe it enhances student learning and makes the exercises more interesting.

I would like to thank the many people who have used and commented on *Mastering ArcGIS*, and I have tried to take those lessons to heart. I hope that this text continues to serve their needs in the rapidly evolving world of GIS.

Previous experience

This book assumes that the reader is comfortable using Windows™ to carry out basic tasks such as copying files, moving directories, opening documents, exploring folders, and editing text and word processing documents. Previous experience with maps and map data is also helpful. No previous GIS experience or training is necessary to use this book.

Elements of the package

This learning system includes a textbook and web site, including

- Twelve chapters on important concepts in GIS data management and analysis
- Comprehensive tutorials in every chapter to learn the skills, with each step demonstrated in a video clip
- A set of exercises and data for practicing skills independently

This book assumes that the student has access to ArcGIS Pro and an organizational account for ArcGIS Online. The Spatial Analyst extension is required for Chapter 11.

Philosophy

This text reflects the author's personal philosophies and prejudices developed from 20 years of teaching GIS at an engineering school. The main goal is not to train geographers but to provide students in any field with GIS skills and knowledge. It is assumed that most students using this book already have a background of discipline-specific knowledge and skills upon which to draw and are seeking to apply geospatial techniques within their own knowledge domains.

- **Concepts and skills are both important.** Students must be able to understand the geographic and database concepts that are integral to spatial data management and analysis. It is not enough to know a series of software steps; one should understand the "why" behind them.
- **GIS is best learned by doing it.** The tutorials constitute a critical component of the book, integrating theory with practical experience and promoting a hands-on, active learning environment.
- **Independent work and projects are critical to learning GIS.** This book includes exercises that encourage students to find solutions independently without a cookbook recipe of steps. A wise instructor will also require students to develop an independent project.

Chapter sequence

The book contains an introduction and 12 chapters. Each chapter includes roughly one week's work for a three-credit semester course. An introductory chapter describes GIS and gives some examples of how it is used. It also provides an overview of GIS project management and how to develop a project. Chapters 1 through 11 follow a roughly project-based sequence: mapping basics, data compilation and management, and spatial analysis. The final chapter explores sharing GIS work with others. These chapters are the core of an introductory GIS class and, by the end of it, students should have little difficulty developing and carrying out an independent GIS project.

Chapter layout

Each chapter is organized into the following sections:

- **Concepts:** provides basic background material for understanding geographic concepts and how they are specifically implemented within ArcGIS. Most chapters have two sections, one (About GIS) covering general GIS concepts and theory, and another (About

ArcGIS) covering the specific implantation of those concepts within ArcGIS Pro. A set of review questions and important terms follows the concepts section.

- **Tutorial:** contains a step-by-step tutorial demonstrating the concepts and skills. The tutorials begin with detailed instructions, which gradually become more general as mastery is built. Every step in the tutorial is demonstrated by accompanying video clips.
- **Exercises:** presents a series of problems to build skill in identifying the appropriate techniques and applying them without step-by-step help. Through these exercises, the student builds an independent mastery of GIS processes. Brief solution methods are included for all exercises, and maps of the results are shown when applicable. A full answer and methods document is available for instructors at the McGraw-Hill Instructor web site.

The book web site, http://www.mhhe.com/Price_pro1e, also contains all the data needed to follow the tutorials and complete the exercises.

Instructors should use judgment in assigning exercises. The typical class would be stretched to complete all the exercises in every chapter. Very good students can complete an entire chapter in 3 to 6 hours, most students would need 6 to 8 hours, and a few students would require 10 or more hours. Students with more computer experience generally find the material easier than others.

Using this text

In working through this book, the following sequence of steps is suggested:

- READ through the Concepts sections to get familiar with the principles and techniques.
- ANSWER the Chapter Review Questions to test comprehension of the material.
- WORK the Tutorial section for a step-by-step tutorial and explanation of key techniques.
- REREAD the Concepts section to reinforce the ideas.
- PRACTICE by doing the Exercises.

Using the tutorial

The tutorial provides step-by-step practice and introduces details on how to perform specific tasks. Students should be encouraged to think about the steps as they are performed and not just race to get to the end.

It is important to follow the directions carefully. Skipping a step or doing it incorrectly may result in a later step not working properly. Saving often will make it easier to go back and correct a mistake in order to continue. Occasionally, a step will not work due to differences between computer systems or software versions. Having an experienced user nearby to identify the problem can help. If one isn't available, however, just skip the step and move on without it.

Using the videos

The web site contains videos of each tutorial step. They are numbered in the text for easy reference. The videos are intended as an alternate learning strategy. It would be tedious to watch all of them. Instead, use them in the following situations:

- When a student does not understand the written instructions or cannot find the correct menu or button
- When a step cannot be made to work properly

- When a reminder is needed to do a previously learned skill in order to complete a step
- When a student finds that watching the videos enhances learning

Using video and data components

To view the videos:

The videos are embedded in the electronic version of the text, and they are also available for download from the book's web site. Each chapter may be downloaded separately.

To install the training data:

The gisclass_Pro1e.zip archive contains a folder with the documents and data needed to do the tutorials and exercises. Students must extract this folder to their own hard drives. If more than one person on the computer is using this book, then each person should make a personal copy of the data in a separate folder. The data require approximately 360 MB of disk space.

Extracting the zip file creates a folder named gisclass. It should be extracted to a location on the C:\drive. Do not install it in a user Documents folder or on the Desktop because GIS data often function poorly in those locations.

System requirements

Hardware:

ArcGIS Pro requires a PC 64-bit multiprocessor machine with at least a dual core, and a quad core processor or higher is recommended. Pro requires a minimum of 8 GB of RAM and a good graphics card with at least 2 GB of RAM and 24-bit display color depth.

For a complete description of the system requirements, consult Esri (http://pro.arcgis.com/en/pro-app/get-started/arcgis-pro-system-requirements.htm).

Software:

Windows 10 (64-bit Home, Pro, or Enterprise) or Windows 8.1 (64-bit Pro or Enterprise)

ArcGIS Pro™ 2.1.2 or higher (Basic Level); Spatial Analyst extension required for some exercises

A web browser, such as Chrome, Edge, Firefox, or Internet Explorer

A zip utility such as WinZip or 7zip

A media player that can display the .mp4 video format

Other:

Pro is tightly coupled to ArcGIS Online (AGOL), a cloud-based system built to encourage sharing of GIS data, workflows, and other resources between organizations and users. It is strongly recommended that the users have at least a public account, and a subscription account provides access to significantly more data and tools. A subscription account with publishing privileges is required for some optional exercises in Chapter 12.

Internet access is required for ArcGIS Pro installation and for exercises requiring the use of ArcGIS Online.

For assistance in acquiring or installing these components, contact your system administrator, hardware/software provider, or local computer store.

Acknowledgments

I would like to thank many people who made this book possible. Governor Janklow of South Dakota funded a three-month summer project in 2000 that got the original *Mastering ArcGIS* book started, as part of his Teaching with Technology program. Many students in my GIS classes between 2000 and 2018 tested the text and exercises and helped immensely in making sure the tutorials were clear and worked correctly. Reviewers of previous editions of *Mastering ArcGIS*, including Richard Aspinall, Joe Grengs, Tom Carlson, Susan K. Langley, Henrietta Loustsen, Xun Shi, Richard Lisichenko, John Harmon, Michael Emch, Jim Sloan, Sharolyn Anderson, Talbot Brooks, Qihao Weng, Jeanne Halls, Mark Leipnik, Michael Harrison, Ralph Hitz, Olga Medvedkov, James W. Merchant, Raymond L. Sanders, Jr., Yifei Sun, Fahui Wang, Michael Haas, Jason Kennedy, Dafna Kohn, Jessica Moy, James C. Pivirotto, Peter Price, Judy Sneller, Dave Verbyla, Birgit Mühlenhaus, Jason Duke, Darla Munroe, Wei-Ning Xiang, L. Joe Morgan, Samantha Arundel, Christopher A. Badurek, Tamara Biegas, John E. Harmon, Michael Hass, Nicholas Kohler, David Long, Jaehyung Yu, Sarah Battersby, Gregory S. Bohr, Kelly R. Dubure, Colleen Garrity, Raymond Greene, Joe Grengs, Eileen Johnson, James Leonard, and Tao Tang, provided detailed and helpful comments, and the book is better than it would have been without their efforts.

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Esri, Inc., was prompt and generous in its granting of permission to use the screen shots, data, and other materials throughout the text. I extend heartfelt thanks to the City of Austin, Texas, for putting their fine GIS data sets in the public domain. I thank George Sielstad, Eddie Childers, Mark Rumble, Tom Junti, and Patsy Horton for their generous donations of data. I am grateful to Tom Leonard and Steve Bauer for their long-term computer lab administration, without which I could not have taught GIS courses or developed this book. I thank the McGraw-Hill team working on this new first edition, especially Michael Ivanov and Jodi Rhomberg. I am grateful to Daryl Pope, who first started me in GIS, and to John Suppe, who encouraged me to return to graduate school and continue doing GIS on a fascinating study of Venus. I thank Charles R. Bacon, with whom I was privileged to work on the geologic map of Crater Lake. I thank my partner, David Stolarz, who provided unfailing encouragement when it seemed as though the writing of this new edition would never end. Last, and certainly not least, I thank Curtis Price and my daughters, Virginia and Madeleine, for their understanding and support during the many, many hours I spent working on this book.

Chapter 2. Mapping GIS Data

Objectives

- Using properties of symbols to differentiate features or rasters in maps
- Distinguishing among nominal, categorical, ordinal, and ratio/interval data
- Creating maps from attributes using different map types
- Selecting appropriate classification methods when displaying numeric attributes
- Displaying thematic and image rasters
- Understanding the relationship between a layer and its source data set

Mastering the Concepts

GIS Concepts

Geographic Information Systems are used for many purposes, but creating maps is one of the most common. The practice of cartography, or mapmaking, has a long history. Although a computer makes the process easier and offers the ability to explore and edit designs, the cartographer must still understand the basic principles behind portraying spatial data and the aesthetic challenges in designing an effective and attractive way to communicate ideas.

Choosing symbols for maps

Cartographers may choose from many strategies to symbolize features in a map. A layer may simply be portrayed using one symbol, or different features can be assigned different symbols depending on the value of an attribute field. Point data are shown with marker symbols, line features with linear symbols, and polygon features with shaded area symbols (Fig. 2.1).

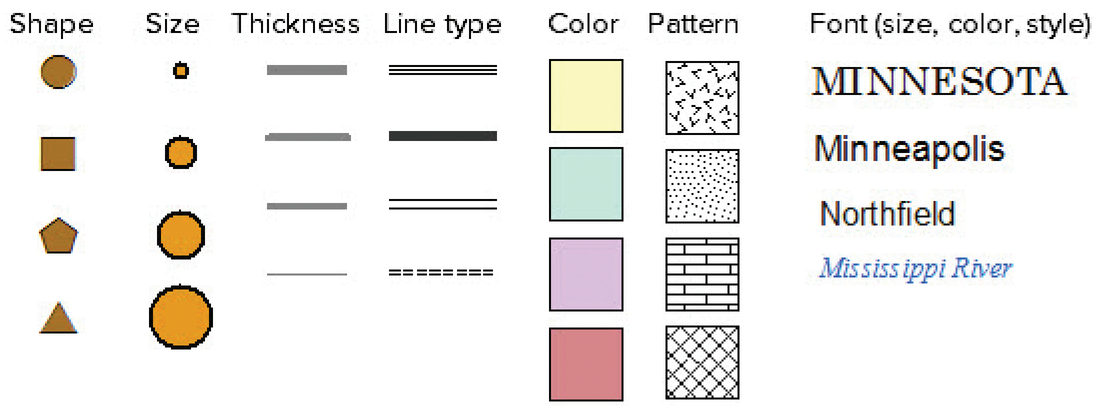

Fig. 2.1. Variations in symbols used to differentiate objects in a map

Cartographers have many ways to signify differences between features in a map: shape, size, thickness, line type, color, pattern, and font (Fig. 2.1). Traditionally these variations are used to show either changes in category (the type of thing) or changes in quantity. Shape, line type, pattern, and font are typically used to show changes in category, such as different types of wells (points), different classes of roads (lines), or different soil units (polygons). Size and thickness are generally used to indicate increases in quantity, such as the population of a city (points) or the discharge of a river (lines) (Fig. 2.1). Text symbol variations usually indicate categories (towns vs. rivers), although font size can indicate qualitative differences in value, such as town size, as long as not too many different sizes are used.

Color may be used to indicate either category or quantity. Colors may be designated using one of several common methods. The **CMYK** model is often used for printing, and it specifies mixtures of inks used in printers or plates (cyan, magenta, yellow, black).

The **RGB** model is based on mixing different proportions of red, green, and blue light on a scale from 0 to 255. If the value of the red light is high (close to 255) and the other two colors have low values near zero, a bright red color will result. If red and green are both high and blue is low, a mixture of red and green will create yellow. (Mixing light is a different process than mixing paint, and different colors will result.) Figure 2.2 shows two possible mixtures and the resulting colors. The RGB model can specify 256^3 different colors (over 16 million).

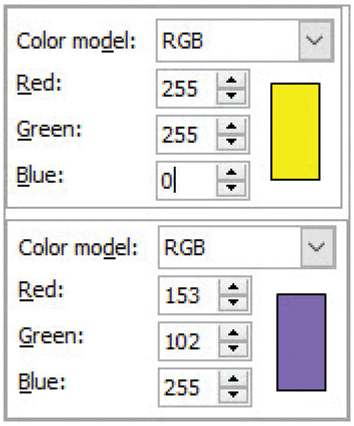

Fig. 2.2. Computers store and identify colors as mixtures of red, green, and blue light, each measured on a scale from 0 to 255.
Source: Esri

The **HSV** method is instructive for discussing the use of color in portraying features on a map. HSV stands for **hue**, **saturation**, **and value** (Fig. 2.3). **Hue** refers to the shade of color (such as red, blue, or yellow) and is established by the wavelength of the light observed. Typically hue is portrayed as a color wheel so that the color values range in degrees from 0 to 360. **Saturation** corresponds to the intensity of the color and is measured as a percentage. Imagine mixing a can of paint, starting with a white base and adding a single pigment—a small amount of pigment yields a low saturation, but a large amount of pigment results in high saturation. **Value** refers to how light or dark the color is, somewhat like putting pigment into a can of base paint that varies from black through gray to white. Value is also measured as a percentage. Any color can be defined using a combination of the three properties.

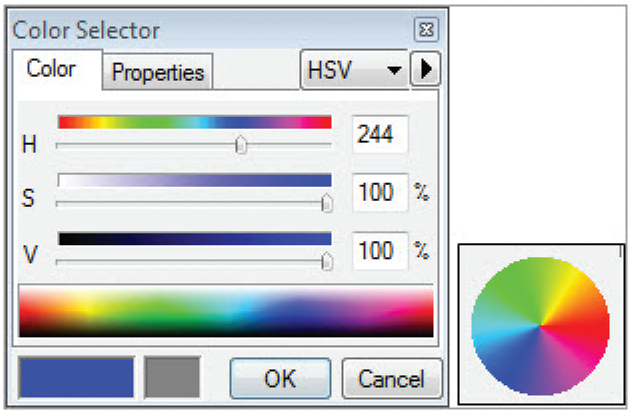

Fig. 2.3. Hue, saturation, and value method of defining color
Source: Esri

A fourth parameter, named **alpha**, may be used with either the RGB or HSV model. It refers to the opacity of a color, or the degree to which it is transparent or see-through, like tinted glass. A zero value indicates that the color is fully transparent, and the highest value, which may be represented either as DN = 255 or 100%, means it is not transparent at all.

The set of colors chosen for a map layer should follow certain guidelines. Figure 2.4 shows three different sets of five colors. A set based on variations in hue should be used to depict changes in category, such as different soil units (Fig. 2.4a). For categories, the saturation and value of the colors should be similar. Quantities are generally indicated using differences in saturation or value, with light or unsaturated colors indicating lower quantities

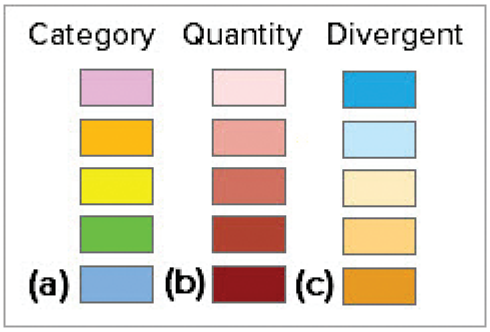

Fig. 2.4. Color ramp variations

and darker or more intense colors indicating higher quantities (Fig. 2.4b). Sometimes a **divergent color set** is helpful in showing variation around a significant middle value (Fig. 2.4c), such as in a climate change map. Areas with no significant temperature change are shown in the middle neutral color, colder temperatures are shown in blue, and warmer temperatures are shown in orange.

The importance of black-and-white symbol schemes cannot be neglected. In commercial printing or copying, color still costs more than black and white. Publishing figures in professional journals or reports may also cost significantly more in color. One should consider, too, how most viewers will see the map. Figures in a master's thesis may look wonderful in color, but some of the people reading it may receive a black-and-white version from inter-library loan. There are many reasons why one might wish to design a map in black and white at the outset. In a black-and-white map, only four or five different shades of gray are typically discernible, so symbol selection relies heavily on variations in shape, size, thickness, line type, or pattern rather than value.

Combinations of these factors may also be used when specifying symbols, such as using points that change in both shape and color, polygons that change color and pattern, or text that has differences in size and font and style. However, combinations should be used sparingly, as the more complex and varied the symbols become, the more difficult it may be to interpret them. In Figure 2.5, both volcanoes and highways are shown using combinations of color, shape, and size (thickness). The combinations serve to accentuate differences within the layer and could be used to emphasize one type of feature, such as using a larger, saturated pink symbol to call attention to the stratovolcanoes. However, this strategy would backfire if multiple point layers were being displayed because it would become difficult to interpret which features belonged to which point layer.

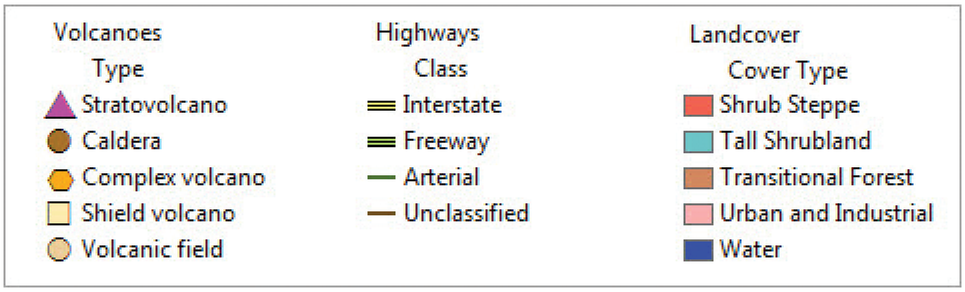

Fig. 2.5. Examples of categorical data representation for points, lines, and polygons

Color choice is complicated by the fact that about 10% of men and 1% of women are color-blind. Different types of color blindness are possible, although red-green color blindness is the most common. If layers are being symbolized for data exploration by one person, then the user may employ any set of colors that aids in the interpretation of the data. However, if the maps are intended for use by many people, it is better to avoid red-green color sets and rely on saturation, value, pattern, and shape variations instead. If divergent colors or multiple hues are needed, combinations such as brown-purple or orange-blue can be interpreted by most color-blind viewers.

Cartographers also need to be sensitive to conventions and connotations associated with different colors or symbols. A **convention** refers to the use of a particular color or symbol in a commonly understood way; for example, using blue to display water, blue and red to contrast cold with heat, or a blue cross to indicate a hospital. Conventional symbols help readers to interpret the map. **Connotation** is an emotional or psychological impact associated with a particular symbol, such as the color red indicating danger, or red, white, and blue evoking feelings of patriotism. However, connotations are often culturally specific. Red may indicate danger in the United States, but it is associated with joy in Thailand and with national pride in China. Making maps for an international audience demands particular care and knowledge in the choice of colors and symbols. Context can matter as well; even in the United States, a red-green map at Christmas might engender more joy than fear.

Types of data and types of maps

Geographers, statisticians, and others characterize measurements or attributes as belonging to one of a set of data types: **nominal, categorical**, **ordinal**, **interval**, or **ratio**. The type of data affects how it should be stored in a database and what types of analyses or statistics are appropriate. In mapping, the data type also influences the kind of map used to display the feature attributes.

Nominal data name or identify objects, such as the names of states. Nearly every feature will have a different name. Nominal data are often text values, but they don't have to be: a parcel number or a tax identification number also serves the purpose of uniquely identifying an object. Nominal data are usually portrayed on a map by labels. Each layer typically has one text symbol, but different text symbols may be used to accentuate different layers, such as using all uppercase for state names or italic blue text for rivers.

Categorical data separate features into distinct groups or classes. Figure 2.5 shows examples of categorical data for point features (volcano type), linear features (road class), and polygon features (land cover). Other examples include soil types, ethnic groups, and geological rock formations. Categorical data are often stored as text, but it is also possible to represent the categories with numeric codes, such as Commercial Services = 20 and Industrial = 40. Categorical data are represented by a **unique values map**, which gives each category a different symbol based on shape, line type, color, or pattern (Fig. 2.5) as shown in the geological rock units map in Figure 2.6.

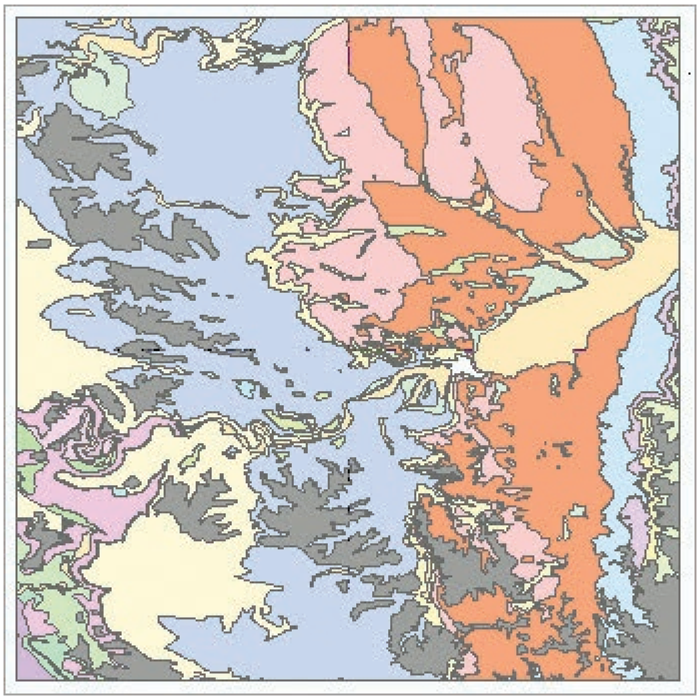

Fig. 2.6. A unique values map based on geological rock types
Source: South Dakota Geological Survey

Ordinal data have categories that are ranked based on some quantitative measure, although the measure may not be linear. For example, urban settlements might be classified as villages, towns, or cities. Students are assigned grades of A, B, C, D, or F. Soils are designated as A, B, C, or D depending on their infiltration. Ordinal data must be represented by unique values maps if the values are text, but value or saturation should be varied instead of hue or pattern so that the quantitative increase can be easily interpreted. Numeric ordinal data may be represented either with unique values maps or graduated color maps.

Quantitative data represent phenomena that fall along a regularly spaced measurement scale, such as distance or rainfall. Equal changes in interval involve equal changes in the quantity being measured. For example, the energy needed to heat a thimble of water from 16 to 17°F is the same as that needed to heat it from 96 to 97°F. **Ratio data** have a meaningful zero point that indicates the absence of the thing being measured. Precipitation is an example of ratio data; zero precipitation corresponds to a total lack of rain, and two inches of rain is twice as much as one inch. Ratio data support all four arithmetic operations of addition, subtraction, multiplication, and division. **Interval data** have a regular scale but are not related to a meaningful zero point. Temperature data measured in the familiar Celsius or Fahrenheit scale are interval data because a temperature of

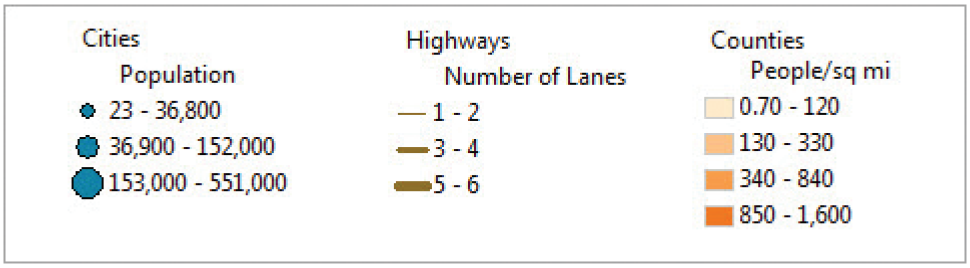

Fig. 2.7. Examples of numeric data representations for points, lines, and polygons

zero does not correspond to a complete lack of temperature (heat energy). Any scale that can have negative values, such as elevation, is an interval scale. Interval scales support only addition and subtraction. Today's high temperature of 80°F might be hotter than yesterday's high of 40°F, but it cannot be said to be twice as hot, except as a figure of speech.

Quantitative numeric data take on values along a continuous scale of possibilities; every state, for example, has its own population value. In order to symbolize numeric data, the values must be partitioned into groups with specific ranges.These ranges are called classes, and the maps are called classified maps. In Figure 2.7, the cities and roads have three classes of values, and population density has four classes. Each class is symbolized using variations in symbol size, thickness, or color saturation or value.

Point or line data are usually displayed by varying symbol size or thickness and are portrayed using a **graduated symbol map**. However, point or line data can also be portrayed using a **proportional symbol map** in which the numeric value is used to proportionally determine the size of the symbol. Instead of a few size classes, the map has a continuous range of symbol sizes. This style is often referred to as an unclassed map. Figure 2.8 compares graduated symbol and proportional symbol maps for the populations of state capitals.

Numeric data classes for polygons are represented using color-shaded symbols (Fig. 2.9); the resulting maps are called **graduated color maps** or **choropleth maps**. The maps are usually symbolized using changes in value or saturation (with a monochromatic color ramp) so that the increase in quantity is clear, as shown in the county population map in Figure 2.9a. Although rainbow color ramps are popular in software packages, using them for graduated color maps is usually a mistake because it is difficult for the mind to interpret hues as representing larger or smaller quantities (Fig. 2.9b). Generally the eye cannot distinguish between more than seven or eight levels of the same color, so no more than that number of classes should be used.

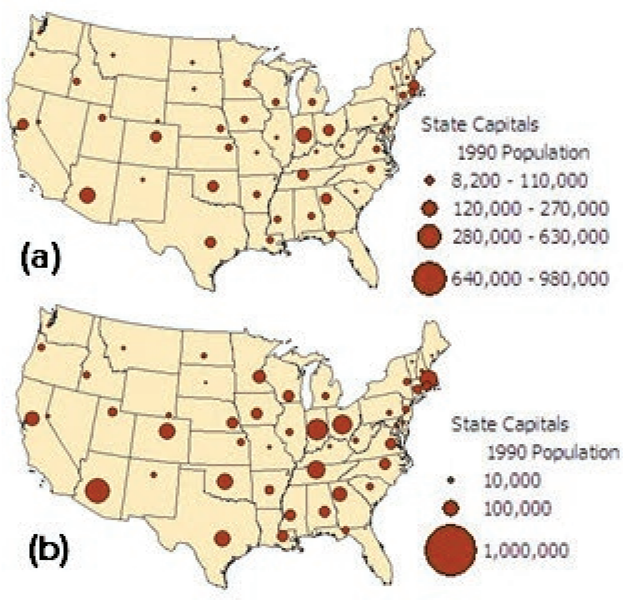

Fig. 2.8. Comparison of (a) a graduated symbol map and (b) a proportional symbol map showing the populations of state capitals
Source: Esri

The modifiable areal unit problem

Data are often measured over one set of areal units, such as a census block, but then combined, or **aggregated,** into a set of larger areal units, such as block groups, tracts, and counties. When the measurement and aggregation units are arbitrary shapes and sizes instead of a regularly spaced grid, the size and shape of units will influence the recorded values. For some measurements, such as the number of farms or lightning strikes, units with larger areas tend to have higher values just because they are larger. In Figure 2.10a, the number of farms is greater in the bigger states like Texas and California. Certain variables, such as the number of home vacancies, are strongly linked to population, and maps made from them reflect population rather than giving insight into underlying patterns. In Figure 2.10b, the largest and most populous states have the most vacancies.

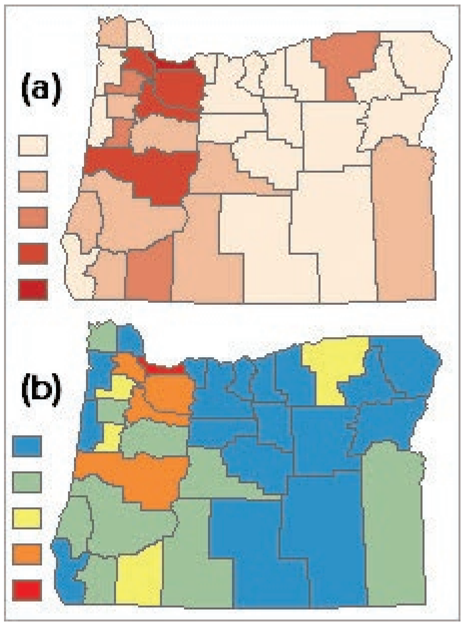

Fig. 2.9. A choropleth map showing population by varying (a) saturations and/or value, and (b) hue
Source: Esri

Another issue that can arise is that larger polygons receive greater prominence in the map simply because of their size. In Figure 2.10, the large western states attract more attention than the eastern states. Both of these issues are examples of a phenomenon known as the **modifiable areal unit problem**, or **MAUP**, which occurs when measurements are being aggregated over arbitrarily defined areas. Analyzing spatial or statistical patterns becomes more difficult because the patterns are obscured by the aggregation scheme. However, methods to reduce the effects of MAUP on maps are available.

One approach is to **normalize** the data, dividing each value by a specified variable. If one is concerned that the size of the aggregation area is influencing the magnitude of values, one can divide by the feature area as shown in Figure 2.11a, where the number of farms is divided by state area (compare to Fig. 2.10a). If the values are being influenced by population, then one can divide by population or other suitable variable, as in Figure 2.11b, where the vacancies are divided by the number of housing units, giving a far more interesting and informative map than Figure 2.10b. Another normalization method, less commonly used, shows percentages of the total quantity falling in each feature; Figure 2.11c shows the percentage of Congress controlled by each state, accomplished by showing the number of districts in each state as a percentage of the total number of districts.

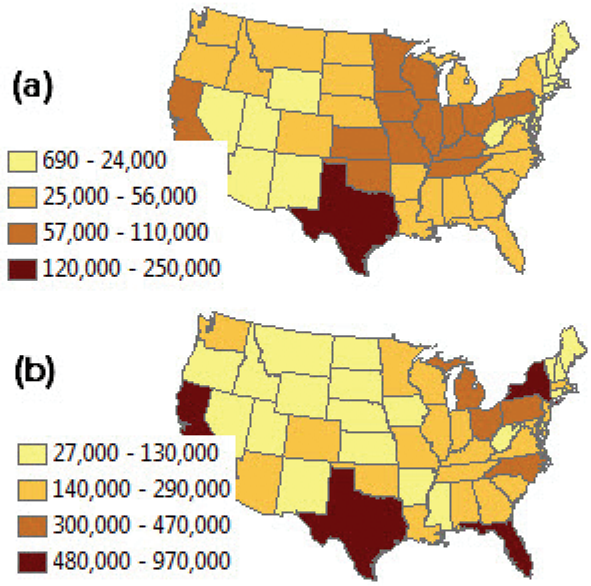

Fig. 2.10. (a) Number of farms; (b) number of vacant housing units
Source: Esri

However, not all attributes need normalization. In a precipitation map, each value already represents inches of rain falling at any location. The median rent for a county does not depend directly on the area of the county. These attributes would not be normalized. Before mapping any attribute, it is important to stop and consider how the aggregation unit might affect the map and determine whether the values should be normalized, and by what.

The visual MAUP issue, which occurs when large polygons dominate the map, can be addressed by changing the map type. A graduated symbol map applied to polygons places a symbol at the center of each polygon, minimizing the visual imbalance, as shown in a graduated symbol map of the density of farms (Fig. 2.12a; compare to Fig. 2.11a). A **dot density map** uses randomly placed dots to show the magnitude of a value in the attribute table (Fig. 2.12b). Each dot represents a certain number; in this map, 2000 farms. Note that the locations of the dots, which are randomly placed, do not necessarily represent the distribution of farms in the state.

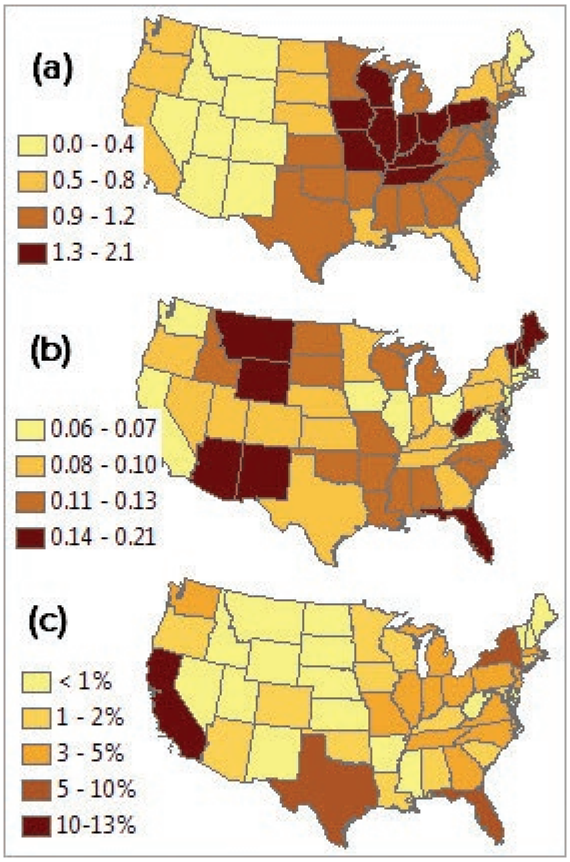

Fig. 2.11. (a) Farms normalized by state area; (b) vacancies normalized by housing units; (c) percentage of Congress controlled by each state
Source: Esri

Chart maps

A **chart map** expands the number of attributes that can be displayed on a map by replacing a single symbol with a chart representing several attributes. The chart could be a pie chart, bar chart, or stacked bar chart. Figure 2.13 shows a pie chart map with the proportions of Caucasians, African Americans, and Hispanics in each state. The pie sizes can be all the same (Fig. 2.13a) or proportional to the sum of the three categories, thus showing the relative number of people in the state as well (Fig. 2.13b). Notice how the pie colors are chosen to facilitate recognition of the classes: cream for Caucasians, dark brown for African Americans, and reddish for Hispanics. Such details help make maps easier for the reader to interpret, and they lessen the need for the reader to look back and forth between the legend and the map.

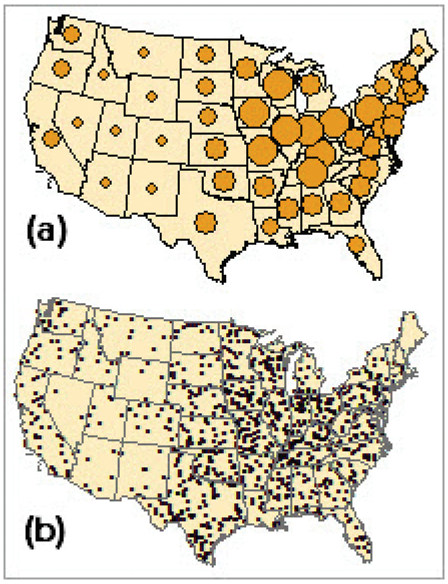

Fig. 2.12. Number of farms shown using (a) an area-normalized graduated symbol map or (b) a dot density map
Source: Esri

Displaying rasters

Recall from Chapter 1 that the raster model is a cell-based data model in which an array of cells or pixels store numeric values relating to some feature or quantity on the earth's surface. Rasters may be broadly grouped into three main types, each of which is displayed differently: thematic rasters, image rasters, and indexed rasters.

Thematic rasters

A **thematic raster** represents features or quantities, such as roads, geology, elevation, or vegetation density (Fig. 2.14). The raster model is designed to store **continuous** values that may occur anywhere on the earth's surface, such as elevation. However, they may also store **discrete** objects, such as roads or land use polygons. Thus we can speak of a raster as being a continuous or a discrete raster.

Values in a raster are always stored as numbers and may be characterized as categorical, ordinal, or interval/ratio. (Nominal data are not stored in rasters—it would be inefficient.) The methods used to display thematic rasters are similar to those used for displaying vector data and also depend on the data type.

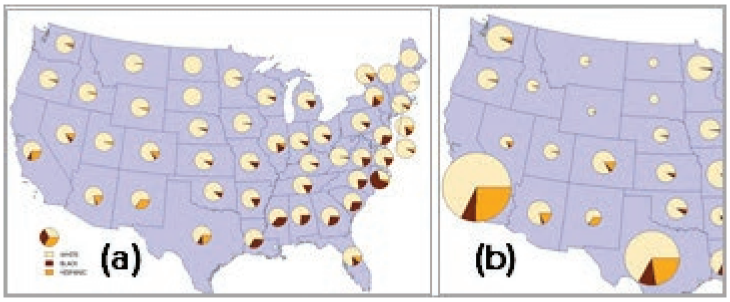

Fig. 2.13. (a) A chart map can represent several attributes, such as the proportion of ethnic groups. (b) The pie size can represent the total population.
Source: Esri

A discrete raster representing categorical or ordinal data is displayed using a unique values map. Just like the unique

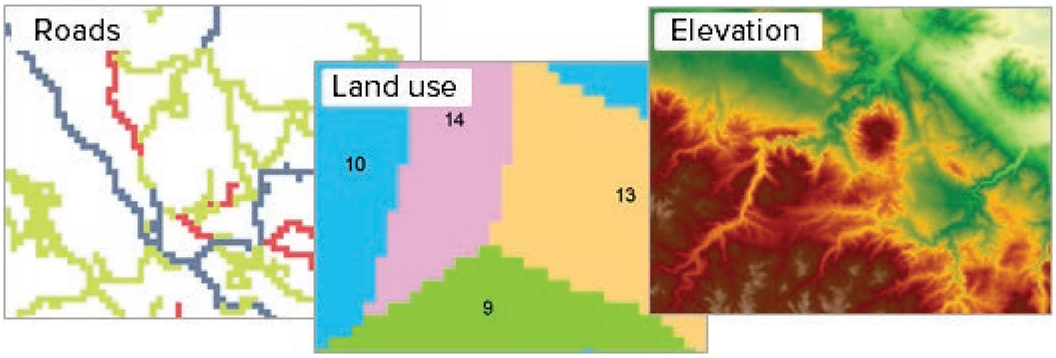

Fig. 2.14. Thematic rasters. Discrete rasters store feature data, such as road types or land use polygons. Continuous rasters store values that exist everywhere, such as elevation.
(Roads): Source: Black Hills National Forest; (Land use and Elevation): Source: USGS

values map used for data sets, each value of the raster receives its own color, as in the geology map shown in Figure 2.15a. Color schemes for unique values maps have 32 possible values and work best with data that have relatively few categories. When representing ordinal data, a monochromatic color scheme is used to communicate a sense of increase.

A thematic raster containing interval or ratio data must be classified into ranges in one of two ways. The **classified** display method divides the values into a small number of bins, similar to

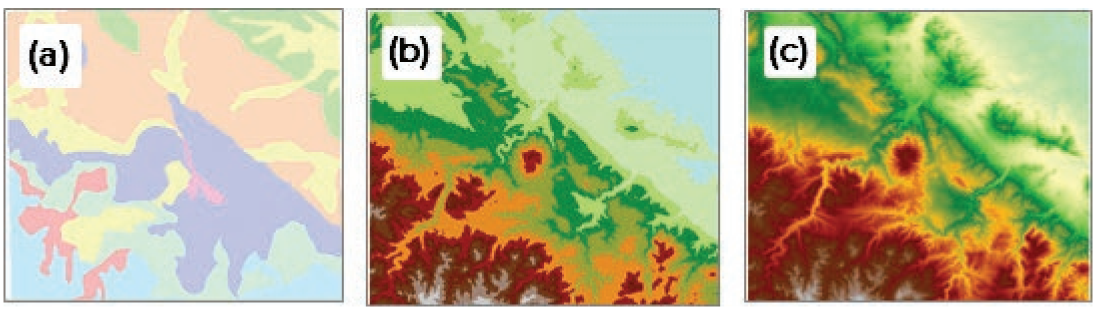

Fig. 2.15. Display methods for thematic rasters: (a) unique values geology; (b) classified elevation; (c) stretched elevation
(a): Source: South Dakota Geological Survey; (b-c): Source: USGS

a graduated color map. A color ramp is chosen to assign the colors to each bin. The elevation map in Figure 2.15b has 12 classes represented by 12 colors from a color ramp. The **stretched** display method scales the image values to a color ramp with 256 shades (Fig. 2.15c). The raster is first subjected to a **slice**, which rescales the elevation values (ranging from 800 to 1600 m) into 256 bins, then matches the bins to the 256 shades in the color ramp. A slice is essentially a classification that creates 256 classes.

The colorful ramps, like those in the elevation rasters in Figure 2.15, ignore the guideline to use saturation or value rather than hue to represent quantities, yet the eye has no trouble interpreting the elevation increase. Continuous rasters typically represent surfaces with an underlying structure, such that low values occur near low values and high ones near high. This structure imposes a visual order and allows the eye to interpret the greater number of colors. Such ramps are not suitable for features or all rasters, but they can be effective when appropriate.

The property that values close to each other tend to be more similar than values farther apart is present, to a greater or lesser extent, in many geographic data sets. It is so common, in fact, that this property is often called the first law of geography, or **Tobler's law**. Not only does it play a role in data visualization, as discussed previously, but it is also a fundamental factor in spatial analysis.

Image rasters

Image rasters include aerial photography and satellite data. The pixels represent degrees of brightness caused by light reflecting from materials on the surface. The brightness values are usually placed on a scale of 0 to 255 DN (digital numbers). If one brightness value is given to each pixel, the image is usually displayed with a grayscale ramp; a dark shadow would have a low brightness and a low DN, and a white cement road would have a high brightness and a high DN (Fig. 2.16a). Such images are displayed using the same **stretched** method that is applied to continuous thematic rasters. Images based on the 0 to 255 scale do not need to be sliced, but some images contain larger values and do require slicing. To display a color image, each pixel is given three DN values representing red, green, and blue light, thereby specifying a unique color combination, as discussed earlier. This display method is called an **RGB composite** (Fig. 2.16b).

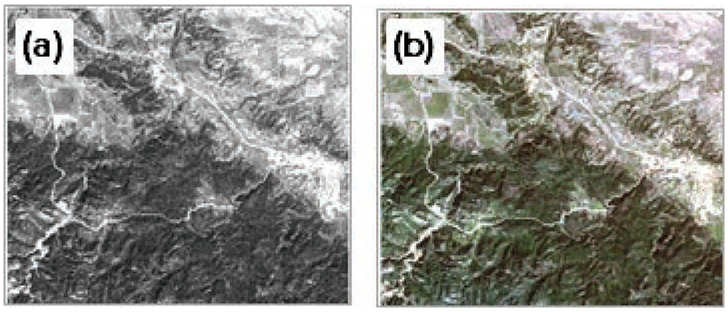

Fig. 2.16. Raster display methods for images: (a) stretched image; (b) RGB composite image.
Source: USGS

Stretching image values

Image DN values are often normally distributed. Figure 2.17a shows a typical **histogram** of cell values, with the horizontal axis showing the range of values with the corresponding grayscale color ramp and the vertical axis showing the number of cells for each value (color). The image has few values near 0 or 255, with most of the pixels occurring in the middle gray range. The image is shown in Figure 2.17b, and it appears dim and featureless with little contrast.

The **stretched** display method can improve the display of normally distributed values by ignoring the tails of the distribution. One method assigns the lowest and highest image values to 0 and 255, respectively, and stretches the remaining colors along the ramp. This is called a minimum-maximum stretch. Even greater contrast can be developed using a standard-deviation stretch, which uses only the values within two standard deviations of the mean (Fig. 2.17c).

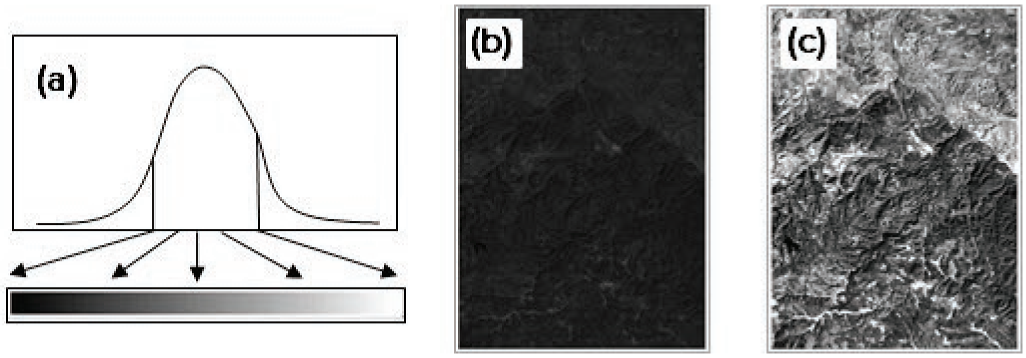

Fig. 2.17. The effects of stretching: (a) stretching an image histogram; (b) no stretch applied; (c) a standard-deviation stretch
(b–c): Source: USGS

Stretches can be applied to thematic continuous rasters as well as images and can be helpful when the image values are not evenly distributed.

Indexed color rasters and colormaps

The RGB color model is capable of storing millions of different colors and is best for fine rendering of images. However, it uses large amounts of memory and storage space. An alternate method for storing color identifies a restricted set of colors that appear in the image. It assigns an integer from 0 to 255 to each color and stores the RGB proportions needed to make it. This list of colors is called the **colormap** and is stored with the image. Each value in the raster is portrayed using its assigned color. Figure 2.18 shows part of a digital raster graphic (DRG). A DRG is a scanned US Geological Survey topographic map. The contours are represented by pixels with the value 4 and displayed using the assigned brown color. Every pixel value and defined color used in the map is shown in the accompanying colormap: green for vegetation, black for text, and so on.

Fig. 2.18. An indexed-color raster stores a colormap that assigns a color to each value in the raster.
Source: USGS

Indexed color rasters are commonly produced when scanning large color maps. Storing them in RGB could use hundreds of megabytes or more. An indexed-color map typically uses less than a tenth of the space needed for an RGB map, and the eye cannot easily distinguish between the two.

Classifying numeric data

Mapping numeric data, raster or vector, requires classifying a range of values into a small number of groups, each of which can be represented by a different color or symbol size. This process is called **classification**. There are many ways to classify data, and the choice of method affects the appearance of the map and the message that it portrays. Some common methods are compared in Figure 2.19 using the same data set of average farm size by state.

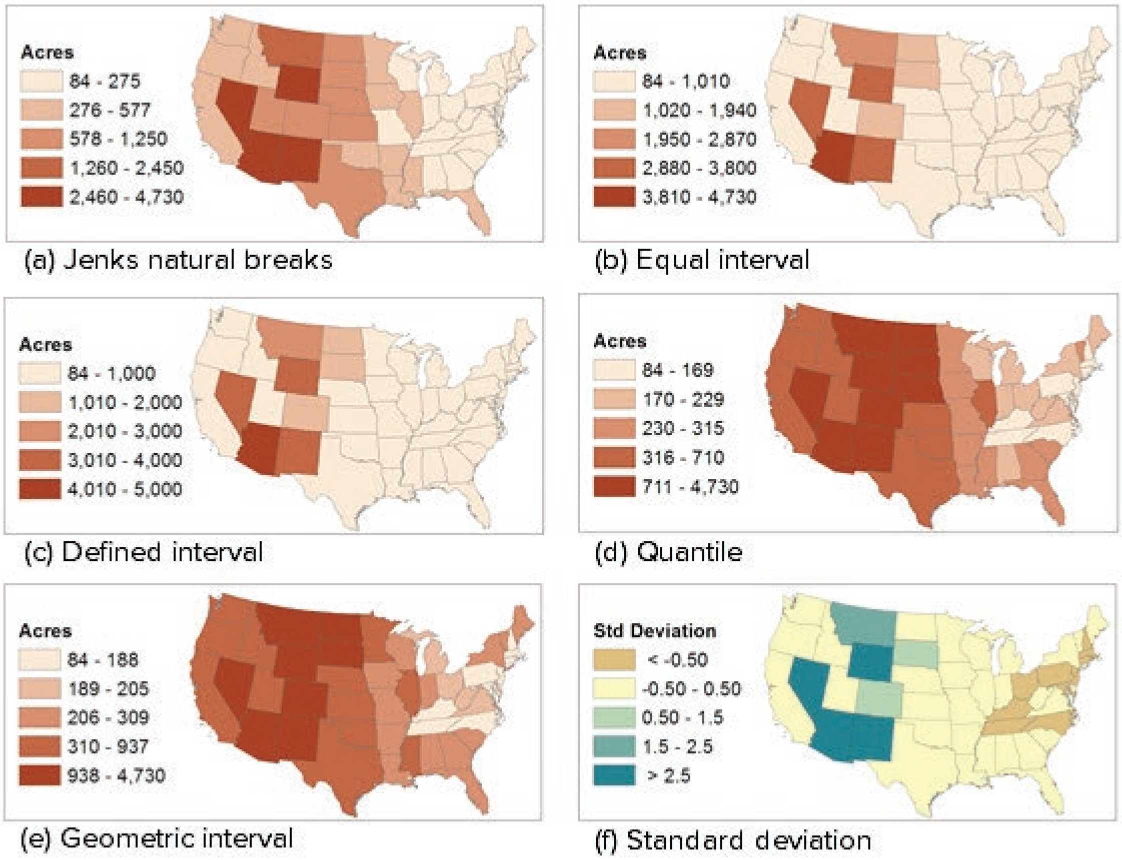

Fig. 2.19. Comparison of different classification methods using the same data set of average farm size in acres by state

Source: Esri

The **Jenks method** sets the class breaks at naturally occurring gaps between groups of data (Fig. 2. 19a). Each class interval can have its own width, and the number of features in each class will vary. The Jenks method works well on unevenly distributed data, such as populations of the capitals shown in Figure 2.8. There are many low-population and medium-population capitals and a few very high-population capitals. The Jenks method works well with almost any data set, making it a natural choice for the default classification scheme in ArcGIS Pro.

The **equal interval** classification divides the values into a specified number of classes of equal size (Fig. 2.19b). This method is useful for ratio data, such as income or precipitation, because it gives a sense of regularity to the observed increases. However, it is hard to predict how many features will end up in each class. Notice in the farm size example that nearly all of the states fall into the first class. Compare this map to Figure 2.19a.

A **defined interval** classification is similar to an equal interval one, except that the user specifies the size of the class interval, and the number of classes then depends on the range of values (Fig. 2.19c). This method will create rounded values in the classes that are easy to interpret. Defined interval maps are ideal when comparing classes composed of percentages, dollars, temperatures, and other values when specific break values are desired (100, 200, etc.). It does, however, suffer the same disadvantages as the equal interval classification.

A **quantile** classification puts about the same number of features in each class (Fig. 2.19d) and enables the display of groups, such as quartiles, commonly of interest in statistics. This method will create a balanced map with all classes equally well represented, but some of the features in the same class could have very different values, and features in different classes could have similar values. Quantile classifications are best applied to uniformly distributed data. Notice that a quantile classification highlights differences between the eastern states that are hidden in the Jenks, equal interval, and defined interval classifications.

A **geometric interval** classification (Fig. 2.19e) bases the class intervals on a geometric series in which each class is multiplied by a constant coefficient to produce the next higher class. A geometric interval classification is designed to work well with continuous data like precipitation and to provide about the same number of values in each class range. It works especially well with positively skewed data distributions.

A **standard deviation** classification apportions the values based on the statistics of the field. The user selects the class breaks as the number of standard deviations, and the data range determines the number of classes needed. This method excels at highlighting which values are typical and which are outliers, especially since a divergent color set is used to accentuate below- versus above-normal values. In Figure 2.19f, the yellow states are close to the mean farm size, several eastern states appear to have smaller-than-average farms, and some western states have much larger farms than average. This map is best applied to normally distributed data.

Finally, if none of the preceding options gives the desired map, the user can manually set class break points to any chosen values. This option works for assigning a logarithmic or exponential scale as well.

Choosing the classification method

The choice of classification method depends on the mapmaker's purposes and on the type of data. Jenks shows the "nearest neighbors" in a distribution, whereas a defined interval or equal interval map does a better job of portraying relative magnitude. Notice the difference between the maps in Figures 2.19a and 2.19b. The Jenks map gives the impression that many states have large farms because the class sizes increase slowly; an equal interval map shows that farms in most states actually average 1000 acres or less. Figure 2.19b makes this observation clear at first glance.

Some data possess the quality that the magnitude of the values has an intrinsic meaning. Percentage data, for example, have a physical and a psychological meaning—people have an intuitive understanding of the difference between 50% and 100%. Differences in median rent occur in dollar values to which people can attach meaning. When dealing with such data, it is wise to use a defined interval map to choose classes with logical break points, such as 20%, 5 inches of rain, or $200, rather than 12.6%, 1.47 inches of rain, or $187. The reader can more effectively interpret the classes.

The distribution of values has impact also. Jenks and geometric interval classifications are designed to work well with unevenly distributed data. Equal interval, defined interval, and quantile maps can be used with any data but show better results with evenly distributed data. The statistics behind standard deviation maps assume that the data are normally distributed.

About ArcGIS

Layers

When a data set is added from a folder to a map in ArcGIS Pro, we call it a **layer**. Although we tend to think of these layers as data sets, there is actually an important distinction. When a picture is inserted in a Word document or a slide show, a *copy* of the picture is stored inside the document, so it is always there if the document gets copied or e-mailed. Even if the original picture is deleted from the hard drive, the copy remains in the document. We are accustomed to this treatment of information, so it is difficult to realize that Pro does NOT treat map data this way. We will learn more about the reasons in Chapter 5.

When data are added to a map, no copy is made. The information remains in its original location, and the map layer simply points to it. The original data on which the layer is based are known as the **source data**. When a layer's properties are changed, such as giving it labels or displaying it with different colors, the source data set does not change. The layer finds the source data each time and manipulates them within the map to produce the desired effect. A layer is like a cooking recipe—it describes where to find the data file (the ingredients) and how to display it (the cooking instructions). The information in the layer, such as which symbols should be used and whether the features have labels, is called the **layer properties**. Layers are held in memory and stored when the project is saved. If the source data set is deleted, renamed, or moved, the map will be unable to display it.

When working in Pro, it is important to always remember that a layer and the geospatial data it references are different objects. The data set may be stored on a disk, or it may come through a portal from ArcGIS Online or another server. ***A layer points to the location of a geospatial data set and stores information about how to display and use it***. The same data set can be accessed by multiple layers and maps to present different views of the same information, whether within a single map, within the same project, or across many maps created by different users. Figure 2.20 shows a counties data set stored on a network drive; the same data set has been used by several students in their projects.

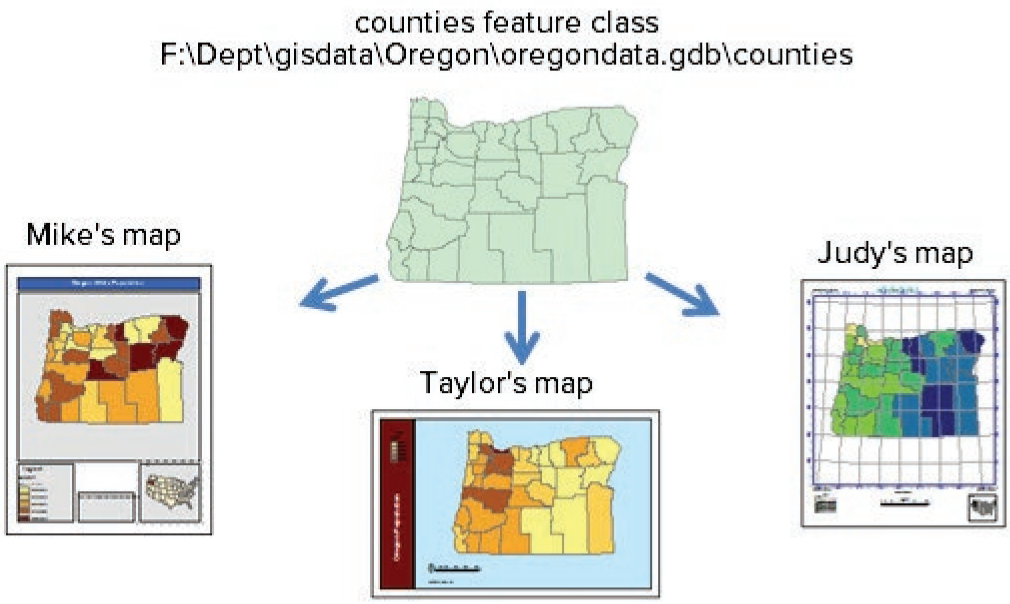

Fig. 2.20. The same feature class can be used in many maps, even by different people.
Source: Esri

A layer may be saved as a **layer file**. This file stores the location of the referenced data set and the properties of the layer. Saved layer files can be used to quickly add a layer with predefined symbols to a map document. Group layer files can organize multiple layers with predefined symbols into thematic maps or base maps. Geologic map symbols, for example, use many specific colors and patterns and can take hours to set up.

In Figure 2.21, a user has combined different sizes, colors, and even shapes to produce a specific classification that shows the arsenic values for water wells, with x indicating values below the detection limit, blue circles to show values less than the Environmental Protection Agency (EPA) standard, and orange circles for values above the EPA standard. By saving the finished layer as a layer file, we can quickly transfer the classification scheme to new layers and preserve the consistency of the symbols.

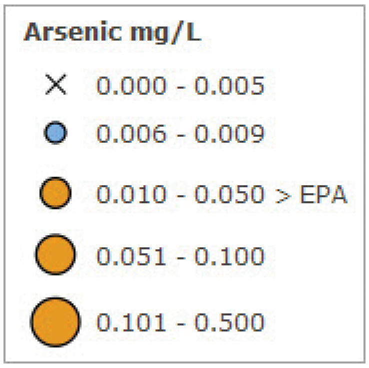

Fig. 2.21. Custom arsenic classification combining shape, color, and size

Styles

ArcGIS provides an extensive set of tools for symbolizing features and rasters. Within the Symbology pane (see Fig. 2.22), the user can choose from a variety of predefined symbols and modify the properties of those symbols, such as the fill color, outline width, and outline color, when the available ones are not suitable. The software provides complete flexibility to modify individual symbol layers and create virtually any symbol desired.

Symbols are organized into groups for ease of use. A **style** contains a set of symbols with a related theme and typically includes different symbol types, including point markers, line styles, polygon shades and patterns, color sets, text styles, and even north arrow or scale bar symbols. Pro has two default styles named ArcGIS 2D and ArcGIS 3D. The ArcMap program included many additional styles customized for specific industries or purposes, with themes such as Geology 24K, Environmental, Civic, Crime Analysis, or Hazmat. Although these styles do not appear within Pro, they can be imported if needed.

Users with very specific symbol needs can create their own styles and fill them with symbols copied from other styles, modified from other styles, or newly created. A search function in the Symbology pane allows the user to search by keyword for matching symbols in any of the installed styles. Searching for `tree`, for example, yields various symbols from different styles.

Summary

- Differentiating between features on a map requires variations in symbol shape, size, thickness, line type, color, pattern, or font.
- Attribute data have a data type designation: nominal, categorical, ordinal, interval, or ratio. The data type determines the kind of map and even the types of analysis that may be performed on that attribute.
- Nominal data name things or uniquely identify them and may be text or numbers. Each feature usually has its own value, and repeats are the exception.
- Categorical data group objects into smaller sets identified by a unique value. Numbers may be categorical when they are used as codes. Ordinal data consist of categories that are ranked in some way.
- Interval data are measured on a regular scale, and ratio data are measured on a regular scale with a meaningful zero point.
- Single symbol maps and labels are used to map nominal data. Unique values maps are used for categorical or ordinal data. Interval or ratio data are displayed using graduated color, graduated symbol, proportional symbol, dot density, or chart maps.
- Rasters may contain thematic or image data. Discrete thematic rasters can be displayed using a unique values method. Continuous thematic rasters may be classified or stretched. Image rasters use a stretched or RGB composite display.

- Continuous numeric data are classified before being mapped. Classification methods include Jenks natural breaks, equal interval, defined interval, quantile, geometric interval, standard deviation, and manual. The best classification method depends on the type of data and the data distribution.
- Data sets become layers when added to a map. Layers reference the original data and store information on how to display them.
- In ArcGIS, symbols are grouped into similar themes called styles. Tools are available to allow the user to create virtually any symbol needed for a map.

Important Terms

aggregated	discrete	interval data	ratio data
alpha	divergent color set	Jenks method	RGB composite
categorical data	dot density map	layer	saturation
chart map	dynamic labels	layer file	slice
choropleth map	equal interval	layer properties	source data
classification	geometric interval	modifiable areal unit problem (MAUP)	standard deviation
classified	graduated color map		stretched
CMYK	graduated symbol map	nominal data	style
colormap	histogram	normalize	thematic raster
connotation	HSV	ordinal data	Tobler's law
continuous	hue	proportional symbol map	unique values map
convention	image	quantile	value
defined interval			

Chapter Review Questions

1. For each of the following types of data, state whether it is nominal, categorical, ordinal, interval, or ratio. Explain your reasoning.

arsenic concentration in mg/L	elevations of climate stations
vegetation type	football team rankings
annual precipitation in inches	number of students in universities
customer zip codes	letter grades given to students
social security numbers	college student majors

2. For each of the following attributes, state whether a single symbol, graduated color, or unique values map would be most appropriate. Explain your reasoning.

political party chosen by voting districts	river flow volumes (cfs)
lung cancer rates by county	restaurant locations
flow rates of wells in gallons/minute	soil class, such as loam, clay, etc.

3. If mapping the following attributes for counties, indicate which ones would generally be normalized, and discuss what attribute field(s) should be used.

average annual snowfall	median home price
home vacancy rate	number of crimes reported
Native American population	number of car accidents

4. State whether a unique values, classified, stretched, or RGB composite display method should be used for each of the following rasters, and justify the choice.

land cover classes	black-and-white aerial photo
7-band satellite image	tree canopy percent
elevation	slope in degrees

5. Explain the merits of unclassed maps as compared to classed maps.
6. Describe the difference between a geospatial data set and a layer.
7. Explain the difference between thematic rasters and image rasters.
8. For each of the following map types, find a map from the Internet that uses this type of symbolization: graduated color, graduated symbol (lines), graduated symbol (points), unique values. Turn in a screenshot of each map with a citation. For each one, explain how the differentiation between features is achieved, and critique the choice of symbols used.

Expand your knowledge

Expand your knowledge of ArcGIS Pro by exploring these sections of the Help.

Help > Maps > Author maps > Symbology > Symbolization
Help > Maps > Author maps > Text
Help > Projects > Project Items > Styles
Help > Data > Data types > Imagery and raster > Appearance and Symbology

Mastering the Skills

Teaching Tutorial

The following examples provide step-by-step instructions for doing basic tasks and solving basic problems in ArcGIS. The steps you need to do are highlighted with an arrow →; follow them carefully. Click on the video number in the VideoIndex to view a demonstration of the steps.

Setting basic symbols

For this tutorial, we will start by creating a new, blank project. By default, a project is created inside a folder with the same name, which also includes a home geodatabase.

1→ Start ArcGIS Pro. Under the *Create a new project* heading on the right, click Blank to create a new blank project.
1→ In the Name box, type OregonMaps.

1→ Click the Browse button for the Location and click the C:\ drive to open it. Navigate into your gisclass folder.
1→ Click the ClassProjects folder to select it as the location (don't go inside it). Click OK.
1→ Keep the *Create a new folder for this project* box checked and click OK.

A blank project will open with the Catalog view visible in the display area. The Catalog view is a larger and more versatile version of the Catalog pane. The home geodatabase is initially empty, of course. We will be using some data from the external mgisdata folder, so we need to add a folder connection to access it.

2→ Click **Insert: Project: Add Folder** and click the C:\ link on the left.

2→ Navigate into your gisclass\mgisdata folder. Click on the Oregon folder to highlight it (don't go inside it) and choose OK.

2→ In the Catalog pane (make sure the Project tab is active), expand the Folders entry to see OregonMaps (the project folder) and Oregon (the folder just added).

2→ Expand the Oregon folder to see two geodatabases and two Excel files.

3→ Click **Insert: Project: New Map**.

3→ In Contents, click the map name (Map) twice, slowly, and rename it *Geography*.

3→ Save the project, and remember to save periodically.

TIP: It is helpful to keep the Catalog and Symbology panes open throughout this tutorial. Dock them in the same window to enable switching back and forth easily, as shown at the bottom of Figure 2.22.

Begin by adding some data sets from the Oregon geodatabase.

4→ Click the **Map: Layer: Add Data** button. Click on the Folders entry on the left side of the window to show the project folder connections.

4→ Double-click the Oregon folder to open it. Double-click the oregondata geodatabase to open it.

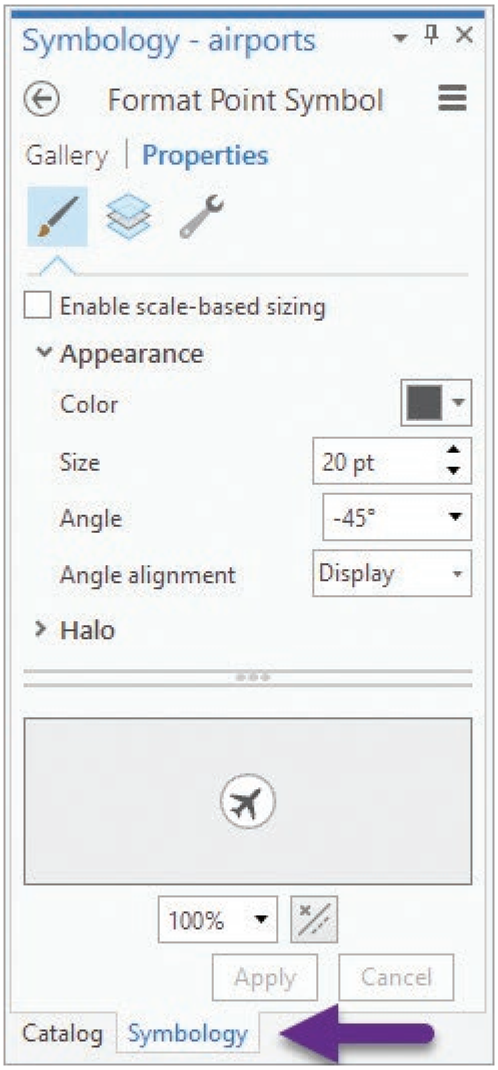

Fig. 2.22. Dock the Catalog and Symbology panes in the same window.
Source: Esri

4→ Hold the Ctrl key down while selecting first the counties and then the volcanoes feature classes from the Oregon\oregondata geodatabase, so that both are selected. Click OK to add them to the map.

Remember, the Catalog pane can also be used to add data to the map.

5→ In the Catalog pane, expand the oregondata geodatabase and then expand the Transportation container.

5→ Hold the Ctrl key to select both the airports and highways feature classes. Then click and drag them into the map.

5→ Add the rivers data set from the Water container.

TIP: From here on, use whichever method is easiest to add data to the map.

We'll make sure that the full extent of the map is set to the Oregon counties layer.

6→ In Contents, double-click the Geography map icon to open the map properties.

6→ Examine the Extent settings. Fill the button to use a Custom extent and set the drop-down to calculate it from counties. Click OK.

7→ In Contents, click on the airports symbol. It opens to the Format Point Symbol pane.

7→ Click the Gallery tab and examine the symbols to select from.

7→ Type airplane into the search box and click Enter.

7→ Change the drop-down box for Project Styles to All Styles to see more symbols.

7→ Choose the largest Airport symbol from the ArcGIS 2D style.

7→ Click the Properties heading and select the icon for the Symbol panel.

7→ Set the Size to 20 pt. and Angle to -45 degrees. Click Apply.

Recall that color may be viewed as a combination of three variations: hue, saturation, and value. Let us examine how these variations affect the color produced.

8→ In the Format Point Symbol panel, hover over the Color swatch to view the RGB combination values for the gray color (R:88 G:89 B:91)

8→ In Contents, right-click on the symbol for counties and choose Color Properties.

8→ In the Color Editor, click in the multicolor box on the right to select a color. Examine the Red-Green-Blue DN values. Choose several more colors, and examine the values.

8→ Set the Red Green Blue values each to 255. What color results?

Notice that the DN values increase from the bottom to the top of the box, and the color proportions change from left to right. Now let's examine the HSV color model.

8→ In the Color Editor, change the Color Model from RGB to HSV.

8→ Use the sliders to vary the hue, saturation, and value of the current color to understand how these vectors affect the color produced. Click Cancel.

9→ In Contents, right-click the line symbol for rivers and change the color to deep blue.

9→ Right-click on the symbol for counties and change the color to light yellow.

9→ In the Symbology pane, click the Symbol representation to open the Format Polygon Symbol pane. Click the Properties heading and change the Outline Color to Gray 50% (hover over a color to see its name). Click Apply.

The rivers seem to be cluttering the map at this scale, so they would benefit from a scale range.

10→ In Contents, select the rivers layer and open the **Feature Layer: Appearance** ribbon.

10→ In the **Visibility Range** group, click the **Out Beyond** drop-down and select 1:1,000,000 from the list (if there is no list, type 1000000 in the box and click Enter).

10→ Zoom in until the rivers appear. Then click the **Map: Navigate: Full Extent** button.

TIP: Click in the Out Beyond dropdown and choose Customize to load a default set of scales to choose from, such as ArcGIS Online/Bing Maps/Google.

Labeling features

Nominal data are usually portrayed using labels. **Dynamic labels** can be created for a layer using an attribute field and can be turned on or off for the entire layer. They use an auto-placement function to avoid overlaps, and not all labels may be shown. Dynamic labels are redrawn each time the map is redrawn, and they may change as the scale changes or when the map is printed.

11→ In Contents, select the airports layer and open the **Feature Layer: Labeling** ribbon.

11→ Click the **Label** button in the **Layer** group to turn on the default labels.

11→ In the **Label Class** group, verify that the **Field** is set to NAME.

11→ In the **Text Symbol** group, click the **Text Symbol Style** drop-down to view a collection of preset styles, but do not select any.

11→ In the **Text Symbol** group, set the font to Arial 9-pt. bold.

11→ In the **Label Placement** group, click the **Label Placement Style** drop-down and set it to the **Basic Point** option.

Basic labels are easy to set, but they often are not quite what is wanted. Additional options to control dynamic labels, such as adding a halo to help them stand out, are available. Recall that the small arrow in the lower right corner of a ribbon group opens advanced settings.

12→ Click the **Feature Layer: Labeling: Text Symbol** group **Options** arrow.

12→ In the Label Class pane, on the Symbol tab, expand the Halo entry.

12→ Click the Halo symbol drop-down and choose White fill 50% transparency (third from left). Increase the Halo size to 2 pt. Click Apply.

12→ Take a moment to examine the other settings on the Symbol tab.

Label classes can be created to assign different symbols to groups within a layer. For example, we could display the busier airports with larger symbols.

13→ Click the **Feature Layer: Labeling: Label Class: Class 1** drop-down and select **Create label class**.

13→ Enter a new label class name of Busiest Airports and click OK.

13→ Click the SQL button next to the Class box.

13→ In the Label Class pane, click Add Clause. Enter the expression: TOT_ENP is Greater than 300000. Click Add. Click Apply.

14→ Click **Feature Layer: Labeling: Label Class: Class** > **Create label class**. Name the class Less Busy Airports.

14→ In the Label Class pane, click the Class drop-down to see or assign which class is currently being modified. It should read Less Busy Airports.

14→ Click Add Clause and enter the expression: TOT_ENP is Less Than or Equal to 300000. Verify the expression and click Apply.

14→ Leave the Label Class pane open; we will use it again shortly.

TIP: The Label Class pane contains many different settings for customizing the appearance and placement of labels. Experiment and explore the Pro Help on labeling to learn more.

We can use the Contents pane to manage the new label classes and easily set their properties. When a label class is selected in Contents, the ribbon settings are applied to that class.

15→ In Contents, click the icon for the Labeling panel.

15→ Under the airports layer, uncheck the Class 1 box to turn off the default labels.

15→ Click the Busiest Airports label class.

15→ On the **Labeling** ribbon, change the symbol to Tahoma 10-pt. bold.

15→ In Contents, click the Less Busy Airports class to select it.

15→ On the **Labeling** ribbon, change the symbol to Tahoma 8-pt. regular.

The labels should appear similar to those shown in Figure 2.23.

TIP: If you have trouble finding ribbons, buttons, or settings, check the Contents pane and make sure that the appropriate item is selected.

16→ In Contents, still in the Labeling panel, select rivers to work with those labels now.

16→ Check the box for the rivers layer to turn the labels on. They don't show yet because the rivers have a display scale set, and the labels initially use the same one.

16→ Zoom to ~1:1,000,000 to make the rivers and labels appear.

16→ On the **Labeling** ribbon, change the symbol to Arial 8-pt. dark blue italic.

It is traditional to curve labels along rivers instead of using straight text.

17→ On the **Labeling** ribbon in the **Label Placement** group, click the Label Placement Style drop-down and select **Water (Line)**.

17→ Click the **Feature Layer: Labeling: Map: View Unplaced** button. With this setting on, labels that don't fit are shown in red.

17→ Zoom and pan around the map to find some unplaced labels. Dynamic labels may change as the map scale and extent change.

17→ Click the **View Unplaced** button again to turn the unplaced labels off.

Symbols and labels may be combined when labeling.

18→ Use the **Map: Navigate: Full Extent** button to zoom to all of Oregon.

18→ In Contents, still in the Labeling panel, right-click the highways layer and choose Symbology. In the Symbology pane, click the symbol.

18→ In the Format Line Symbol pane, click the Gallery tab.

18→ Enter *point* in the search box and click Enter. Choose the 2.0 Point symbol. Switch to the Properties tab and change the color to light brown. Click Apply.

19→ In Contents, select the highways layer and open the **Feature Layer: Labeling** ribbon.

19→ In the **Label Class** group, change the **Field** to HWY_SYMBOL.

19→ In the **Text Symbol** group, click the **Text Symbol Style** drop-down, then scroll down to find and select the Shield 8 symbol.

19→ In the **Label Placement** group, click the **Label Placement Style** drop-down and select the Shield option.

19→ In Contents, check the box beside highways to turn on the labels.

19→ In the **Labeling**: **Visibility Range** group, set the **Out Beyond** limit to 1:1,000,000.

19→ Zoom in to 1:1,000,000 to see the labels. Then return to the Full Extent of the map.

20→ Give the counties Arial 8 pt. bold labels in a 50% Gray color with a 2-pt. halo. Don't assign a scale range. The map should look similar to Figure 2.23.

20→ In Contents, return to the List By Drawing Order panel.

Fig. 2.23. Oregon map labels and symbols
Source: Esri

Creating maps from attributes for points

Currently, each data set is displayed with a single symbol. Maps can also be symbolized from attributes containing categorical, ordinal, interval, or ratio data. Let's examine the table fields.

21→ In Contents, right-click the volcanoes layer and choose Attribute Table.

1. What is the data type of these two attribute fields in the volcanoes data set?

ELEVATION _______________ TYPE _________________

The ELEVATION field contains numeric data, so it must be portrayed using a quantities map, and the values must be classified.

21→ Close the table and select the volcanoes layer in Contents.

21→ Click the **Feature Layer: Appearance: Drawing: Symbology** button.

21→ In the Symbology pane, change the Symbology from Single Symbol to Graduated Colors (Fig. 2.24).

21→ Set Field to ELEVATION if needed. A set of five classes appears with the default Jenks Natural Breaks classification.

21→ Set the Color scheme to Yellow-Orange-Red (5 classes) as shown in Figure 2.24.

The symbols show which volcanoes have lower elevations and which have higher ones. However, the small symbol size makes the colors difficult to see—a common problem with graduated color maps for point data. We can edit the base symbol to make the map easier to interpret.

22→ In the Symbology pane, click the More drop-down and choose Format All Symbols.

22→ In the Format Point Symbols pane, click the Gallery tab and select the Triangle 1 symbol. The symbols will all turn black, but don't worry about that now.

22→ Click the Properties heading and change the symbol size to 12 pt. Click Apply.

22→ Click the back arrow in the Format Point Symbols pane to return to the main Symbology pane. Reset the Color scheme.

TIP: Choosing a triangle symbol that mimics a volcano's shape helps readers to more easily interpret the map.

23→ Turn off the airports and highways layers.

23→ Right-click the counties layer and choose Label to turn off the labels. The settings are stored in the layer, and the same labels can be turned on again at any time.

Observe that the eastern volcanoes are generally lower in elevation, and the highest volcanoes lie in the north. Let's try a graduated symbol map instead.

24→ In Contents, select the volcanoes layer.

24→ In the Symbology pane, change the Symbology drop-down to Graduated Symbols. Keep the Field set to ELEVATION.

24→ Click the Template symbol, click the Gallery tab, and choose the Triangle 3 symbol.

24→ Click the Properties heading and set the color to a reddish brown. Click Apply.

24→ The smallest class symbol is barely visible. Click the circled arrow to return to the main Symbology pane. Change the number of classes to four. Set the minimum size value to 6 pt. and the maximum size to 20 pt.

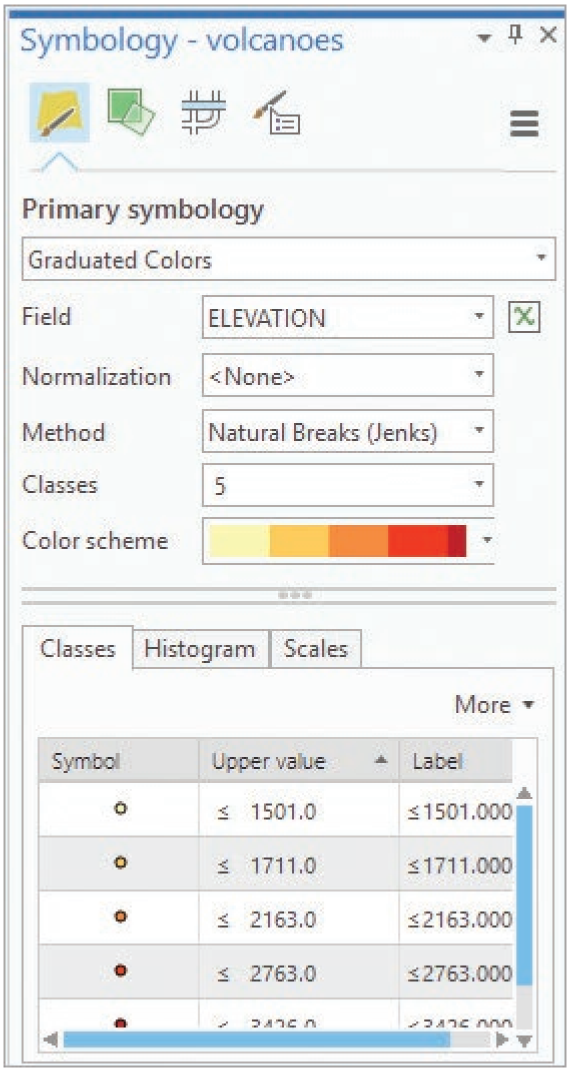

Fig. 2.24. Symbolizing volcano elevations with a graduated color map

Source: Esri

The same data can be presented in different ways, and the mapmaker must choose the method that best communicates the intended message. In your opinion, did the graduated color or graduated symbol map better portray the differences in elevation?

25→ In Contents, rename the volcanoes layer Volcano Elevation.

The elevation legend in the Contents pane shows many decimal values, which is undesirable for two reasons. First, they are pointless because they are all zeros. Second, the significant figures used for labels should be consistent with the precision of the values being reported.

25→ In the Symbology pane, open the Advanced symbol options panel.

25→ Expand the Format labels heading.

25→ Under Rounding, fill the button for *Significant digits* and set the number to 2.

25→ In Contents, click twice slowly on the ELEVATION heading in the Volcano Elevation legend and type (meters). The legend should appear as in Figure 2.25.

25⟶ Save the project.

TIP: Evenly rounded class labels give a more professional look to a map.

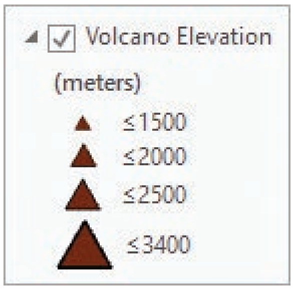

Fig. 2.25. Elevation legend
Source: Esri

Next, we will symbolize the volcanoes based on type. However, we don't want to lose the elevation map, so we will create a copy of the layer. One advantage of layers is that we can create different views of the same data set.

26⟶ In Contents, right-click the Volcano Elevation layer and choose Copy.

26⟶ Right-click the Geography map icon and choose Paste.

26⟶ Rename the new Volcano Elevation layer (above the old one) *VolcanoType*. Drag it below the airports layer.

26⟶ Turn off the Volcano Elevation layer.

Consider how to symbolize the volcano TYPE field. It contains repeating entries like "Stratovolcano" and "Volcanic field," which represent categorical data. The proper type of map for categorical data is a unique values map.

27⟶ In Contents, select the Volcano Type layer.

27⟶ In the main Symbology pane, change the Symbology drop-down to Unique Values (see [1] in Fig. 2.26).

27⟶ Change the Value field to TYPE (2).

TIP: Widen the Symbology pane, if needed, to see all of it. If it is docked, place the cursor over the shared edge with the map window until it becomes a double-sided arrow; then click and drag the boundary to the desired width. If it is undocked, resize it like any other window.

Notice the <*all other values*> entry at the bottom of the categories list. This offers the option of grouping small categories together. Currently, no features appear in this class.

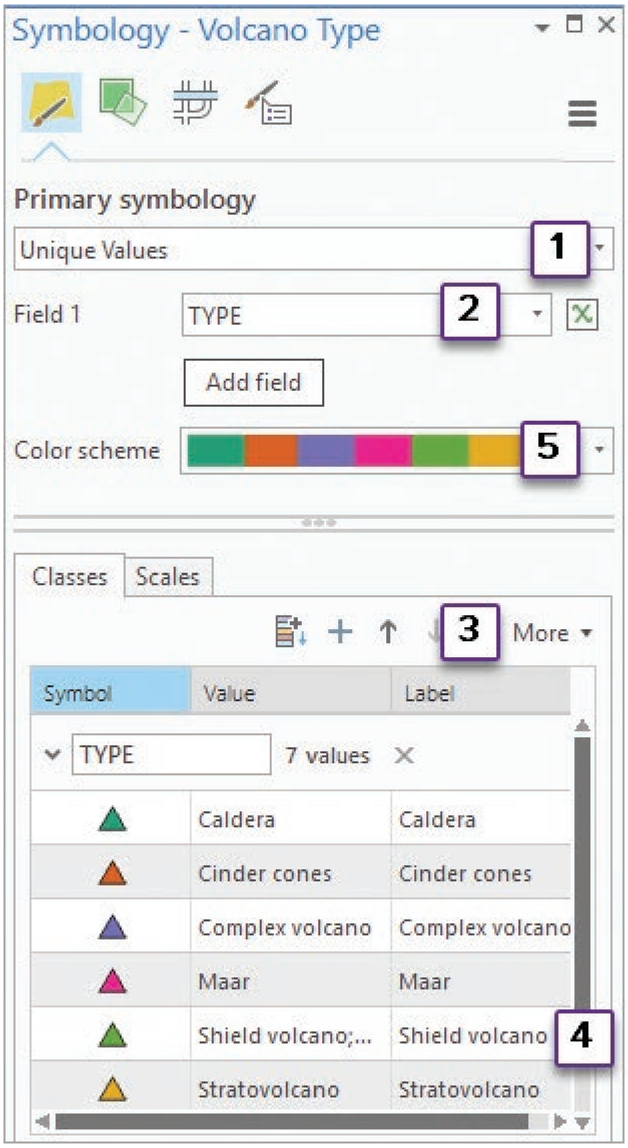

Fig. 2.26. Symbolizing the volcano types
Source: Esri

27→ Click the More drop-down (3) and select *Show all other values* to uncheck it and turn this category off.

Notice the two classes for Shield volcano(es). A data entry error separated these two groups that belong together. We could edit the source data to fix the error, but for now we can work around it.

28→ Click the Shield volcano entry (4), then hold down the Ctrl key and click the Shield volcanoes entry so that both rows are highlighted.

28→ Right-click in the Shield volcano label box (4) and choose Group Values.

28→ Click in the Label box containing the double entry, edit it to simply Shield volcano, and click Enter.

TIP: Changing the label here only changed the display properties of the layer. The data entry error is still present in the stored data set referenced by this layer.

29→ Click More (3) and choose Symbols > Format All Symbols. Click the Gallery tab and set the symbol to Triangle 3.

29→ Click the circled back arrow to return to the main Symbology pane. Change the color scheme (5) to one with dark, bold colors that will show up well.

29→ Examine the map and the final Symbology pane (Fig. 2.26).

2. List two ways to open the Symbology pane.

Editing legend details

Portraying a layer effectively sometimes requires modifying the default legend properties. We symbolize the highway types next, but first check the attribute fields available in the table.

30→ In Contents, turn on the highways layer; then right-click it and choose Attribute Table. Examine the HWY_TYPE field.

3. What three values are found in this field? Examine the other fields for clues and list what the three values represent.

Again we have categorical data, and the unique values map type is the appropriate choice.

30→ Close the table and select highways in the Contents pane.

30→ In the main Symbology pane, select the Unique Values map type.

30→ Set the Value field to HWY_TYPE.

30→ Choose More > Show Count to view the number of features in each category. Notice the lone H value and the 58 unlabeled roads.

It is reasonable to assume that “I” stands for interstates, “S” stands for state highways, and “U” stands for US highways, but what could the “H” represent? With only one, it may be a data entry error. We also have no idea what to label the blank highways. However, we can edit the legend categories to create a clearer legend.

31→ Right-click the row containing the “H” value and choose Remove. It removes the category and places the feature in the <all other values> entry.

31→ Right-click on the row with the unlabeled features and remove it also.

31→ Click twice in the “U” box in the Label column to highlight it. Edit the label and change it to US Highways.

31→ Replace the “S” label with State Highways, the “I” label with Interstates, and the <all other values> label with Unclassified (Fig. 2.27).

31→ Above the classes, edit the HWY_TYPE box and change it to Road Class.

31→ Click the US Highways row to select it. Click the Up arrow to move it below the Interstates row.

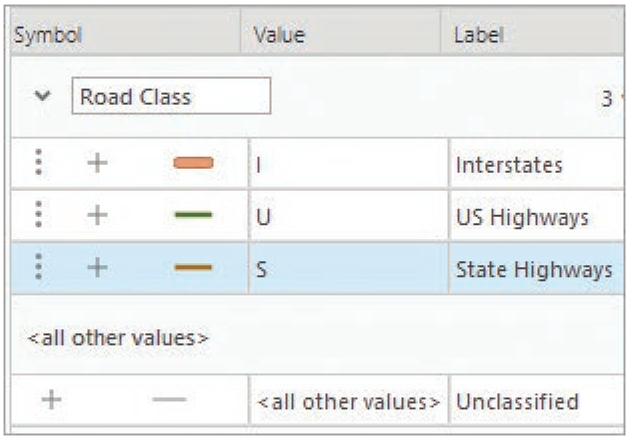

Fig. 2.27. Final legend for the highways
Source: Esri

Now we have symbols based on highway type, but the thin colored lines do not distinguish the types well. This classification would benefit from using differences in symbol, thickness, and color to distinguish the different road classes.

32→ Click the symbol for the Interstates to open the Symbol Gallery.

32→ Choose the first Highway symbol and click the back arrow.

32→ Click the symbol for the US Highways. Select the 2.0 Point symbol. Click the Properties heading in the Format Line Symbol window and change the color to dark green. Click Apply and click the back arrow.

32→ Change the symbol for the State Highways to match the U.S. Highways but with a light brown color.

32→ When finished, the legend should look as shown in Figure 2.27. Examine the map and the legend in the Contents pane.

Creating maps for attributes of polygons

Let’s create maps based on population using the counties layer.

4. What kind of data does population represent? What kind of map should be used to display it?

33→ In Contents, click the counties layer symbol.

33→ In the main Symbology pane, change the Symbology to Graduated Colors.

33→ Set the Field to POP2014 if necessary.

Remember, population data are usually normalized to the area of the aggregation unit.

33→ Choose SQMI as the Normalization field (near the bottom of the list).

33→ Change the color ramp to a monochromatic one, such as light to dark orange.

33→ Open the Advanced symbol options panel and expand the Format labels heading.

33→ Give the labels two significant digits and check the box to *Show thousands separators*. Return to the Primary panel in the Symbology pane.

We will create a new layer for every symbology, to keep each one for reference.

34→ In Contents, rename the counties layer Population Density.

34→ Right-click on the Population Density layer name and choose Copy.

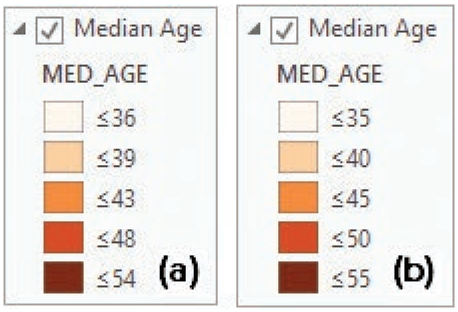

Fig. 2.28. Median age classification: (a) Jenks; (b) defined interval
Source: Esri

34→ Right-click on the Geography map icon and choose Paste. Leave it on top for now.

Next we will map the median ages of people in the counties. Unlike population, median age is not affected by the size of the area being measured. This attribute should not be normalized.

35→ Rename the new layer (on top) Median Age.

35→ In the Symbology pane, change the Field to MED_AGE. Change the normalization field to <None>.

35→ Use the Advanced symbol options panel to format the labels to two significant digits (Fig. 2.28a). Return to the Primary symbology panel.

Classifying data

We have been using the default Natural Breaks classification so far, but it is not always the best method. Examine the uneven class ranges for the Median Age layer. The legend might make more sense if the age ranges increased by five years each time.

36→ In the Symbology pane for the Median Age layer, change the Method to Defined Interval. Ignore any warning, set the Interval Size to 5, and click Tab.

36→ Reset the value format to two significant digits, and then return to the Primary symbology panel. Examine the legend in the Contents pane (Fig. 2.28b).

Most readers would find this classification easier to understand than the uneven classes produced by the Jenks method. Next, symbolize the population of the cities.

37→ Add the majcities data set from the oregondata geodatabase.

37→ In the Symbology pane for the majcities layer, set the Symbology to Graduated Symbols and set the Field to POP2014.

37→ Notice the tabs in the lower half of the Symbology pane: Classes and Histogram. Click the Histogram tab (Fig. 2.29).

37→ Examine the spacing of the class breaks and horizontal bars showing the number of cities in each class.

37→ Hover over the X symbol to see the mean value. Click More > Show Statistics to see more information. Click it again to turn them off.

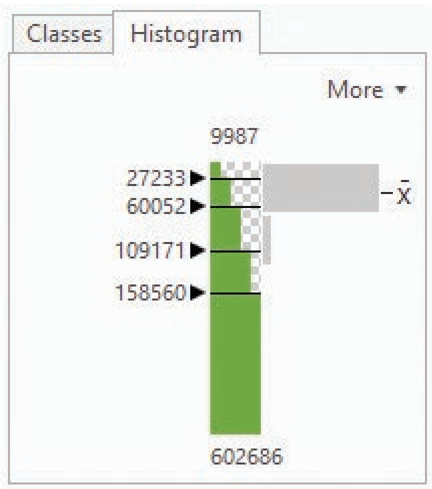

Fig. 2.29. Legend Histogram view
Source: Esri

TIP: Slide the class break lines up or down to create a manual classification, or click the number and type a class break value.

This data set is skewed, with many small cities and one very large one. The default Jenks Natural Breaks is probably the best classification choice. Five classes are a little difficult to distinguish based on size, though, so let's reduce the number to three.

38→ Set the number of Classes to 3.

38→ Click the Template symbol and set the color to a light one that will show up well when the symbols overlap. Click Apply. Return to the main Symbology pane.

38→ Use the Advanced symbol options panel to format the labels to three significant digits with thousands separators; then return to the Primary symbology panel.

Let's look at the activity of the volcanoes now.

39→ Make a copy of the Volcano Elevation layer and paste it into the Geography map. Name it *Known Eruptions* and turn it on.

39→ In the Symbology pane for Known Eruptions, keep the Graduated Symbols map type, but change the Field to KNOWN_ERUP. Examine the class values.

The -999 values are flags to indicate a missing value, and they are messing up the classification statistics. We can specify values to exclude from the classification.

40→ Open the Advanced symbol options panel and expand the Data Exclusion entry.

40→ Click Add Clause and enter the following expression: KNOWN_ERUP is Less Than 0. Click Add and use the green check mark symbol to verify the expression. Click Apply.

To see the difference, reset the symbols in some way.

41→ Return to the Primary symbology panel. Set the classification method to Defined Interval and set the Interval Size to 3.

41→ In the Label column, change the <excluded> label to *No Info*.

41→ Examine the map and the legend in Contents.

An alternative to exclusion is to make a new layer that only shows the features of interest, such as showing only the active volcanoes with at least one known eruption.

42→ Click **Analysis: Geoprocessing: Tools** to open the Geoprocessing pane.

42→ Search for the Make Feature Layer tool and open it.

42→ Set the Input Features to the *Volcano Elevation* layer.

42→ Name the Output Layer *Active Volcanoes*.

42→ Click Add Clause and enter the expression: KNOWN_ERUP is Greater Than 0.

The appearance of the table is also part of a layer's properties. Let's turn off some fields to better focus on the ones of interest. Remember, these changes are just part of the layer properties, and they do not modify the source data.

43→ In the Field Info section, uncheck all fields except NAME, TYPE, and KNOWN_ERUP.

43→ Click Run to run the tool. Close the Geoprocessing pane when it finishes.

43→ In Contents, turn off the other volcano layers. Right-click the Active Volcanoes layer and choose Attribute Table.

Notice that the table contains only the fields specified and only volcanoes with at least one eruption. Now, before we finish with the volcanoes, let's try an unclassed map, which holds the advantage that no classification is required, and the view of the data is unbiased.

44→ Close the table.

44→ In Contents, select the Active Volcanoes layer and open the Symbology pane.

44→ Set the map type to Proportional Symbols. Set the Field to KNOWN_ERUP.

44→ If the map symbols don't appear in different sizes (possible software bug), change the Unit to Miles and then back to <Unknown>.

44→ Click the Template symbol and change it to the Triangle 3 symbol with a light color. Click Apply and click the back arrow.

44→ Set the Maximum size to 40.

44→ Click the Classes tab and set the Legend count to 3. Examine the map.

Displaying thematic rasters

Thematic rasters portray map data, such as soil types, roads, elevation, or precipitation. The current map is crowded with layers already, so we'll create a new map to experiment.

45→ Save the project.

45→ Click **Insert: Project: New Map** and wait for the new map to open.

45→ In Contents, rename the map Rasters.

We will begin with a digital elevation model (DEM), a raster that portrays an elevation surface. This DEM has a pixel size of one kilometer.

46→ Add the gtopo1km raster from the oregondata geodatabase to the map.

46→ In Contents, double-click the gtopo1km layer to open its properties. Examine the Source settings. Note that the vertical units (elevations) are in meters. Close the properties window.

46→ In Contents, right-click the gtopo1km layer and choose Symbology.

5. What kind of data type is elevation? What kind of raster display method(s) could be used to display it?

Pro chooses an initial display method based on the raster type. In this case, it chose the Stretch method with a grayscale color ramp. Notice the minimum and maximum elevation values, from 1 to 3124 meters. The Stretched method slices these values into 256 bins for use with the 256-grayscale ramp.

47→ In the Rasters map view, click on the raster to view values for a pixel.

Figure 2.30 shows the results when a gray pixel is clicked. The Pixel Value is the elevation, 1453 meters. The Stretched value indicates the bin number, 173. This bin is displayed as light gray. The COUNT field tells how many pixels have this value.

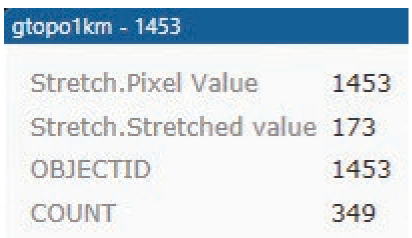

Fig. 2.30. Examining pixels in the DEM

Source: Esri

47→ Click on more pixels, choosing black, white, and gray ones. Compare the pixel values and the stretched values for each one. Close the information pop-up when done.

48→ Examine the Symbology pane. A Standard Deviation stretch is being used with 2 standard deviations.

48→ Change the Stretch type to None and click Apply. Examine the map.

48→ Try the Minimum-Maximum stretch; then change the Stretch type back to Standard Deviation.

49→ Try choosing different color schemes.

49→ End by choosing the color scheme shown in Figure 2.31 (Elevation #1).

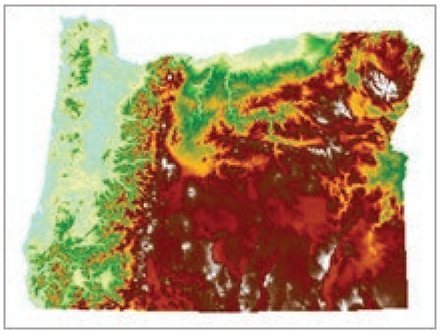

Fig. 2.31. Elevation terrain color ramp, stretched
Source: USGS

The Stretch method uses 256 equal interval classes. The classified display method gives control of the number of classes and the classification method.

49→ Rename the gtopo1km layer *Elev-Stretched*.

49→ Copy the Elev-Stretched layer and paste it into the Rasters map. Rename the new layer *Elev-Classified*.

50→ In the Symbology pane for Elev-Classified, change the Symbology method to Classify. Find the same Elevation #1 color scheme and select it.

50→ Set the number of classes to 10. Continuous data, because they often have underlying spatial patterns, can use more classes and colors.

50→ In the map window, click on the map to examine the pixel values and the class values (which go from 0 to 9 rather than 1 to 10). Close the information pop-up.

This display method permits the classification parameters to be modified. The classification defaulted to Jenks Natural Breaks. However, elevations are best displayed in even classes with rounded numbers.

51→ In the Symbology pane for the Elev-Classified layer, change the Method to Defined Interval. Set the Interval size to 200 meters.

Notice how few white pixels show now (Fig. 2.32). The Stretched method and the Jenks classification overemphasized the areas with high elevations.

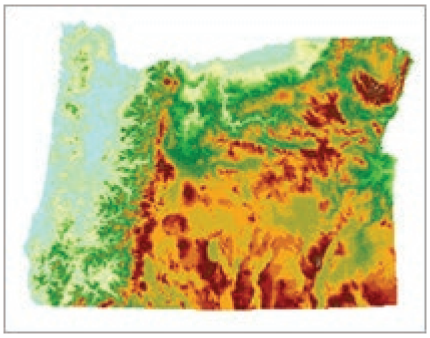

Fig. 2.32. Elevation terrain color ramp, classified
Source: USGS

52→ Add the gtoposhd raster from the oregondata geodatabase to the map.

This hillshade raster is derived from a DEM by modeling how the illuminated surface might appear, and it contains brightness values from 0 to 255. Hillshade rasters provide an intuitive and detailed view of the surface and make a useful base for transparent overlays.

52→ Click on the Elev-Classified layer and drag it above the gtoposhd layer in the Contents pane. Remember, layers are drawn from bottom to top.

52→ With the Elev-Classified layer still highlighted, open the **Raster Layer: Appearance** ribbon. In the **Effects** group, use the **Transparency** slider to set the layer transparency to 50% (Fig. 2.33).

53→ In Contents, collapse the legends for all layers

53→ Add the oregondata\slopeclass raster to the map. It shows areas of low, medium, and high slope indicated by the values 1, 2, and 3.

6. What type of data does this raster contain? What type of map should be used to display it?

53→ In the Symbology pane, change the Color scheme to a monochromatic ramp.

54→ Add the oregondata\landcover raster to the map.

54→ Examine the Symbology pane for landcover. Scroll down and examine the color symbols and labels in the list. A total of 150 different colors are represented.

54→ In the map, click on different colors of the landcover raster to view the habitat codes and names. Close the pop-up when finished.

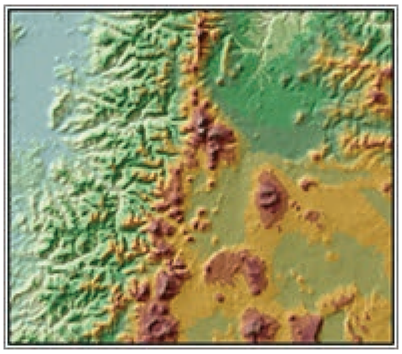

Fig. 2.33. Transparent elevation displayed over a hillshade raster
Source: USGS

The Symbology defaulted to the Colormap method, which assigns preselected colors to each raster value using an alpha-red-green-blue combination. If a raster file includes a stored colormap, then this display method will be initially used.

In the information pop-up, the first row shows the pixel value (57 in Fig. 2.34). The second row contains the color mixture values. The raster table includes a field called HABNAME, which groups the cover classes into fewer categories. Let's display the land cover using this field.

55→ In the Symbology pane for landcover, change the display method to Unique Values.

55→ Change the Value field to HABNAME and choose a color scheme.

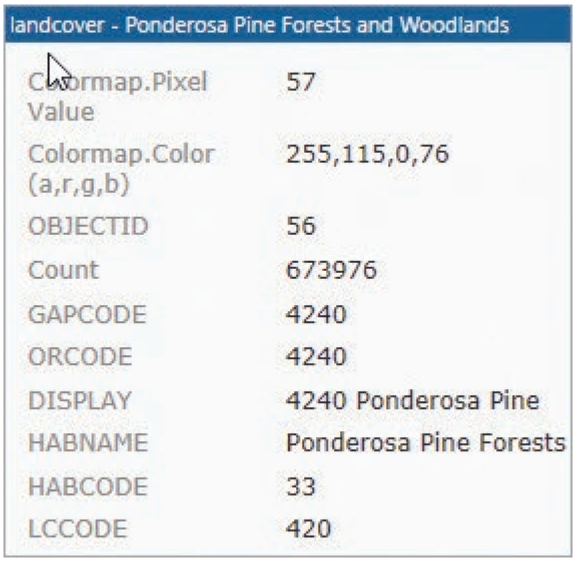

Fig. 2.34. Identifying land cover pixels
Source: Esri

Images represent brightness of land features as measured by a camera or spectrometer, usually using the RGB color model.

56→ Turn off all layers in the Rasters map.

56→ In the Catalog pane, click the Portal tab and select the All Portal icon.

56→ Type *naip* in the search window. Find the imagery layer icon labeled USA NAIP Imagery: Natural Color, and add it to the map.

56→ Examine the Symbology pane for the NAIP layer, noticing that it defaulted to the RGB symbology method. The legend in Contents shows the RGB symbols also.

Typically, an imagery layer gets more detailed at larger scales. This feat is accomplished using scale ranges showing different sets of imagery depending on the map scale.

This is the end of the tutorial.

→ Save the project and close ArcGIS Pro.

Practice Exercises

In this exercise, you will create four new maps in your OregonMaps project, each one using a different theme: Volcanic Hazards, Agriculture, Housing, and Physiography. Use the data in the oregondata geodatabase. Make each map both aesthetic and legible.

In the Volcanic Hazards map:

1. Show the population density of the counties. Also show the hospitals, marked with blue crosses.

2. Create a proportional symbol map of the volcanoes based on the KNOWN_ERUP field.

In the Agriculture map:

3. Create a map of counties showing the density of farms. Label the county names.

4. Create a map showing the transportation routes, symbolized by type (road type, rail, and air).

In the Housing map:

5. Create a map showing the vacancy rate of the counties. Which field is most appropriate to normalize this data? Label the county names.

6. Show the major cities data set (majcities) symbolized by population.

In the Physiography map:

7. Add the state boundary (statedtl) and the county boundaries, and then add the World Imagery service from ArcGIS Online. Use a hollow symbol and a contrasting outline color for the state and county boundaries so that they show up well against the imagery.

For all the maps:

8. Examine the legends in the Contents pane. Be sure they use good classification schemes, rounded label values, and appropriate significant digits or decimal places. Be sure that each layer has an informative capitalized name.

9. Capture a screenshot of each map. Make sure that the screenshot includes the Contents pane showing the corresponding legends for each map.