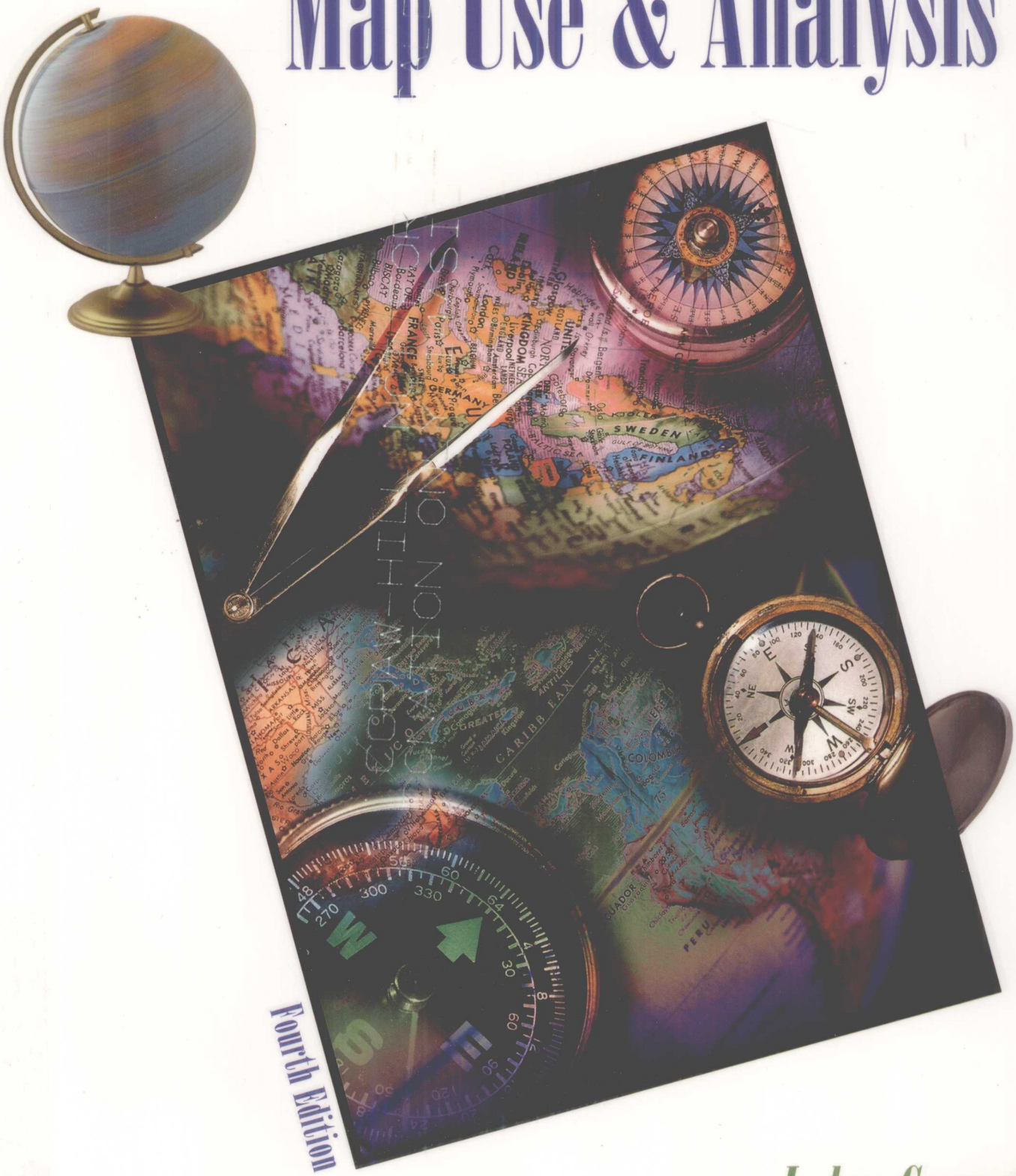
Map Use & Analysis



Fourth Edition

John Campbell

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PREFACE

This book is designed to serve as an introduction to the fascinating world of maps. It explains how to use maps to obtain information about a wide variety of topics. Throughout the book, maps are viewed in a broad framework. Thus, the discussion includes mental maps, aerial photographs, remotely sensed images, computer-assisted cartography, and geographical information systems, in addition to traditional printed maps. The writing style is neither formalistic nor casual, with an emphasis on clarity of explanation. The discussions assume that the reader has no specific prior knowledge of the topic, so that even novice map users can understand and use the information and techniques presented.

Chapter 1 explains why maps are useful and lists the many types of maps available. Then, mapping processes are discussed in Chapter 2 because an understanding of how maps are produced provides a necessary basis for their proper use. For similar reasons, important aspects of the size and shape of the earth are reviewed. Chapter 3 surveys the characteristics of map projections, especially from the standpoint of the appropriateness of certain projections for specific purposes.

A variety of locational and land-ownership systems, which are essential for specifying location and for describing land ownerships, are explained in Chapter 4. These include latitude and longitude, the Universal Transverse Mercator and State Plane Coordinate systems, metes-and-bounds surveys, the U.S. Public Land Survey System, and the similar Canada Land Survey System. The link between scale and generalization is discussed in Chapter 5, as are methods of scale determination.

Because maps are used for measuring distances and areas, Chapter 6 discusses methods for carrying out these measurements. Techniques used in route selection and navigation on land and water and in the air are examined in Chapter 7.

Chapter 8 examines how terrain is represented on maps. Contour interpretation techniques and techniques for producing profiles and determining slopes are provided in Chapter 9. Chapter 10 follows with extensive illustrations of a variety of landform types. The examples shown are, in large part, selected from the definitive U.S. Geological Survey collection *A Set of 100 Topographic Maps Illustrating Specified Physiographic Features*.

More abstract topics are introduced in the following three chapters. Chapter 11 discusses methods by which thematic maps are used to convey a variety of qualitative and quantitative information. Chapter 12 surveys the characteristics of mapped distributions, such as the shape and pattern of point distributions. The analysis of stream patterns and transportation systems through the abstract concepts of networks and trees is covered in Chapter 13.

Cartograms are surveyed in Chapter 14. This chapter also discusses a variety of special-purpose maps, including highway and street maps, weather and climate maps, geologic maps, maps of the past, maps of the moon and the planets, and maps in journalism and on television. Chapter 15 is devoted to the interpretation of graphs. Graphs are important in their own right, but they are also extensively used as map symbols and as map supplements. Map misuse and the use of maps as powerful propaganda tools are examined in Chapter 16.

Remote-sensing techniques are becoming increasingly important and accessible to map users. Therefore, aerial photography as well as remote sensing from space are explained in Chapters 17 and 18.

Chapter 19 describes modern techniques of computer-assisted cartography, and Chapter 20 discusses applications of digital maps, including electronic atlases, electronic road maps, and automated automobile navigation. Geographic information systems are examined in Chapter 21. Both computer-assisted cartography

and geographic information systems are increasingly used to produce unique products and analyses of interest to map users.

At appropriate points in the text, supplementary treatments of a variety of topics are provided, including discussions of the analemma, dates and time zones, units of measurement and map scales, the National Map Accuracy Standards, and levels of measurement.

A survey of U.S. and Canadian map producers and map sources is provided in Appendix A. This appendix also includes comments on major map collections that map users will want to visit when their travels permit. Next, Appendix B briefly discusses the special problems often encountered when dealing with foreign maps. Other appendixes discuss background topics, including copyright protection, the use of the magnetic compass in the field, map storage and cataloging systems, and the British National Grid.

New to This Edition

A number of improvements were made to this fourth edition. The more significant ones are listed here for your convenience.

- All of the chapters were carefully reviewed for accuracy and to make their content as up-to-date as possible. Similarly, the addresses and telephone numbers of mapping companies and agencies were verified and updated. (Some companies and agencies were removed because they no longer emphasize mapping activities.) In addition, recent changes in the organization of mapping activities in Canada were incorporated into Appendix A.
- E-mail addresses and World Wide Web URLs were removed from the text due to the frequency with which they change. Instead, they will be placed on the book's World Wide Web site, (www.mhhe.com/earthsci/geography/campbell/), and will be regularly updated there.
- Overall, there are 17 new or revised illustrations in the text. These include a new radar image and a 1-meter resolution remote-sensing image, which only recently became available.
- Chapter 1 includes the addition of a discussion of common map elements, including typography, neatline, scale, orientation, and types of insets.
- Chapter 2 now includes additional coverage of methods of longitude determination, including the importance of John Harrison and his development of the chronometer.
- Chapter 3 was extensively rewritten with the aim of reinforcing an appreciation for the wide range of distortions associated with the map projection process and the importance of projection selection in map use. Four new illustrations were created to support this presentation.
- A brief discussion of the use of maps as tools for analyzing the culture landscape was added to Chapter 4.
- In Chapter 5, the origin of the acre as a measure of land area in the U.S. Public Land Survey is explored.
- A discussion of the importance of map projection and scale on the accuracy of map-based measurements was added to Chapter 6.
- A description of direction determination methods, including cardinal compass directions, points of the compass, and degrees, was added to Chapter 7. Also included in this chapter is an update regarding the various ways of distributing the *Notice to Mariners* publications.
- In Chapter 9, a discussion of measures of surface inclination, including slope and gradient, was added.
- A description of fire insurance maps, especially Sanborn Maps, was added to Chapter 14.
- Chapter 18 now includes updated information on the status of Landsat, including Landsat 7 and the Enhanced Thematic Mapper Plus system. Also in Chapter 18, the description of SPOT was updated to include SPOT 4. In addition, a new color plate illustrating remote-sensing image classification was obtained for this chapter.
- Chapter 19 contains a revised discussion of the Geographic Names Information System (GNIS) and of TIGER®.
- Two changes were made specifically to assist students. (1) The information about map producers, map sources, and foreign maps (formerly Chapters 22 and 23) were changed to appendices. This information was always designed to serve simply as a reference source, and not to be learned in the same manner as the subject-matter chapters. At the same time, the agency and company names were changed from boldface to regular-face type and removed from the glossary. (2) Similarly, the names of landform types in Chapter 10 were removed from the glossary and are no longer shown in boldface type. Students are not expected to memorize the many landform types illustrated in the chapter. The goal of the chapter is simply to illustrate the usefulness of topographic maps in revealing information about the configuration of the earth's surface.

Acknowledgments

As has always been the case, many people have helped in various ways during the process of preparing

the fourth edition. I thank all of them for their general support. I would especially like to thank the reviewers who offered many helpful suggestions for revisions to this edition: Andrew J. Bach, Western Washington University; Kent B. Barnes, Towson State University; Michael Camille, Northeast Louisiana University; Richard A. Crooker, Kutztown University; Charles Ehlschlaeger, Hunter College; Robert M. Hordon, Rutgers University; Thomas W. Paradis, Northern Arizona University; and Charles Roberts, Florida Atlantic University. These reviewers' recommendations were instrumental in my revision decisions. I followed their advice as fully as I could, although some useful ideas could not realistically be implemented.

Daryl Bruflodt and Bob Smith, both editors at McGraw-Hill, generously supported the preparation of a new edition, and Kassi Radomski, freelance editor, provided helpful advice during the revision process. Joyce Watters and the rest of the production team at McGraw-Hill also contributed their special skills to the publication of this book. Without the expertise of all these people, the project would have been impossible.

Finally, I must thank my wife Hazel for her assistance in important parts of the project, and for her continuing encouragement and support.

John Campbell
Racine, Wisconsin

CONTENTS

CHAPTER 1

INTRODUCTION

WHY USE A MAP?

Maps are an ancient invention, probably having existed for over four thousand years. Remnants of clay-tablet maps dating to about 2200 B.C. have been found (Figure 1.1). In addition, primitive, maplike scratchings in the sand, as well as maps in other forms, likely existed for many millennia before that.

These early maps performed useful functions for their creators, functions that maps still perform for us today. For example, maps are especially effective devices for recording and communicating information about the environment. Most importantly, they clearly preserve the locational attributes of that information; that is, they show the relationships between one feature and another. Not only do they show that there is a forest outside of town, but they also indicate the extent and limits of both forest and town. This is something that other forms of recording and communicating information, such as written descriptions, tables, and graphs, generally do not do as effectively or efficiently. Furthermore, maps can also indicate distances and directions between locations, or the areas occupied by different types of land uses or features.

In more recent times, maps have offered other benefits. For example, they are useful for determining the patterns formed by many types of distributions on the earth's surface. The arrangements of cultural features, such as the spacing between towns or the patterns of roads and other transportation facilities, can be analyzed using maps. Similarly, the alignments of physical

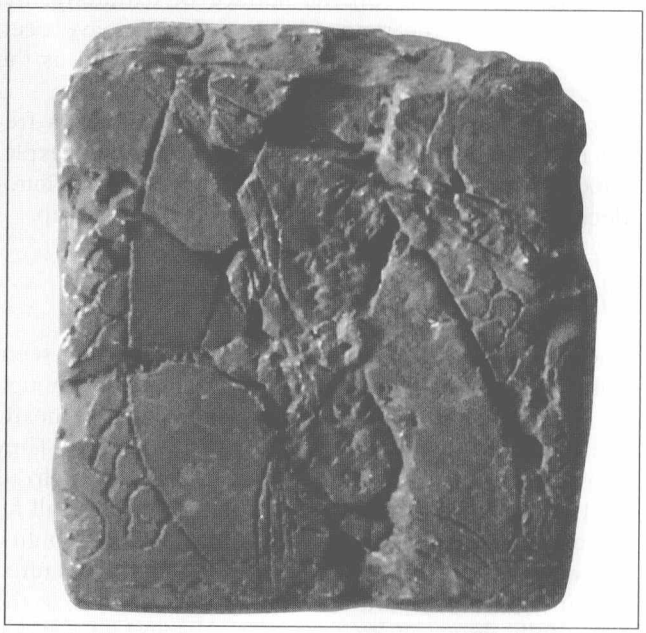

Figure 1.1 Clay tablet map, c. 2200 B.C. This is the oldest known map, discovered in the ruins of GA.SUR (modern Yorghan Tepe) in northern Mesopotamia by the American School in Baghdad and Harvard University. The map is oriented with east at the top. Two rivers join at the left of the map (north) and flow toward the upper right corner (northeast). Three hundred acres of arable land are shown just below the confluence of the rivers. Localities of special interest are designated by circles within which the names are written. (Size 7.6 × 6.5 cm.)

Source: From the collections of the Semitic Museum, Harvard University. Used with permission.

features, such as streams and lakes and the crests of hills and the floors of valleys, can be determined. The arrangements of such features can be explored, organized, and analyzed by visual and statistical methods, using maps as the database. These techniques have helped investigators to generate hypotheses about why the patterns are as they are. These investigations have suggested, for example, that certain economic relationships underlie the locational pattern of settlement and that the pattern of some physical features affects the location of specific human activities. Similarly, regular physical relationships underlie the patterns of stream erosion, the arrangement of drumlins in glaciated regions, and the alignment of river tributaries, to name just a few of the vast multitude of possible examples.

Maps are not limited only to showing information about physical and cultural features on the earth's surface. They are also used to show distributions of more abstract features, such as the flow of trade, the use of communications, the extent of political influence, or the areas occupied by peoples of various races, languages, or religions. They provide a major source of historical documentation and are used for regional planning and property-assessment purposes. In addition, features found on the surface of extraterrestrial bodies, such as the moon and the planets, have been mapped, as have imaginary environments used as the settings for works of fiction.

Regardless of the topic or the locale, maps frequently play a role in providing information and explanations regarding topics of interest. The rest of this introductory chapter examines just what constitutes a map.

What Is a Map?

The answer to the question, What is a map? may seem rather obvious to someone who is interested enough in maps to read this book. Maps, after all, are neatly drawn, bird's-eye views of the earth's surface. They show where places and things are located and help us find our way from one place to another. We are all familiar with many kinds of maps—from those confusingly folded, multicolored road maps that are stuffed into the glove compartments of our automobiles; to the beautifully drawn illustrations in books and atlases that provide information about the distribution of climates, vegetation types, languages, income, political patterns, and myriad other topics; to the topographic sheets whose intricate contours and drainage patterns serve as guides for our hiking or fishing expeditions. A visit to the map collection of your community or university library will convince you that a tremendous variety of maps is available. The International Cartographic Association has defined **cartography** as the art, science, and technology of making such maps, together with their study as scientific documents and works of art. This book deals with both aspects of the definition, to some extent, but does not deal with the specifics of traditional map production processes.

In recent years, new methods of gathering, analyzing, and presenting information about the earth have been introduced, including aerial photography, satellite-based remote sensing, and computer methods. These developments have made it necessary to recognize that the conventional maps mentioned previously are only part of the contemporary map picture and that the definition of maps must include an extremely broad range of "products." Some of these products (such as road maps), show topics that are physical, some (such as language maps), show more social or cultural topics, and some (such as maps of income levels), show even more abstract subjects. Many products, such as aerial photographs or satellite images, serve purposes similar to those served by maps, even though they differ from conventional maps. It also has been suggested that some "maps" are not even visible. Invisible maps may exist only as bits of electronic information stored in the memory of a computer or, even more abstractly, only in our minds. Finally, maps are not limited to representing information about the earth. They are equally useful, for example, for showing features found on the moon or the other planets, and they can present patterns that exist on the ground (topographic maps), under the ground (geologic maps), or above the ground (weather maps).

Given the variety of possible maps, this text uses a broad, flexible definition: A **map** is any concrete or abstract representation of the features that occur on or near the surface of the earth or other celestial bodies. The great variety of map concepts that fall within this definition may be classified as either (1) real maps or (2) virtual maps.[1]

A **real map (cartographic map)** is any tangible map product that has a permanent form and that can be directly viewed (often referred to as *hard copy*). Conventional drawn or printed products (traditionally called *maps*) fit into this category, as do maplike aerial photographic products or the end product of some other type of remote sensing, maps produced using devices controlled by computers, block diagrams and similar drawings, and relief models and globes constructed to represent some part or all of the earth's surface.

Virtual maps are related to real maps in one way or another and have qualities that allow them to be converted into real maps. They are divided into three types.

[1]The classes used here are simplified from those proposed by Harold Moellering in "Real Maps, Virtual Maps, and Interactive Cartography," in *Spatial Statistics and Models,* ed. Gary L. Gaile and Cort J. Willmott (Dordrecht, Holland: D. Reidel Publishing, 1984), 109–32.

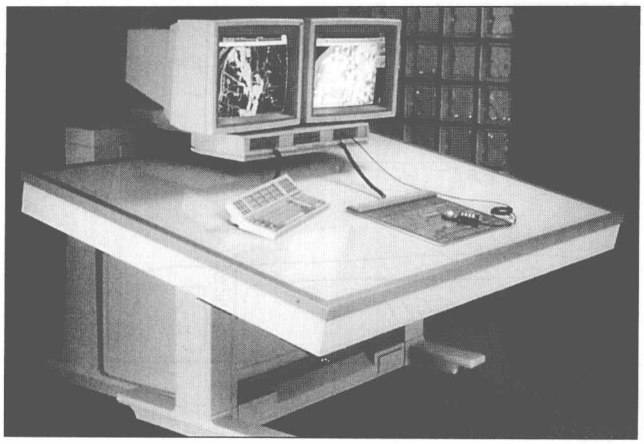

Figure 1.2 Computer workstation, with map images displayed on the screens of two monitors.
Source: Courtesy of Intergraph Corporation.

One type of virtual map consists of images that can be directly viewed but are not permanent. A map image projected onto the screen of a computer monitor is an example (Figure 1.2). Such an image is real while the device is turned on, and the information that it presents is similar or identical to that of a real map of the same topic. The difference is that as soon as the monitor is turned off, the image vanishes.

A second type of virtual map consists simply of mental images that are in many ways the conceptual equivalent of a conventional printed map.

The third type of virtual map consists of information gathered by researchers in the field or obtained by remote-sensing methods about such topics as surface elevations, rock types, soils, ethnic types, income levels of inhabitants, types of crops, and names and locations of geographic features. Such geographic data are traditionally stored in written notes, books, or computer printouts, all of which can be directly viewed. Increasingly, however, they are stored in digital form in a computer memory or storage device, such as a magnetic disk. This form of map is common for remotely sensed information, which is often gathered and stored directly in digital form, but also frequently includes information converted from printed or written sources. Computer software and hardware systems permit this type of information to be seen in tabular form or in the form of a visual image.

All three types of virtual maps can be converted into visible, "real" map products.

While there is not complete agreement on the use of the term *virtual map,* the label does convey the idea that a map is simply a special format for the storage of geographic data. Whether the information is called *map data* or *virtual maps,* there is no doubt that it is an integral element of the mapping process. Virtual maps are discussed frequently in this book, beginning with the next section.

VIRTUAL MAPS

Mental Maps

As already noted, the current concept of maps must encompass much more than the artifacts traditionally called *maps.* Indeed, the most familiar but, at the same time, most unusual forms of maps are the virtual maps called *cognitive maps,* or *mental maps.*

Mental maps are images we have in our minds. These images provide us with an awareness of the location of places in the world, the relationships between places in terms of direction and distance, the size and characteristics of regions, and so on. Mental maps have been called "the environmental image, the generalized mental picture of the exterior physical world that is held by an individual."[2] Some mental maps are a kind of miniature map in the mind, sometimes rather vague and ill-formed but sometimes complete with accurate details. Other mental maps are more subtle and difficult to define because they are somewhat more abstract and are tailored to one's individual conceptions, experiences, and needs, even to the point of distortion. Indeed, it has been suggested that mental maps "are quite unlike [real] maps . . . because they are personal, fragmentary, incomplete, and presumably, frequently erroneous."[3]

One aspect of the mental map concept is easily illustrated. Simply visualize the route that you usually follow from your home to the shopping center, or recall the general outline of the United States and the locations of its cities and states. Consider how easily you move about in different environments with the help of your mental images. The framework that mental maps provide allows you to tell others about the route that you follow, and they may be able to visualize it as well. Furthermore, such a mental image provides a frame of reference to which you can add information on the basis of new experiences. A mental map can be converted into a more conventional real map by sketching its image on a piece of paper (Figure 1.3). We all do this when we want to guide our friends to our new house or to indicate to a stranger the best route to follow to see the local tourist attractions.

Another aspect of mental maps is illustrated by considering where in the country you would prefer to live if you were given a choice. You are almost sure to have a ready answer to the question. Certain regions,

[2]Kevin Lynch, *The Image of the City* (Cambridge, Mass.: M.I.T. Press, 1960), 4. Much of the discussion that follows is based on this book.
[3]John S. Keates, *Understanding Maps* (New York: John Wiley & Sons, Inc., A Halsted Press Book, 1982), 53.

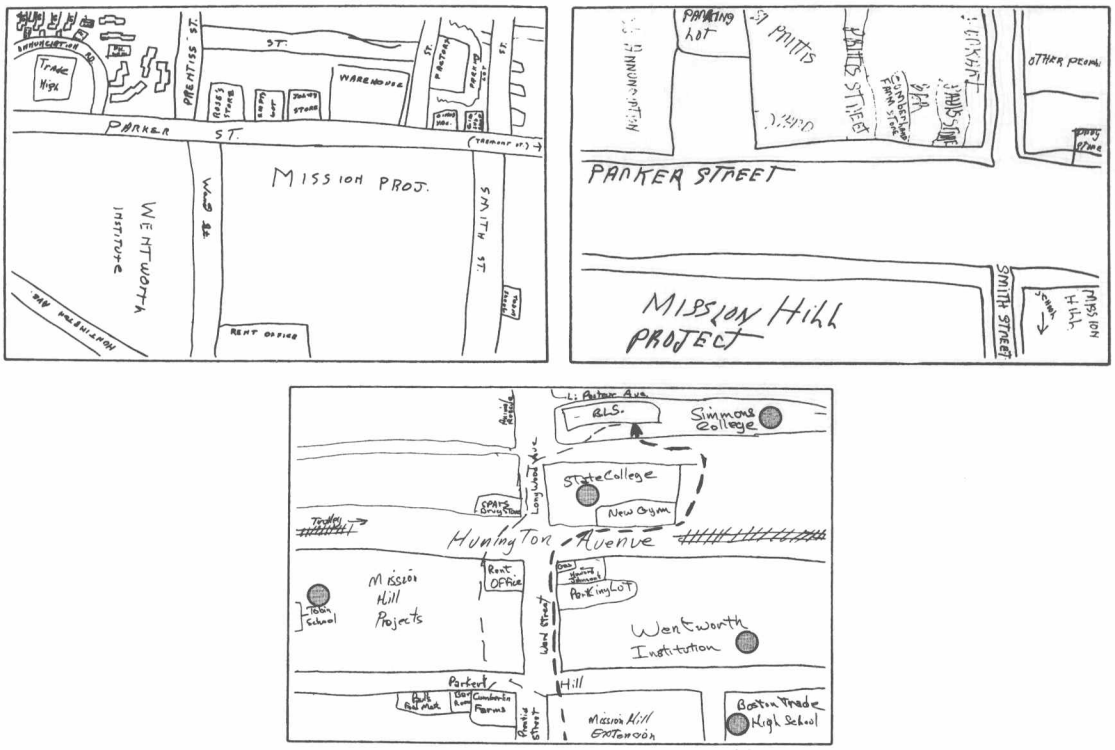

Figure 1.3 Mental map images of the same neighborhood, drawn by three different boys: Dave, Ernest, and Ralph.
Source: From Peter Gould and Rodney White, *Mental Maps* (Pelican Books, 1974). Reprinted by permission.

states, or cities undoubtedly appeal to you, whereas others have absolutely no allure, and still others fall somewhere in between. Almost everyone, it seems, has somehow endowed different locations with images of relative attractiveness or repulsiveness. Such images are often shared with others who have been exposed to the same physical and cultural environments.

A number of considerations undoubtedly affect your feelings about where you would like to live. For example, what is the climate like? Is there a year-round monotony about it, or is there a variation between summer and winter weather, with the spring and fall transitions that many people find attractive and invigorating? If you are a sports buff, you may prefer a location that promises a long snow season to facilitate skiing, or a year-round warm climate suited to swimming and other water sports.

Other factors that you may consider include scenery: Is the view that meets the eye an unvarying, flat plain, or are there mountains or seashores to bring variety? How about pollution? Are the air and water clear, or is there likely to be contamination of either or both? Even the reputation of a state for having a good or bad government can enter into your mental rating.

Social contacts and preferences may also affect your mental image of the place you would like to live. Regional reputations differ with regard to the sociability and openness of the residents toward newcomers, and one may appeal to you more than another, depending upon your own social style. Economic conditions are also important. If an area has a reputation for economic growth and activity, it may appeal to you because it provides the potential for prosperity.

In the end, your mental image of a region is a composite of a whole range of considerations. Certainly, not all considerations are equally important. If one element has greater importance, you will give it greater weight than another less important element. Such weighting is not necessarily systematic, but the relative importance of the factors is taken into account in forming your mental map. Obviously, not everyone's mental map will be the same. All of the preferences are subjective, but they are nevertheless real.

How are these subjective images of desirability or repulsiveness formed? Partly by direct experience. You may have traveled in certain areas, for example, and formed impressions based on your experiences and observations. Even such direct experience must be recognized as subject to error. This is especially true if the period of observation is too short, or if it occurs under conditions that are different from those of your ordinary, day-to-day existence.

Other, less direct, factors may also enter into the formation of opinions about the relative desirability of

different locales. You may be influenced by geography courses, news broadcasts, maps, television programs or movies, or conversations. If the information you obtain is inadequate, inaccurate, or otherwise misleading, your conclusions will be faulty. Although opinions based on indirect sources may not be as solid as those drawn from direct experience, they are no less influential.

Experimentation has shown that there are certain similarities among people's mental maps of where they would like to live, even though they find themselves at different locations. In Figure 1.4, some mental map concepts have been converted to more familiar map form. These examples summarize the spatial preferences of groups of students enrolled in universities located in different regions of the United States. The students were asked to rank the forty-eight contiguous states in terms of desirability (the higher the score, the greater the desirability).

The rating maps have general tendencies in common. For example, some parts of the country are consistently viewed as more attractive. Western California, central Colorado, and, to a lesser extent, northern New England fall into this category. Other areas, such as the South (especially Alabama and Mississippi) and the Dakotas, are generally seen as less attractive. On the other hand, the maps also show that people like areas with which they are familiar. In each case, the home territory of the raters tends to be viewed as relatively attractive. Alabamians, for example, have high regard for their home state and adjoining parts of Florida and Georgia. Minnesotans and Pennsylvanians have similar views of their home territories. Each of these ratings contrasts with the views of the other three groups. Californians also view western California as attractive, thus reinforcing the general trend. In addition, however, they extend their preference area farther north and south along the coast. You may find it interesting to compare these maps with your own preferences.

Digital Data

Increasingly, computer methods are being used in mapping and related fields. Computers are being applied to the processing and analysis of remote-sensing data, to the production of maps (called **computer-assisted cartography**), and to the operation of **geographic information systems.** These applications are discussed in Chapters 19 and 21.

Computer techniques can introduce a number of potential advantages, including speedier, easier, and more accurate map design and production. Other manipulations, including scale and projection changes and the statistical analysis of data, can also be more easily accomplished using computer techniques. Increased timeliness is also anticipated because updated information can be made immediately available to all users from a centralized database. Overall, computer methods should provide the cartographer with the flexibility to produce more innovative and effective maps.

Although the potential advantages of computer applications in cartography are not always achieved, progress is being made, and more frequent computer applications are inevitable in the future. Some of the results produced by computer methods will be indistinguishable from conventional maps. Other results, however, may be quite different, and some knowledge of the methods by which they were produced will help you to understand and evaluate them. For all of these reasons, portions of this book are devoted to computer applications in mapping.

Real Maps

Virtual maps have limitations that frequently make the use of more conventional real maps a necessity. It has been suggested that "one of the main reasons for making maps must be that 'mental maps' are inadequate as useful stores of locational information."[4] For this reason, much of this book deals with actual, physical map products and with concepts and measures related to them. The sections that follow briefly summarize the many types of maps and maplike products.[5] The topics introduced here are discussed in greater detail throughout the rest of the text.

Common Map Elements

Most real maps have a number of elements in common. These elements, some of which are discussed in detail in other parts of the book, are summarized here in an introductory fashion.

Typography

Typographical information (including titles, legends, names, and notes) is part of almost all maps. This type of information is crucial to the understanding of individual maps.

The title, and any subtitles it may contain, indicates the purpose for which the map was prepared. A properly worded **title** helps the map user by stating the subject of the map, the time period to which it applies, and other aspects of its content. The title of a map, therefore, should suggest whether the map is likely to be suitable for the purpose at hand.

Most maps also contain legends, sometimes in a special legend box. **Legends** show map symbols, along with an explanation of their meaning. Legends

[4]Keates, *Understanding Maps*, 53.
[5]Modified from Morris M. Thompson, *Maps for America*, 3d ed. (Washington, D.C.: U.S. Department of the Interior, U.S. Geological Survey, 1987), 15–17.

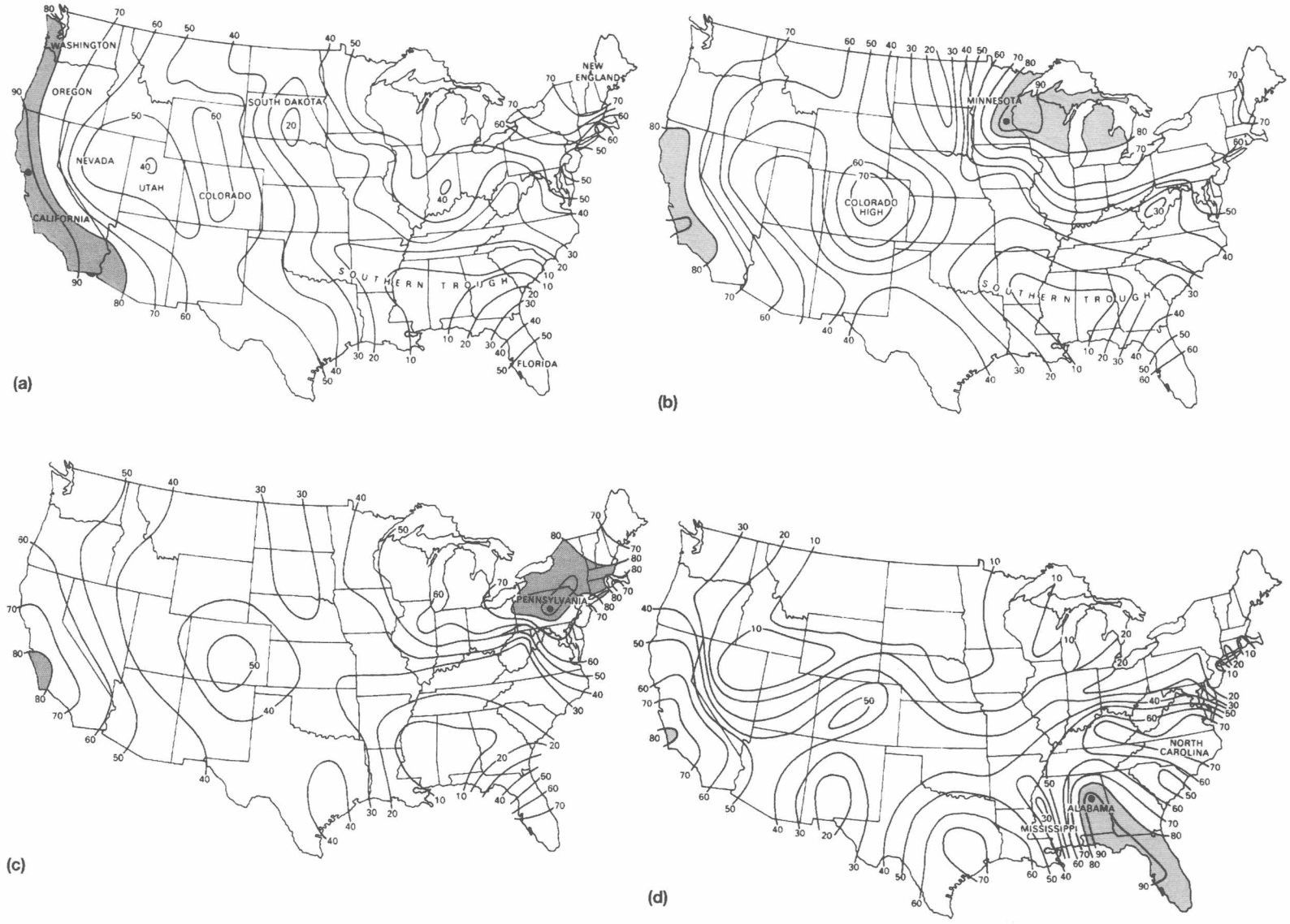

Figure 1.4 Mental maps representing students' views of the desirability of the forty-eight contiguous states. Views are from: (*a*) California, (*b*) Minnesota, (*c*) Pennsylvania, and (*d*) Alabama.

Source: Adapted from Peter Gould and Rodney White, *Mental Maps* (Pelican Books, 1974). Reprinted by permission.