Cartographic Communication

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9. Examination and Study Questions

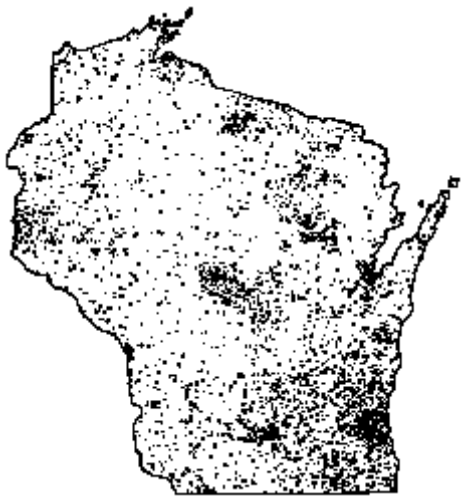
1. The Value of Maps

Maps are perhaps as fundamental to society as language and the written word. They are the preeminent means of recording and communicating information about the location and spatial characteristics of the natural world and of society and culture. Some would say that the use of maps distinguishes geography from all other disciplines. The truth is that maps, though of special concern to geographers, are used throughout the sciences and humanities and in virtually every aspect of day-to-day life. Millions of maps are produced and used annually throughout the world by scientists, scholars, governments, and businesses to meet environmental, economic, political, and social needs. Many cartographers have reflected on the important role played by maps in society. One of the most recent statements worth considering is Denis Wood's book *The Power of Maps* (New York: Guilford Press, 1992).

Maps gain their value in three ways:

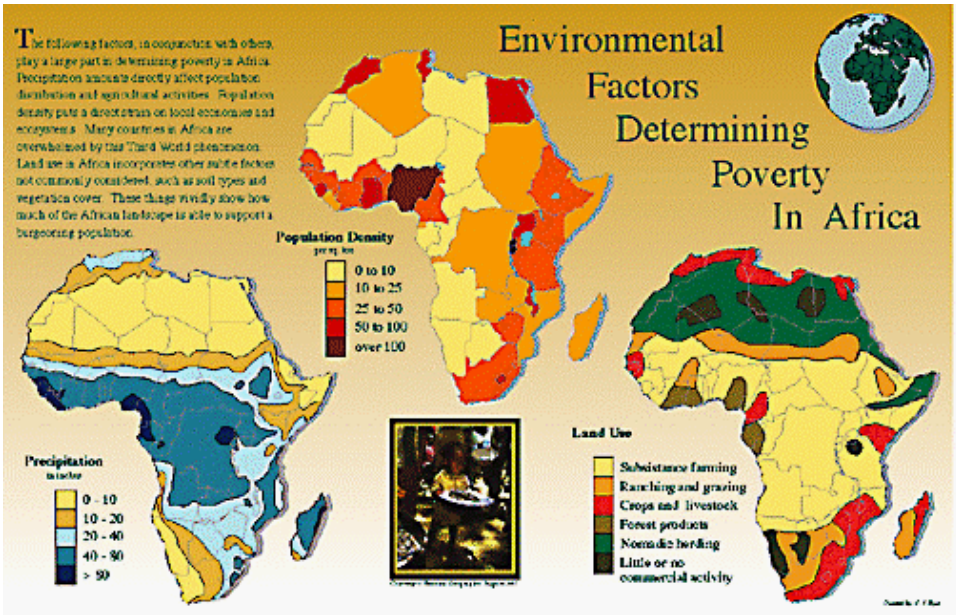
1.1 As a way of recording and storing information

Governments, businesses, and society as large must store large quantities of information about the environment and the location of natural resources, capital assets, and people. Included are plat, parcel, and cadastral maps to record property, maps of society's infrastructure or utilities for water, power, and telephone, and transportation, and census maps of population.



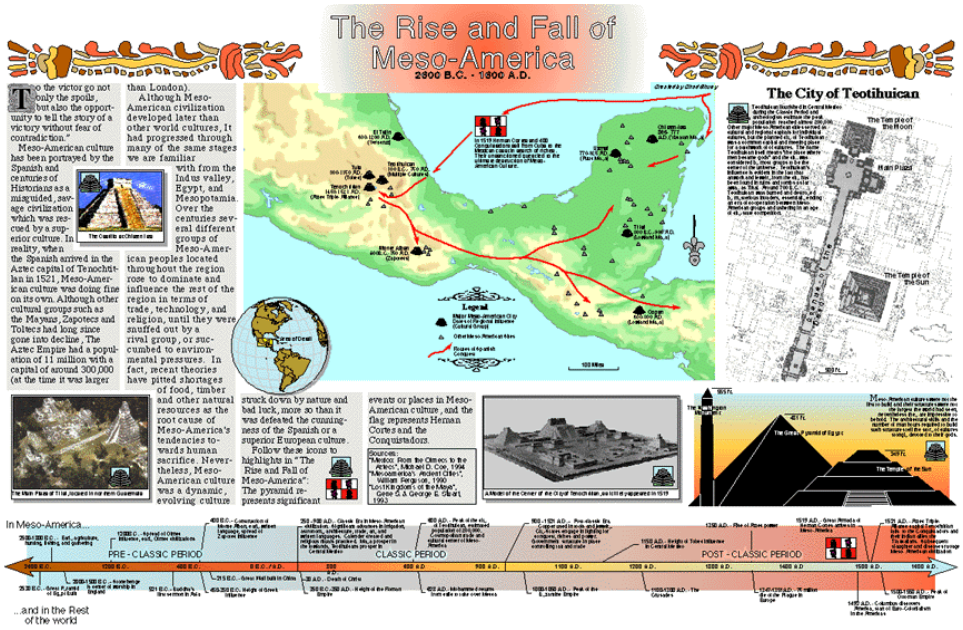
1.2 **As a means of analyzing locational distributions and spatial patterns**

Maps let us ***recognize*** spatial distributions and relationships and make it possible for us to ***visualize*** and hence ***conceptualize*** patterns and processes that operate through space.



1.3 **As a method of presenting information and communicating findings**

Maps allow us to convey information and findings that are difficult to express verbally.



Maps can also be used to convince and persuade, or even propagandize.

To realize this potential, it is useful to learn some basic principles of cartographic communication and map design. Cartography is a special type of communication that does require training. But,

attention invested in learning the basics will pay off handsomely in the production of more effective maps. Sometimes people assume that such training is too highly technical to be mastered easily and forego the use of maps. This is unfortunate because maps could be used more widely in the natural sciences, social sciences, and humanities for analysis and communication, particularly now that computers can be used as an aid to production. Some attention to first principles is still warranted. Apart from the following notes, you may wish to consult:

- Cuff, David J. and Mattson, Mark T. 1982. *Thematic Maps: Their Design and Production.* New York: Methuen.
- Dent, Borden D. 1985. *Principles of Thematic Map Design.* Reading, Mass.: Addison-Wesley Publishing Co.
- Monmonier, Mark . 1993. *Mapping it Out: Expository Cartography for the Social Sciences and Humanities.* Chicago: University of Chicago Press. A very readable introduction to the principles of cartography aimed particularly at students and scholars who have had little training in geography or cartography.
- Muehrcke, Phillip C. 1986. *Map Use: Reading, Analysis, and Interpretation, 2nd ed.* Madison, Wis.: JP Publications.
- Robinson, Arthur H., Joel L. Morrison, Phillip C. Muehrcke, A. Jon Kimerling, and Stephen C. Guptill. 1995. *Elements of Cartography*, 6th ed. New York: John Wiley and Sons. This is the classic textbook, recently revised to reflect the tremendous changes in cartographic production resulting from widespread adoption of computer-based techniques and GIS.

2. Cartography as Communication

One of the most useful approaches to the study of cartography is to view maps as a form of visual communication--a special-purpose language for describing spatial relationships. Although it is perhaps unwise to draw a direct analogy between cartography and language, concepts such as "grammar" and "syntax" help to explain, at least metaphorically, the sorts of decisions cartographers make as they compose maps. Cartographers seek to make use of visual resources such as color, shape and pattern to communicate information about spatial relationships. The analogy with language also helps explain why training in principles of effective cartography is so important--it allows us to communicate more effectively. Without a knowledge of some of these basic principles, the beginning cartographer is likely to be misunderstood or cause confusion.

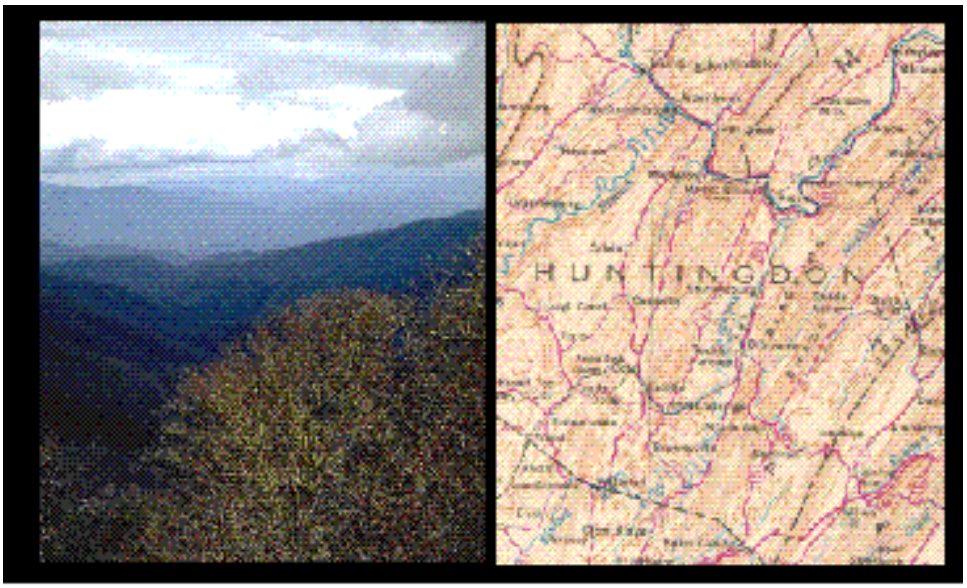
2.1 Cartography is closely related to graphical communication

Cartography is related to, but different from other forms of visual communication. Cartographers must pay special attention to coordinate systems, map projections, and issues of scale and direction that are in most cases of relatively little concern to other graphic designers or artists. But, because cartography is a type of graphical communication, some insights to the demands of cartography can be gleaned from the literature of graphical communication and statistical graphics. Often cartographers are faced with some of the same challenges faced by graphical designers and can learn much from their insights. As you begin to study cartographic design, you may find it useful to consult some of the standard works on graphical communication. You will find the following books particularly interesting, and maps are often the focus of discussion.

- Cleveland, William S. 1985. *The Elements of Graphing Data.* Monterey, CA: Wadsworth.
- Schmid, Calvin F. 1983. *Statistical Graphics: Design Principles and Practices.* New York: John Wiley and Sons.
- Schmid, Calvin F. and Schmid, Stanton E. 1979. *Handbook of Graphic Presentation, 2nd ed.* New York: John Wiley and Sons.

- Tufte, Edward R. 1983. *The Visual Display of Quantitative Information.* Cheshire, CT: Graphics Press.
- Tufte, Edward R. 1990. *Envisioning Information.* Cheshire, CT: Graphics Press.

2.2 Maps are symbolic abstractions--"generalizations" or "representations"--of reality



By stressing cartography as a form of communication, it is easier to make the point that maps are really symbolic abstractions--or representations--of real world phenomena. In most cases, this means that the world represented on a map has been greatly simplified, or generalized, with symbols being used like words to stand for real things. Some of the most important decisions cartographers make in the process of cartographic design revolve around: 1) how much to simplify the situation being depicted; and 2) how to symbolize the relationships being represented.

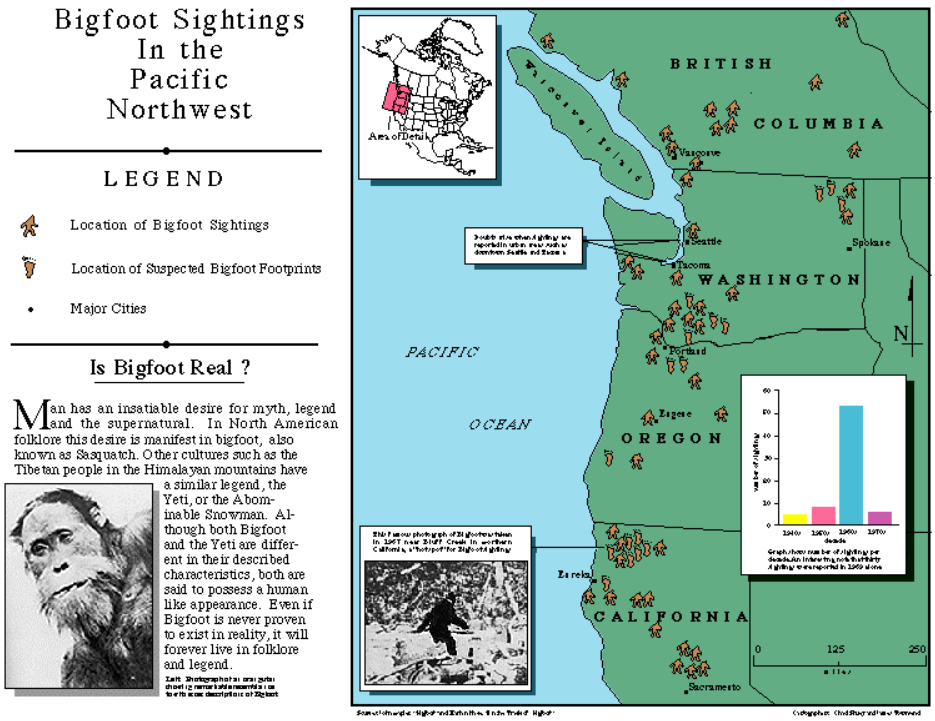
3. What Is a Good Map?

If cartography is a form of communication, the measure of a good map is how well it conveys information to its readers to enlighten, convince, or persuade. Too often the pure aesthetic appeal of a map is equated with its communicational value. Aesthetic issues certainly play a role in effective cartography, but it is the issue of communication that holds the central role in cartographic design. To ask "what is a good map?" is to ask how well it communicates with its audience.

This means that one always begins a project by considering the message to be conveyed and the audience to be addressed. This raises a series of questions that must be addresses at the start of a project:

3.1 What is the motive, intent, or goal of the map?

In effect, the question asks what the reader should gain from the map or how the reader should respond. Motives vary greatly. Many maps are intended solely to convey accurate information about spatial relationships, others to sway public debate. Obviously, the motive will have a great bearing on the content of the map (the information included) and its form (the cartographic strategies employed).



3.2 Who will read the map?

A cartographer must be able to identify the type of reader being addressed for two principal reasons. First, it is important to have an idea about what the audience is likely to know about the subject matter of the map. Second, it is useful to know how much background the readers have in using maps. A map intended for specialists who have a background in cartography might be organized far differently than one intended for use as a prop in a public debate.

3.3 Where will the map be used?

An audience is always addressed within a particular context or frame of reference which has a bearing on map design. Maps may be published alone, or in newspapers, magazines, journals, books, or atlases. They may appear in reports, term papers, theses, and dissertations. They may be used in lectures, briefings, presentations, speeches, and announcements. Some maps are used only once and then discarded. Others are intended to used for reference for decades or centuries. For these reasons, context can influence both the form and content of a map in ways both great and small.

3.4 What data is available for the composition of the map?

Decisions about map design are tempered greatly by source materials themselves, by what is available and how easily it can be communicated. Sometimes our source materials have limitations or are incomplete. They may present special problems of

presentation because of technical terminology or because of the quantities of detail required to make a point. Some data needs to be qualified. These limitations must be considered from the very start of a project so that they can be addressed in the design of the map.

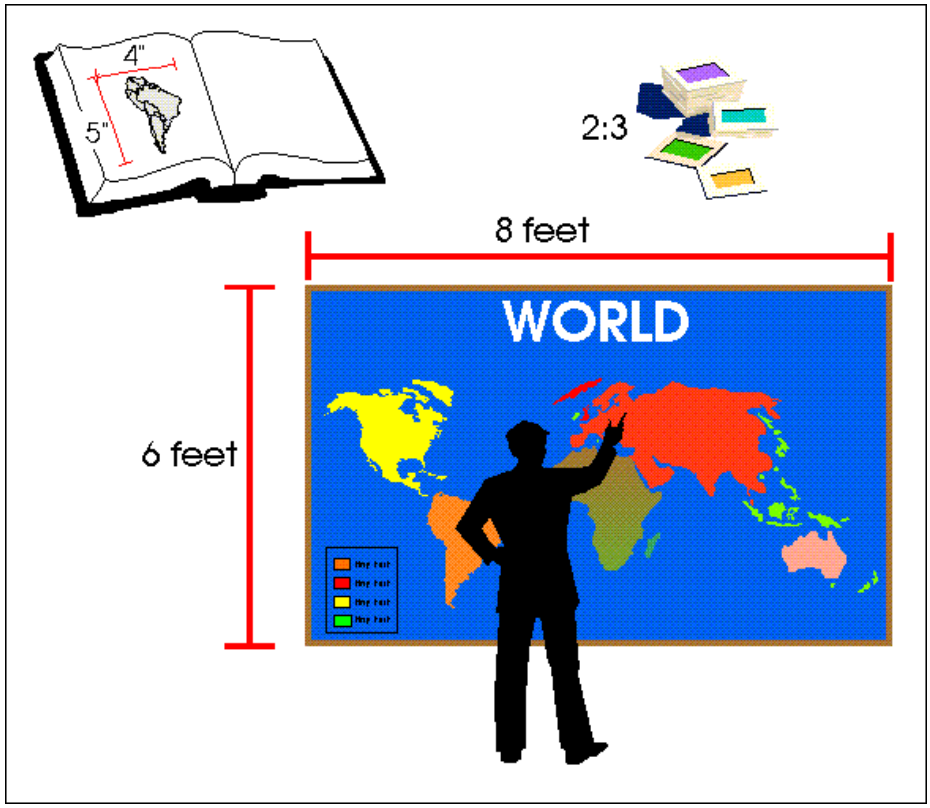
3.5 What resources are available in terms of both time and equipment?

Finally, one must consider the twin questions of how much time to invest in a project and what systems to use, whether manual or automated and, if automated, what type of software. Both questions are, of course, best addressed with experience. However, it is important to realize that production time drops dramatically with practice. Sometimes scholars avoid using maps because of the time expense involved in their production. Yet once a person has a learned a few basics, this expense is greatly reduced. Computer systems have also made it much easier to produce maps, but, again, practice is required. Situations remain where manual or semi-manual production remains time effective. One must also remain aware of the strengths and weaknesses of various automated systems (see discussion below) and that, in practice, a variety of software systems may be used together to achieve the desired results.

4. Basic Elements of Map Composition

As the questions of message, audience, and context are addressed, one can turn to issues relating to the form, layout, and composition of a map. In this section, we will begin by raising questions about size and proportion, about simplification, and about the general types of information that are arrayed on maps. Although symbolization is critical to map composition, it is so important a subject that it will be considered in the next section.

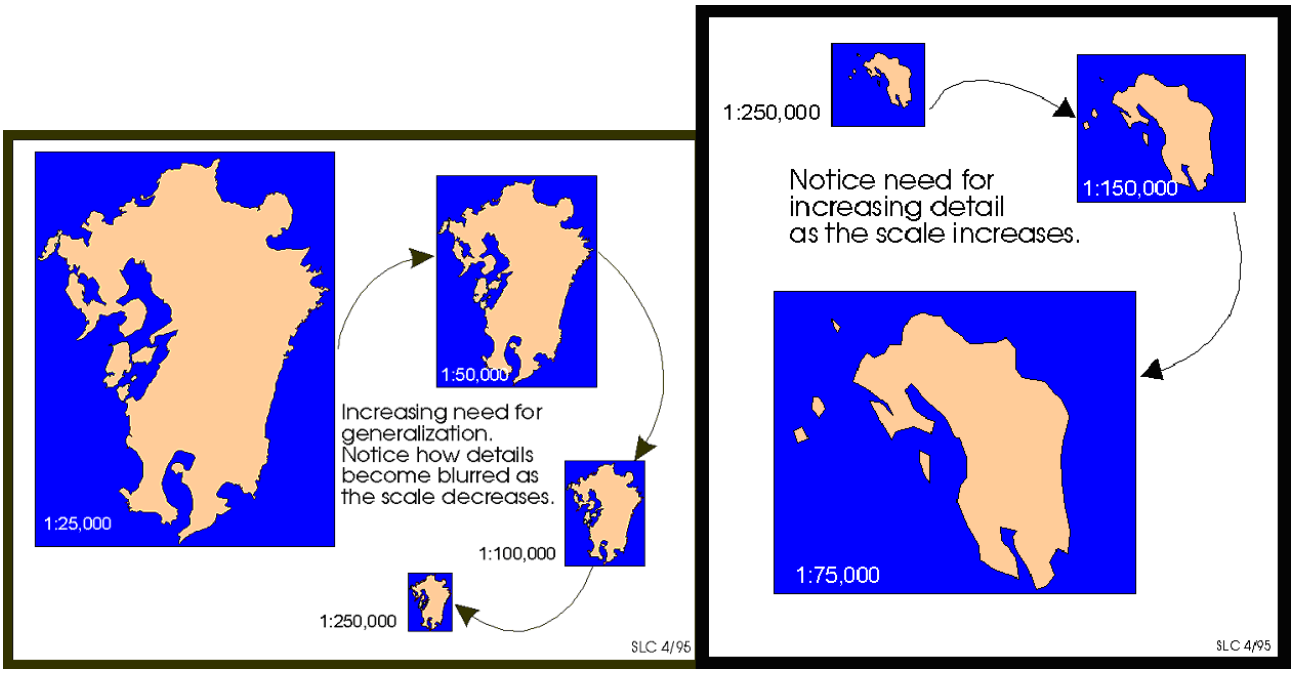
4.1 The format of the final production?



From the very start of a cartographic project, you must keep an eye on the format of the final production--its final size and proportions and the media that will be used for production. If your final map will occupy a half page in a journal printed on 8x10 inch paper in black on white, you must design without color, with the frame of the map in the proportion of 4:5, and make allowances for lettering and symbols that may be illegible at small sizes. Strategies that work for one paper size may not work for another. The same is true for different types of media and printers. Each has its strengths and limitations with respect to the colors, patterns, and lettering that can be produced. Also, a map placed in a book, journal, or thesis will usually be captioned rather than titled and some of the other information needed for effective communication will move to this caption.

4.2 The issue of generalization, simplification, and abstraction

Cartography is very much a process of abstraction in which features of the real world are generalized or simplified to meet the demands of the theme and audience. Not all elements or details have a bearing on the pattern or process being studied and so some are eliminated to draw the reader's attention to those facts that are relevant. Too much detail can even hide or disguise the message of a map. The amount of detail that can be included is very much dependent on the scale at which the map will be produced, as the following examples demonstrate. A small-scale map of an area must, almost of necessity, be more generalized. Some automated systems now have the ability to provide assistance in the generalization and simplification of features. If such routines are not available, you should study a test plot of your map at its final scale. If linework or lettering touches itself and blurs together, you should consider generalizing the features and enlarging the lettering.



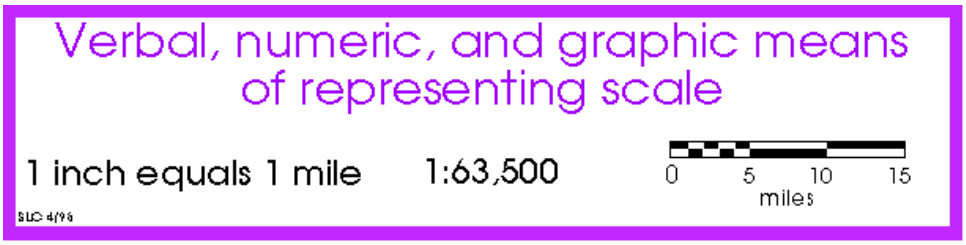
You may wish to map one part of a larger area--one country out of a continent, or one state out of many. The amount of surrounding territory and the number of neighboring features you include will vary substantially by context. In effect, the more your audience knows, the less you have to show. Be aware, however, that adding just "a little" information, unless done wisely, can lead to confusion. Sometimes locator and index maps (see below) are used to help orient the reader to the location of the area of interest.

4.3 Basic map elements: Information commonly needed by the map reader

Almost all maps must include certain basic elements that provide the reader with critical information. Among these are the title, scale, legend, body of the map, north arrow, cartographer, neatline, date of production, projection used, and information about sources. The placement of this information and the style of its depiction will vary greatly from map to map depending--as always--on the audience and message. Some elements are found on almost all maps no matter what the theme, others are depend heavily on the context in which the map will be read. Let us consider these elements to see how they are depicted and why their importance may vary from map to map.

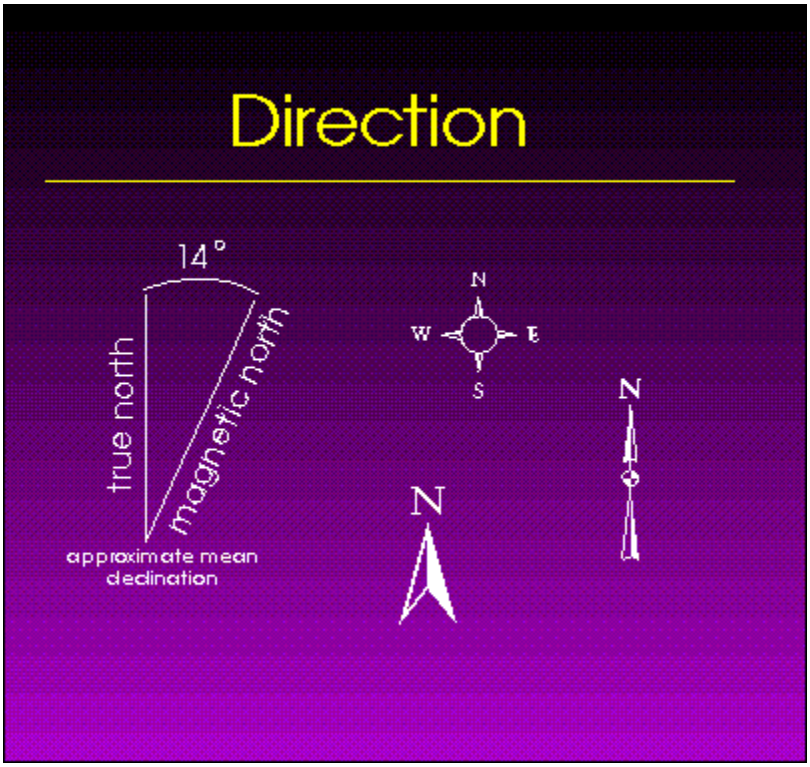
Distance or scale

Distance or scale must always be indicated or implied, unless the audience is so familiar with the map area or distance of such little relative importance that it can be assumed by the audience.
Distance and scale can be indicated in a variety of ways on a map in **verbal, numeric, or graphic form**.



In using computer systems, the graphic form of representing scale is often preferred. With computers, maps are often drafted at different scales than they are printed. In using verbal or numeric scales, the cartographer must be certain that the map is printed at precisely the scale indicated. If a graphic scale is inserted in a digital map, it will always maintain its relative size with respect to the digital map no matter how it is printed. Remember, scale varies significantly across the area of some maps. If this is true of yours, be sure to note the adjustments required.

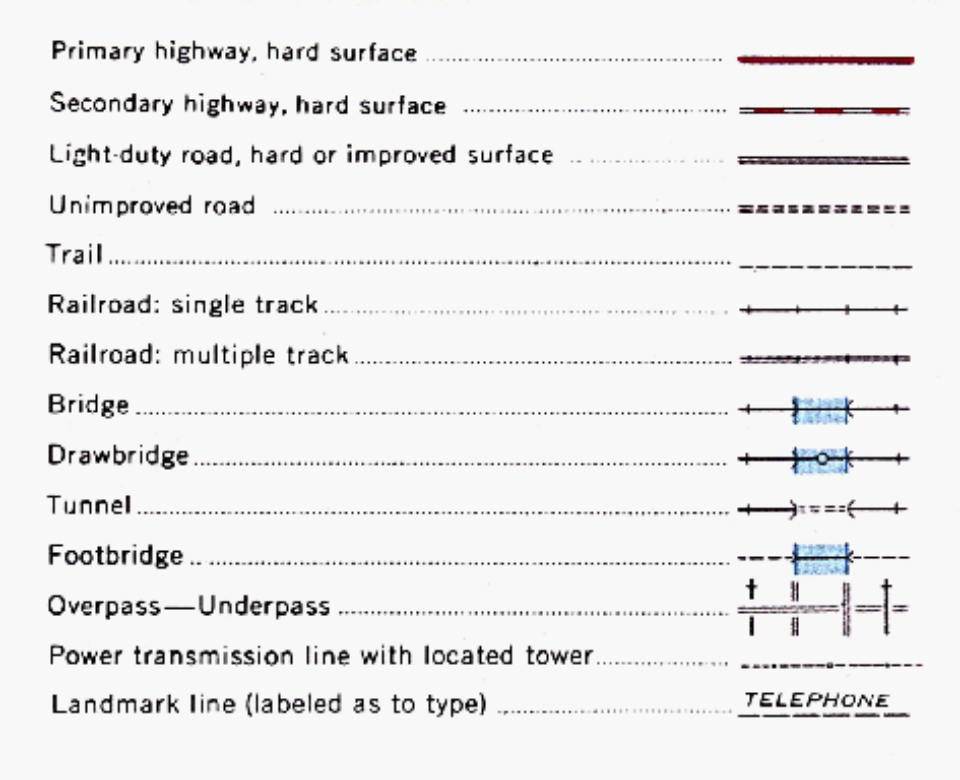
Direction



The question of **what is north** can be an issue on some maps. On the earth, **true north** (the direction to the North Pole) differs from **magnetic north**, and the

magnetic north pole moves due to changing geophysical conditions of the earth's crust and core. Many reference maps indicate both. Most maps we compose are oriented to true north, even though compass readings in the field are angled to the magnetic pole. Adjustments for these compass deviations are made routinely.

Legend



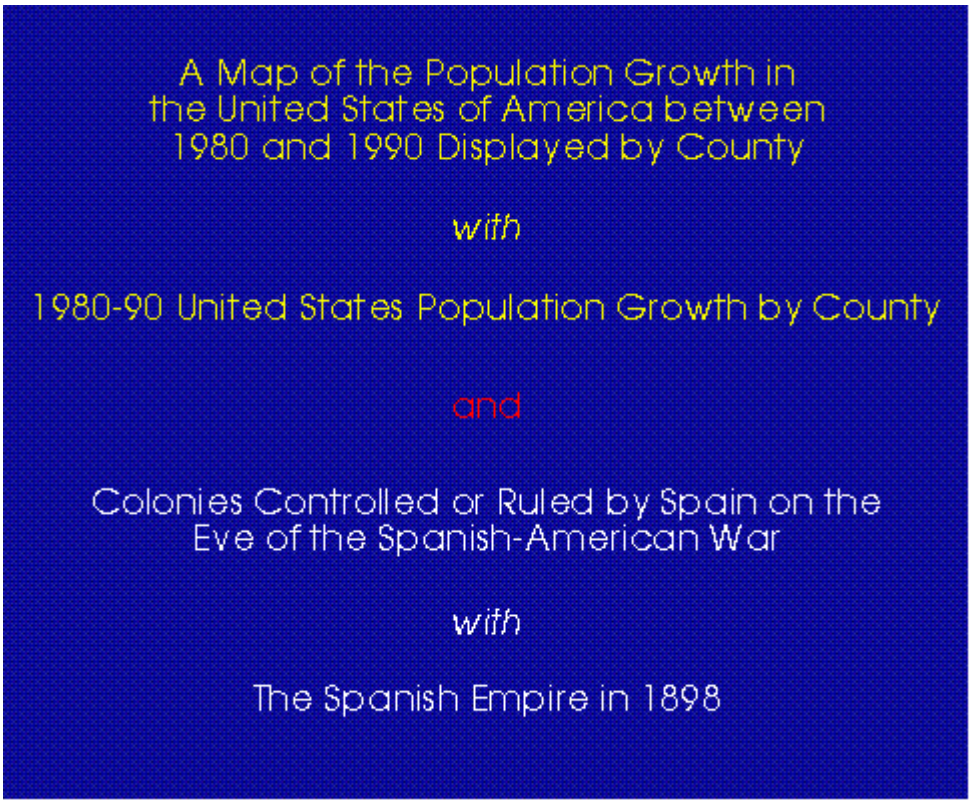
The legend lists the symbols used on a map and what they depict. These symbols should appear in the legend exactly as they are found in the body of the map and be described clearly and fully. Do not treat the legend as an afterthought; it should receive careful attention. Be aware, however, that not all maps require legends. Sometimes the necessary information is put in a caption, or subsumed by textual annotations placed directly on the body of the map.

Sources of information and how processed

Unless it is absolutely clear from the context in which a map appears, readers will need to know about the sources from which the map was derived. You must identify your sources so that the reader could, if needed, track them down to check your information and interpretation. Often the age, accuracy, and reliability of sources is critical to the interpretation of a map and should be noted. Sometimes it is also important to indicate how the data was processed, grouped, generalized, or categorized.

ESSENTIAL ELEMENTS THAT ARE SENSITIVE TO CONTEXT:

Title



The title of a map is usually one of it's most essential features. As such, it should receive very careful attention so as to match the needs of the theme and audience. A short title might suffice if readers can be assumed to be familiar with the theme being presented, more information is needed for less experienced readers. The content of the title should also be measured against other lettering applied to the map, for example in the legend or annotations. Sometimes, legends and annotations supplant much of the content of a title. Also, be aware that captions usually take the place of titles for maps appearing in publications such as books and journals.

Projection

The projection used to create a map influences the representation of area, distance, direction, and shape. It should be noted when these characteristics are of prime importance to the interpretation of the map. Some widely used locational reference systems such as the U.S. State Plane Coordinate system and Universal Transverse Mercator system are based on predefined projective geometries that are implicit in the use of the coordinate systems themselves.

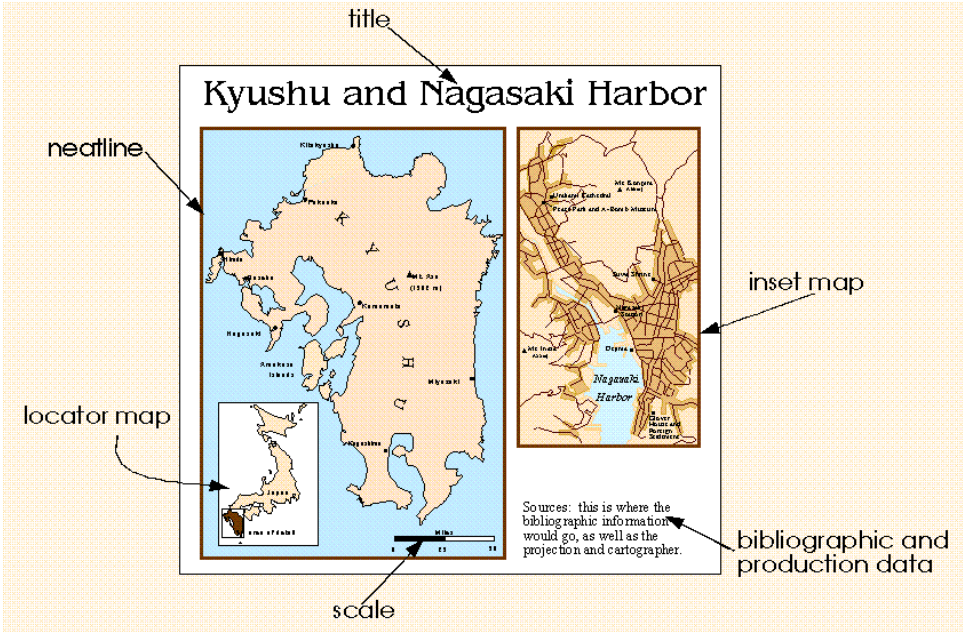
Cartographer

The authority lying behind the composition of a map can be of prime importance in some situations. Most maps note the name, initials, or corporate identity of the cartographer(s).

Date of production

The meaning and value of some maps--such as those relating to current affairs or weather--are time sensitive. The reader must know when they were produced to gauge whether to trust them. An out-of- date road atlas or city map can cause tremendous frustration. Other maps are less sensitive to the passage of time, but the date of production can still be important if, for example, better information becomes available in the period after publication. Be sure to indicate the date of production for your map, or make sure that it can be inferred from the context in which it is to appear (maps that appear in newspapers, magazines, and journals can be dated in this way). The detail with which you specify the date of production will depend again on the nature of your theme and audience.

ELEMENTS THAT ARE USED SELECTIVELY TO ASSIST EFFECTIVE COMMUNICATION:



Neatlines

Neatlines or clipping lines are used to frame a map and to indicate exactly where the area of a map begins and ends. The outer neatline of a map--its border--helps to frame the entire map composition to draw the reader's attention to the various elements of information. Neatlines are also used to "clip" the area of the body of the map and of locator, inset, and index maps. Neatlines are not always needed to trim the body of the map. ***Examples***. Some geographic areas can, so

to speak, be suspended in space without a neatline. In other cases, the areal extent of a map can be made apparent in other ways.

Locator maps

Some maps portray areas whose locations may be unfamiliar to readers. In such cases, the cartographer adds a "helper" or locator map that places the body of the map within a larger geographical context with which the reader can be expected to be familiar. A detailed map of troop movements on the first day of the Battle of Gettysburg may require, for example, a locator map indicating Gettysburg's position within the road network of south central Pennsylvania and northern Maryland in 1863.

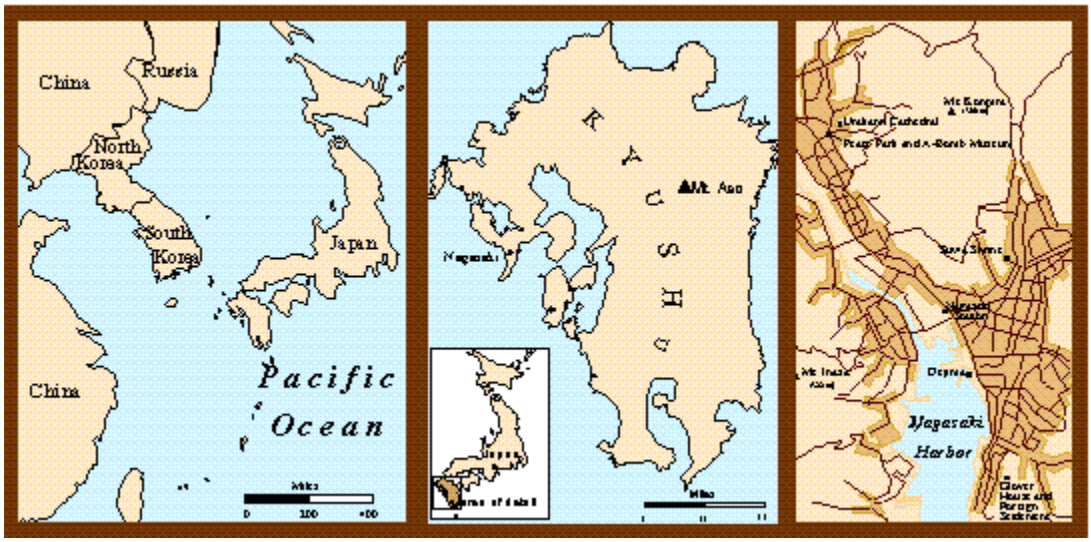
Inset maps

Sometimes observations and data are so densely clustered in small sections of a larger map that the cartographer must provide the reader with additional close-up, "zoomed-in" maps of these smaller areas. Otherwise the data will obscure itself. These close-up detailed maps are called insets.

Index maps

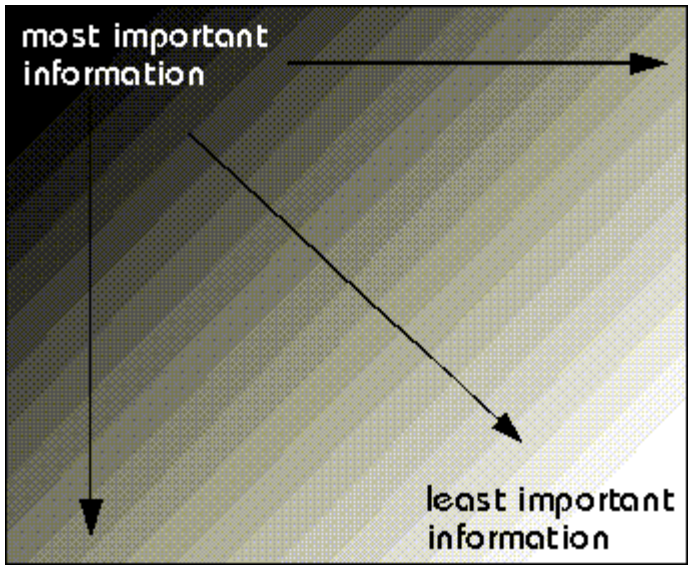
There are limits to the amount of information that can be placed effectively in the body of a map, even though this information is useful to readers. Sometimes labels and other information have to be moved to an index map.

The maps of Japan shown below are part of a series of maps designed for inclusion in a book. Therefore, they are not titled -- that function will be served by captions. The maps are designed to show the location of Japan, Kyushu, and Nagasaki. Because no thematic information is included, a legend is not necessary.
The maps move from a rather large scale down to a very precise representation of Nagasaki. Because the three maps are shown together, it is not necessary to include a locator map in the map of Nagasaki. If, however, a map of Nagasaki is intended to stand alone, a locator map is absolutely necessary.

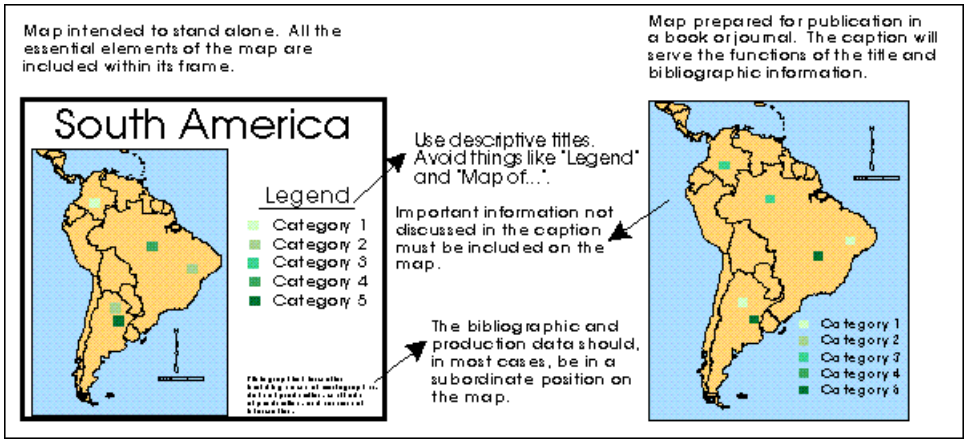


4.4 Elements are balanced within the visual hierarchy and frame of the map

As one considers each map element, the cartographer must determine its importance to and priority within the overall map design. The most important elements in a given design should be featured in more prominent positions and perhaps occupy a larger area within the map frame. As a first approximation, the most important information should be featured near the top or to the left of the map. Less important and ancillary map elements can be positioned toward the bottom and right. In this way, the importance of the various map elements can be matched to the visual hierarchy of the map itself. In general terms, the importance of a given map element should be reflected in its position and the amount space it occupies on the map.



Once the elements are arranged to reflect their importance, attention can be given to their overall balance in the map frame. The idea here is to distribute the elements as evenly as possible within the map frame to avoid unnecessary crowding or, conversely, large blank areas. The cartographer can also align map elements within the frame to allow readers to more easily scan the page



4.5 Experiment with map layouts

Experimentation is often required to achieve an effective layout. You might begin by preparing some simple sketches of you map blocking out how you will use the available space. Sketches such as this allow you to consider alternative layouts before you begin to compose the elements in detail. Sometimes computer-assisted drafting systems can be useful at this stage because of the ease with which they permit you to experiment with possible layouts.

4.6 There should be a defensible reason for each element placed on a map and for its composition

As you develop a design for a map, think carefully about every element--does it play an essential function, could it be simplified, does it require elaboration, is it of critical importance to reader comprehension, or only of background interest. Such questioning of every detail is important to effective map making. Everything that appears on a map should be there for a defensible reason relating to message and audience.

4.7 Less is more

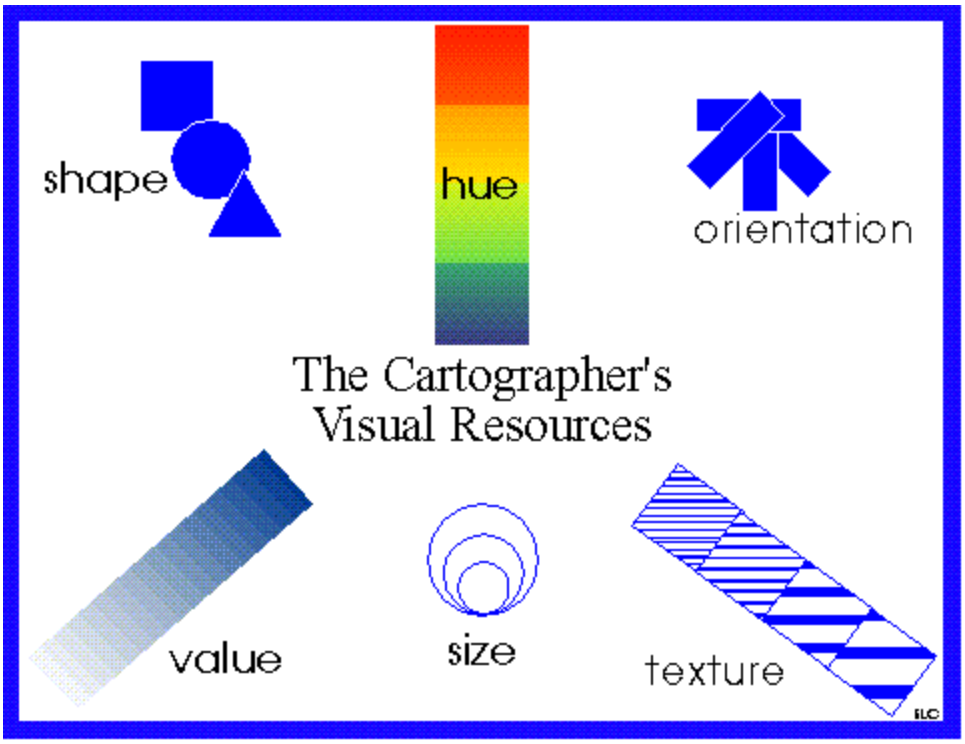
As you consider the elements of your map, it is sometimes useful to apply the adage *less is more*. As you work, consider ways in which you can simplify your design and make it more legible. Too much detail or too complex a layout can confuse readers and work against effective communication. Do not avoid experiments, but be sure to test them carefully with your potential readers.

5. The Cartographer's Palette: The Semiotics of Cartography

Cartographers employ symbols to represent location, direction, distance, movement, function, process, and correlation. These features of the real world are abstracted and symbolized on maps as points, lines, and areas. A tremendous amount of practice and skill is involved in choosing effective strategies for symbolization. One of the best ways to learn about these strategies is to consider the sorts of visual resources available to the cartographer.

5.1 The range of visual resources

As cartographers reduce the world to points, lines, and areas, they use a variety of visual resources. Jacques Bertin in his book *The Semiology of Graphics* (1983), inventories these resources using the categories of size, shape, value, texture or pattern, hue, orientation, and shape.

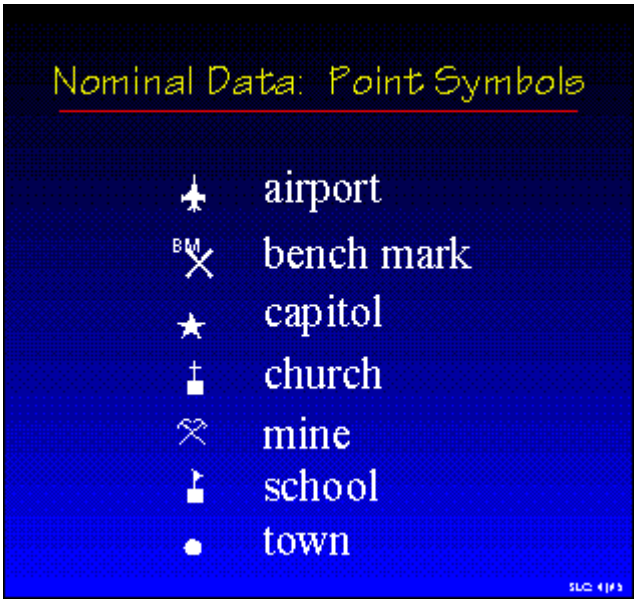


Cartographers can apply these resources to points, lines, and areas in a variety of ways. Each of these resources can be used individually to draw attention to map features, or they may be used in combination. Sometimes cartographers deploy several of these resources simultaneously to stress particularly important information or to improve its legibility.

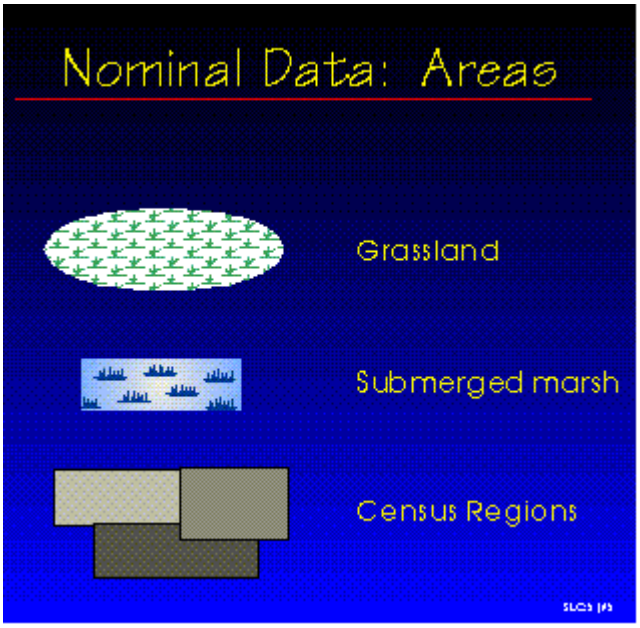
5.2 Strategies of symbolization

With such a range of resources available, the question arises as to what strategies to use in assigning these resources to points, lines, and areas. The strategies employed vary greatly depending on the nature of the phenomena being mapped. We distinguish among four **levels of measurement** in describing real-world phenomena:

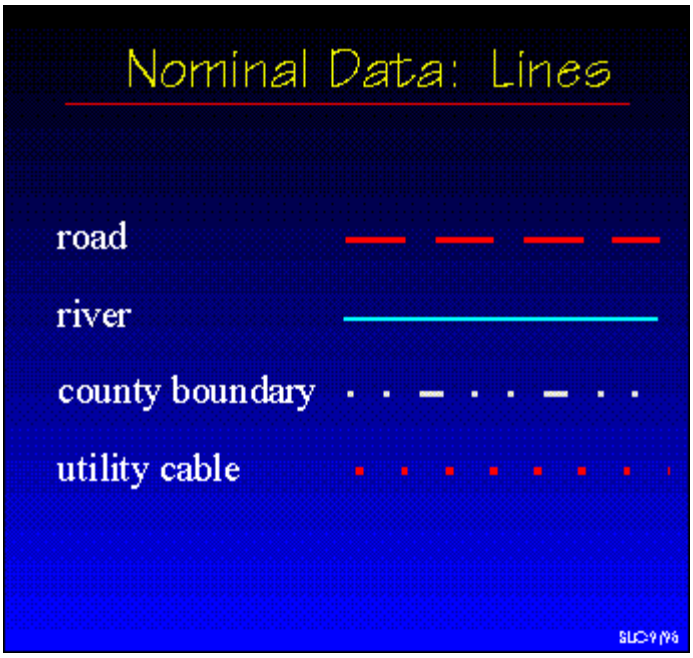
Nominal data is information that is simply grouped into categories on the basis of qualitative considerations: a road distinguished from a river or a forest distinguished from an open field.



points

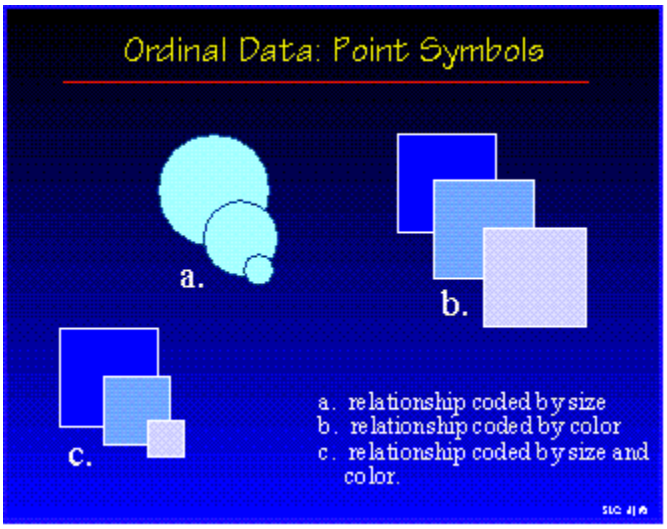


areas

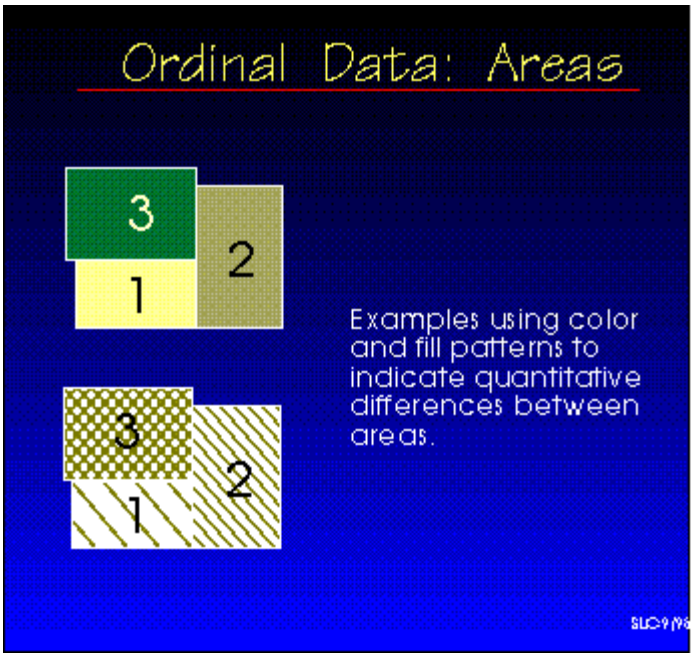


lines

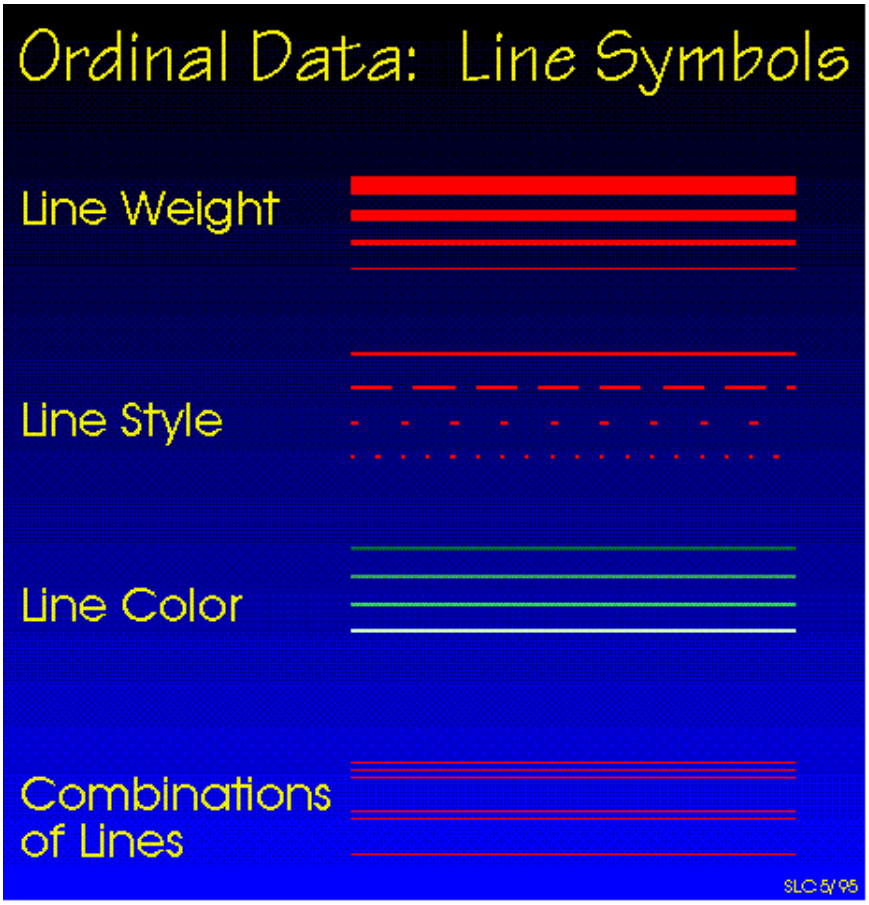
Ordinal data is grouped by rank on the basis of some quantitative measure: small, medium, and large cities or single-lane, double-lane, and four-lane roads.



point


Ordinal Data: Areas
3
2
1
3
2
1
Examples using color and fill patterns to indicate quantitative differences between areas.

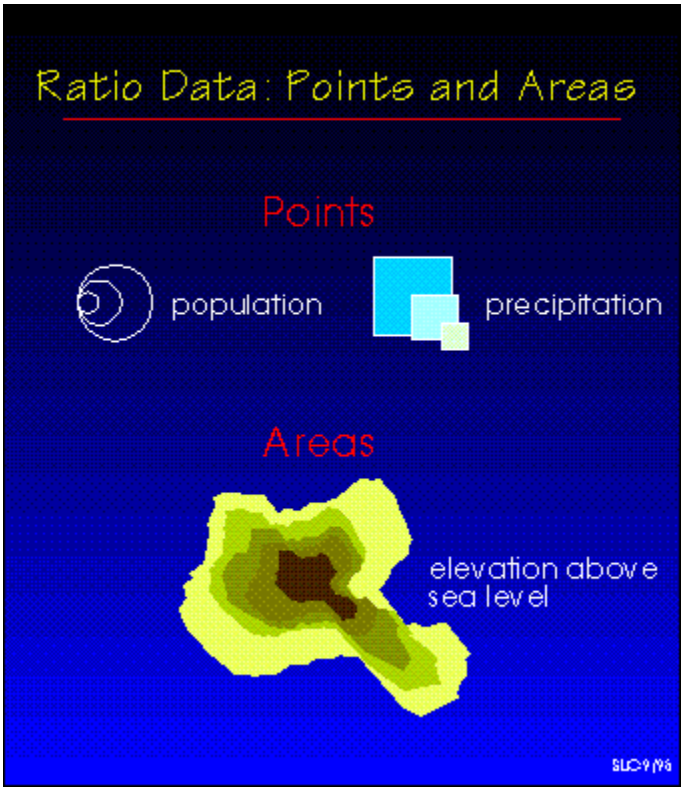
area


Ordinal Data: Line Symbols
Line Weight
Line Style
Line Color
Combinations of Lines

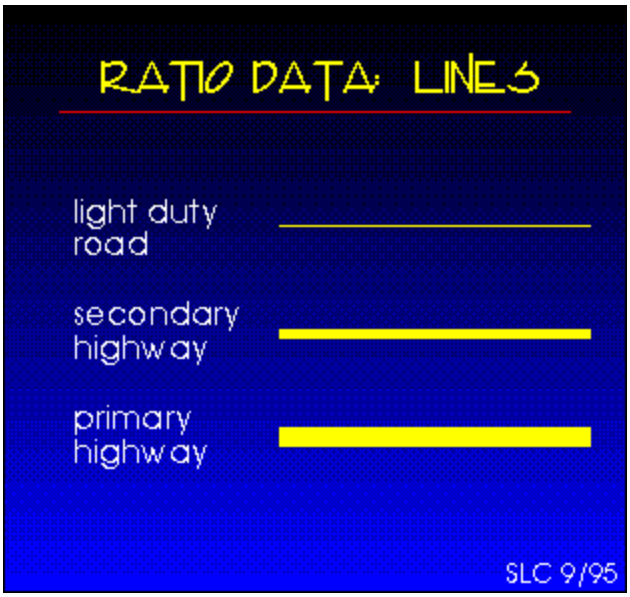
line

Interval data is information that can be arranged using a standard scale along which operations of addition and subtraction have meaning. Temperature is an example of an interval measure.

Ratio data is information that, like interval data, can be arranged along a scale but, in addition, the scale begins at a non-arbitrary zero point. At the zero point, no features are present. The operations of multiplication and division can be employed with ratio data to consider proportions and magnitudes. Elevation above sea level, precipitation, and population are all examples of ratio data.



points and area



lines

These resources can be used in a wide variety of ways and several may be used at once to highlight or reinforce a single relationship. Thus, for example, if only a single ordinal variable is being mapped, several visual resources may be deployed at once. If several ordinal variables are being displayed, the visual resources may have to be used more selectively.

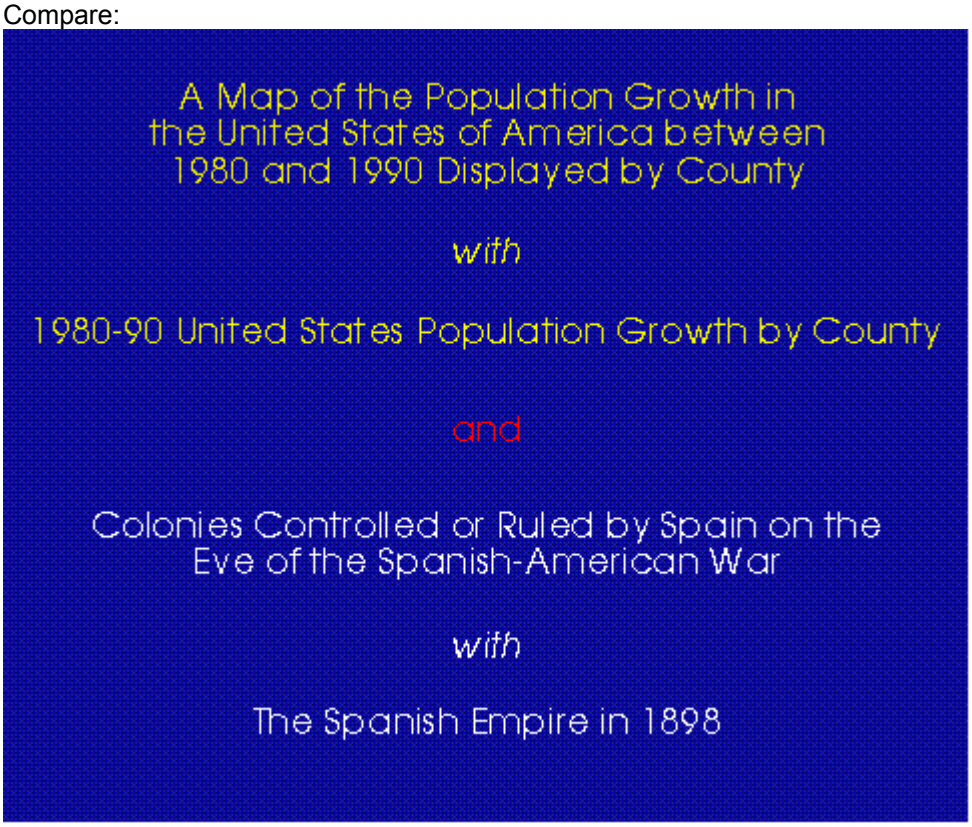
5.3 Typography and lettering

Adding text to a map is one of the cartographer's most demanding tasks. The cartographer must be concerned both with the **content** and the **form** of the text, that is the wording and the way the text is displayed on the map. Indeed, the verbal content of a map is one of the most powerful communicational resources available to the cartographer. Its effective use is often the point of difference between high-quality, professional maps and less skillfully executed maps. Compare the following maps and notice how much difference lettering makes to overall readability. Pay special attention to the differences--the size of the lettering, how it is aligned, and the fonts and cases used.

A. Content

Concise, carefully formulated captions and annotations make a tremendous difference to a map.

Compare:



One way to test the effectiveness of your text is to ask others to read and interpret a draft of your map. If they are confused or misinterpret the theme, rewording is essential. You should also check your map for redundancies so as to avoid repeating yourself in the title, legend, and annotations. That is, consider all of the map text together and balance its content to convey your message without being repetitious. Finally, avoid using abbreviations unless you are certain your audience will be familiar with their meaning.

B. Form

Bertin's semiotic resources apply to text just as they do to points, lines, and areas. However, with respect to text, some of these resources are given special names. Font refers to the shape and pattern of letters. Hundreds of fonts have been created since the invention of the printing press and are available using automated systems. Fonts are often grouped into several broad categories. A distinction is made between serif and sans serif fonts, as well as between **Roman** and *Italic* fonts. The weight of text is classified as **bold**, **medium**, or light.

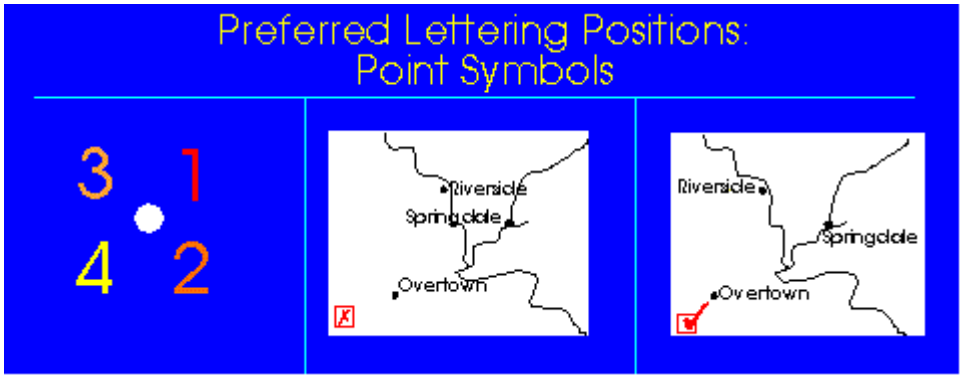
Sans serif fonts can be scanned more rapidly by most readers, although less information seems to be retained than would be the case if the same text was displayed with a serif font. Italic fonts are used for the titles of books and journals and for some proper names. Since it was impossible to print italic characters with typewriters, underscoring was used to indicate the placement of italic characters. It is no longer necessary to employ this convention with automated systems capable of printing italic characters. Traditionally the size of lettering was measured in picas or point size. Increasingly, automated systems measure size using conventional units such as inches and millimeters. The

horizontal and vertical distances between lettering are traditionally referred to as *leading* , but increasingly today as inter-character and inter-line spacing.

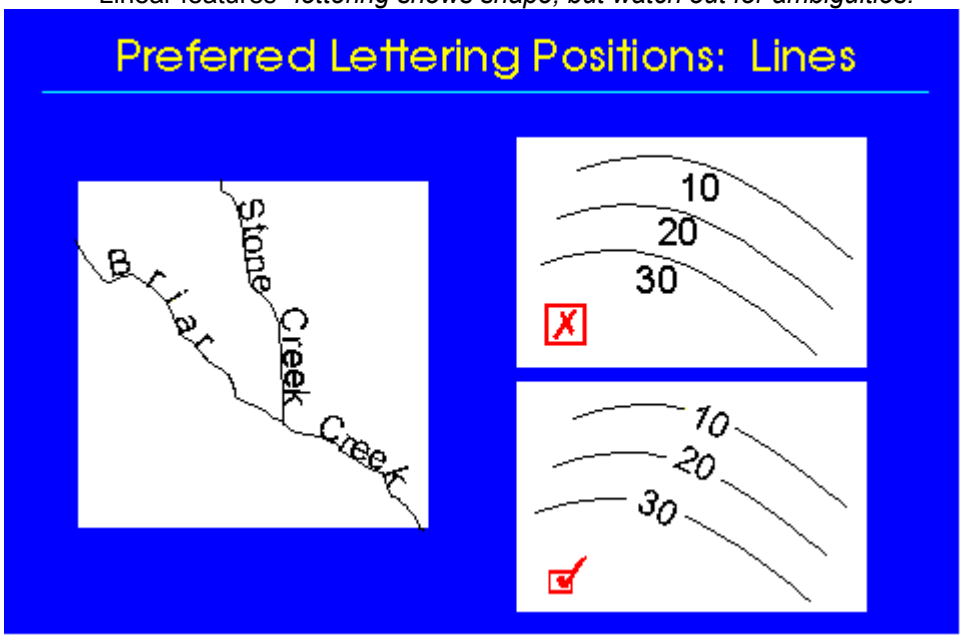
Although automated systems offer a wealth of fonts and sizes, good practice dictates that these resources be used sparingly. Too many fonts (and sizes) can potentially confuse the reader. Traditionally, typographers try to use no more than four fonts or font sizes on a given page of print. Apply the same principle to your maps. Use different fonts and sizes only when you have a compelling reason to do so. Lettering is also distinguished by case: UPPER CASE, lower case, and Mixed Case.

If you consider professionally produced maps, you find that font, size, and case are used very carefully to encode text. In effect, the text is used to group information into useful categories that reflect the theme of the map.
Special attention must be paid to the orientation of text with respect to the features being labeled. In this respect, text can be used as an important cue to different map features.

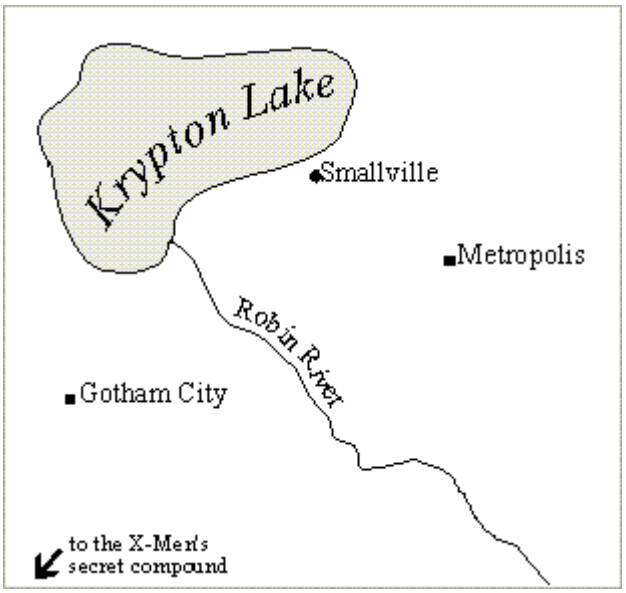
Point features--*lettering "points" to feature, but try to avoid lettering across boundaries.*



Linear features--*lettering shows shape, but watch out for ambiguities.*



Area features--*lettering occupies the area.*



In following these guidelines, conflicts will always emerge. On maps crowded with information it is nearly impossible to arrange all text without striking compromises among these principles. The point is to follow the guidelines as much as possible and, when conflicts do arise, consider options carefully in light of the map theme and competing cartographic elements.

The arrangement of letters can also be used to convey quite subtle distinctions. For example, in the following map, lettering pertinent the map theme is aligned with the map frame whereas lettering that describes the background features is aligned with the graticule.

Quite apart from labeling features, text is used for convey other information about the map--sources, date, methods of compilation, projection, and cartographer. This ancillary information is usually placed in a subordinate position within the frame of the map. However, the readability of your map will be improved if you position this text in relation to the major map elements. That is, your map can be composed with implicit margins and tabs that can be used as a means of alignment for subsidiary text.

5.4 Foreground-background (figure-ground) relationships

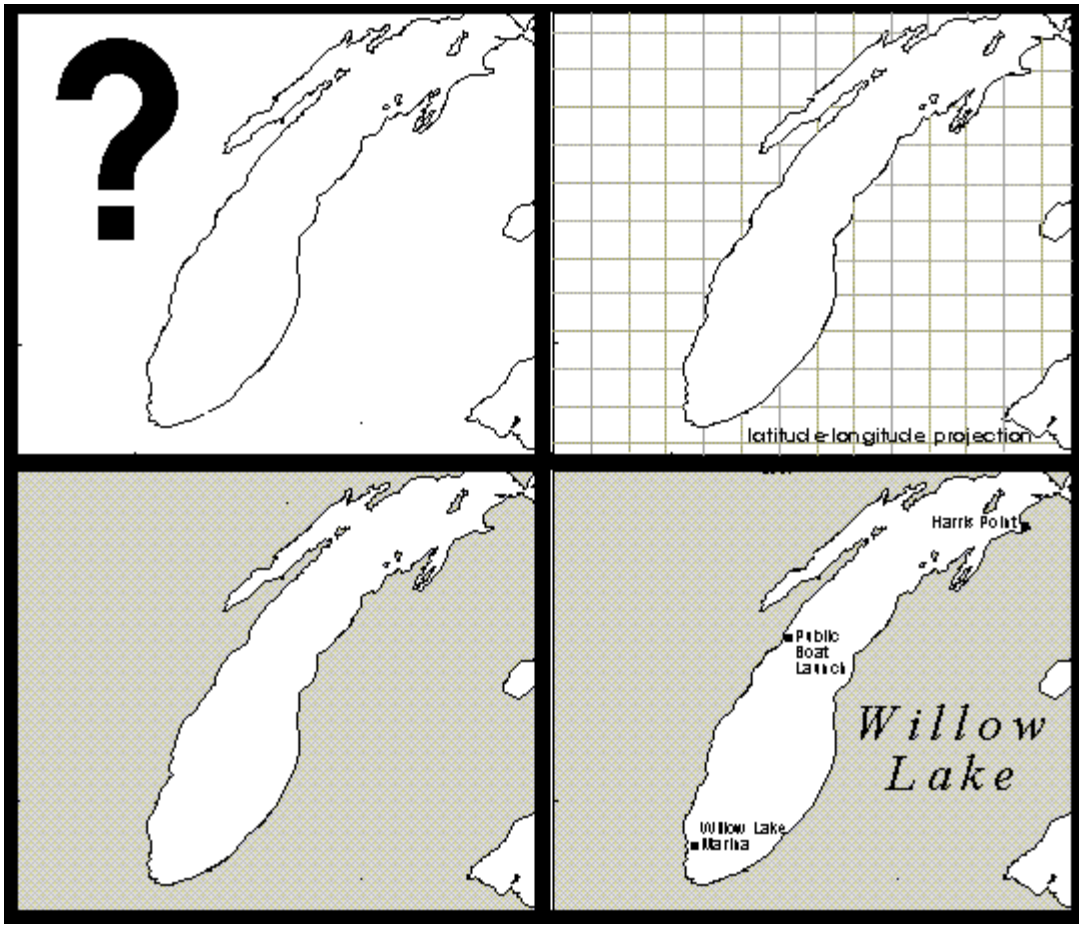
Good cartography involves bringing the most important map information into the *foreground* of the reader's attention, even though other detail must be displayed in the *background* to make the map intelligible. Differences between the foreground and background are critical to some maps where clear distinctions must be made between certain types of features like the boundaries between land and water bodies. Cartographers employ a number of devices to make it easier for readers to distinguish between these features and to sort out a map's most important message.

The key to resolving foreground-background relationships is to use color, value, and patterning to "raise" some map features into the foreground. In some respects this is like using color, value, and patterning to produce a sort of three-dimensional effect in which certain key features appear to rise off the map's two-dimensional surface. In fact, these resources can be used to create a sort of three-dimensional visual hierarchy.

This idea can be put to practical use in a wide range of situations where the reader would otherwise have difficulty sorting out information displayed on a map.

Understanding the dynamics of foreground-background relationships can also help resolve certain ambiguities that sometimes arise in mapmaking. Consider the following example:

In this map it is difficult to distinguish between water and land because both are arrayed at the same level of the visual hierarchy. This ambiguity can be resolved in several ways: shading, adding a graticule, vignetting, and lettering.



Depending the map and mapping system you employ, any of the options might be used either singly or in combination.

5.5 Highlighting the theme

The theme of your map must rise to the foreground. Now that you are aware of the cartographic resources available, you can use them to highlight the most important thematic information. This may involve using a vivid or saturated color to bring the information forward, using heavier line weights, or a contrasting, bold pattern. These resources can, of course, be used in combination.

6. Issues of Statistical Generalization

6.1 The importance of attending to issues of statistical generalization

When maps are used to display statistical information, cartographers take special care to depict as accurately as possible the underlying distribution of data. This is a difficult task because the whole point of displaying the data cartographically is to generalize the data to facilitate the search for spatial patterns. But by generalizing and simplifying the data, the cartographer may just as easily obscure subtle gradations in the underlying distribution. Therefore, in mapping statistical data, the cartographer is always trying to strike a balance between remaining true to the underlying data distribution and generalizing the data sufficiently to reveal intrinsic spatial patterns.

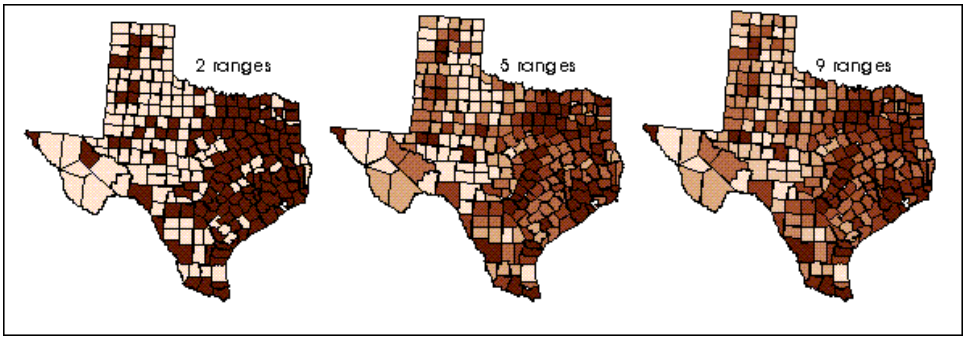
Although these issues of statistical generalization can be applied to data that is to be symbolized by points, lines, and areas, this discussion will be developed around the mapping of areas in choropleth maps. This is in part because choropleth maps are used so widely, but also because they are difficult to execute effectively. This is because choropleth maps have an inherent weakness--they involve the aggregation of data within areal units that do not correspond exactly with the underlying spatial distribution of data. By focusing on choropleth mapping in the following examples, some of these weaknesses can be revealed and discussed.

6.2 What a difference this issue makes to maps

To understand the importance of this issue, it is useful to examine a set of maps developed from the same dataset using different numbers of categories and different ranging methods.

A. Comparison of maps using different numbers of categories

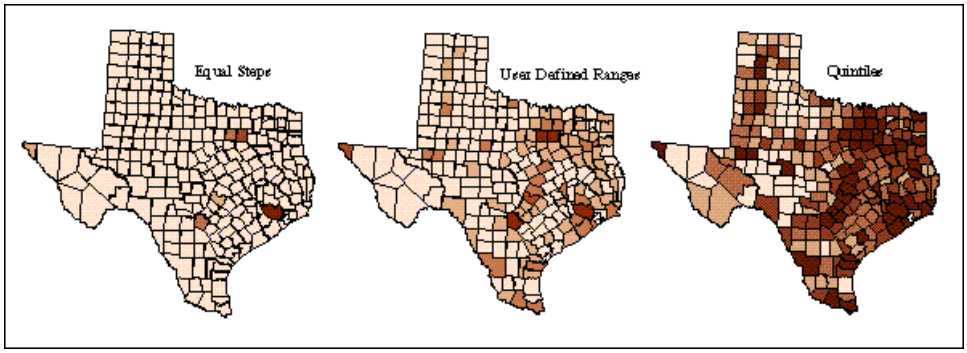
These three maps are divided into quantiles of two, five, and nine categories, respectively.



If too few categories are used, the map may obscure the contours of the data distribution. Too many categories are just as fruitless and equally unlikely to reveal any existing spatial patterns in the dataset. Indeed, it is difficult for most map readers to distinguish among more than about seven categories. Beyond seven, a map becomes little more than an illustrated table. Most statistical maps will use between three and seven categories.

B. Comparison of maps using different ranging methods

These three maps each have five ranges of data, but they were determined using different methods. The first map uses *equal steps*, the second has *user defined ranges*, and the third is divided into *quintiles*.



Even though these maps were developed from the same dataset, they seem to convey quite different spatial patterns. Some seem to stress the lowest values in the distribution, others the highest. The point is that cartographers use different ranging methods to generalize different types of data distributions. Each method is suited to a particular "shape" distribution. Therefore, the first step in preparing a choropleth map is to explore the dataset to come to an understanding of its underlying distribution.

6.3 Exploring your data and its "shape"

You should get to know the shape of any statistical distribution you plan to map. Plot a scattergram or histogram of the data and employ basic descriptive statistics to explore its distribution. Many automated mapping programs provide options which graph data and will automatically calculate descriptive statistics like mean, mode, median, range, and standard deviation. Take advantage of these options explore your data.

Diagrams of different shapes:

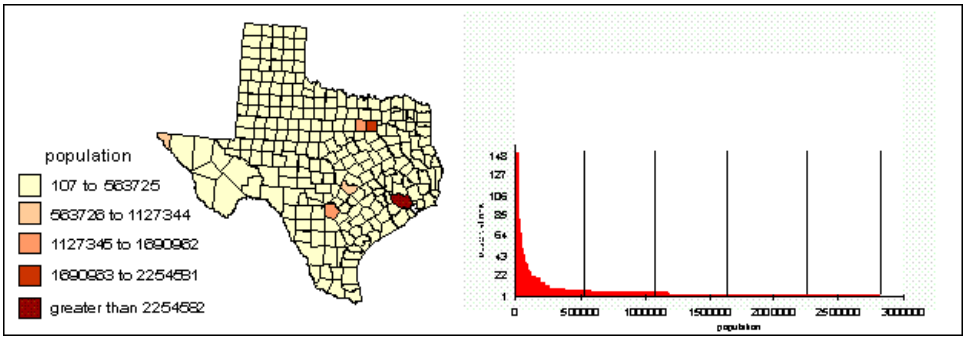
Be aware also that mathematical transformations change the shape of a distribution--implying that the ranging method must change also. Shown below is a histogram of population growth of Texas counties between 1980 and 1990. Note that the distribution is J-shaped with a pronounced peak on the left--meaning most Texas counties grew very little in this decade. However, if this same data is represented as a percentage of 1980 population, the histogram looks very different--because even the smallest counties did grow substantially in proportion to their 1980 population.

6.4 Commonly employed ranging methods for assigning cutpoints

The articles listed below by Michael Coulson (1987), Ian Evans (1977), and George Jenks (1963) provide detailed overviews of the ranging methods commonly employed by cartographers as well as necessary computational algorithms. It is essential that you consult these articles as soon as possible because they cover many more techniques than can be discussed here, and in far greater detail. The following discussion will simply highlight a few of the methods that many computer systems provide as "defaults."

In generalizing statistical distributions, cartographers use the term "cutpoint" to refer to the boundaries between categories. All the following methods pertain to the calculation or assignment of these cutpoints. Remember, all systems of classification depend upon the use of "exhaustive" and "mutually exclusive" categories. Exhaustive means that the categories classify all values of a given data range--no values within that range are omitted from the classification system. Mutually exclusive means that any given observation can be placed in one and only one category--data categories cannot overlap. Please be sure, if you are using an automated mapping system, that the the system does not assign overlapping cutpoints automatically when it creates the map legend.

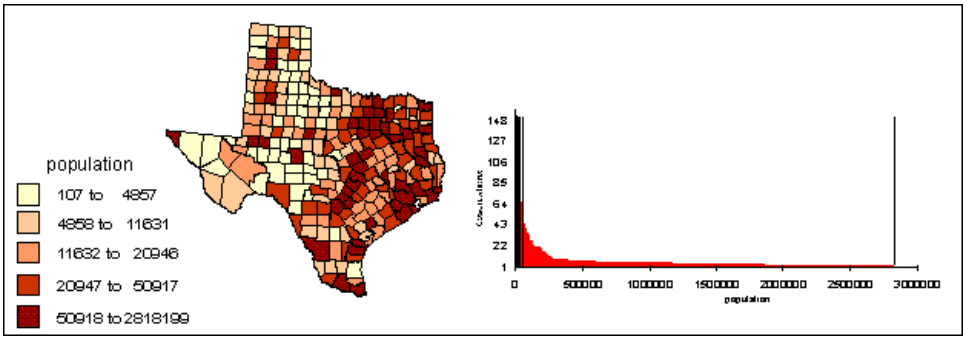
A. Equal Steps



This method takes the difference between the low and high values of a distribution and divides this difference into evenly spaced steps. If the 0 and 10 were the low and high values of a distribution and you decided to divide the data into five categories, the cut-points would be: 0, 2, 4, 6, 8, and 10.

The method is useful for mapping rectangular distributions. It is also useful for exploratory analysis, at times when you wish to develop a "feel" for the characteristics of a data distribution.

B. Quantiles

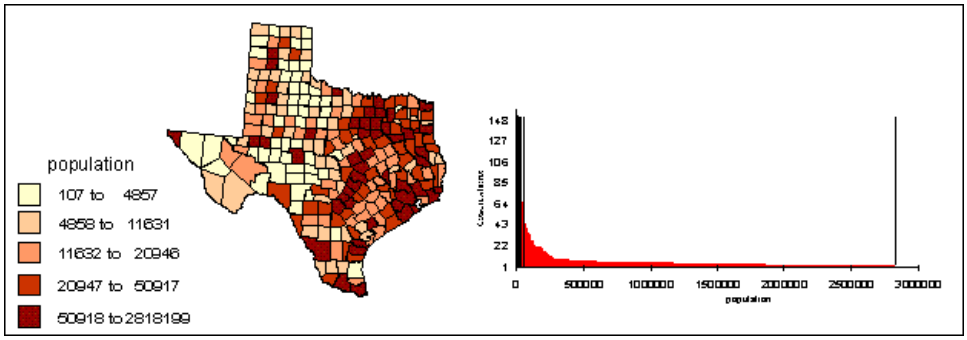


This method arranges your observations from low to high and places equal numbers of observations in each category. If your data included one hundred observations and you wished to divide the data into five categories (quintiles), the

lowest twenty observations would be placed in the first category, the next twenty in the second, and so forth until the highest twenty observations were placed in the last category. The term quartiles is used when the data is divided into four categories, quintiles when five are used, sextiles for six, septiles for seven, and so forth. Note that when data is divided in this way, the cutpoints of the distribution may be arranged at irregular intervals along the span of the distribution.

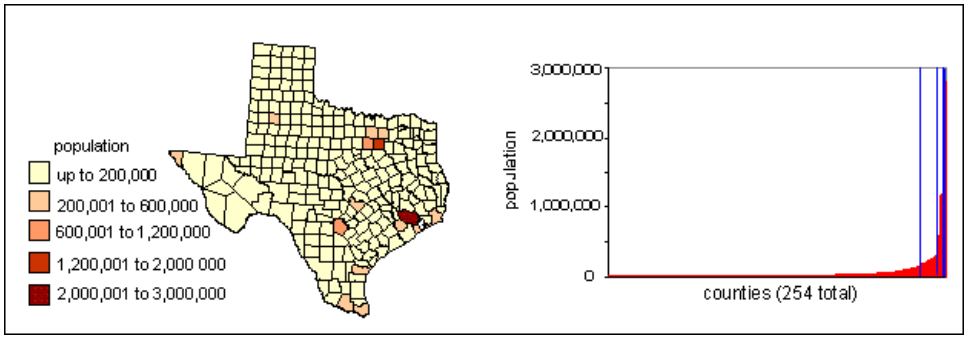
The method is useful for mapping rectangular distributions. It is also useful for exploratory analysis, at times when you wish to develop a "feel" for the characteristics of a data distribution.

C. Percentiles



This method places equal percentages of the observations in each of the categories selected. If you select five categories, twenty percent of the observations will placed in each of the categories beginning from the smallest value to the largest. The percentile method is equivalent to the quantile method described above. The method is useful for mapping rectangular distributions. It is also useful for exploratory analysis, at times when you wish to develop a "feel" for the characteristics of a data distribution.

D. Arithmetic Progressions



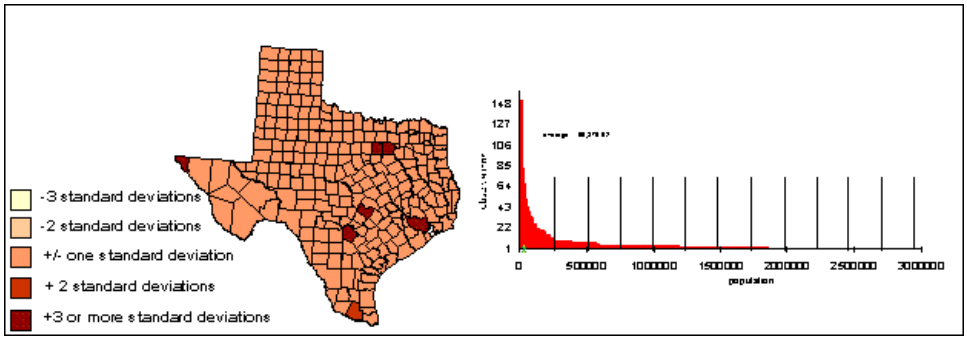
In this method, the widths of the category intervals are increased in size at an arithmetic (that is, additive) rate. If your first category is one unit wide and you choose to increment the width one unit at a time, the second category would be two units wide, the third three units wide, and so forth to the end of the distribution. This method can be applied effectively to data that is J-shaped with a peak at the low end of the distribution.

E. Geometric Progressions

In this method, the widths of the category intervals are increased in size at a geometric (that is, multiplicative) rate. If your first category is 2 units wide, the second would be 2x2 or 4 units wide, the third 2x2x2 or 8 units wide, and so forth to the end of the distribution.

This method can be applied effectively to data that is J-shaped with a peak at the low end of the distribution but with a long "stretch" between low and high values.

F. Standard Deviation



In this method, the standard deviation of the distribution is used to set the cutpoints above and below the average.

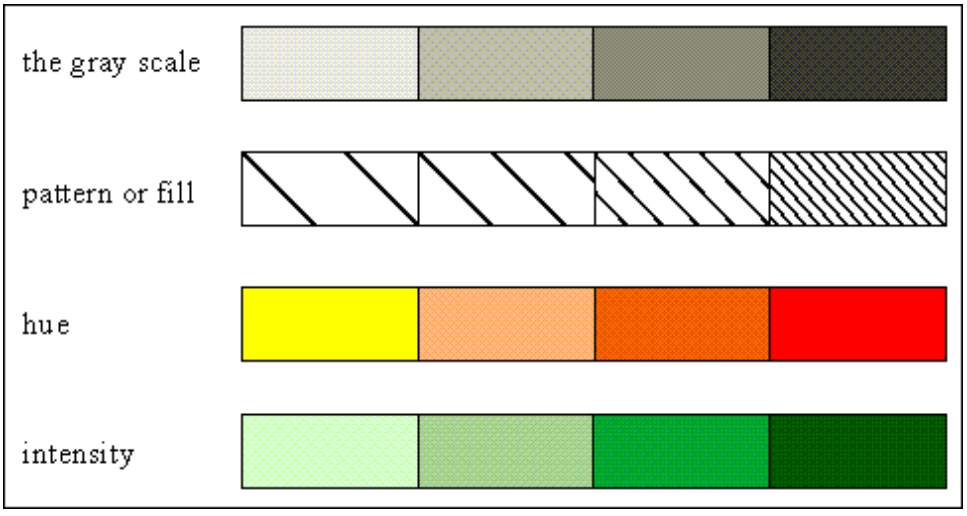
This method can be applied to distributions that approximate a normal curve.

G. Inverse Methods

If your data is J-shaped with a peak at the high end of the distribution, the inverses of the arithmetic and geometric progressions can be employed. By inverting the cutpoints, the smallest intervals between cutpoints will be closest together at the high end of the distribution.

6.5 Symbolizing the Category Ranges

Once you have divided your data into categories, you must use the visual resources at your disposal to symbolize them on the map. Because your interval-ratio data have now been ordered into ordinal categories, the idea is to use color, value, or pattern to create a visual index between category symbols and their value. You can order the symbols using:



6.6 Statistical annotations are needed for some complex datasets

In some situations, you might find it useful to add statistical annotations to your map. These may indicate to the reader the nature of the statistical distribution being displayed and the means by which it was classified. Sometimes it is sufficient to note some of the descriptive statistics for a distribution, such as its range, mean, median, and mode. At other times, you may wish to add bar graphs, scattergrams, or other statistical diagrams.

7. Problems of Realizing Ideals with Computer Systems

Mapping software provides cartographers with the same sorts of advantages that text-processing software offers writers. Computers assist cartographers with the accurate drafting that has traditionally required tremendous manual skill, patience, and training. They also make it far easier to revise maps, to experiment with layout, composition, and symbolization, and to duplicate information from one map to another when producing series of maps. Still, the effective use of automated systems requires that the cartographer be just as familiar with the strengths and limitations of each automated system as with principles of effective cartography. The point is that computers can be used to produce poor maps as readily as good maps and the responsibility to know the difference rests with the cartographer. Perhaps the thought to keep in mind is that *computers don't make good or bad maps, cartographers do.*

In turning to the use of computer systems, one should consider a number of related issues:

7.1 Systems vary greatly in their strengths and weaknesses: Be aware of both

Most software systems are customized to meet the demands of specific mapping tasks. They are intended to do one or two things very well--perhaps demographic or contour mapping--and are not so good when deployed outside their domain. By acquainting yourself with a system's *raison d'être* you will also be able to surmise potential limitations. More importantly, do not assume that all your mapping needs will be subsumed by a single software system. It is common practice to use a variety of systems to produce even individual maps. Some computer-assisted drafting packages make it very easy to create precise base maps, but these base maps will be transfered to other graphics or drawing programs to add shading or lettering. Contour mapping and terrain modeling software may offer very advanced features for surface modeling, but limited capabilities for text, annotations, and shading; these can be added with other systems. These days it is relatively easily to move digital maps and graphics from one software system to other so as to capture the virtues of each and avoid their deficiencies.

7.2 Consider availability of needed functions and ease of use

In selecting software it is often easy to distracted by "bells-and-whistles" -- features that promise the potential of extra "pizzazz"-- such as hundreds of fonts or millions of colors. These extra capabilities can be nice to have, but it is essential to keep one's eye on a couple of critical issues. First, how well will the system perform the functions that you use most often, perhaps on a daily basis? Extra features can be useful, but they are of little concern if you only intend to use them once a year. Second, how easy will it be learn the system well enough to incorporate it in your work? This is more than asking whether the system comes with tutorials and instructional materials. Such materials are of course important, but for every extra feature a system offers, time is added to the learning process. Even the rudimentary drawing packages provided free on many computer systems can produce exceptional maps, and they are very easy to learn. Some advanced

systems for computer-assisted drafting and geographic information systems can produce maps of equal or better quality, but require weeks or months to master. Do not feel you need to acquire more "power" than you need right now. Software changes so rapidly that you may be investing in capabilities that will be surpassed before you need them.

7.3 Be aware of the problems of designing for particular output devices

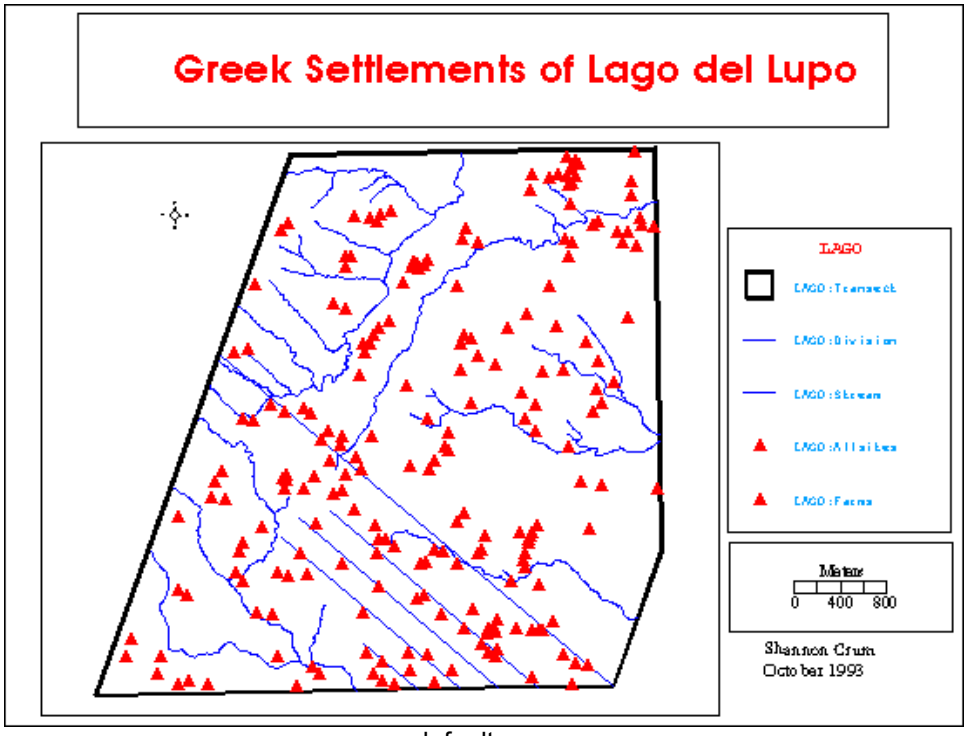
Be aware that the destination in map production is particular a output device: a screen, or pen, inkjet, thermal, and electrostatic plotters. These devices vary greatly in their ability to depict linework, symbols, colors, and so forth. Cartographers have had to wait decades for the quality of low-cost, easy-to-use output devices to catch up with the capabilities of computers and mapping software. But such equipment is now available offering excellent resolution and color in A and B formats for less than $500. Still, what you see on the screen may not be exactly what the printer produces--colors, patterns, and lineweights may vary. You must design your map to the characteristics of the final output device. It is no use claiming that "it looked good on the screen." It is the final map that matters and experimentation with settings is a key to understanding how output devices vary in their representation of your map.

7.4 Experimentation and multiple iterations are often required

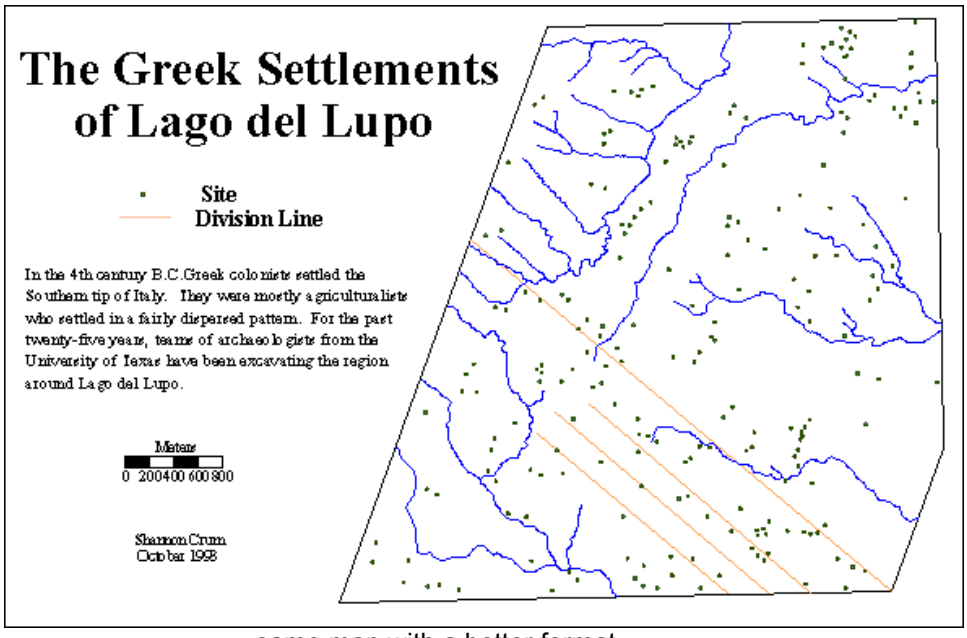
Computer systems are able to assume some of the more onerous drafting tasks associated with map production, but that does not mean that you will produce an effective map the first time around. In working with automated systems, patience is a virtue. Time must be set aside to learn the system and its options. Once a person is familiar with the capabilities of system, map production will speed up, but not necessarily immediately. One has to experiment with settings through multiple iterations of a map. Patient, systematic experimentation with options is vital.

7.5 Never trust defaults

The single most important rule in using automated systems is: Never trust defaults. Without your careful guidance, most systems use "default" settings designed, perhaps, to fit the needs of an "average" user or simply to get you started. These settings should always be questioned from the standpoint of your cartographic goals. Unquestioned, these settings may lead to ineffective or even misleading maps. Many of these settings are, initially, very useful because they will help users find their way around the software system. For example, some systems provide automatic options for titling, legends, shading, and symbology. In some cases, these setting may work for your project. It is more likely that you will need to change them. Learn the options available on your system, and do not feel obliged to use the standard settings simply because they are more convenient. Again, remember, *computers don't make good or bad maps, cartographers do.*



default map



same map with a better format

8. Into the Future

Computer systems are certainly changing the way cartographers produce maps. At the same time they are also raising some interesting conceptual and intellectual challenges for the future.

8.1 Toward the virtual map

New systems allow computers to simulate and model reality by using visual and auditory cues in three dimensions. These same systems might be used to create virtual maps in which users can traverse and study real and simulated environments and landscapes. At issue here is not just how these systems might be developed and employed, but also how they crosscut cartography's core concern of abstracting, simplifying and symbolizing real-world phenomena and relationships. Cartography is a process of interpretation and representation in which the map maker draws attention to critical relationships and patterns. The question is really how can this interpretive and representational task be carried forward into in virtual reality? How will cartographers be employed in cyberspace?

8.2 Animation and other new dimensions

Mapping systems allow cartographers to draft as easily in three dimensions as two. Furthermore, many mapping and drafting systems are clones or close cousins of those used for animation. Such capabilities present cartographers with interesting opportunities to model temporal relationships, reconstruct past environments, or simulate complex processes. Could historical geographers reconstruct past environments in three dimensions or ecologists animate processes of landscape transformation? Tremendous innovation seems arrayed along the horizons of cartography.

1. Essay Questions

Limit each essay to two double-spaced typewritten pages plus references.

1. Discuss the ten elements of a map.

2. Short Answer

Limit your answers to no more than 100 words.

1. To position map elements within a "hierarchy of importance" means that:
2. How does the principle of "less is more" apply to the drafting of effective maps?
3. Why is the assignment of category boundaries (cut-points) critical to preparing and effective chloropleth map of ordinal or interval data?
4. How do cartographers match the importance of map elements to the visual hierarchy of maps?
5. List three different ways in which scale can be indicated on a map and give an example of each?
6. What is the function of a neatline on a map?
7. To what extent will the audience for a map determine its content?
8. Provide specific examples of how color can be used to improve the effectiveness of maps.
9. You are preparing a map of population density in twenty nations of Central and South America. In population per square kilometer, the figures are: 6.8, 11.1, 12.0, 17.2, 17.8, 17.9, 22.4, 31.6, 32.1, 32.5, 39.0, 45.2, 47.4, 61.0, 87.3, 97.5, 151.3, 225.6, 240.2, 256.8.
    1. Divide this list into quintiles, what are the cutpoints?
    2. Divide this list into equal steps, what are the cutpoints?
    3. Which is the more effective method in this situation, and why?
10. You are making a map of precipitation in the Texas Panhandle. Your map considers the amount of precipitation distinguishing between rainfall and snowfall. In this situation:
    1. Precipitation is an: interval-ratio, ordinal, nominal variable (choose one).

    2. Rainfall-snowfall is an: interval-ratio, ordinal, or nominal variable (choose one).
11. What are six visual resources available for thematic mapping?
12. Explain why choropleth maps are inherently misleading?
13. What are four types of information that can be distorted by map projections?

3. Multiple-choice questions

Choose the best or most appropriate answer(s) to the question.

1. What are the four ways to manipulate a map projection?
    1. coordinate manipulation, spheroid simplification, aspect, geometric form
    2. **aspect, case, light source, geometric form**
    3. gravity, light source, spheroid simplification
    4. none of the above
2. When preparing maps that record land records and parcels, map projections are preferred that have the following properties?
    1. **equidistant**
    2. conformal
    3. equivalent
    4. azimuthal
    5. **equal area**
    6. orthomorphic
    7. constant scale
    8. zenithal
3. The following features are found on virtually all maps:
    1. **distance or scale**
    2. **direction**
    3. locator map
    4. **legend**
    5. neatlines
4. Maps are valuable for which of the following reasons:
    1. **they provide a method for recording and storing information**
    2. **they are a means of analyzing spatial data**
    3. they help us recognize non-spatial data
    4. **they are a method for presenting information and communicating findings**
5. Cartographers may use a number of visual recources such as:
    1. size and shape
    2. texture or pattern
    3. orientation
    4. 1 and 2 only
    5. **1, 2, and 3**
    6. none of the above
6. The term "nominal data" refers to:
    1. a level of measurement
    2. the quantitative grouping of data
    3. the qualitative grouping of data
    4. none of the above
    5. **1 and 3 only**
7. Ordinal data is grouped by:
    1. rank
    2. uses quantitative measurements
    3. cannot be effectively grouped
    4. **1 and 2 only**
    5. none of the above

8. Automated systems are capable of displaying and printing many different fonts on a map. An advantage of *sans serif* fonts are:
    1. more rapid display
    2. **ease of character recognition by optical scanners**
    3. reading retention is generally better
    4. none of the above
    5. **2 is the best answer**
9. Cartographer use the term "cutpoint" to:
    1. to refer to the neatline on a map
    2. **to refer to category boundaries**
    3. the are that will be trimmed in a bound volume
    4. a method for displaying equal distribution of data
10. In cartography the term "less is more" refers to:
    1. using fewer maps to explain a physical phenomena
    2. **simple and legible map design that effectively communicates the desired information**
    3. limiting your map design to one page
    4. **eliminating non-essential information on a map**