MAPS MAPS MAPS MAPS

A GUIDE TO INNOVATIVE DESIGN

LEVEL II

GERSHON WELTMAN • PERCEPTRONICS INCORPORATED
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1 INTRODUCTION

GERSHON WELTMAN
Perceptronics

PROJECT BACKGROUND

In 1977 the Cybernetics Technology Office of the Defense Advanced Research Projects Agency began a new research effort in the area of computer-based map displays. The intent was to exploit computer technology to provide new ways of displaying geographic information, creating maps which would be unlike conventional maps, and superior to them for certain kinds of map usage. At the beginning of the effort is was decided to review some questions of critical importance to the basic objective, namely: What is the nature of the mapping process? What are currently the most significant areas of innovation for computer-based mapping? In attempting initially to answer these questions, we were assisted greatly by the attendees of a "brainstorming" meeting, held at the U.N. Plaza Hotel, New York City, on June 23 and 24, 1977. The meeting attendees were:

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REPORT PURPOSE

This report, which emerged from work planned at the initial meeting, is directed toward all those who have an interest in maps, but particularly toward those who are active in map design and production. It has several purposes. One is to expand in the reader's mind the basic concept of maps and mapping. To this end the report begins with a review chapter, contributed by Kristina Hooper, that faces the question "What is a map?" from a new psychological perspective.

Another purpose is to introduce map makers to (or to remind them about) a number of innovative map presentational techniques that have proven valuable in other applications. To that end, Susan and Michael Southworth, assisted by Richard Wurman, collected and annotated a large number of map examples, showing many different means of displaying geographic information. This material forms Section Three. The idea is to let the map maker find new options and opportunities in a number of ways, both by browsing through the various illustrations, and by thinking about how to prepare maps for particular purposes. As with every other organized catalogue, there is little doubt that we have misclassified some presentational techniques and inadvertently excluded important or exotic examples, although some of the techniques we have chosen to include are, to say the least, unusual.

The final purpose is to point out some promising areas of advance, and perhaps to inspire further development work in those areas. As computer technology is the major force now opening options for the new kinds of maps, Section Four explores some new possibilities in this direction by: one, giving examples of computer-generated three-dimensional map displays that are under development at this time; and two, describing some promising extensions of this work. This section was written by Steven Levin, Director of Washington Operations for Perceptronics.

It is obvious that this report was truly a group effort. Maps and mapping constitute a fascinating area of inquiry, with many rich historical associations and many promising current activities. It is fair to say that all the contributors to this report found their efforts highly rewarding. We hope that our readers will find the product informative, stimulating, and useful.

2 THE MAPPING PROCESS

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OVERVIEW

Maps enable us to benefit from other people's experiences. They provide us with information about environments in which we have never been. They let us see familiar areas beyond a single glance. They encourage our curiosity and imagination, and provide us with the means for solving immediate problems and for forming future plans. We make maps. We use maps. We study maps. Most of us do a little of each. In each context, it is important to consider carefully the basic dimensions of maps. Such consideration allows us to choose effectively among map attributes in our map making, to interpret map elements correctly in our map using, and to integrate information systematically in our theorizing. It also provides us with a descriptive framework of environments and mapping tasks, which, as future technologies are developed, will allow us to produce better maps for individual purposes.

There are many dimensions to careful consideration of maps, whether one is a map designer, a map user, or a map theorist. A good number of these will be addressed in the following sections of this chapter. The purpose is to give the reader a general sense of maps and of mapping, so that he or she will develop a critical eye in viewing the large number of different maps included in this book, appreciating them both as solutions to specific mapping problems and as guidelines for future work.

It is hoped that this increased sensibility will enable individuals to make better maps, to read maps more effectively, and to understand at a more basic level the complex process of mapping -- which begins with the acquisition and selection of spatial data and ends with actions taken in an environment. In the later sections, we develop a theoretical model of the mapping process. This portion is intended primarily as a guide for the individual who wants to pursue a specific mapping topic in greater detail.

In our discussion, it is important to realize explicitly that, at present, there is little for the map designer to rely upon, besides intuition and rules of thumb, in making mapping decisions. This chapter offers the beginning of a prescriptive typology, and incorporates into it a large amount of relevant information developed in geography and psychology. Although it is expected that the analyses of this chapter, and the design examples of the next, will expand the reader's intuitive appreciation of maps, a definitive analysis of choices in map making is still lacking. Perhaps the current work will inspire the development of such an analysis.

MAPS AND THEIR USES

The Purpose of Maps

Maps are representations of environments. As such, maps contain information about some environmental elements and not about others. They relate these elements according to selected transformations of their original relationships. Maps, then, are not the environments themselves but are, instead, displays designed to present an environment in its absence; displays designed to "re-present" in such a way as to allow the map reader systematically to derive attributes of the mapped environment.

Figure 2-1 shows a number of different map representations of a single environment. Each includes a certain set of attributes and relations from the environment. In looking at each of these different maps, it becomes obvious that there are an incredibly wide range of map elements, relationships, techniques, and intentions. None of these are exactly like the environment. Instead, they are representations developed within a specific mapping context for a particular purpose.

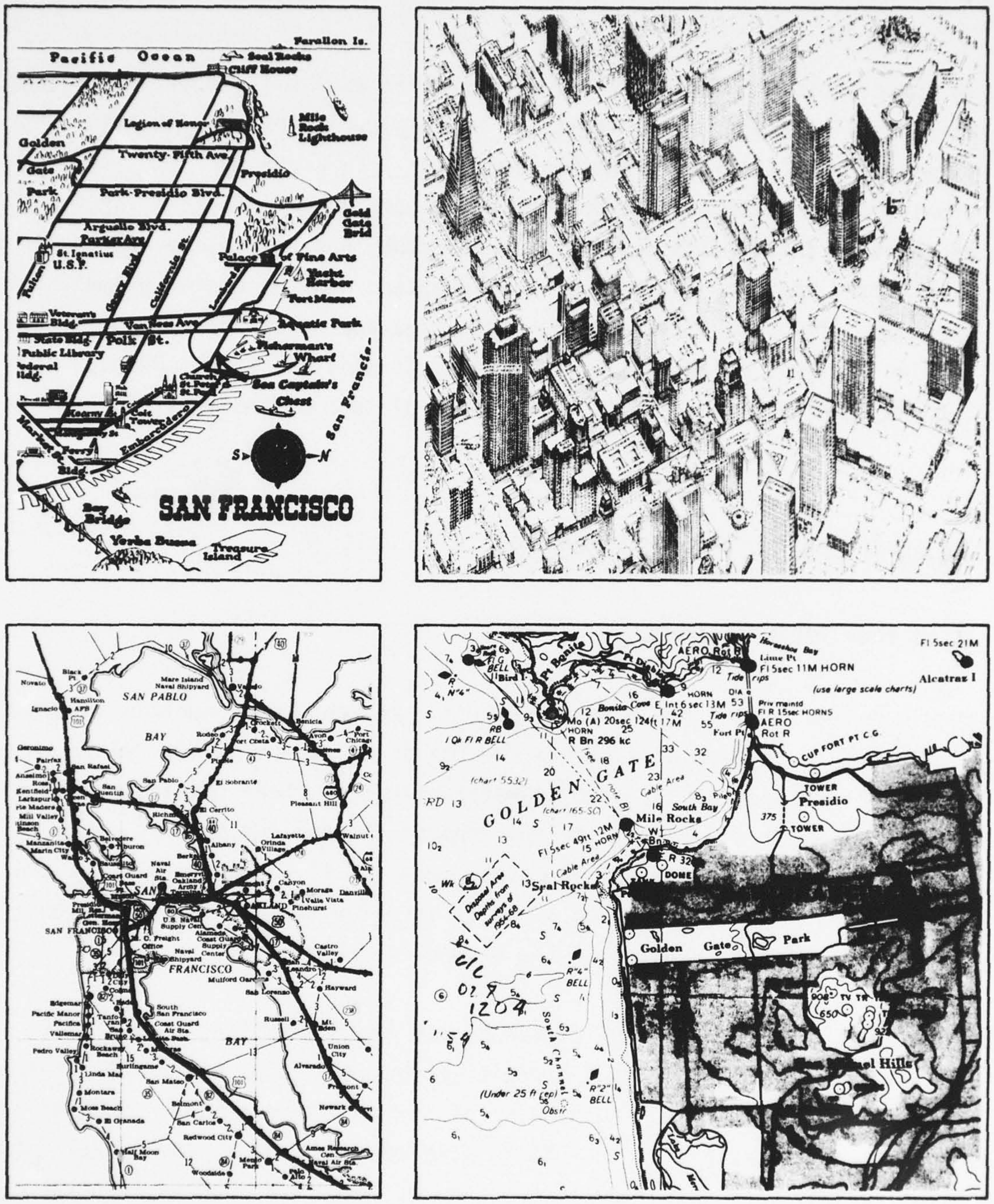

FIGURE 2-1. DIFFERENT MAP REPRESENTATIONS OF SAN FRANCISCO

The primary intent of a map is to convey enough information about an environment to a user so that he or she can understand an environment well enough to plan actions within it. Accordingly, a map cannot be considered in isolation. Rather, it must be considered as the central element in a communication process, a process that considers the nature of the message to be communicated, the language available to the map maker who will sent the message, and the knowledge and competencies of the individual who is to receive the environmental information. Mapping, then, needs to consider both the sender and the receiver of environmental information. This relationship is shown diagramatically in Figure 2-2.

Taking communication into account, the job of a map maker becomes the generation of a map that not only accurately displays an environment, but that also represents an area effectively to a map reader. Accordingly, one might simply state that the purpose of a map is to display an environment accurately. However, it soon becomes obvious that there are more complex concerns involved. For one, it is clear that a map will be used for a particular task and that, within the context of this task, some elements and display techniques will be appropriate, whereas others will not. Purposes are thus constraining factors that reflect the particular tasks to be performed and that direct the map maker by determining what needs to be presented in particular situations. This course of events is illustrated in Figure 2-3.

Let us be more specific. One standard purpose of a map is to describe a particular route; that is, to provide directions for moving from one place to another. In this context, the job of the map maker becomes the presentation of detailed information about the route, particularly the choice points. A linear road map does this particularly well, but such a map is inappropriate for a wide range of other purposes. It is useless, for example, for locating other places in the area, for planning a route

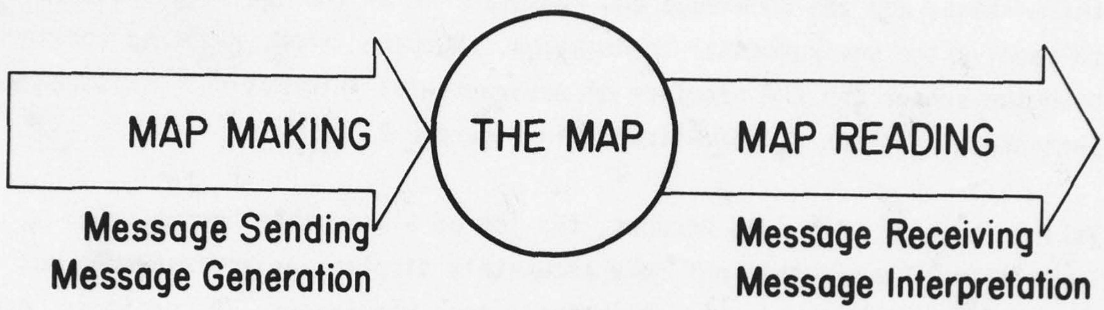

FIGURE 2-2. MAPS AND THEIR RELATIONSHIP TO INFORMATION SENDERS AND RECEIVERS

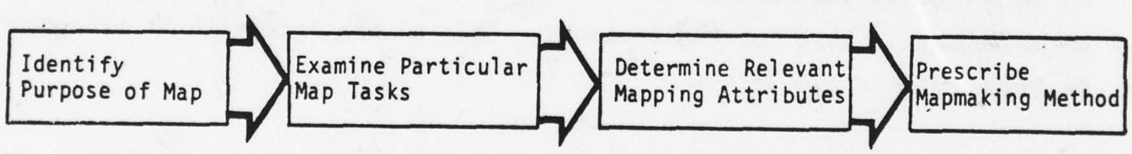

FIGURE 2-3. MAP GENERATION STEPS

between two different places, or for planning a route outside the boundaries of the area shown.

There are, of course, other maps which accomplish these other purposes. For example, if the user wishes to plan multiple routes, the map maker can provide information about how the area of interest relates to adjacent areas. It is important to realize, however, that for some purposes even this detailed information is inadequate. For example, topographical information is required by the user who is interested in planning a route through a mountain range, or who is designing a housing development. Similarly, landscapes, building facades, and other scenic features will be relevant to travelers who want to choose picturesque roadways, or who want to identify a location along their current route. In fact, if the primary task is the identification of location (which it is in many cases), the inclusion of easily recognizable landmarks is often more appropriate than complete and detailed spatial representation.

The point to be made is that different purposes dictate different maps. When one realizes the large set of map uses (including, but not limited to, those listed in Table 2-1) it is evident that the delineation of purpose requires the map maker to identify and dissect particular tasks, in order to prescribe solutions in particular cases. In the past, the map maker had less need for such detailed analysis, as maps were typically designed for multiple purposes. However, given the possibilities of the new mapping technology and the corresponding expansion of map uses, it becomes critical for the map maker to provide what is needed in each unique situation.

Choices in Map Making

As explained above, map making necessitates a number of explicit choices, since they include some dimensions and not others. Similarly, these

TABLE 2-1
MAP PURPOSES

- Show changes over time
- Guide complex navigation
- Store data
- Show a particular route
- Arouse curiosity
- Provide a context for route planning
- Teach
- Show how an area will appear
- Give a general sense of an area
- Describe the location of particular objects
- Show the map user where he/she is
- Point out main elements in an area
- Provide information for decisions
- Relate a plan view and a perspective view
- Give context
- Answer questions
- Act as a mnemonic aid
- Catch a person's attention

dimensions are rendered according to one particular set of transformations, to the exclusion of others. Such considerations imply a large set of deliberate choices.

Figure 2-4 provides a framework for describing the choices made in map making. In essence, it illustrates two map making decision processes; one which determines *what* information is selected, and another which determines *how* this information will be displayed. The first is an assessment of environmental information, be it from direct experience, from surveyor's notes, or from formal data bases, such as those made available by satellite photography. The second is a display of this information according to a particular set of conventions, be they those of projective geometry or axonometric rendering.

The decisions that determine dimension and transformations depend on both technical and psychological factors. The latter are extremely important if one is to take seriously maps as communication devices. In this section we will present a set of guidelines for map making decisions. These will include the characteristics of the map users, the media available for mapping, the attributes of the environment to be mapped, and the presentation of map information. We will see that there are significant interactions among these elements, and we will see that each greatly affects the final form of the map.

<u>The User's Needs</u>. Maps are designed to be used. It is thus crucial that map makers consider, from the beginning, the needs of the ultimate map user. This requires that the map maker become a bit of a psychologist, so as to deal with the display of information within a human framework of comprehension and understanding. Kolacyn (1969) phrased this concern well when he suggested that a map must satisfy the consumer's needs and interests, that it must be easily readable and understandable, that it must be

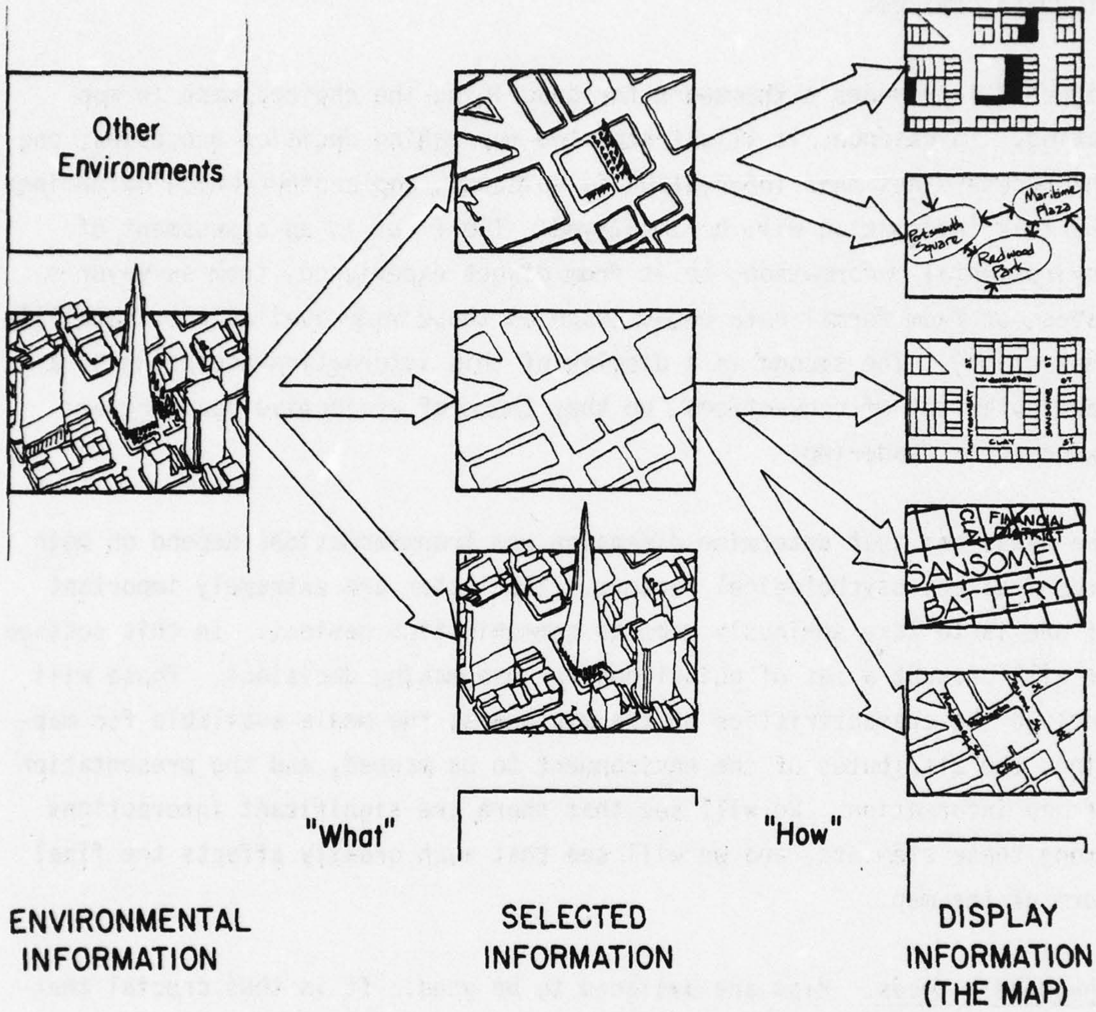

FIGURE 2-4. A FRAMEWORK FOR DESCRIBING THE CHOICES IN MAP MAKING

attractive, and that it must be emotive as well as rational. Muehercke (1972) echoed these sentiments when he asserted that maps should change their emphasis from "physical to social," from "interesting to relevant," and that, in order to fulfill their purposes, maps must be considered within a human context.

What does this mean to the map maker? First, it suggests a careful consideration of basic human perceptual and cognitive capabilities. Second, it requires an acknowledgement of the fact that many map users are not very well trained in map use. Third, it invites creativity in the design of maps that will insure, or at least enhance comprehension. Fourth, it dictates a consideration of the different limitations of map users; for example, poor spatial relations, short attention spans, and poor imagery. Finally, it calls for the personalization of maps wherever possible, and suggests the use of multiple representations to provide the redundancy required by most users.

Mapping Media. The typical map is a flat surface with graphic lines and symbols representation spatial relations between environmental elements. Such maps can be drawn in the dirt with a stick, or in multiple colors on paper by a cartographer or a computer. The primary intent of such maps is to reflect the basic locational attributes of an environment. However, the concept of a map is media-independent, and likewise independent of any particular symbology. As shown graphically by the examples in this book, a large set of media can be used effectively in mapping. A photograph, a diagram, and a sketch can all be maps. Similarly, maps can be sets of verbal directions, computer procedures, or lists of places to visit. In addition, maps can be movies, holograms, environmental data bases, or stories about environments.

Moreover, within each of these media, there are a number of symbologies from which a map maker may choose. In a conventional map, line width, type font, and color may be varied. In a movie map, panning, zooming, and still-framing can be used differentially. In some situations, a movie will be the best map representation, as it can display relational and pictorial information effectively. In other instances, for example when one wants to carry a map into an environment, or when one wants to see overall organizational patterns independent of any point of view, static schematic maps will become more effective. Similarly, verbal symbologies can sometimes be used effectively to point out particular elements; in other instances, different symbologies, such as realistic pictorial displays, will be more appropriate. The choice of media and symbology is greatly influenced, of course, by the map maker's previous experience and by financial constraints. Ideally, one would like a map maker to use the media most appropriate to a particular mapping purpose and to a particular map user.

Environmental Types. In map making, one cannot ignore the attributes of the environment which is to be mapped. Just as purposes, map readers, and media vary, so does the nature of the environment. Open land offers one set of problems in representation; heavily vegetated areas, urban areas, hilly areas, etc., offer others. It is important for the map maker to take account of the particular area to be mapped, and to choose a mapping technique appropriate to this area, as well as to the considerations already set forth. Even a quick glance at maps in this book will illustrate this point: different environments place very different requirements on the map maker.

Information Presentation. Typically, geographic information is the main information given in a map. However, this need not be the case, as information about such things as population, economics, building type, etc., can also be shown. Many examples of such "extra-geographic" maps are included in this book. In addition, maps can be used to represent geographic information at quite different levels. For example, size relationships between cities can be shown in maps, as can the relationships between building sizes on a street. Just a section of a city can be displayed, or the entire city.

Maps can be used to convey a realistic sense of an environment, that is, to give the map reader a sense of just how an environment will appear. In contrast, a map can present abstract characteristics of a place, characteristics which might be unavailable to a traveler's direct experience but which would help him or her to organize those direct experiences. In accomplishing these different tasks, the symbologies included in a map can be perceptual or conceptual. As an example of the former, detailed sketches are often included on maps to display perceptual characteristics of buildings or particular features of the terrain. Relational information is critical for conceptual understanding and can be displayed effectively using diagrams and verbal descriptions. The choice between realistic and symbolic display techniques are *combined* to provide users with multiple environmental perspectives.

An important aspect of information presentation is that of emphasis. As a representation, a map need not be precisely like the environment which it represents. Instead, it need only be systematically related to this environment. The representational nature of maps is a great advantage, for it allows maps to be designed especially to convey information that is critical for the transfer of complex environmental experience, and to encourage rapid understanding of particular experiences in an area.

One important means of emphasis is the use of graphics to focus attention on critical environmental elements. In addition, there is a useful set of distortion techniques which can be used to exaggerate environmental features so that elements appear as they are "known," rather than simply as they are "seen." Of course, in the application of such techniques it is important that the map reader understand the nature of the distortions used, so that he or she can readily anticipate and adapt to the actual environment.

Choices in Map Reading

It is tempting to assert that once a map is made there are no longer important choices present in the mapping process. Yet, closer study makes it obvious that this is untrue. For one, map readers generally have a choice of maps. Further, they are usually able to choose a scale and a technique of rendering that is appropriate to their personal style and their immediate mapping task. More importantly, perhaps, map readers have a large amount of control in examining a map. They can ignore certain elements if they choose, or they can emphasize portions of the map according to their particular intent. Similarly, they can combine pieces of available information, making conculsions and inferences according to their own point of view. Map reading is an active process, and must be considered as such. It requires involvement and selection, just as does map making, and it greatly affects the nature of the mapping communication process.

A MODEL OF THE MAPPING PROCESS

The preceding sections have described the major elements involved in mapping. The intent of this section is to expand on these descriptions, to place them within one theoretical model, and to relate the geographic and psychological literature of mapping to this model. The model proposed is illustrated in Figure 2-5. It is an abstract model composed of five different *knowledge states*, S_1 - S_5, all of which are related by specific *mapping operators*, M_1 - M_4. Each of these knowledge states represents a set of information elements which have been selected and organized according to the rules explicated by the mapping operators.

Briefly described, the mapping process begins with the environment and ends with the actions, based on maps, taken in this environment. More specifically, the model of the mapping process shown in Figure 2-5 includes the propositions that:

(1) The *environment* (S_1) is represented in an environmental *data base* (S_2) according to a set of rules which determine *data selection* (M_1).

(2) The environmental data base is displayed as a *map* (S_3) using the rules specified by the *map making* operator (M_2).

(3) Individuals interpreting a map generate a corresponding *cognitive map* (S_4); this is derived from the map according to the rules of *map reading* (M_3).

(4) Individual cognition knowledge determines *plans for environmental action* (S_5) according to the rules of spatial *problem solving* (M_4).

In the following section, each knowledge state and associated mapping operator will be considered in turn, and geographic and psychological analyses will be placed into this context.

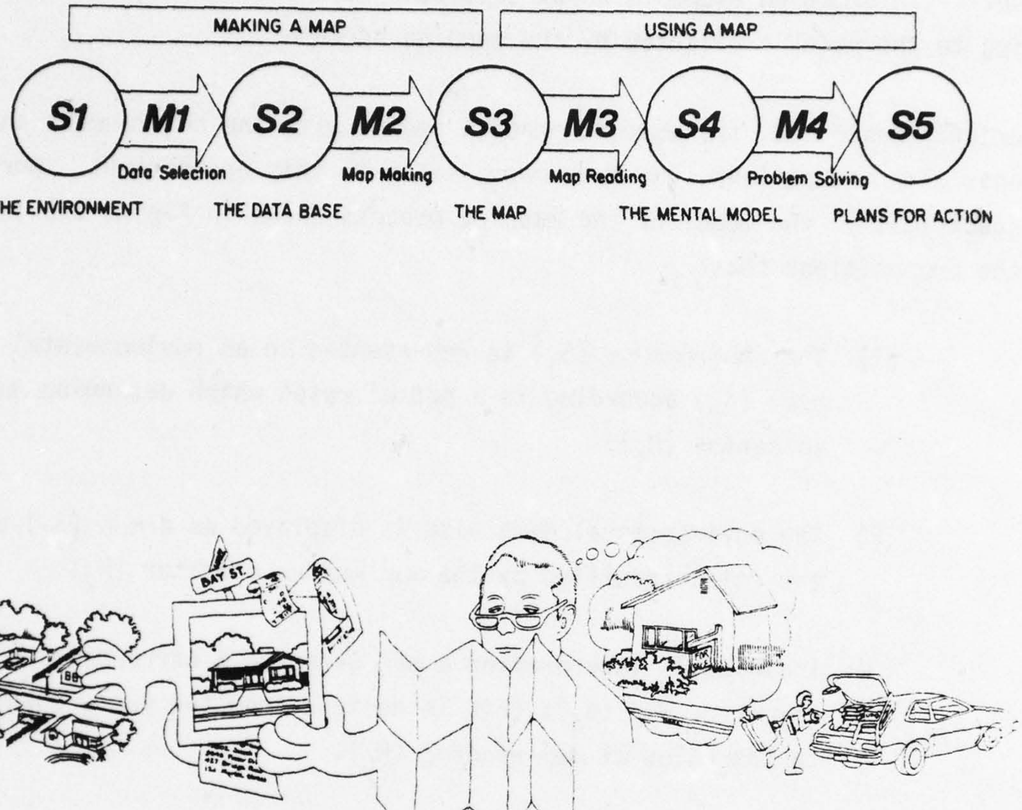

FIGURE 2-5. A MODEL OF THE MAPPING PROCESS

Environment and Data Selection (S_1 and M_1)

The environment (S_1) represents all of the information which is available for sampling in making a map. It includes, for example, sets of objects, the locational relationships between objects, perceptual descriptions of objects (e.g., color, shape, size) and information concerning environmental change. It is the world to be mapped.

Information must be sampled from the environment and stored in an environmental data base so that it can be used in map making. The data selection operator (M_1) represents this sampling and storage. For example, it encompasses the acquisition phases in practical techniques such as aerial photography (Berlin, 1971; Koeman, 1970), ground level surveys, and the use of remote sensors (Rabshevsky, 1970; Price, 1975). It also involves basic decisions concerning the form and organization of the environmental data base itself.

The Environmental Data Base (S_2)

The data base (S_2) is media independent. It might be magnetic tape, it might be a set of surveyor's notes or photographs, it might be a map, or it might be digital data in a computer. The only constraint is that it provides information for the mapping process. It is interesting to note that data acquisition is often not explicit in individual instances of cartographic process. Frequently, the data base is an old map. A map maker only rarely refers to original sources of environmental data because of the logistics involved, and although an old map is a form of environmental data base, it is highly problematic as a sole source, particularly when map makers begin to make generalizations of generalizations.

To deal with this and related problems, an attempt is currently being made to format environmental data in such a way that it can be stored directly in a computer for easy access at later times. Muehrcke (1972), for example, asserts that observed measurements should be reported directly in digital form, and suggests that digitized pictures or numerical maps obtained directly from remote sensors provide the most efficient approach. However, there are conceptual and technical problems in digitizing (Rhind, 1973). Consider, for example, information which deals with the traversability of certain routes and which includes the ground level appearance of an area and the identification of key landmarks. This information is typically contained in ground surveyor's notes, yet it is usually generalized away in higher technology representations. Yet, this is the information that will be important to the map user, given the idiosyncrasies of the world with which the map user must deal.

Of course digitization and computer storage is not limited to any specific form of data, and may well be organized to include such things as detailed surveyor notes, feedback given by map users in particular areas, sketches of important landmark features, and even analog data, such as films. Currently, however, it seems as though digitization schemes are being designed solely on the basis of storage capacity, and not with regard to the purposes of maps or the capabilities of human map readers.

Map Making (M_2)

To be useful, data included in an environmental data base must be meaningful to a map user. The choice of how environmental data will be represented is determined by the map making operator (M_2). Its function is to select which elements from the environmental data base are to be included in the map presentation, and to dictate how elements chosen for representation will be displayed to insure comprehension in particular instances.

This operator represents a critical transformation in the mapping process, as it connects the earlier processes of map making, which center on the physical attributes of environments, and the later processes of map usage, which center on the psychological processes of the map user.

Unfortunately, there are no precise rules available for the choice of environmental elements or map elements in the desired form of:

> ...*if* there exists a particular environment X, to map for purpose Y, *then* include environmental elements e_1, e_2, ...e_n using representational elements r_1, r_2, ...r_n.

While we are awaiting the development of such systematic rules, map makers must continue to rely upon intuition, upon the examination of examples, such as those included in this book, and upon scattered research. In the following paragraphs, existing research relevant to the choice of environmental and map elements will be discussed.

Choice of Environmental Elements. The simplest approach to choosing environmental elements is to include all known elements of an environment in a map. In most situations, this approach is impractical, either because of the costs of data gathering, or because of the limitations of the map presentation format. Yet, even if these obstacles were eliminated, a non-selectional approach would be generally ineffective. In fact, for most situations, it is the function of a map to develop conceptual understanding through selection of relevant attributes and presentation of appropriate information.

As an example, consider the inclusion of pictorial information in maps. Such information explicitly represents perceptual characteristics of an environment, in addition to its general spatial relations; it provides users with a realistic sense of an environment as well as a spatial characterization. Ancient maps included a large amount of pictorial information -- at the extreme showing ships at sea, monsters, beautiful damsels, and fair young knights. Similarly, ancient Chinese scrolls represented entire journeys in detail. Many modern representations, including the pictorial maps of Herman Bollman, the maps in the Michelin Guides, and the pictorial displays prescribed by Lo (1973), have continued this tradition. They show detailed, three-dimensional characteristics of objects, in addition to providing two-dimensional displays of their location.

In many ways, these kinds of presentations subscribe to a non-selective approach to map making. Yet, it is important to note that these representations are not totally realistic nor all-inclusive. Just as pictorial maps accent selected locational attributes, these maps accent certain perceptual characteristics and not others. In addition, their very nature makes them ineffective for many purposes. Southworth (1970), for example, showed that though pictorial maps were preferred by map users, and though they worked well in tasks that required maps to be related directly to visual scenes, plan views of a city were more efficient for route planning than were pictorial maps, and they were easier to use for such tasks.

It seems, then, that in many instances of map making environmental information should be abstracted, that there are instances in which details should be omitted and certain aspects emphasized, and that this should be done in due consideration of purpose. Wright (1947) accentuated the importance of selection and emphasis in maps by describing the task of the geographer to be the portrayal of environmental information "with aesthetic imagination in selecting and emphasizing aspects of the region which are distinctive or characteristic" (p.6). In a similar context, Imhof (1963) stated that the cartographer's task is to "transform, emphasize, eliminate, summarize, exaggerate, and enlarge certain things" and that "in spite of this miniature detail, the map should highlight the principal focus of the landscape and also some characteristics, details, and important features, such as main roads" (p.17). Potash (1977) adds that these processes of emphasis and selection operate currently in even the most standard map making, as features which are too small to be drawn to scale, for example, will either be deleted or magnified, depending upon their importance to the purpose of the map.

Research has supported these assertions. Granda (1976) showed that though users preferred detailed maps, there were no significant differences between standard maps and reduced detail maps in map use performance, amount of information requested, or time taken for particular mapping tasks. Similarly, enhancement of important features such as rivers, roads, and mountains, has been shown to improve map performance (U.S. Army, 1974).

When we accept the idea that not all the available information needs to be represented, that instead information must be selected for particular purposes, then the mapping task becomes the identification of relevant environmental elements. An approach to such identification is to ask map users what kinds of information they would like included on a map. This technique has been used often, and has generated a good amount of data. One study of pilots (Huizar, 1972, as quoted in Potash, 1977) showed that pilots want information included in maps about the surfaces and widths of roads, elements that they find important in navigation. They also want information about the amount of vegetative cover, because they can use this information in locating themselves. Another study of pilots (McGrath & Borden, 1968, as quoted in Potash, 1977) showed that pilots request information which helps them to interpret contours; they asked for explicit descriptions such as "depressions," "cuts," and "fills," instead of contour lines or less specific descriptions. Pilots also indicated that water courses, and paved roads were important to their orientation.

A study by Zannaras (1973) showed that traffic lights, open spaces, churches, and shopping centers were critical to urban navigation, and that the saliency of these features varied across different cities. For example, a study of British road users by Shepard and Adams (1971) indicated that hills, railways, bridges, turns and junctures were the most important features in the description of routes. Another British study by Astley (1969) indicated that travelers believed indications of road worthiness and location of eating facilities should be included on the maps. These same users would also prefer that unnecessary information which they felt included churches, rivers, ancient monuments, and railways, were removed from the maps, to avoid being distracted. Lorry drivers in this study suggested the development of heavy haulage maps that showed low bridges, tight bends and weight restrictions.

These user judgments suggest that map makers should choose environmental elements based upon descriptions of mapping tasks and particular user perspectives. However, the fact that Wheaton, et al, (1976) demonstrated that user preferences are often poor predictors of eventual map performance, suggests that other indicators of the importance of environmental elements should also be considered in the map makers' selections.

One alternative method for selecting important environmental features is to determine which environmental information is perceived and remembered by people who move around effectively in a certain area. For example, as Lynch (1960) suggests, if residents of an area recall landmarkes such as tall buildings and busy intersections, these should be included in a map to communicate the resident's view to the stranger. This approach was applied by Hooper and Cuff (1976); they selected perceptual features chosen by residents of the environment to be mapped. Although this approach does not deal with the mapping tasks of particular users, it does provide map makers with some general guidelines for feature inclusion. In order to determine more precise rules for the selection of environmental elements, research is needed which systematically includes or excludes particular information and then evaluates the effects of these changes on particular mapping tasks. Unfortunately, this research is not presently in the literature.

Choice of Map Elements. Two sequential choices must be made in determining which map elements should be included in a display; the choice of media and the choice of representational elements. The choice of media must be made taking into account the purposes of the display, the available display technologies, and the conditions of map viewing. Standard paper maps are excellent for portraying spatial relationships on a ground plan and are convenient to use in the field, but they are ineffective in providing a realistic sense of the area. Movies are excellent for providing a naive user with a ground level preview of an area, though they are ill-suited for many other applications. Verbal descriptions are good for communicating a few easily identifiable choice points, but are ineffective for transmitting precise spatial relations in an area. Any choice of media must consider a particular situation.

Once a map media is chosen, specific correspondences between environmental elements and map elements in this media must be determined. If one chooses standard paper as the mapping media, a scale must be chosen in addition to a projection and a map type. In a movie medium, for example, one must consider the use of edits as opposed to continuous shooting, and also the rules for panning, zooming, and film speed variations. In generating verbal descriptions, one must choose phrases which effectively represent key elements, choice points, landmarks, and spatial directions.

The scale is determined by the size of the area to be represented, the constraints on the size of the final map, and the level of detail required by the user. Small scale maps, such as 1:500,000 scale, are appropriate for planning tasks and air navigation (Watson, 1970), whereas larger scale maps, such as 1:50,000 scale, are more appropriate for ground level field tasks (U.S. Army, 1974). In choosing a scale, it is important to realize that different scale maps of an environment are not simply enlargements or reductions of each other. The accuracy of representation is greatly affected by choice of scale, given the constraints of map reading and of the printed media.

For a particular mapping purpose, rules of generalization can be chosen which will produce efficient conceptual representations. Rhind (1973) describes a number of elaborate techniques for line sinuosity reduction (roads and rivers), feature transpositions (a way to deal with overlapping features at small scales), amalgamation of data types, and feature elimination. To minimize drawing costs, however, these generalizations have been developed primarily to minimize drawing costs. It is not clear that they are effective for map users. Watson (1970) provides a number of excellent examples which caution that generalizations must be based on the purpose of maps. He describes, for example, how information about the condition of road surfaces, height and density of vegetation, the availability of water, the composition and nature of the ground surface, and the traversability of specific routes is lost with most generalizations. He asserts that this loss is "to the detriment of the derived map and to the disadvantage of the map user" (p.32).

There are a number of standard projections that can be used in making a map. For small areas, the choice is not critically important, as these areas can be considered to approximate a flat plane. With larger areas, one must be concerned with errors in representation, errors in scale, errors in area, and errors of azimuth. Baldock (1972) provides an example of how each of these can be considered for the domains of size information, shape information, and latitude and longitude extent.

There are also a number of standard map types, including aerial photographs, line maps, topographic maps, and color-enhanced maps. In a review of these different type maps, Potash (1977) reported that the best photo-based maps produce performance comparable to that obtained with standard line maps. He also states, unfortunately, that "an analysis of what photo-based maps portray as contrasted with standard line maps does not seem to be in the literature" (pp. 146-147), so we don't have any way to generalize this result in order to extend it to other instances. Wheaton, et al (1967), in an extensive study of twenty-six different photomaps, that varied according to background image, technique, contour density, enhancement, and annotation design, found that enhancement in maps improved map performance and that picto-maps compared favorably with line maps. Berry and Horowitz (1961) found that map readers performed equivalently in answering general map questions such as "are there any houses on your display?" based on either topographic maps or aerial photographs. It is interesting to note, however, that on questions simulating those required for action, such as, "what is the distance from C to D?", or "trace... the easiest route of travel between point C and D," the performance of subjects using aerial photographs was consistently better than the performance of subjects using topographic maps. In addition, subjects using aerial photographs identified features of a terrain more accurately and completely. For example, while the topographical map group described the features of an area as "road," "flat area," and "hill," the aerial photograph group used descriptions such as "fire-break road," "tree-lined road," and "foothills" in their responses. This makes one remember, once again, that any kind of map evaluation must be based on particular tasks and particular criteria, and that any choice of map elements must reflect a particular purpose.

The Map (S_3)

The map, represented as S_3 in Figure 2-5, is the central element of the mapping process; it is the culmination of the large set of map making decisions just described, and the beginning of a large set of map-using decisions. In describing the content of maps, it is useful to consider a number of different levels of analysis, corresponding roughly to levels within language. However, it is important to realize that the language represented in a map is a language in many ways unlike spoken and written language. For one thing, elements in the mapping language always refer to unique items in a particular environment. There is no abstract mountain on a map; instead, there is a mountain with a specific set of attributes at a particular location. Also, in contrast to written language, the structure of a map, as seen in its spatial organization, is largely determined, in the sense that it cannot be manipulated extensively for alternative methods of presentation. In addition, the rules of organization of any mapping language are those dictated by the physical world, as well as by the conventions found to enhance understanding.

Yet the primary intent of a map, like spoken and written language, is the communication of an idea. Hence the four levels of linguistic analysis -- phonemes, syntax, semantics and general knowledge, form a useful analogy, provided that the reader is careful in generalizing. The following sections address each of these linguistic levels in turn and include references to the mapping literature dealing with each level of representation.

<u>Symbols by Themselves (Phonemes)</u>. Map symbols can be taken as isolated elements, considered outside of relational contexts, and judged not according to complex dimensions of meaning or comprehensibility, but according to internal attributes such as size, legibility and shape. A number of research investigations have focused on this level of representation.

For example, Bartz (1970) studied different type faces, finding that differences did not affect performance on a visual search task. Meihoefer (1973) examined the visual perception of circles on thematic maps, showing that range-graded circles can enhance size judgments. Crawford (1973) studied perception of graduated squares as cartographic symbols, showing that the size judgments of the squares was based upon area rather than on linear dimensions. Such investigations provide guidance at the most basic level of map making, and for the analysis of map reading failures and successes.

Relationships Between Symbols (Syntax). The second level of analysis involves how symbols on the map surface combine to form identifiable patterns. A number of studies are relevant to this level of analysis. Potash (1977), in an extensive review of map design, addresses a large set of syntactical rules which describe modes of coding and interrelatedness of symbols. As an example, he reports how color can be employed effectively to show relationships between areas in a map, stating that our excellent memory for color makes it an important map element. Berry and Horowitz (1961) describe how relationships between contour lines are interpreted, and others (Wheaton, et al, 1967) describes instances in which enhancement and shading is found effective in displaying map information. Wood (1972) describes how the gestalt rules of perceptual organization and processing can help predict an individual's perception of element patterns.

Relationships Between Symbols and Environmental Referents (Semantics). Considered in its simplest context, this level of analysis addresses the correspondence between single symbols and their referents -- those relationships which are typically described in map legends: a certain symbol is a school, an area with particular shading stands for an orchard, and different roads are shown with different numbers of solid and broken lines. In many instances, the arbitrariness of these symbols interferes with map reading. Muehercke (1972) suggests, in fact, that the untrained map reader must be provided with map elements that are more realistic and less symbolic than those typically used. Potash (1977) states that iconicity is important for symbols, but reports that there is now widespread agreement as to how iconicity should be defined.

In a study examining these contentions, Berry and Horowitz (1961) found that some standard topographic symbols are widely agreed upon, including shore lines, swimming pools, and airfields. However, they also identified a subset of topographic features that were not agreed upon, such as railroad tunnels, telephone lines and fences. (It is interesting to note that when subjects in these studies were asked to spontaneously generate symbols, they generated representations which showed elements in realistic three-dimensional fashion, often from a ground-level viewpoint). In order to deal with this level of comprehension, there have been a number of attempts at standardization of symbols. The intent is to provide a single, easily-taught language for map communication.

A more complex consideration of relationships between symbols and environmental referents is that which addresses the relationships between patterns of symbols and patterns in the environment. Termed "recognition of properties of symbol groups" by Olson (1976), this level of processing necessitates that patterns in the environmental domain and in the map domain be related. The interpretation of contour lines is an example of a task that requires this kind of analysis.

<u>Relationships Between Symbols and Memory (General Knowledge)</u>. Map symbols can be analyzed in terms of their effectiveness in triggering map readers' memories. An effective symbol at this level provides distinct reference to past experience, so that the map reader can go beyond the relationships

explicitly presented, in order to derive inferences about the environment based on experiences with similar environments and from information previously gathered from other sources. Olson (1976) describes maps addressed at this level as decision making devices which promote inferences by allowing the integration of the map symbols with other information. Situations which require a user to generate expectations of an area necessitate a careful consideration of this level of representation.

Map Reading (M_3)

The map reading operator (M_3) represents the map comprehension process. It transforms the information displayed on a map into a mental model held by the reader. In general, cartographers attribute many failures of cartographic communication to the map reading process, suggesting that training in map reading, rather than changes in map making, be instigated to improve map understanding. Map reading courses have been proposed for the general school system (Balchin and Coleman, 1966), and in the context of specialized mapping schools. Such programs have been developed, of course, and in many instances have been successful. Tellarico (1954), for example, reports that a map training course improved the map skills of both high and low intelligence subjects. Riffel (1974) has prepared a book to train people to learn map reading by comparison with stereoscopic aerial photographs, and claims that this method is extremely effective.

In a number of other instances, map training courses have been unsuccessful. In fact, Muehercke (1972) states that our present understanding of map reading is dismal and that researchers are not able to describe what training is required for map interpretation. Olson (1976) adds that current map training only produces changes in performance within a certain level of information, such as that required to relate symbols groups, and that changes in map making techniques are necessary if there is to be any overall improvement in map comprehension.

In any approach to map reading, one must consider two very different map reading situations: those map reading tasks which are performed directly in the represented environment (environment dependent), and those which are performed outside the represented environment (environment independent).

Environment-Independent Map Reading. Map readers who use maps outside of the represented environment have different requirements, and map information in these cases is handled differently at a cognitive level. In this class of situations, new representations of environments must be stored in memory and old memories must be modified. One class of environment-independent map reading is map learning. The task of the map reader in these instances is to learn a map in order to make decisions about it at a later time. Shimron (1976) studied map learning in a series of experiments. In these experiments, people were presented with a map which included highways, a river and a set of towns. They were then required to perform a series of tasks, including describing the map, answering questions such as "What is the northernmost city?", and completing requests such as "Name the cities on Route 7 going from City X to City Y."

The results of these experiments are consistent with current ideas of general perceptual memory. For example, Shimron found that his students made great use of the organizational characteristics of the map in recalling it. They mentioned patterns of elements on the map (e.g., "S-shaped river"); they used the map directions (e.g., "the southern route"); and they integrated local information around integrative features (e.g., highways). Other experiments verified the importance of organization in map learning. Shimron showed, for example, that local features of the map are learned initially, and that with more time global integration is accomplished. Also, he found that people learned more efficiently when they were explicitly shown the integration of areas rather than pieces alone, and when stories about the area were included in the map presentations.

The studies of Collins, et al (1976) were likewise directed toward map learning, namely, learning the geography of South America by means of an interactive computer display system. They found that maps presented on the computer display were learned much more efficiently than were hard-copy maps. In their explanation of this result, they suggested that the computer display system effectively focuses the users' attention on critical information, and that its interactive nature maintains the interest and involvement necessary for learning. Consistent with Shimron's results, Collins, et al, found that organizational aids included in presentations were important to map readers. Thus, it seems that the map reader benefits from organization and makes good use of procedures which focus attention on important environmental elements. Of course, in this class of exercises, map readers need not "understand" the map. Instead, they must be able to mentally replicate map as if they were pictures that included a set of words.

Expectation Generation. Another map reading task is to imagine how an area will appear before arriving in that area; to generate a basic schema in which environmental information can be organized at a later time. Generally stated, the task of the map reader in these instances is to look at the map symbols, and to generate a mental image of the represented environment. If a map reader is presented initially with a realistic map, for example, a three dimensional projection, or a movie about an area, the interpretation task is minimal. Similarly, the task is relatively straightforward when the map is presented at a number of sequential levels, that is, the map reader is initially given the gist of the area ("a broad valley with high grass") and details are added in order of their importance and distinctiveness. However, these kinds of maps are atypical. Typically, map readers must make their own transformations on symbolic data to generate their own expectations. They must rely on contour lines to determine the basic topographical features, and they must interpret abstract symbols to form ideas of vegetation and other basic environmental elements. The task of the map reader in these instances is to select the key elements of a map and to put these together to get a gist of an area, to develop a framework that will allow surprises and that will structure individual map elements, yet allow for surprises on actual contact.

Integration. A final form of map learning is that of integration, in which a person refers to a map to learn more about a previously experienced environment. The task of the map reader is to match memories with symbols, to view the symbol relationships, and then to change the memories appropriately. In other words, readers piece together mental images of areas, and, on the basis of matches or mismatches between mental representations and map representations, can change these mental images accordingly. In these instances, maps are used as devices to generate a "deeper" understanding of phenomena, showing new relationships between "things" (Salichtchev, 1973).

The Mental Model (S_4)

The fourth knowledge state (S_4) is a "cognitive map" -- the mental model that represents the perceptual and spatial attributes of the environment. The mental model is the knowledge that generates expectations of an environment, expectations which allow effective interaction with the environment. In the present context, we emphasize the effects of map reading on the cognitive maps. Yet it is important to realize that a cognitive map is not only a function of experiences with maps but, in addition, is based on a lifetime of direct experiences with the environment. As such, it includes things other than perceptual and spatial information; for instance, it may include information about personal events, facts about history, and knowledge of how to solve problems. It is not at all a direct reflection of the physical environment, and clearly not a reflection of maps themselves.

One thing that makes a mental model much different from the environment is the inclusion of procedural knowledge. Included in the cognitive representation of an environment might be instructions for climbing a certain mountain, or knowledge of what to look out for in a river crossing. General strategies are also included; these could be strategies for organizing bits of experience gathered over time, for remembering environments, for making inferences about an area, or for how and when to read a map if it is available. Clearly these things are not directly stored in the environment.

Another important characteristic of a cognitive model is that it is not an accurate representation of the physical world. Human memory is not a passive recording device but is, instead, an active processor that is continually seeking information and organizing it in accord with diverse goals and objectives. Memory is selective; some environmental elements are included and others are not. Memory distorts; information is stored in idiosyncratic ways so that it is useful for particular purposes and inappropriate for other purposes. Memory is always changing; with each new experience or thought, new information is integrated into the system. These changes in the memory system are quite different from the changes which occur in an environment.

The general study of memory and human information processing is included in the field of cognitive psychology. Such study centers on how individuals store and process information, and on how they use information in solving problems and making decisions. Research in cognition deals with general issues of understanding and representation of various kinds of information, e.g., perceptual, linguistic, social, etc. (good summaries of the research can be found in Neisser, 1967 and 1976; Norman, 1976; and Anderson, 1975). Though most of this research is focused on theoretical rather than applied subjects, there are investigations which relate quite directly to the mapping process, and to the cognitive representation of the environment and maps associated with it.

A current issue in cognitive psychology is whether information is stored in memory in some analogical and spatial way, or if it is stored in an encoded form, possibly based on linguistic relationships. An experiment central to this controversy was reported by Shepard and Metzler (1971), who investigated how subjects mentally rotate complex spatial displays. In their study, they found surprisingly strong evidence that people were able efficiently to mentally rotate the forms. Moreover, they found that the time taken to rotate these forms was a direct function of the degrees-of-freedom required for each rotation task. The study provided primary evidence, then, for theorists who suggest analogic mental models ("sand-boxes in the head" and "holographic storage" in the extreme). These theorists suggest that spatial integrity is maintained in mental storage, and that the mind directly reflects the environment to which it is exposed. Other supporting evidence has been provided from studies of reasoning tasks (Huttenlocher, 1968) and of imagery (Kosslyn, 1975; Kosslyn and Pomerants, 1977, and Paivio, 1975).

The argument has not gone unchallenged, however. Hockberg and Gellman (1977) showed that the Shepard and Metzler rotation task was affected by the number of landmark features in the display to be rotated, and that the rotation was therefore not directly analogous to physical manipulation. Clark (1969) has offered nonspatial explanations for the reasoning tasks, and much of the data from imagery experiments have been described in terms of propositional or linguistic encoding systems.

What about geographic information? Surely this information must be represented in a way that maintains spatial coherence. The method of loci, an effective mnemonic that the ancient Greeks used for recalling their speeches, is based on this assertion, as is a good deal of folklore. There is indeed some research that suggests that spatial information is represented analogously in memory. Mandler, et al (1977) demonstrated that even unimportant spatial details are learned frequently in an incidental learning experiment. Shepard and Chipman (1970) showed that spatial information is stored directly and efficiently, and that judgments of shape similarity made from memory were isomorphic to those based on direct perceptions.

Even in the study of geographic information, however, the theory of analogic spatial encoding has been questioned. In a clever set of experiments reported by Stevens and Coupe (1977), a study of map learning and memory for geographic locations, it was found that a hierarchical model effectively describes the storage and use of spatial information. For example, subjects, asked questions such as, "Is Reno east or west of San Diego?" were shown to be greatly affected by the superordinates of these cities (Nevada and California). Thus, their judgments were based in hierarchical relations as well as on locational relations.

Recent work by environmental psychologists, who study environmental cognition and environmental mapping, also questions theories that imply direct and accurate storage of geographic information. (For summaries see Down and Stea, 1973; and Moore and Golledge, 1976). Siegal and White (1975) assert, for example, that cognitive maps are not at all like pictures or maps. They suggest instead that the environmental information is fragmented and distorted, and that spatial relationships are primitive and often inaccurate. They also suggest that rather than a complete mental picture of the environment, people have representations that are composed of landmarks and the relational structures which connect them.

A number of researchers have empirically examined the structure of cognitive maps, using sketch maps of areas or recognition of environmental elements as their data. In an important book, Lynch (1960) examined individual images of cities and found large discrepancies between sketch maps of residents and the structure of their cities. Relevant to this discussion, many of the discrepancies were the result of selective encoding, in that certain elements were included and others were not. DeJonge (1962) and Appleyard (1969) suggested that this selection was a function of attributes, such as form, visibility and distinctiveness of environmental elements. By contrast, Orleans (1973) and Milgram (1972) suggested that exposure to environments and mobility of individuals accounted for omissions in environmental knowledge. Lynch also identified distortions of distances and of the relationships between objects. Siegel and White (1975) explained these distortions in terms of the number of landmarks in an area, while Lee's (1970) work suggested that the directionality of distance estimation depends on the saliency of environmental attributes.

No matter how one explains mental distortion of environmental information, it is important to acknowledge the large variations between individuals in processing of spatial information. The formation of cognitive maps and the ability to use map displays are influenced by fundamental skills in detection, recognition, identification and differentiation, as well as by more basic variables such as intelligence, visual acuity, and spatial relations aptitude. Common experience tells us that some people are much better than others at reading and navigating from ordinary road maps. There is also a good amount of empirical evidence to support the concept of individual differences in map-use facility. For example, after a comprehensive and far-reaching set of studies, Wheaton, et al (1967) found tremendous variations within groups of subjects performing map reading tasks. Lowenthal (1961) describes how different cultures orient themselves to spatial environments in different ways. Southworth (1970) describes how children from varied economic classes store environmental experiences differently. Downs and Stea (1977) describe an experiment by Gittens (1969) which demonstrates that scientists explore an environment differently than writers, and there is a large amount of data suggesting sex differences in spatial abilities.

What does all of this mean for the mapping process? It asserts that mental representations of the environment are quite unlike the environment. They are selective and distorted, often pertaining more to human processing capabilities or to individual differences than to the environments they represent. Why, then should a map maker pay any attention to mental representations? There are a number of reasons. One is that the map maker must attend mental models because they describe the data which the map reader brings to the mapping task. That is, the model defines the set of operators and information that an individual will be able to use in interpreting a given map. In addition, information about mental models can provide the map maker with clues as to what is important in a particular area. For instance, landmarks and distances appearing in sketch maps, though incomplete and distorted, may be those that are important to include in a more precise representation of the environment. Similarly, the organizational schemes used by people in integrating environments will certainly be reflected in their organization of map information. It is to the map maker's advantage to acknowledge and provide for these.

Problem Solving (M_4)

The problem solving operator (M_4) involves a set of hueristic rules which transform environmental knowledge into plans for action. These rules are the procedures which describe how individuals solve map reading problems.

Table 2-2 provides a sampling of specific tests used by researchers in assessing map performance. They provide us with a beginning for an analysis of geographic problem solving. A further consideration of these and other specific tests leads to division of map problem solving into four categories; these are: symbol interpretation, matching a map with an environment, planning actions, and remembering maps.

Symbol Interpretation (Syntax). In these tasks, the map user is required to understand the information on the surface of the map, though he is not required to make judgments about the environment. Evaluation tasks which assess this level of comprehension include those requiring map users to:

(1) Identify map symbols
(2) Measure the distance to an objective
(3) Determine the elevation of a position
(4) Determine the location of a specific object on a map
(5) Shoot an azimuth to a marked location

Matching a Map with an Environment (Semantics). Tasks in this category require the map user to interpret the map display, to use the semantics of the map to either imagine the environment displayed by it, or to explicitly match the map to the environment in field tests. Evaluation tasks which assess map use at this level include those requiring map users to:

(1) Identify land forms
(2) Sketch or describe terrain
(3) Recognize vertical profiles
(4) Describe intervisibility between points
(5) Determine the terrain features which would be encountered following a certain route

TABLE 2-2
MAP ASSESSMENT TESTS

A.	Memory Tests	(Shimron 1976)
	What is the most Northern City?	(Shimron 1976)
	Which city is between Quincy and Forsyth?	(Shimron 1976)
	Name two cities on Route 5.	(Shimron 1976)
	Name the cities from Quincy to Danville.	
	What does _______ stand for?	(Kjellstrom 1967)
B.	Map Reading Tests	
	In which square is the highest hill?	(Berry & Horowitz 1961)
	Are there any flat areas? If so, in which squares do they appear?	(Berry & Horowitz 1961)
	What is the distance from C to D as the crow flies?	(Berry & Horowitz 1961)
	Please trace, with a pencil, the fastest route between A and B (you have a Jeep).	(Berry & Horowitz 1961)
	If you are walking across the terrain represented from top to bottom along the righthand border of the map, the terrain would become: a. More swampy b. Less swampy c. Less heavily wooded d. More hilly e. Less hilly	(Tallarico 1954)
	Sucker Brook is a: a. Slow-moving stream b. Fast-moving stream	(Kjellstrom 1967)

When you stand on a hill marked 400 about ½ mile north of Meadow Knoll Cemetery, you should be able to see:

a. Hutton Hill
b. Meadow Knoll Cemetery
c. Niger Marsh
d. Huckleberry Mountain (Kjellstrom 1967)

C. Field Tests

At the ten stops your truck makes, which way should the truck go to follow the route on the map? (Wheaton, et al, 1967)

Where are you on the map? (Tallarico 1954)

What direction do you want to go to get to your goal? (Tallarico 1954)

(6) Read contours
(7) Determine personal location on a map (field test)
(8) Stay on a marked route (field test)
(9) Orient a map in an environment (field test)

Planning Actions (Use of Knowledge). This category involves the use of the knowledge gathered from a map. It explicitly involves the planning of actions in an environment, planning that builds upon the understanding of map information but that requires other inputs in addition. Evaluation tasks of this sort require map users to:

(1) Plan routes for particular purposes
(2) Act out a scenario of activities, based on the knowledge that particular events will occur at specific locations in the environment (war games and urban planning provide examples of such tasks).

Remembering Maps. The fourth category of tasks require the user to learn a map. In some instances, the user learns the syntax of a map. In others, more complex processing may be involved. Evaluation tasks assessing memory for maps require map users to:

(1) Sketch a map from memory
(2) Sketch a territory from memory
(3) Answer a question about a map that has been presented
(4) Answer a question about an area that has been presented on a map.

Clearly, the above is not an exhaustive listing of problem solving tasks, as one can easily imagine a large set of additional sub-tasks. For example, one can read a map in a nonpurposeful manner, obtaining general information that may or may not be useful at a later time, or one can use a map in describing a place to someone else. Yet this list does give a general sense of the kinds of activities individuals will attempt to use map information for. To extend the analysis, we can look to the problem-solving literature within psychology.

There are three classes of experiments within psychological research that are relevant to the analysis of how people solve spatial problems. The first includes general investigations of problem-solving and decision-making. These investigations attempt to unravel the processes involved in particular tasks, examining the solution of tasks as an active process of information-gathering, information transformation, goal-setting, and decision-making. Very few of these investigations consider geographical tasks, but the processes involved are relevant at a basic level. Good introductions and specific references to these investigations can be found in Newell and Simon (1972), and Lindsay and Norman (1977).

The second class of experiments investigates how people organize local information into global spatial representations. Janssen and Michon (1973), for example, described how subjects piece together parts of spatial networks to identify them. Hochberg (1966) described how single glances can be combined to yield an understanding of a complete scene. In a more explicitly geographic context, Moran (1973) examined how subjects piece together geographic directions to form an image of a route; letting each cardinal direction signify a one-unit move in the named direction, he asked subjects to follow a set of geographic directions and to identify their final location. Moran describes the image-making processes in this task in terms of the development of symbolic structures and the application of problem solving operators to these structures.

The third class of experiments examine how people determine spatial locations in perceptual space (how they determine the location of a point of view). Piaget and Inhelder (1948) studied the development of spatial perception in children, providing a framework for different spatial systems used by individuals in relating to the physical spaces around them. Specifically, they described how an individual moves from a topological representation of space, to a projective space and then to an Euclidean space. In these descriptions, they described in detail the phenomena of spatical egocentrism: seeing the world from one's own point of view and being unable to imagine that it is any different from any other viewpoint. Laurendean and Pinaud (1970), and Huttenlocher and Presson (1973) examined this phenomenon in an experimental framework, confirming the results of Piaget and Ihelder. Hooper (1973) extended the basic paradigm of locational determination to adults. By examining the kinds of location constraints that people use to identify the viewpoint in a picture of a familiar area, it was determined that adult subjects accomplished this task very well, typically choosing a point of view which satisfied all constraints except very specific angular ones.

Kuipers (1976) combines the concepts of the last two classes of experiments in describing a system which integrates local geographic information and determines the location of a reference position. His system, set in an artificial intelligence framework, can execute geographic directions and solve geographic planning tasks in ways that are consistent with the general principles of human processing. The important element of Kuipers' analyses is that they include explicit process descriptions. He delineates very specifically how information is extracted from a representation of an environment, and how this information is organized to generate specific actions in the environment required for particular tasks. This work provides a good model for future research on mapping.

Plans for Action (S_5)

There is a wide variety in the plans for action (S_5) which results from the individual processing involved in map reading. In the most straightforward cases, the plans dictate actions to be taken in the environment. Alternatively, they can generate expectations for later environmental exploration, they can refer the map reader back to a map for new information, they can question and change the map reader's mental models of environments, or they can dictate the actions of other individuals. These plans represent the end of the mapping process described in Figure 2-5.

Some Other Considerations

The model just described omits several of important relationships in its attempt to provide a straightforward analysis of mapping. There are a number of additional considerations that should be briefly acknowledged. For one, in may instances individuals generate cognitive maps (S_4) based on direct experiences with the environment (S_1). Again, in many cases people make maps (S_3) based directly on their own experiences with the environment (S_1) rather than on environmental data acquired and organized by someone else.

Environmental data (S_2) can be directly assessed by interested individuals to generate cognitive representations (S_4). Interactive computer systems provide excellent vehicles for this interaction. The mapping process is not, nor should it be, a one-directional process. It is a process rich with feedback loops, as map readers obtain individual feedback in map reading, and as map readers provide map makers with information about map effectiveness through actions and direct evaluations (McGrath and Kirby, 1969). Finally, the environment (S_1) is itself not a static element; it is changing constantly. It changes by human interactions (including those guided by maps), by cataclysmic events, and by the innumerable other events which accompany the passage of time.

CONCLUSIONS

In the preceding sections, it has been the implicit assertion that there are good maps and bad maps. More particularly, it has been suggested that maps must be generated for particular situations and then judged in the context of these situations. This means that one must delineate standards for maps in terms of the goals which they are supposed to fulfill.

Specifically, there are four basic classes of criteria which are appropriate in evaluating maps. The most stringent of these is the consideration of whether or not an individual using the map is capable of acting effectively in the environment which it represents. This criterion, the *action criterion*, states that the worth of any map is contained in the accomplishment of particular user actions. The *knowledge criterion* asserts that a map should be evaluated in terms of the environmental information it provides to the user. This criterion emphasizes that user knowledge as a critical factor. A third criterion is the *completeness criterion*. This refers to the completeness of information imparted by a map designed for a particular situation. The last criterion, the *accuracy criterion*, considers simply whether or not the information selected from an environment is itself accurate.

What does this tell us about maps? It tells us that we must consider them carefully, both in the process of map making and map reading, for they represent a large set of choices. They are designed for particular tasks and for particular users, and they need to be evaluated in this context. In addition, they include a wide range of elements, in terms of type, level of representation, and symbolic nature. All possible combinations of these elements need to be considered in the totality of the mapping process. The mapping process itself is a complex one, involving a large number of decisions and transformations in domains which are typically greatly separated in time and space. This chapter has been organized to provide a conceptual and theoretical framework that, 1) can be used to accomplish more sophisticated analyses as appropriate technologies and research techniques are made available, and 2) can sharpen the intuitions of readers actively involved in the mapping process.

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3 MAP DESIGN EXAMPLES

MICHAEL AND SUSAN SOUTHWORTH
City Design & Architecture

A NOTE ON THE MAPS

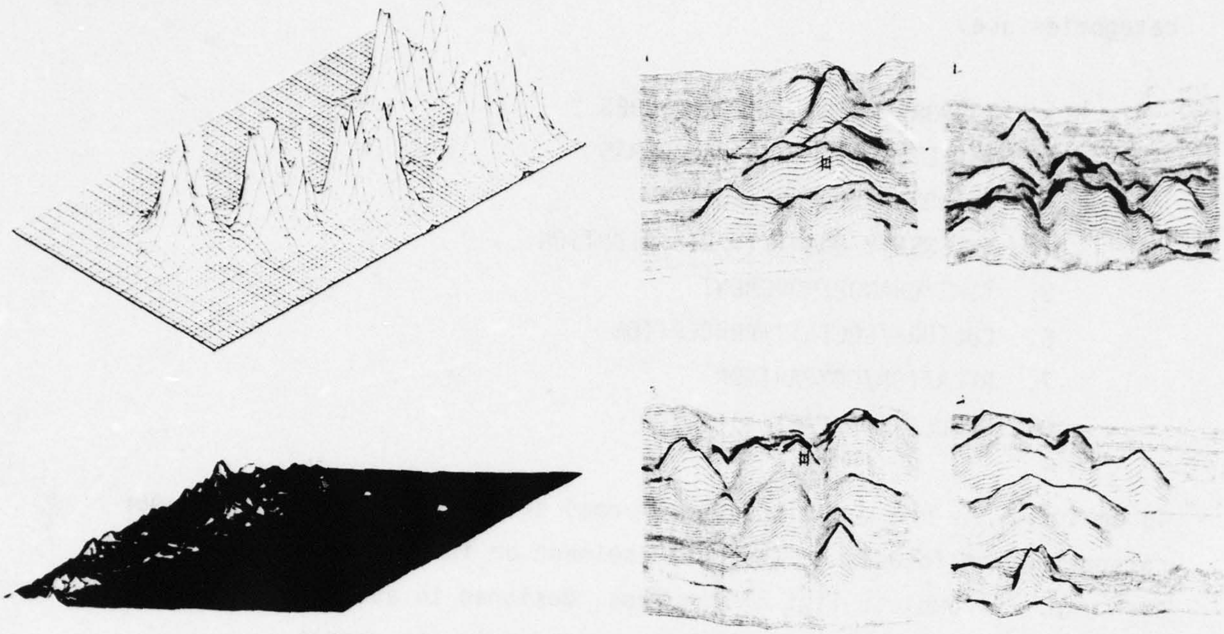
In compiling this survey of mapping techniques we studied more than one thousand maps over a period of several months. While only a sampling of techniques can be presented here, we have attempted to include at least one example of each major type. Emphasis has been placed on maps that depart from the traditional static visual pattern of geographic features seen in the conventional road map or atlas. We have sought maps that allow user input or manipulation and that have been responsive to specialized user needs, for example, the traveler, the meteorologist, or the military strategist. Another concern has been with techniques that help the user make valid connections from map representations to the real world.

Several map examples are still in an experimental stage, but suggest a potentially useful new direction. It should be noted that although some maps are historic, we have found in them a unique approach to mapping that could stimulate the modern map maker. Presentation of several maps has been necessarily limited by the format of the printed report. For example, braille maps and touch sensitive auditory maps must be presented here in the visual mode alone. Similarly, animated or computerized maps that allow user input or participation can only be suggested by one or two static frames extracted from a typical motion sequence. Several maps in which color is a key source of information, such as the New York City color-coded transit map, suffer badly by their presentation in black and white. We hope that future published editions of this work will allow color reproduction, but for the time being, the reader will have to use some imagination with these examples.

Many alternative typologies for organizing the maps are possible, for example, by content, by user type, by medium, or by graphic technique. The system finally selected facilitates use by the map maker or map enthusiast, by employing obvious and non-esoteric descriptive categories that readily identify the major attributes of a particular mapping technique. The descriptive categories are:

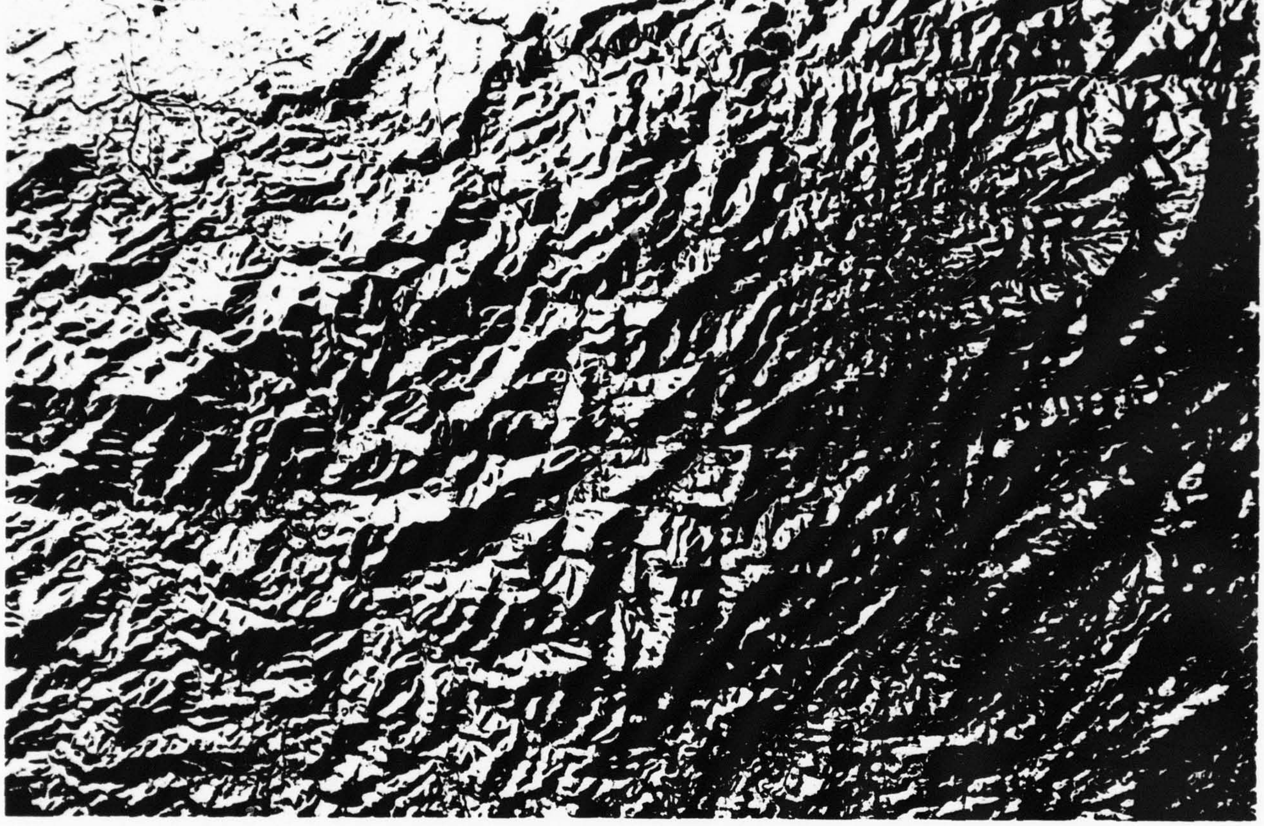
1. TOPOGRAPHY/NATURAL FEATURES
2. STREETS/BUILDINGS/PANORAMAS
3. NETWORKS/SYSTEMS/ROUTES
4. INTENSITY/QUANTITY/DISTRIBUTION
5. TIME/CHANGE/MOVEMENT
6. CULTURE/SOCIETY/PERCEPTION
7. RELATION/COMPARISON
8. SIMULATION/PARTICIPATION

To be sure, any one map displays numerous attributes of map making--our categorization focuses on the most dominant or interesting attributes of each map. A complete list of the maps, designed to assist readers in locating particular map examples, is appended to the report.



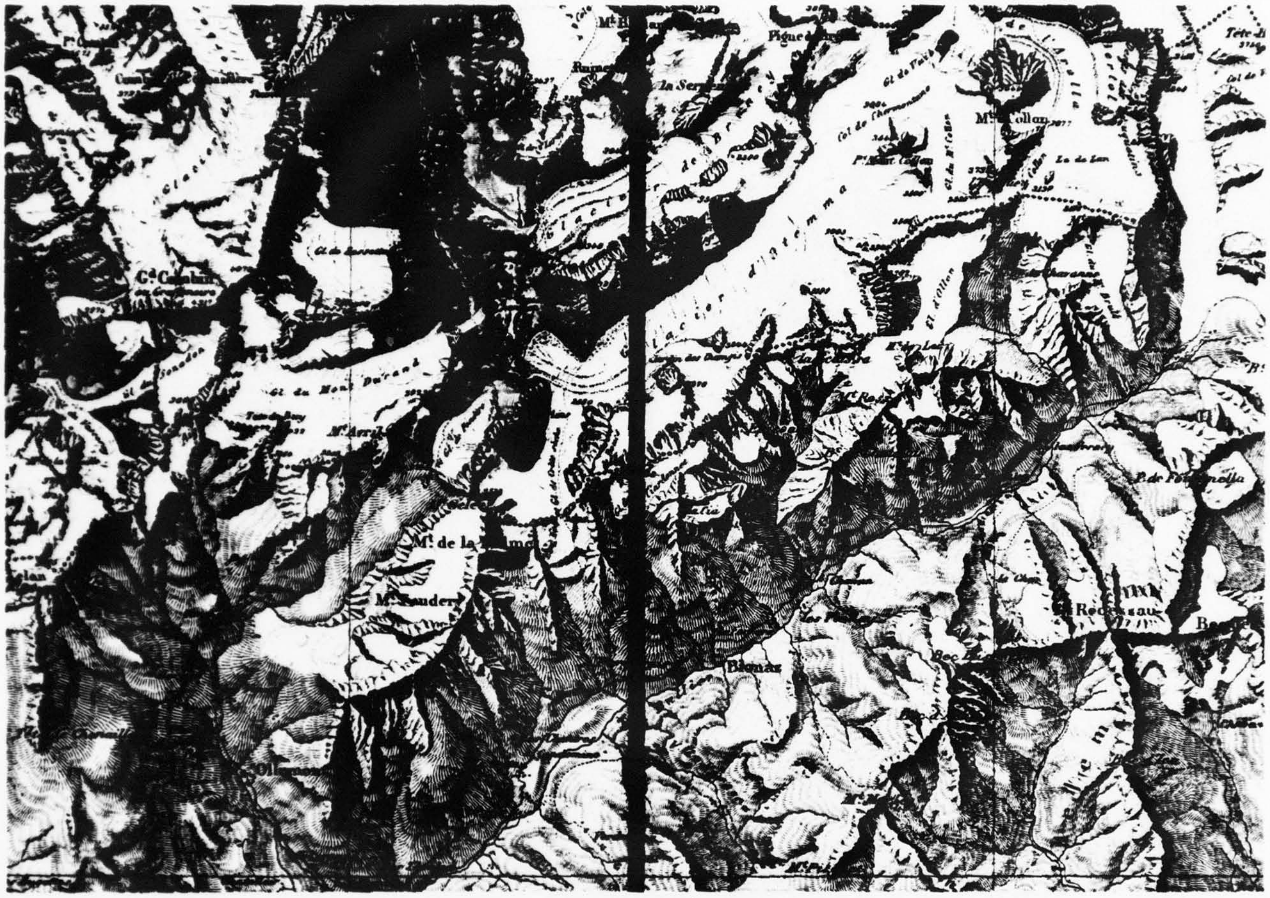
1.1 COMPUTER GENERATED TOPOGRAPHY AND CONCEALMENT MAPS

A few techniques for representing topography are shown in these three computer generated maps. The first uses closely spaced parallel lines which are warped with changes in contour. An open warped grid is used in the second. The third uses parallel lines again, but these are more widely spaced. Here, the same site is shown from four points of view, demonstrating how a military installation, for example, is concealed from view in one approach. (North is shown by the arrow; the box shape indicates the military installation.) Computer storage of topographic data makes analyses such as these routine. Map reprinted by permission of U.S. Army Engineer Topographic Laboratories, Experimental Map Program.



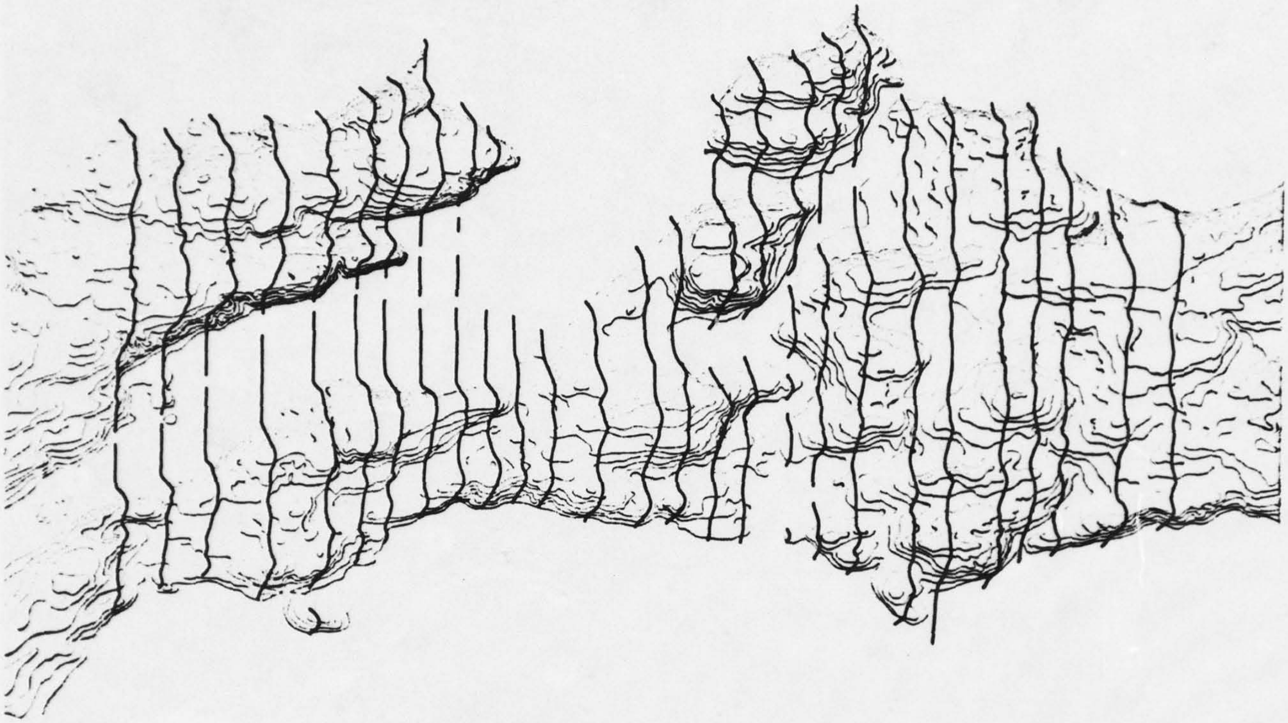
1.2 RAISED RELIEF TOPOGRAPHIC MAPS

Terrain is presented in three dimensional model form on molded plastic sheets. Vertical dimensions are exaggerated. Standard map information on roads, rivers, place names, and boundaries is printed on the map. While it is effective in illustrating mountainous areas, it becomes an ordinary flat map in areas of flat terrain. Such maps are useful for display and teaching and require less interpretation of terrain symbologies than flat maps, but they are somewhat difficult to store. Map reprinted by permission of Defense Mapping Agency Topographic Center, Washington, D.C.; produced by Hubbard, Northbrook, Illinois.



1.3 TOPOGRAPHISCHE KARTE DER SCHEITZ

Artful shading gives this elegant 19th century engraving of the Swiss Alps a very three-dimensional feeling, although it is simply a plan. The original maps were cut into pocket size cards and mounted on a cloth backing. The map was very durable and could be easily folded without fear of tearing along the creases. (Original scale 1:100,000). Map reprinted by permission of General G.H. Dufour (Guillaum Henri, 1787-1875), Bern, 1889.

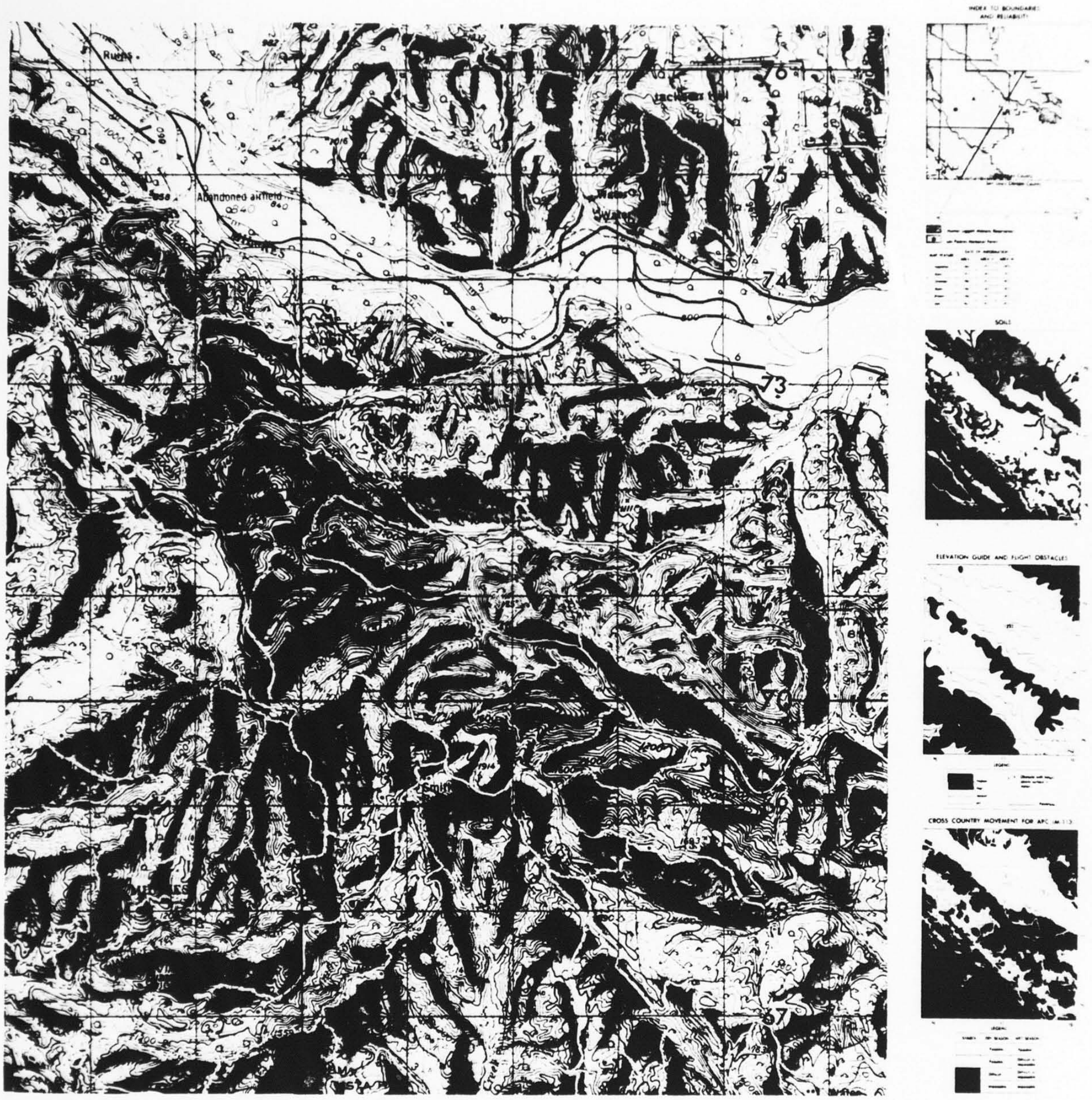


1.4 SEATTLE: SEQUENTIAL SECTIONS

Sequential sections offer an interesting alternative means of displaying topographical information by showing the crosssection of topography for one axis only. This technque gives a better sense than do conventional techniques of travel conditions over the land in the same direction as the contour lines. The selection of the intervals and preferred direction of slicing is obviously crucial. Map reprinted by permission of Urban Design Section, SEATTLE URBAN DESIGN REPORT, Department of Community Development, Seattle 1971.

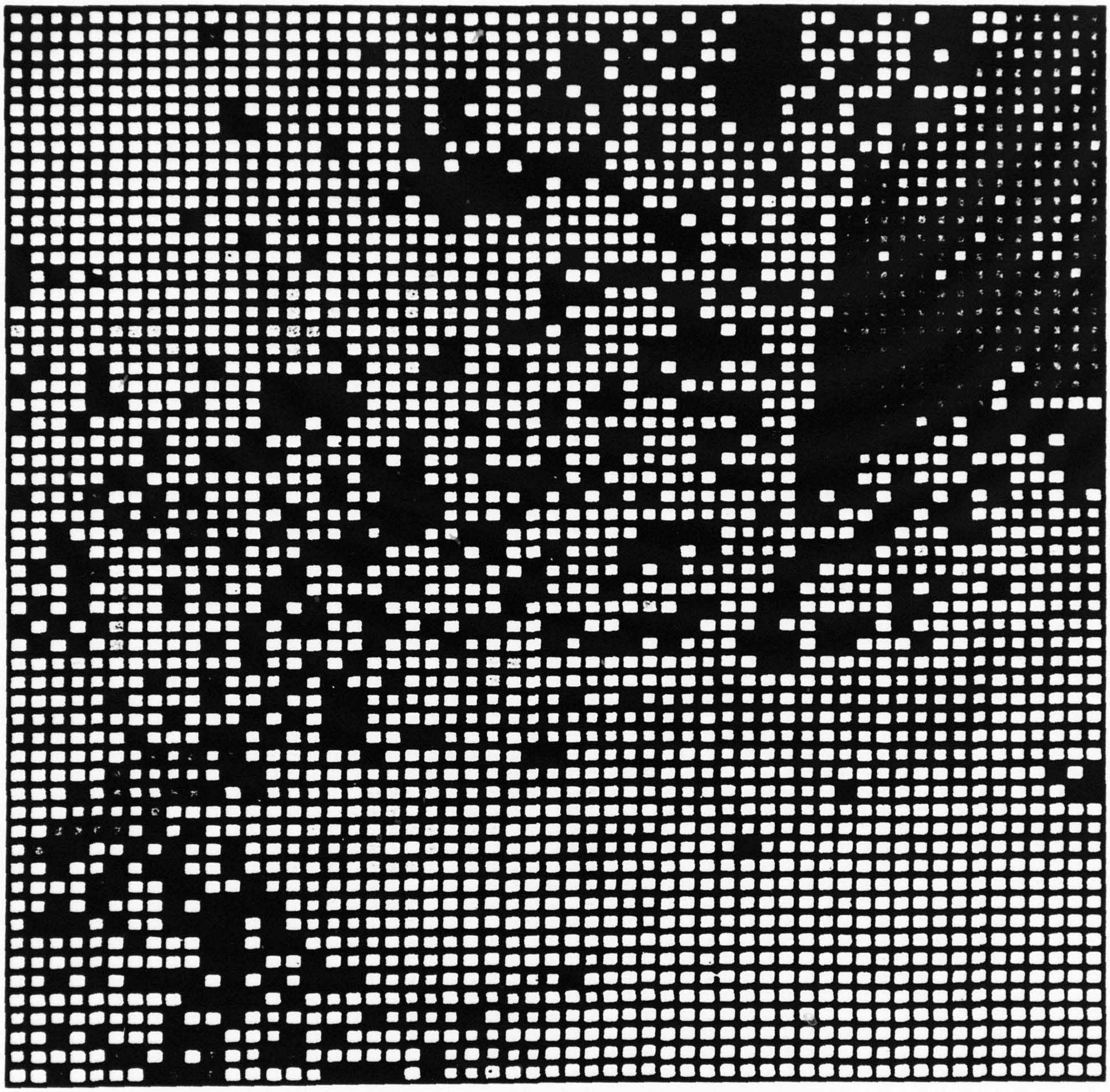
1.5 BRYSON: AIR LANDING GRAPHIC

An aerial photograph is the base for this experimental military map. Color is overlayed to indicate ground cover. The third layer of information relates to helicopter landing zones. Potential sites are outlined in heavy lines and are described by letter codes; detail photos and descriptions of each site appear on the reverse side. Inappropriate landing sites are hatched over with widely spaced diagonal lines. Map reprinted by permission of Defense Mapping Agency Topographic Center and U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Va.



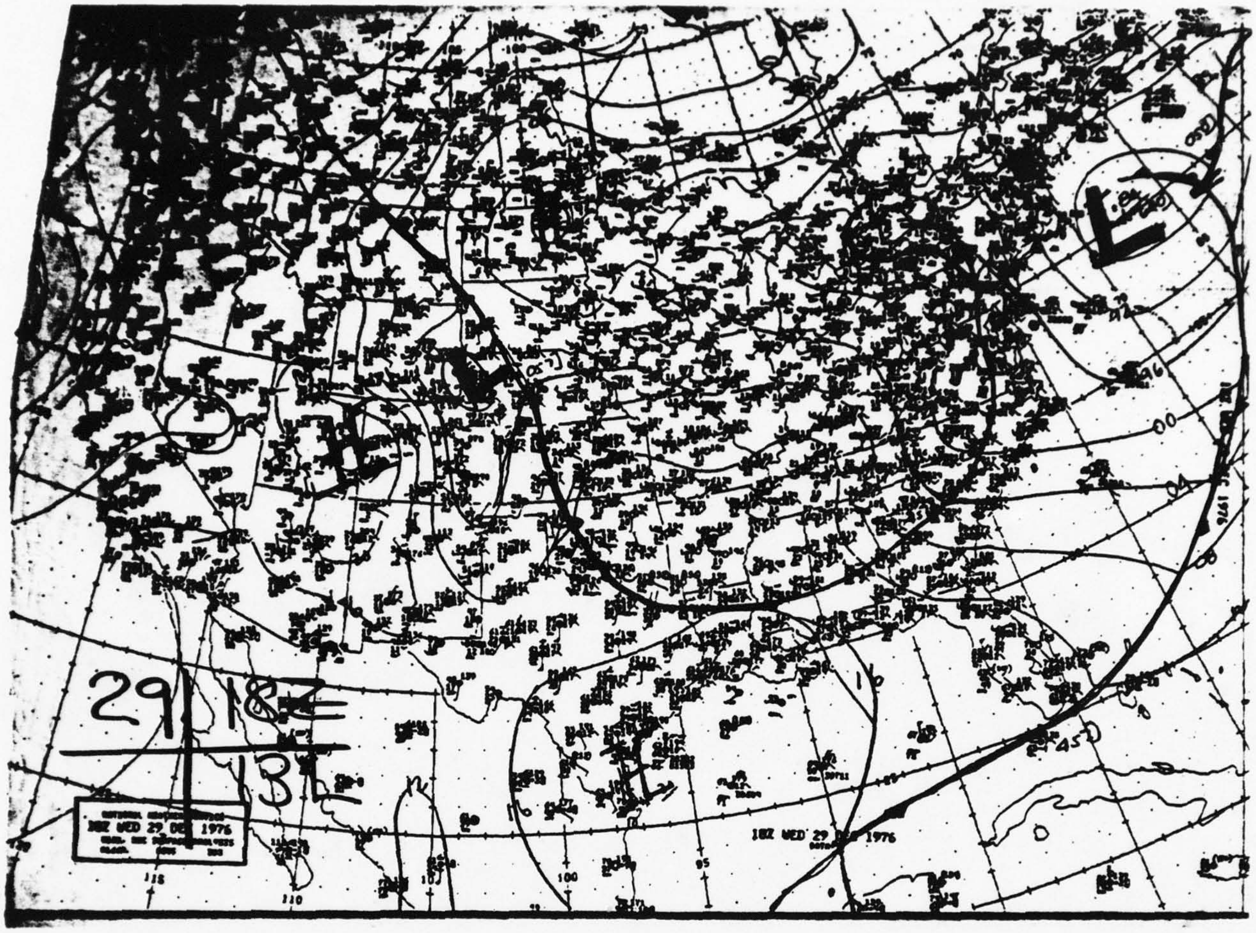
1.6 BRYSON: TOPOGRAPHY AND VEGETATION

Here shadows are used to enhance topography. Color communicates extent of canopy closure in forested areas; darkest colors correlate with 75-100% canopy closure. Four small, highly simplified maps in the margin aid understanding of the detail map; these summarize elevation, ease of cross country movement, boundaries, and soils. Map reprinted by permission of Defense Mapping Agency Topographic Center and U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Va.



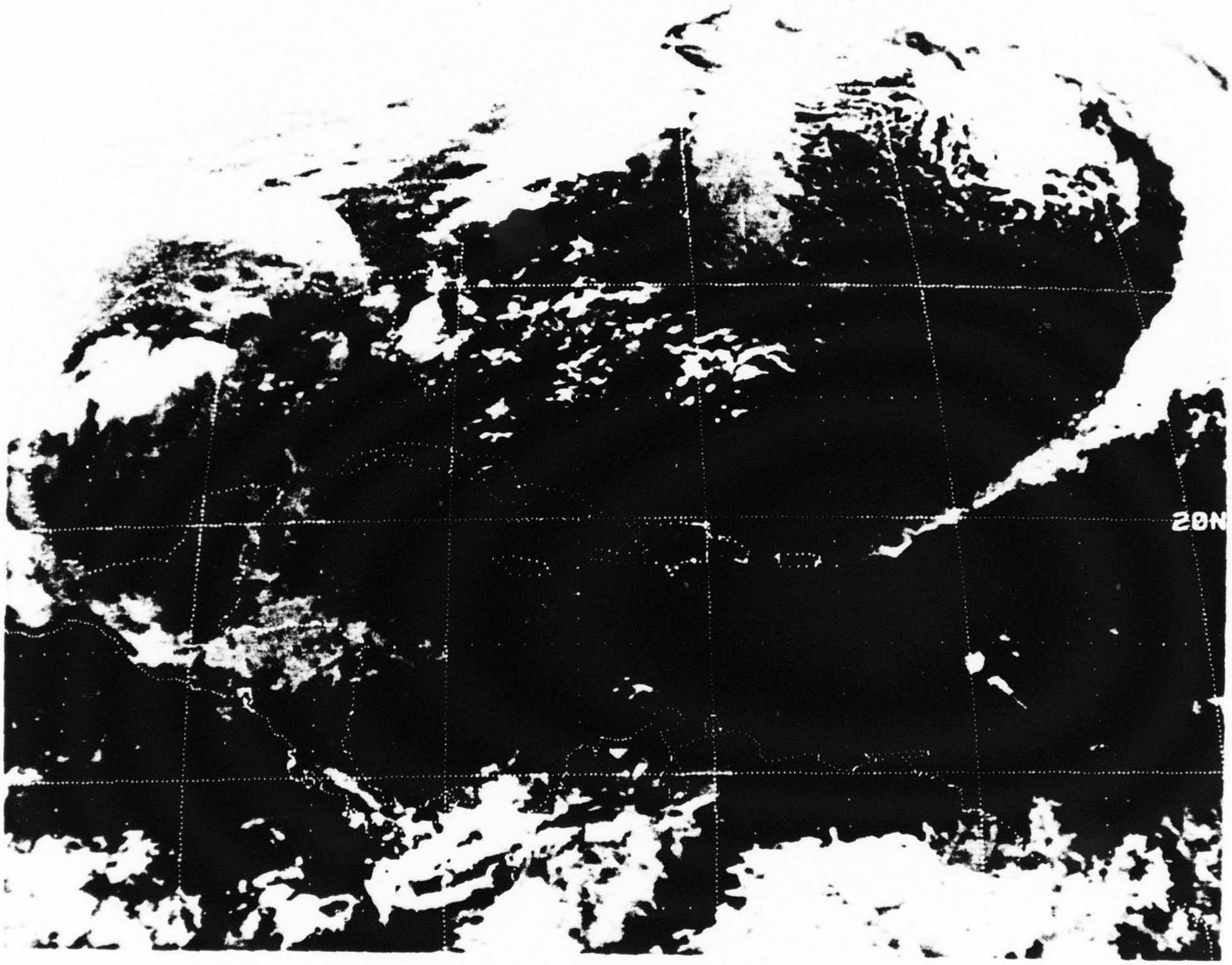
1.7 INFRARED REFLECTANCE

Infrared reflectance of land and water surfaces is expressed in this map of the Middle East. Data were obtained using a high-resolution scanning infrared radiometer on board an unmanned artificial satellite. Information is recorded cell-by-cell and color added. Map reprinted by permission of Norman H. McLeod (NASA), in A.H. Oort, "The Energy Cycle of the Earth", SCIENTIFIC AMERICAN, June 1970.



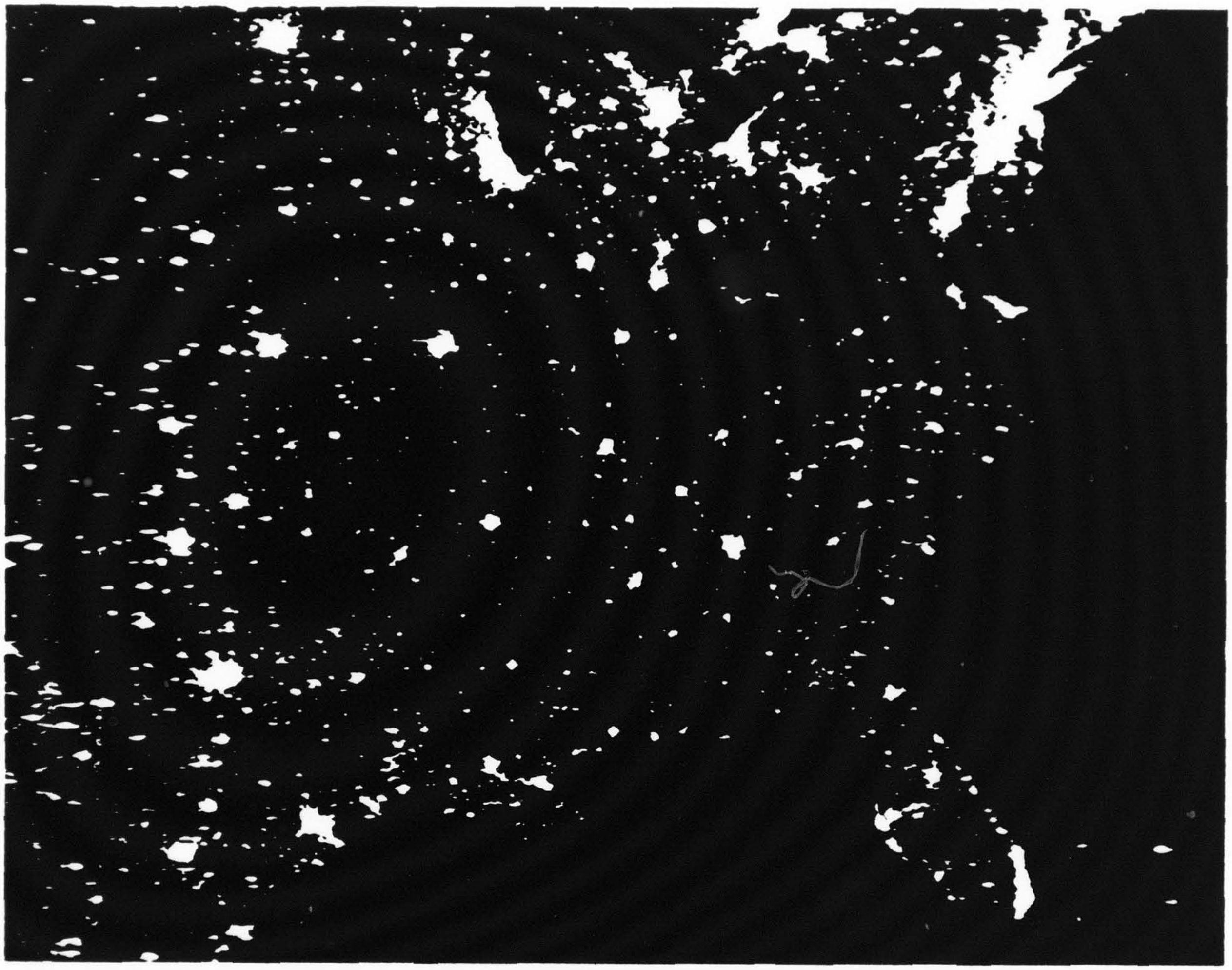
1.8 WEATHER MAP

Computer printout is combined with human analysis in the typical weather "surface chart." Weather observations are entered into the nationwide weather information system once each hour by weather stations across the country. Every three hours, a national surface chart is printed out at each station. The array of numbers is coded to represent various types of weather fronts. A meteorologist interprets the charts to create a weather forecast. Map reprinted by permission of National Weather Service, Logan Airport, Boston.



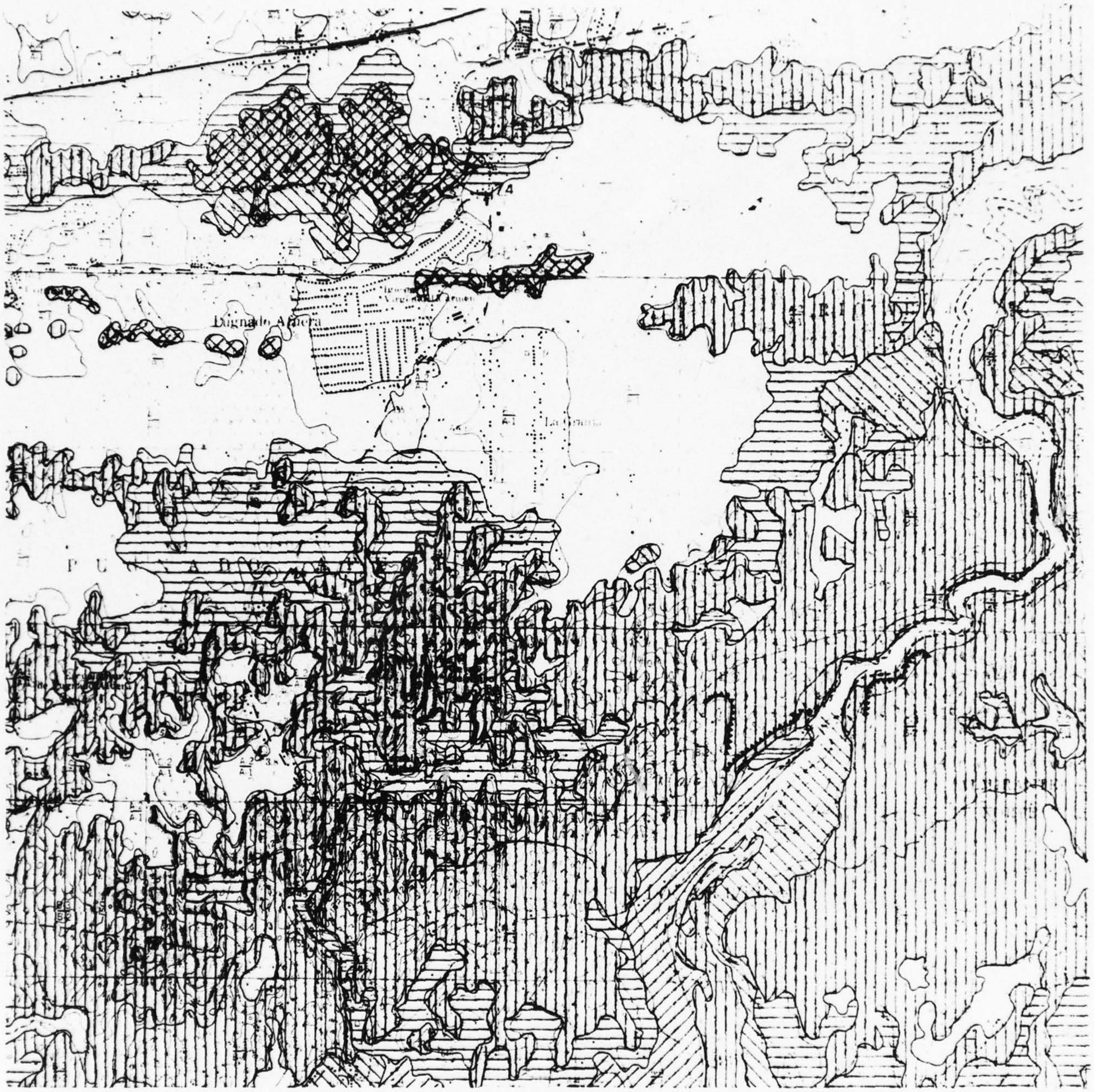
1.9 SATELLITE PHOTO WITH GEOGRAPHIC OVERLAY

This satellite photo of part of the western hemisphere is made more intelligible by a graphic overlay. Geographic coordinates, outlines of land masses, and political boundaries are delineated in dotted lines. Use of dotted, rather than solid, lines reduces interference with the photo base. Map reprinted by permission of National Weather Service, Washington, D.C.



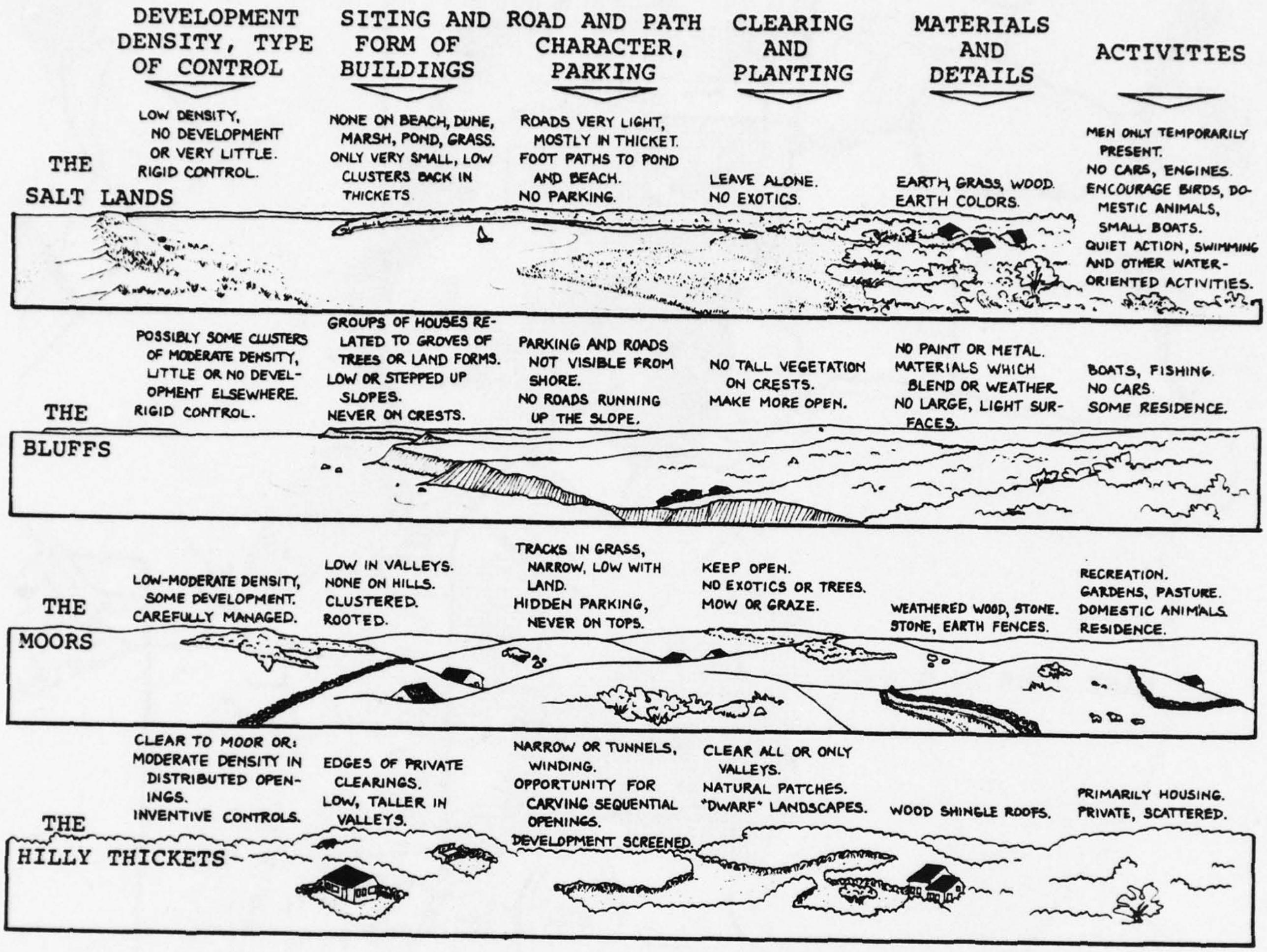
1.10 NIGHT TIME SATELLITE PHOTO

From a weather satellite at night, the U.S. looks more like a galaxy of stars viewed through a telescope. City lights communicate settlement patterns and the great urban concentrations of the Northeast. *Energy consumption of various regions is probably proportional to their* nighttime brightness. Satellite images have also been made of heat loss and dramatically point out energy waste. At a much larger scale where individual buildings may be identified, such photos have great value in energy conservation programs.



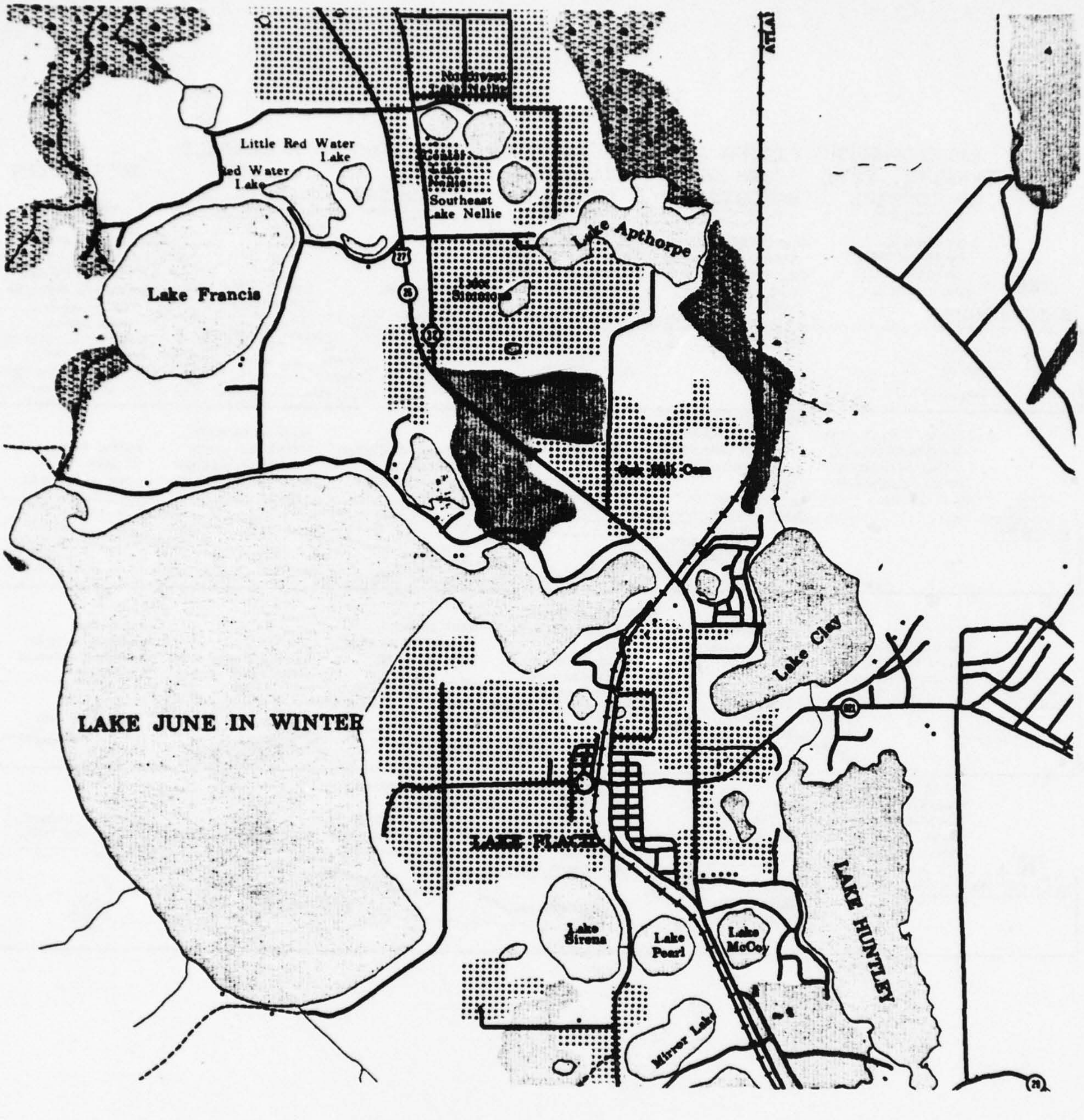
1.11 GROUND TACTICAL DATA: MANATI

Color and texture differentiate areas on this military map of ground tactical data. Color identifies soil type, and texture classifies vegetation. Widely spaced lines show percent of slope; for example, horizontal lines mean 3-10% slope and vertical lines are 45-100% slope. Stream width and depth are shown by various patterns of dotted and dashed lines. The colors and textures of this map have been well chosen to create a highly legible result. Map reprinted by permission of U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Va.



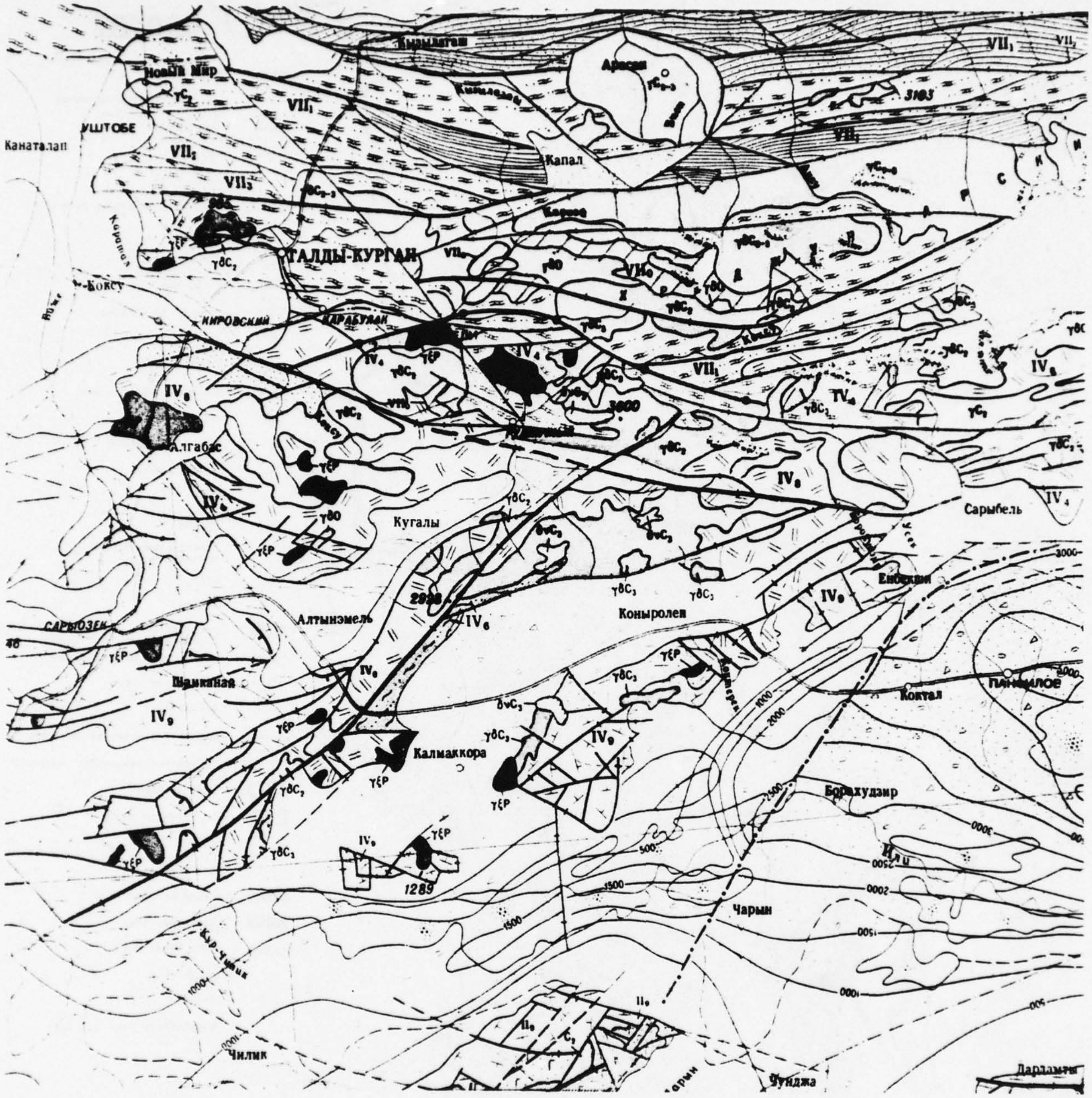
1.12 PICTORIAL MAP GRAPH: FOUR LANDSCAPES

Four typical landscape types are depicted in chart form and are described in terms of 6 critical development related policy variables. The combination of illustrative landscape segments with verbal policy information makes for easy comparison and understanding of both landscape and policy questions. Map reprinted by permission of Kevin Lynch and Sasaki, Dawson, & Demay Associates, Inc., Vera Pratt, Olga Kahn and Mindy Arbo, LOOKING AT THE VINEYARD, Vineyard Open Land Foundation, West Tisbury, MA. Copyright 1973.



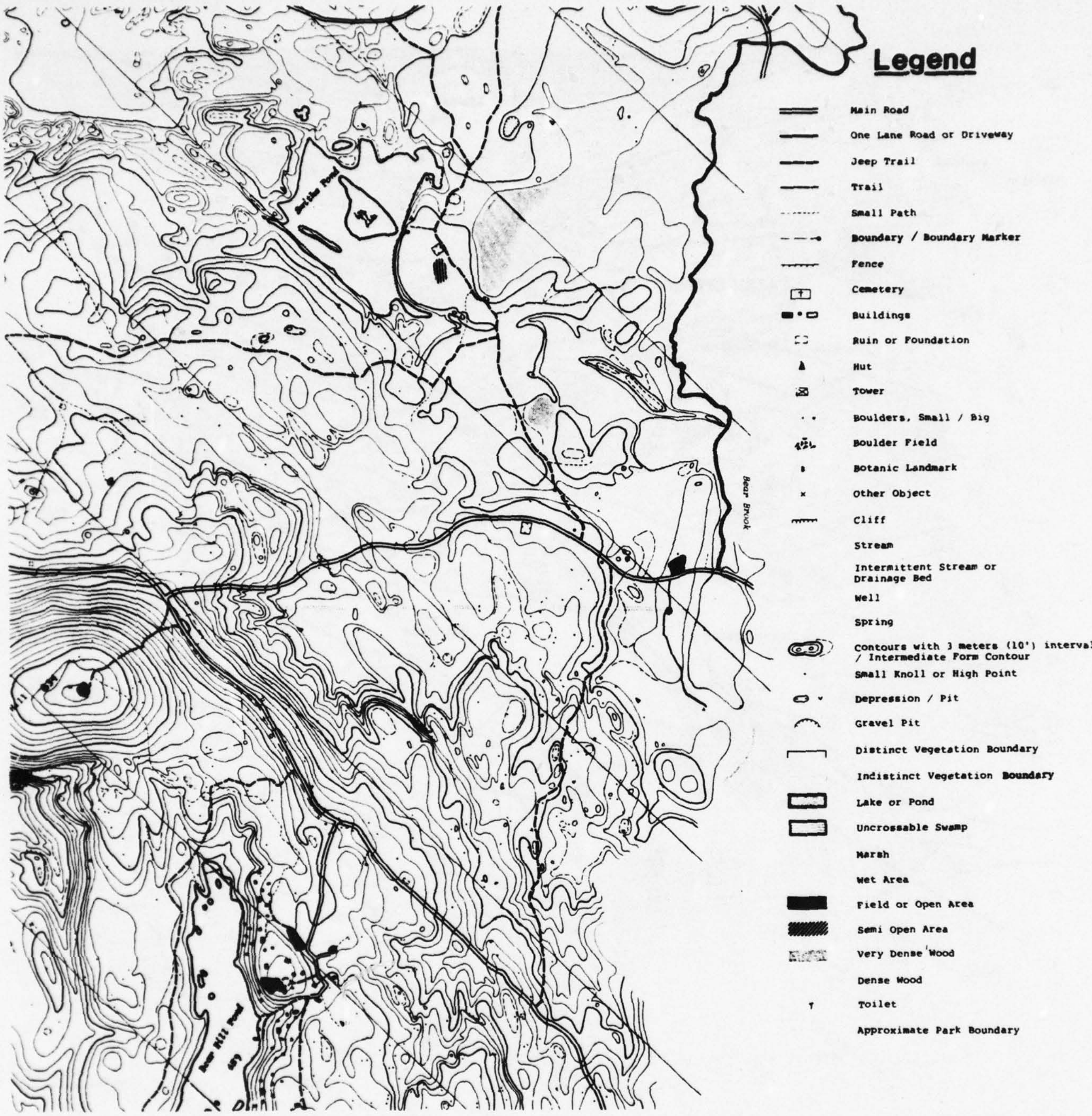
1.13 COMPUTER GENERATED MAP: LAKE ISTOKPOGA

This map was produced to demonstrate the current capabilities for raster processing of map data and to show the quality level associated with a 0.004 inch scan/plot spot size. Scanner/Plotter input consisted of 11 hand-drafted manuscripts, each representing a separate class of data. Computer processing was performed separately for each class of data to accomplish line thinning, raster-to-vector conversion, automatic editing, symbolization, merging of files, and raster plot tape generation. Map reprinted by permission of U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Va. 1976.



1.14 GEOLOGICAL MAP: RUSSIA

A diversity of patterns and colors is used to map geological structure. Included are several dot patterns, "T" patterns, scattered line segments, "L" patterns, circles, open triangles, as well as various shadings and line patterns. In addition, letter and number codes are used. A variety of solid and broken line patterns delineate boundaries. The result is a map of great artistic appeal.



1.15 ORIENTEERING MAP: BEAR BROOK STATE PARK

Orienteering is a sport in which those taking part navigate from point to point with the aid of a special map, as quickly and efficiently as possible, by whatever route they interpret as best for them. The map is based on the topographical map of an area, but refined to include many details of the terrain which most cartographers would ignore. Cliffs, large and small boulders, intermittent stream beds, man-made structures, ruins, fences, and small foot paths are added, giving the orienteer much more data with which to navigate. Map reprinted by permission of the New England Orienteering Club, Inc., Sudbury, Mass.

DEVIL'S HEAD

Route No. 8*

Ref 11888378 34°41'00"E 29°07'30"N

Departure: Aqua Sport – 61 km. (38.4 mi.)

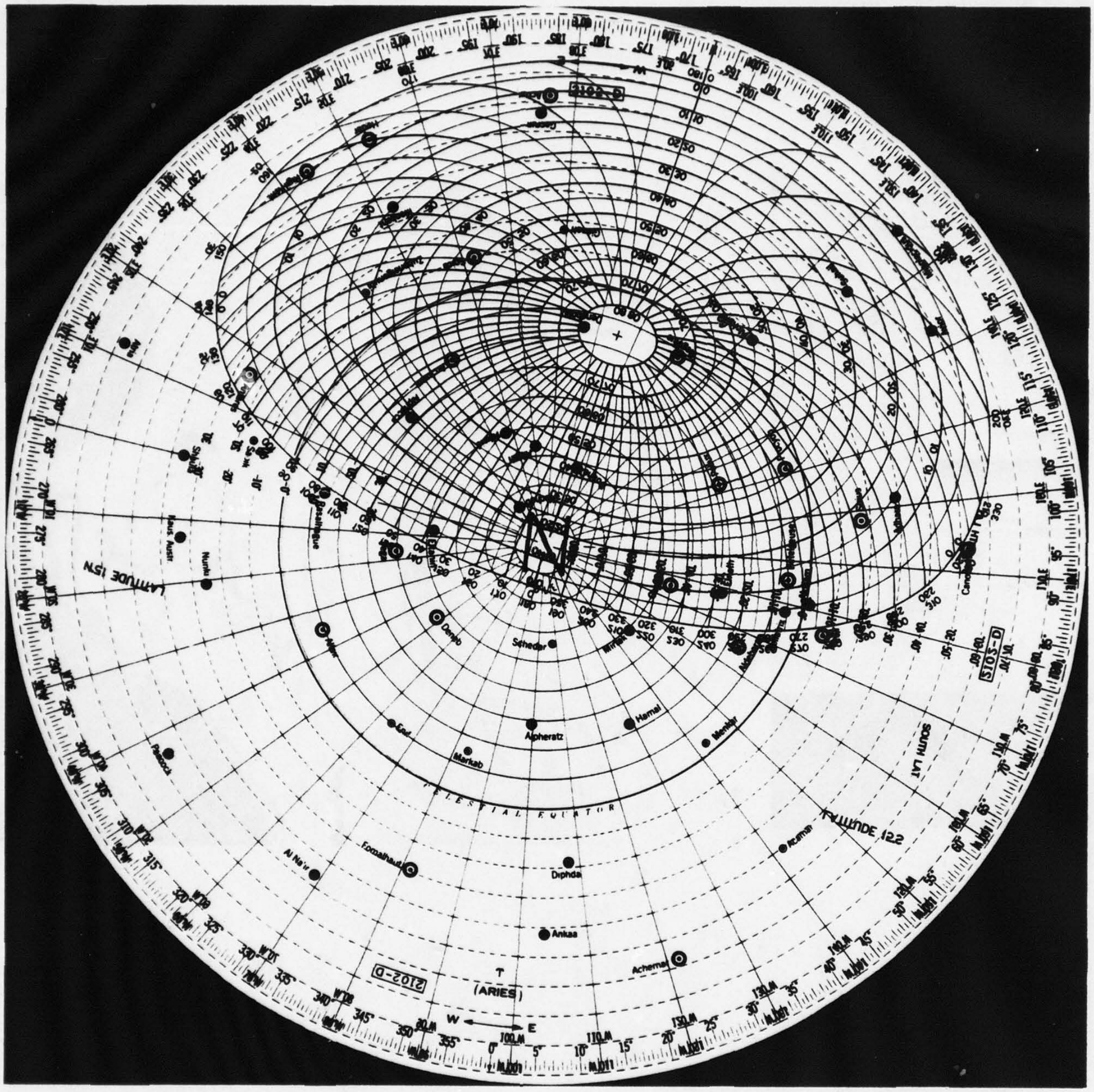
Road Condition & Route: South on the road to Ophira with good asphalt followed by 400 m (1,320 ft.) with Four-wheel drive.

This is a prominent solitary rock on the water's edge sculptured by wind erosion and it can be easily seen from the main highway (A). Both beach roads on each side of the head leading from the highway are extremely difficult and should not be attempted without four-wheel drive.

A vertical reef of 15 m. (50 ft.) depth begins due north of the head and then curves around it to the south. With deep water nearby and the absence of reef patches, one may find large fish along this stretch of coral: schools of *Caranx* and even the occasional shark exploring the reef. The best entry for a dive is on the northern side of Devil's Head where there is sandy bottom and no reef. The rough beach road leading to this point can be easily seen from the highway. If you have an extra driver, dive along the entire reef and finish on the southern side of the head where your vehicle can be waiting.

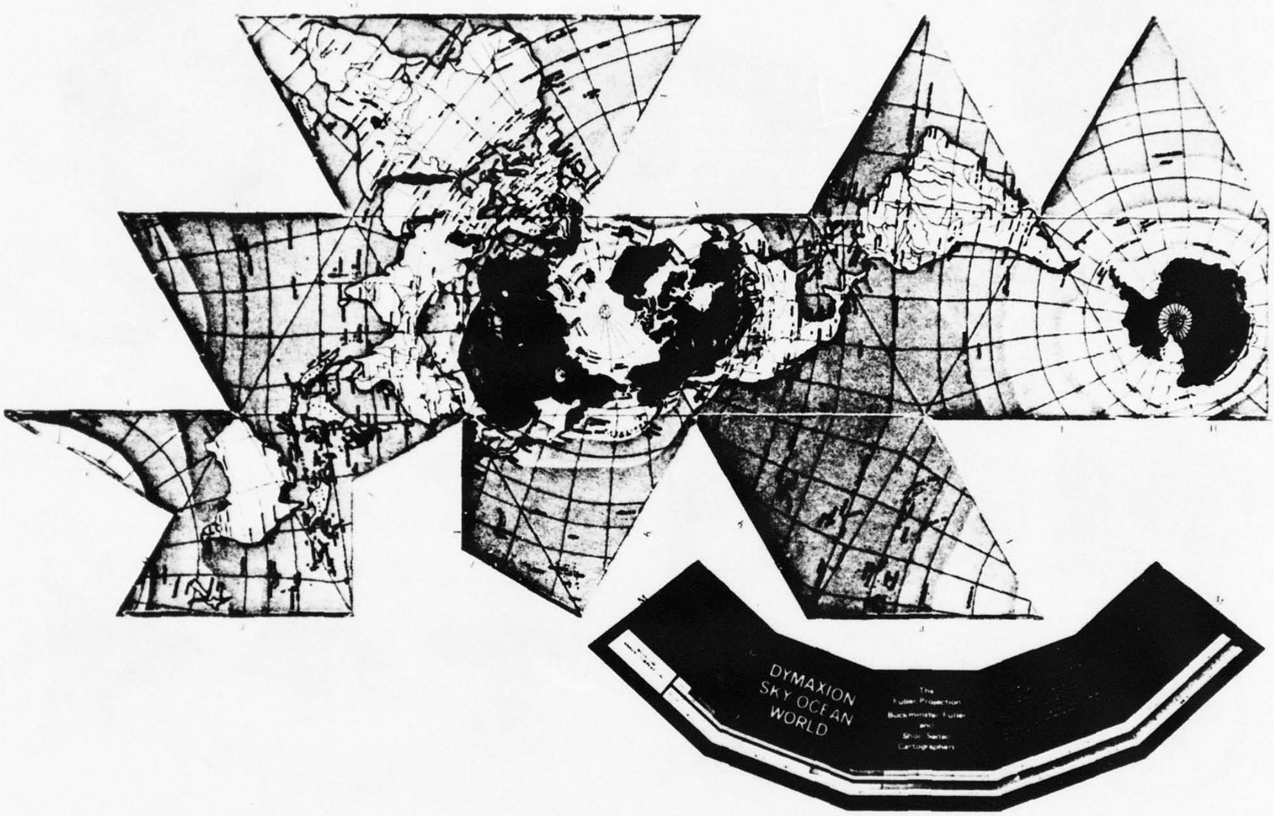
1.16 RED SEA DIVER'S GUIDE

This guide provides site information from various perspectives for a number of sites. Starting at the regional scale, each site is identified on a topographic map followed by an eye level photo of the view one has in approaching the site. An aerial photo of the site and its context has clear route and terrain information superimposed on it in a transparent overlay. A sectional drawing of the site is keyed into the aerial photograph. A final photo shows the diver's view of the underwater site, helpful in deciding whether or not to choose this site or another in the book. Map reprinted by permission of Red Sea Divers, Ltd., RED SEA DIVER'S GUIDE, Tel Aviv, Israel, Copyright 1975.



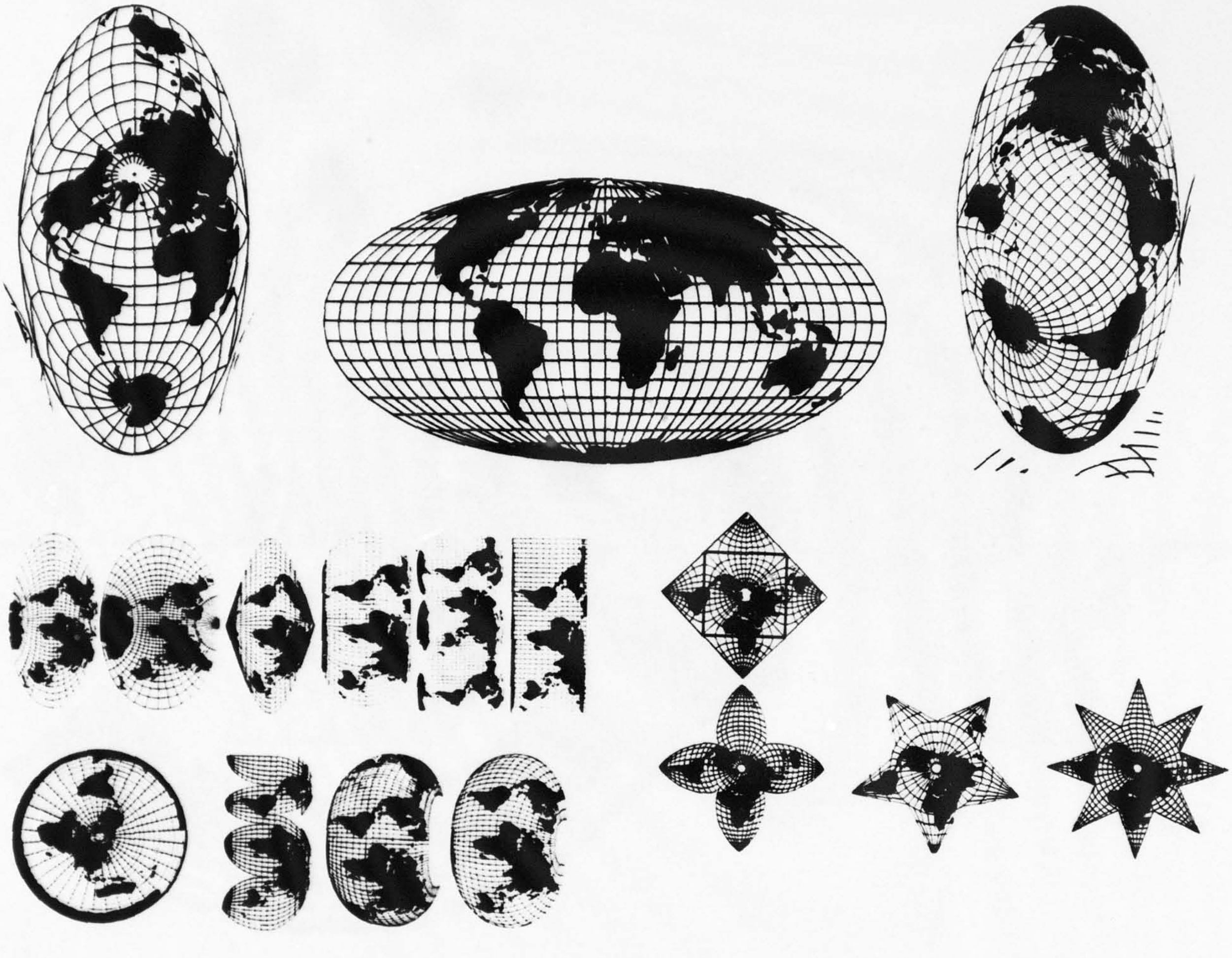
1.17 STAR FINDER

The star finder is designed to locate and identify the 57 numbered stars listed in the Air and Nautical Almanacs, as well as the sun, moon, and planets from any point on the earth. The instrument consists of a star base map for the northern and southern hemispheres, a meridian angle-declination template, and 9 transparent altitude-azimuth templates. The appropriate discs are overlayed on one another and rotated to conform to the observer's location and date. The approximate altitudes and azimuths of celestial bodies above the horizon are then indicated by the curve.



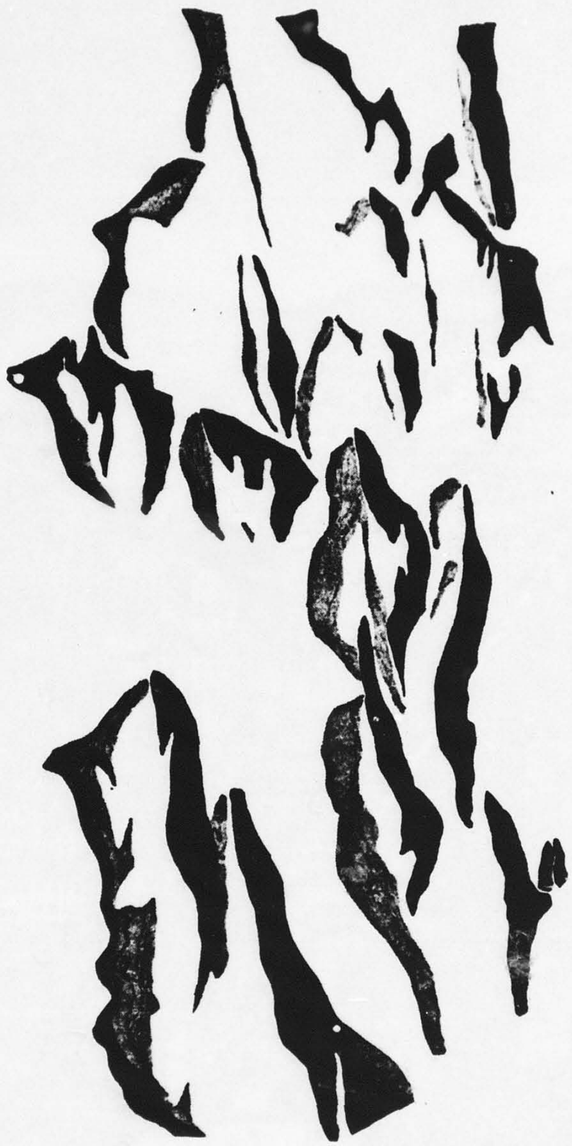
1.18 GEODESIC GLOBE

Buckminster Fuller has converted the earth's sphere into one of his geodesic shapes, composed of a number of contiguous triangles in this case. As a flat map, the geodesic map is more accurate than most other projections. As a globe, it obviously sacrifices some accuracy, but has the advantage of flat printing and storage. It is easily assembled by folding along the edges of the triangles. Map reprinted by permission of Buckminster Fuller & Shoji Sadao, Copyright 1967 by Buckminster Fuller Dymaxion Maps.



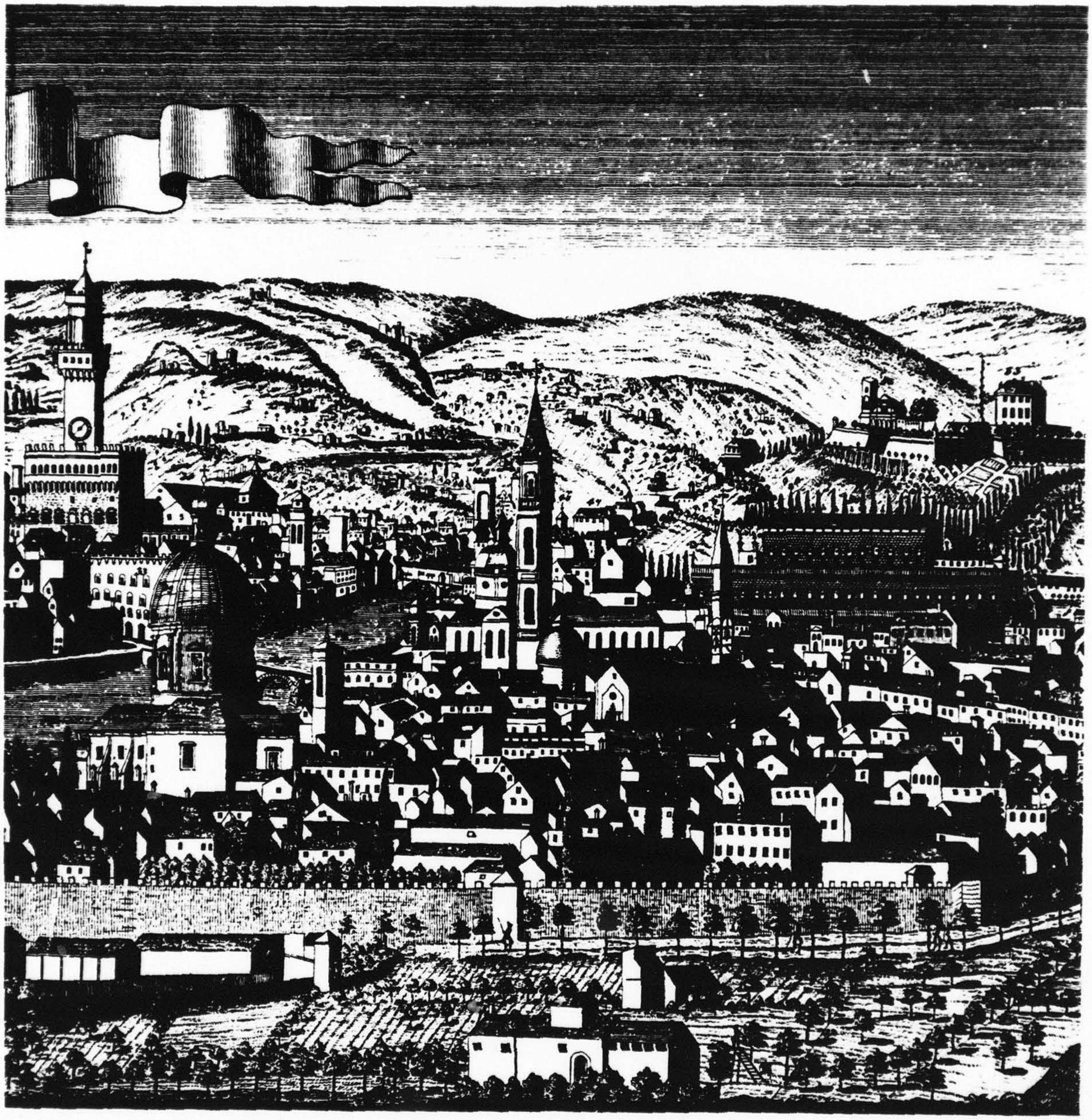
1.19 GRAPHIC SUMMARY OF A VARIETY OF MAP PROJECTIONS

Two dimensional map-making inevitably involves distortion and error since the three dimensional volume of the earth must be converted to a plane. Numerous techniques have evolved for compromising the errors that result from this transformation. Some systems attempt to hold area or shape as accurate as possible to the detriment of other features, while other projections are more concerned with direction or distance. A few projections are illustrated here. Map reprinted by permission of Jacques Bertin, SEMIOLOGIE GRAPHIQUE, 1967, Editions Gauthier-Villars (Paris), Mouton Publishers (Paris, New York, The Hague), Ecole des Hautes Etudes en Sciences Sociales (Paris).



1.20 SEATTLE: SHADOW PATTERNS

Delineation of shadow patterns is another way of indicating topography. They are also useful in site planning. In this map, the light gray tone indicates a mid-morning shadow, and a dark gray tone indicates a late afternoon shadow, on December 22. Black areas are dark both morning and afternoon. Map reprinted by permission. Department of Community Development, Urban Design Section, SEATTLE URBAN DESIGN REPORT, Seattle, 1971.



2.1 PANORAMA: FIORENZA

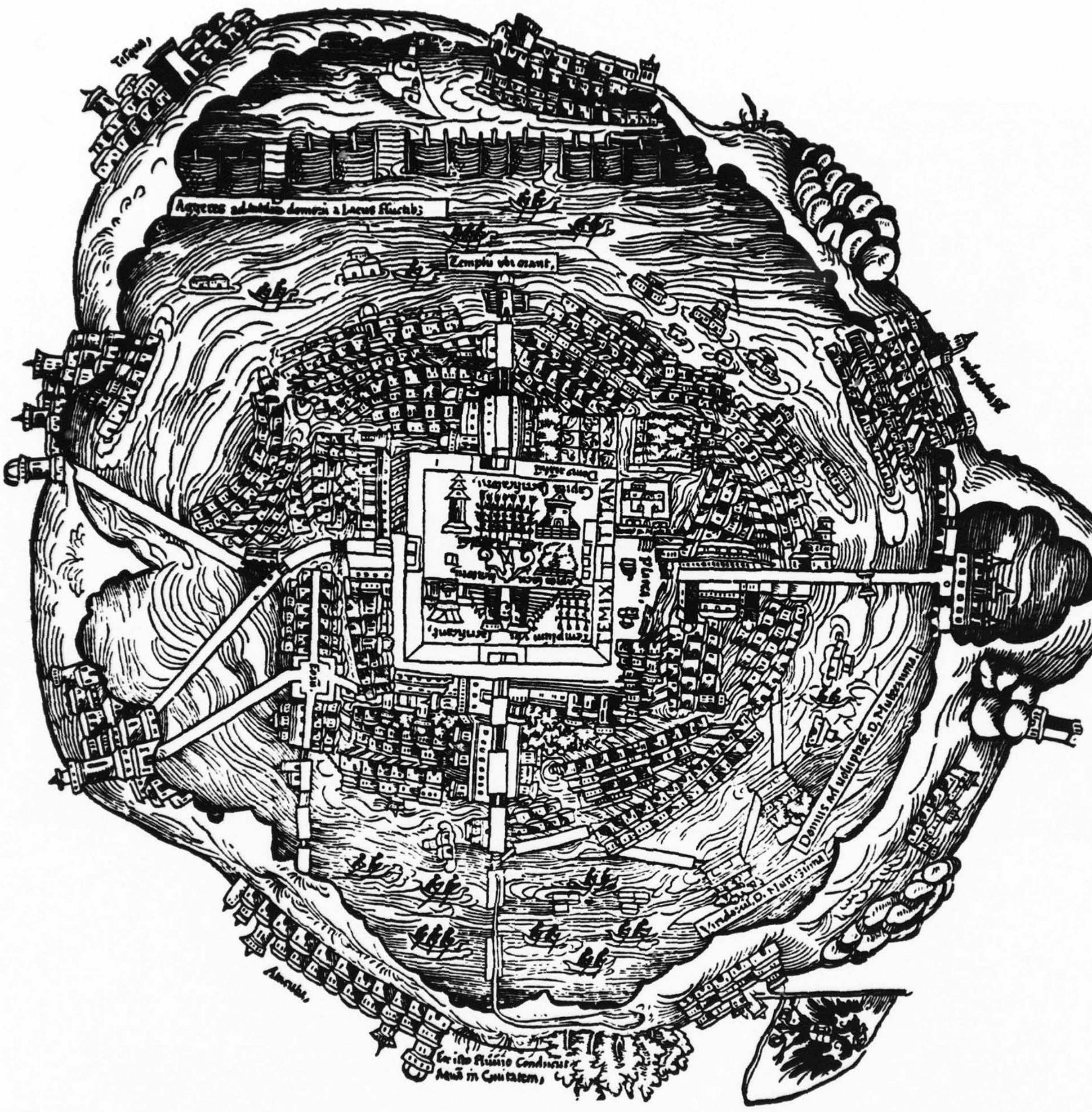
This beautiful old engraving of Florence's skyline shows the city's major architectural landmarks. These are numbered and keyed into the legend at the bottom. Panoramic views such as this obviously are not adequate for navigation within the city, since no streets are shown. However, skyline views can aid general orientation. Shoreline elevations are commonly used in this way for sailing.

2.2 360° PHOTOGRAPHIC PANORAMA OF PHILADELPHIA

Philadelphia is shown in a 360° panoramic view from the top of Three Girard Plaza, a building in the central business district. A comprehensive sense of the city is created, but the extreme wide angle lens distorts street patterns and building shapes. Again, this type of map is not a practical navigation device because of the distortion and the absence of most streets. Its primary use is in landmark identification from one vantage point.

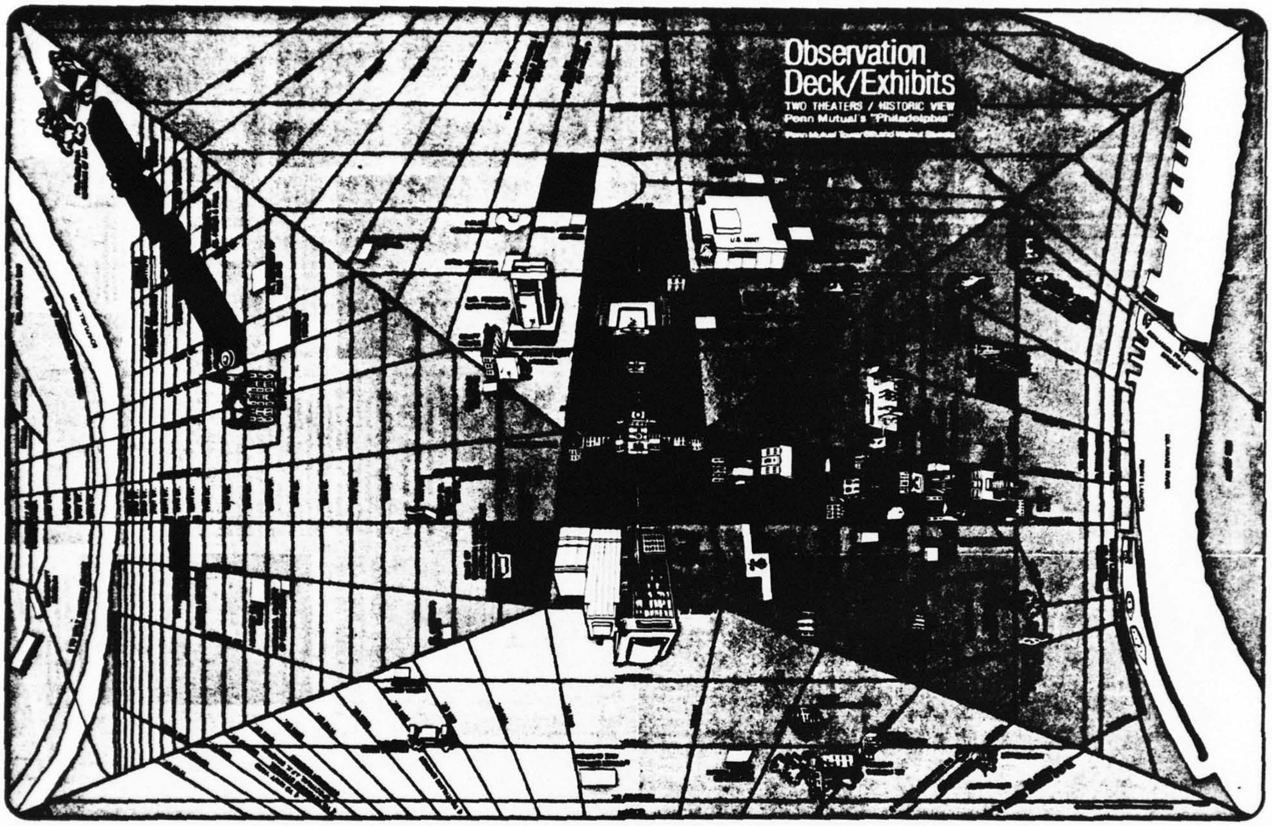
2.3 FISH EYE AERIAL PHOTO OF MANHATTAN

The "fish-eye" lens, by means of distortion, allows the camera to take in a much wider field of vision than would be normally possible. Information is clearest and most useful in the center; extensive surroundings are visible but recede rapidly, giving only impressionistic information. Such photographs are useful in giving a specific place a sense of context or in focusing attention, but their application is limited. Map reprinted by permission of David Langley, Professional Photographer; for McCaffrey and McCall, N.Y.: Copyright 1978 by Hiram Walker Importers, Inc., Detroit.



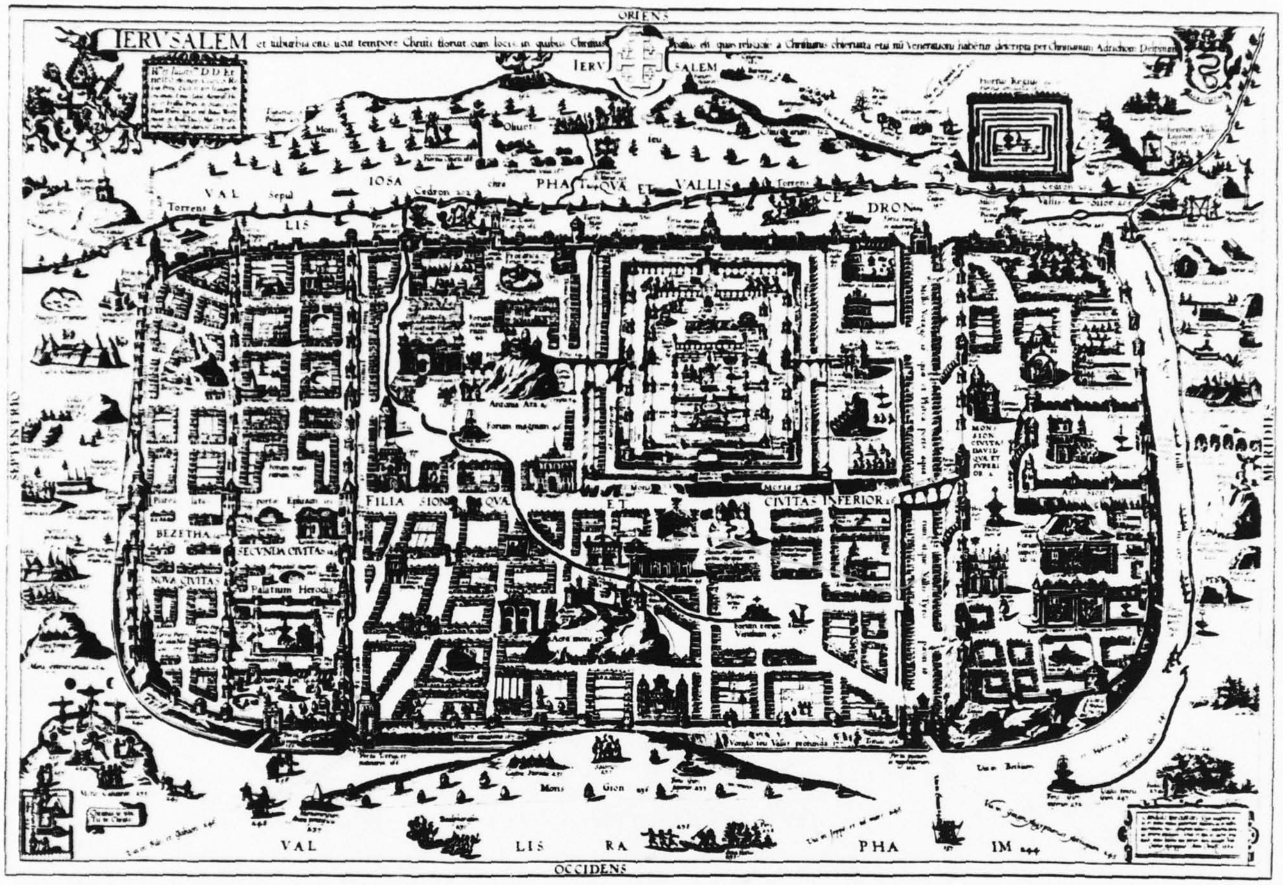
2.4 PLAN/PANORAMA: MEXICO-TENOCHTITLAN

This fascinating 16th century Spanish map, attributed to Hernan Cortes, combines several mapping techniques: plan, elevation, and 360° panorama. The central area shows a plan of the city with elevations of buildings laying flat on the plan. Around this is a 360° panoramic view radiating from the center. Interestingly, some of the boats in the water do not follow the radiating principle and are upside down with respect to everything else. Map reprinted by permission of Ignacio Marquina, ARQUITECTURA PREHISPANICA, Memorias del Instituto Nacional de Antropologia e Historia, I Mexico 1951.



2.5 360° PANORAMIC PERSPECTIVE: PENN MUTUAL'S PHILADELPHIA

Views seen in four directions from the top of the Penn Mutual Tower are shown as aerial perspectives, joined to make one map. The diagonal intersections of the four perspectives create confusing discontinuous street patterns. Street names and site identifications face four different directions, making use clumsy, except when used as a view guide. The map is dominated by the vantage point the Penn Mutual Tower. The technique avoids some of the problems of the "fish-eye" view (which also provides a panorama with central focus) but creates other problems. Map reprinted from Penn Mutual Life Insurance Company, Philadelphia. Map reprinted by permission of Penn Mutual Life Insurance Company, Philadelphia. Copyright 1975.

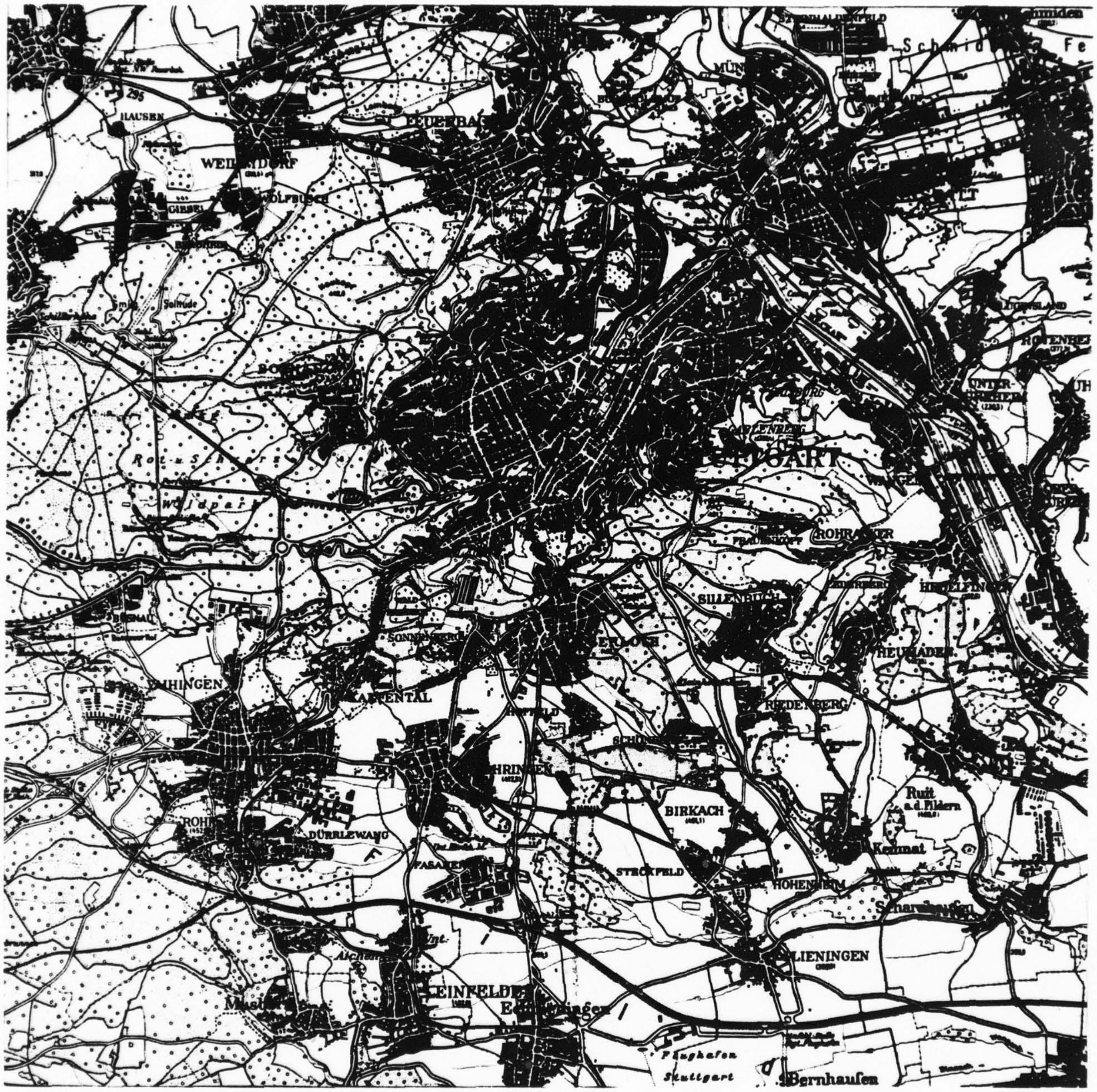


2.6 PICTORIAL/ELEVATION MAP: JERUSALEM--1584

Elevations, aerial perspectives, and plans are combined in this 16th century map of Jerusalem. Important biblical events are illustrated around the perimeter of the wall. Note the hills in foreground and background shown in perspective. Details make this a fascinating historic view into the past life of the city. Because of the naive, non-technical presentation, all of the information is accessible to laymen. Map reprinted by permission of Historic Urban Plans, Adrichomio, THEATRUM TERRAE SANCTAE. 1584 (from reproduction); Ithaca, N.Y.

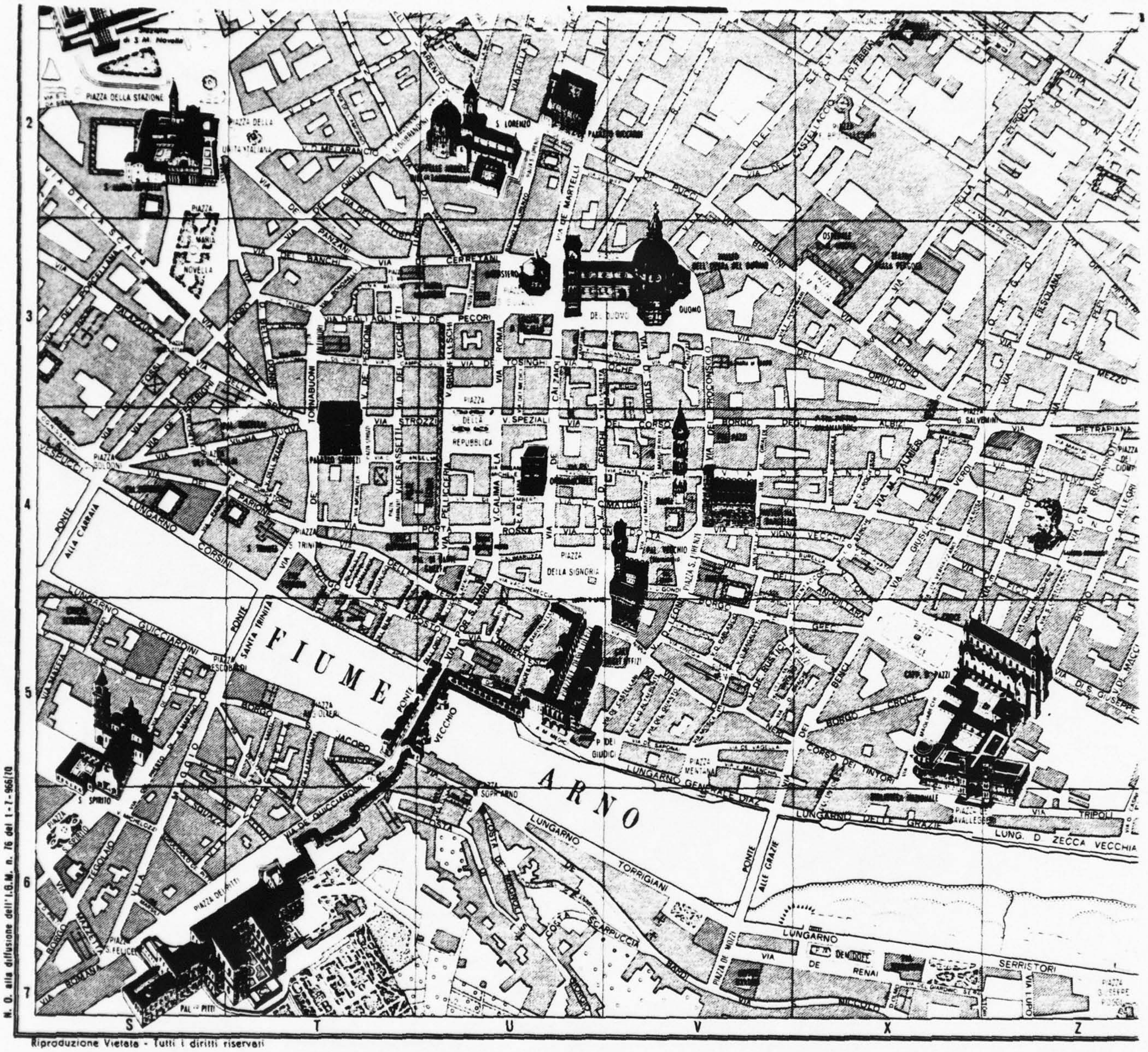
2.7 VINE GROVE, KENTUCKY

Without sacrificing legibility, large amounts of information have been shown on this military map. Locations of indibidual buildings are shown, along with topography and ground cover. Roads and railroads are clearly described in terms of type, capacity, and condition. Finally, political boundaries and compass coordinates are indicated. Such maps are suited to activities requiring detailed planning and action but are rather unsuited for travel or tasks requiring development of broad concepts.



2.8 UBERSICHTSKARTE: STUTTGART UND UMGEBUNG

This map provides a good sense of the texture and density of built up areas and their relation to natural areas. Buildings are simplified into block patterns, leaving fine grained patterns of streets. Major highways are clearly differentiated from other routes. The map can be used for travel on the highway network but not for local travel; it is more useful as a reference map to become familiar with the region than as a guide map.



2.9 FIRENZE: PIANTA DELLA CITTA'

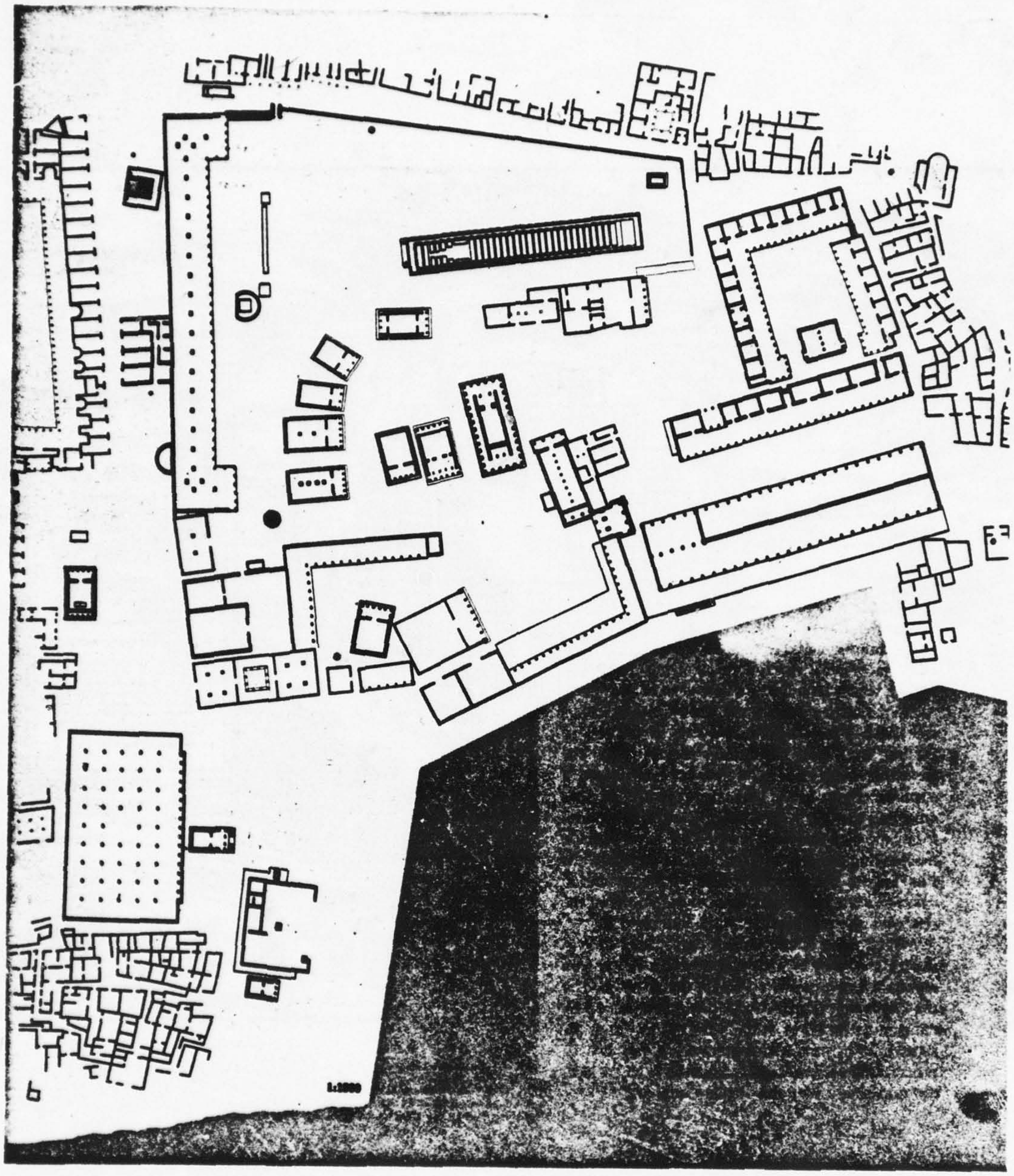
Major landmarks are shown in three dimensions with correct orientation and scale against the background of a simple but correct street map. Because only a few buildings were chosen for representation, there was no need for other distortions such as widening of the streets. Blocks are shaded leaving the streets white and more legible. The map is attractive and easy for strangers to use. Map reprinted by permission of Litografia Artistica Cartografica, Firenze, Italy.

2.10 GENOVA, ITALY

This elegant map of central Genoa in 1903 uses intersecting concentric line patterns flowing out from the land to create a striking pattern of the harbor. Parks, piazzas and built-up areas are identified, as well as churches and major public buildings of interest to a tourist. Everything is handled in plan form with no indication of three-dimensional qualities except for the hills. Buildings of tourist interest are shaded darker than the surrounding blocks but in the same color, making them somewhat difficult to identify. Map reprinted by permission of Karl Baedeker, ITALY: HANDBOOK FOR TRAVELLERS, PART I, Twelfth Edition 1903, Charles Scribner's Sons, New York.

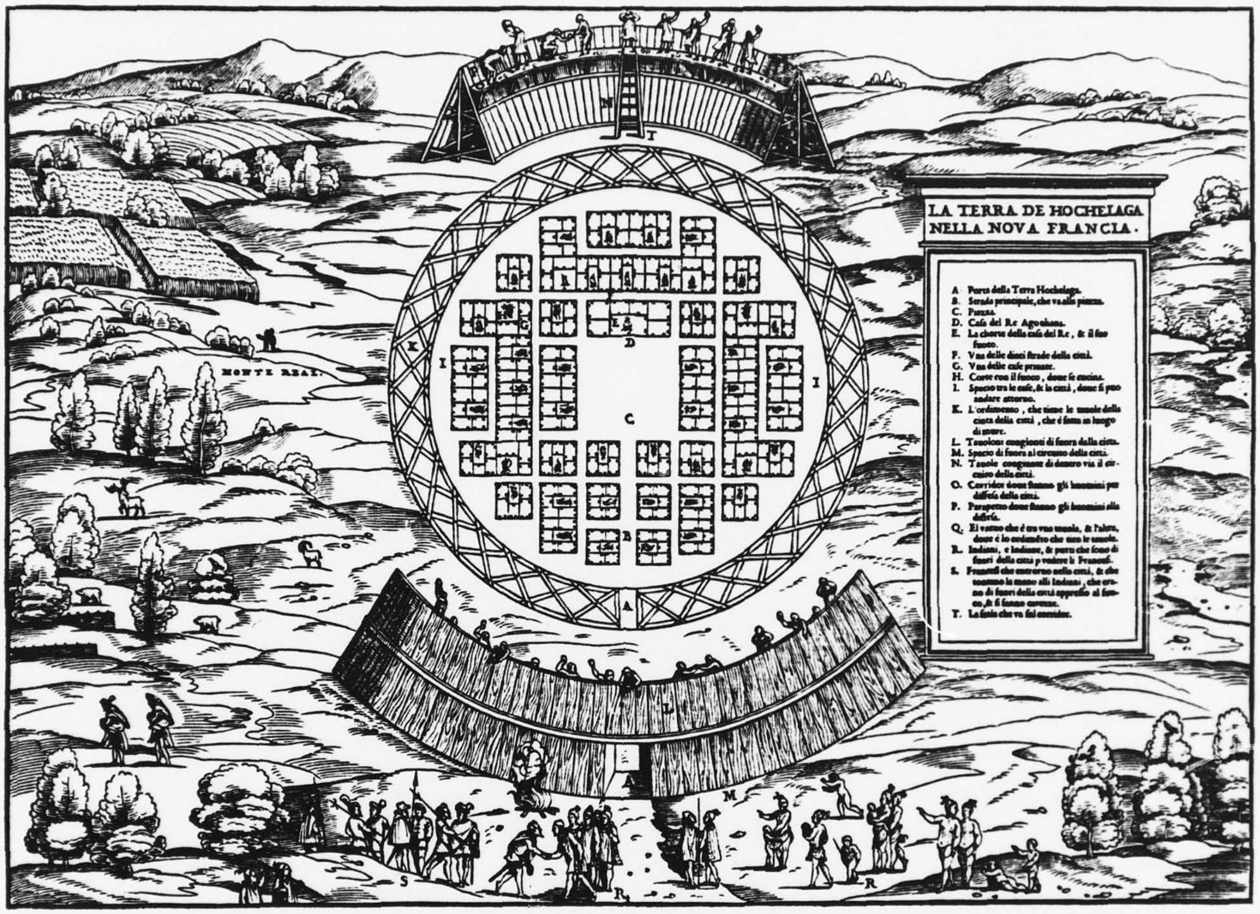
2.11 ARCHEOLOGICAL MAP: DELOS

The ancient Greek city of Delos is shown in plan on topographic contour lines of the site. By combining architectural plans with topography at a large scale, a compelling archaeological plan is created. The map can also be used for travel, but might be confusing to the layman. Map reprinted by permission of Edmund N. Bacon, DESIGN OF CITIES, Viking Press, New York, Copyright 1967.



2.12 DEVELOPMENT OF MILETUS

Development, overtime, of the ancient Greek town of Miletus is expressed by means of color *in this sharply delineated ground plan. Black lines represent Greek construction* at the end of the 4th century B.C. Hellenistic additions in the mid 2d century B.C. are shown in blue, and Roman work from the 2d century A.D. is shown in yellow. The flow of public and semi-public spaces at the ground level is beautifully expressed. Map reprinted by permission of Edmund N. Bacon, DESIGN OF CITIES, Viking Press, New York, Copyright 1967.

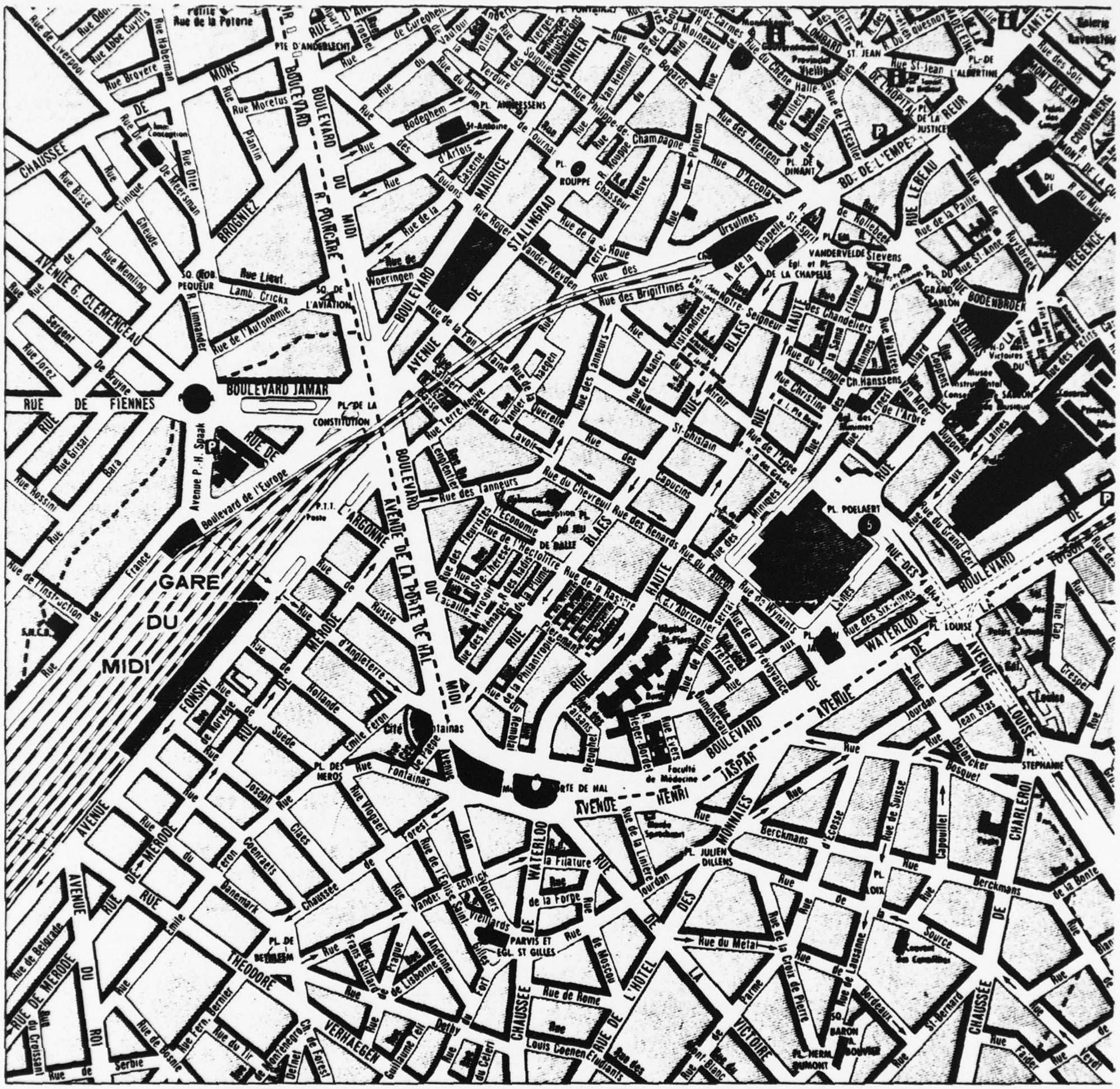


2.13 PLAN/PERSPECTIVE: LA TERRA DE HOCHELAGA NELLA NOVA FRANCIA

Based on the description of Jacques Cartier, this drawing of the fabled Indian city on the site of montreal originally appeared in Ramusio's "Delle Navigationi et Viaggi," published in Venice in 1556. The village is shown in plan, with elements keyed into the legend at the side. The stockade is shown in aerial perspective around the plan. The town is superimposed on a perspective view of the region showing terrain, vegetation, Indians, and Europeans. Map reprinted by permission of HISTORIC URBAN PLANS (reproduction), Ithaca, N.Y.

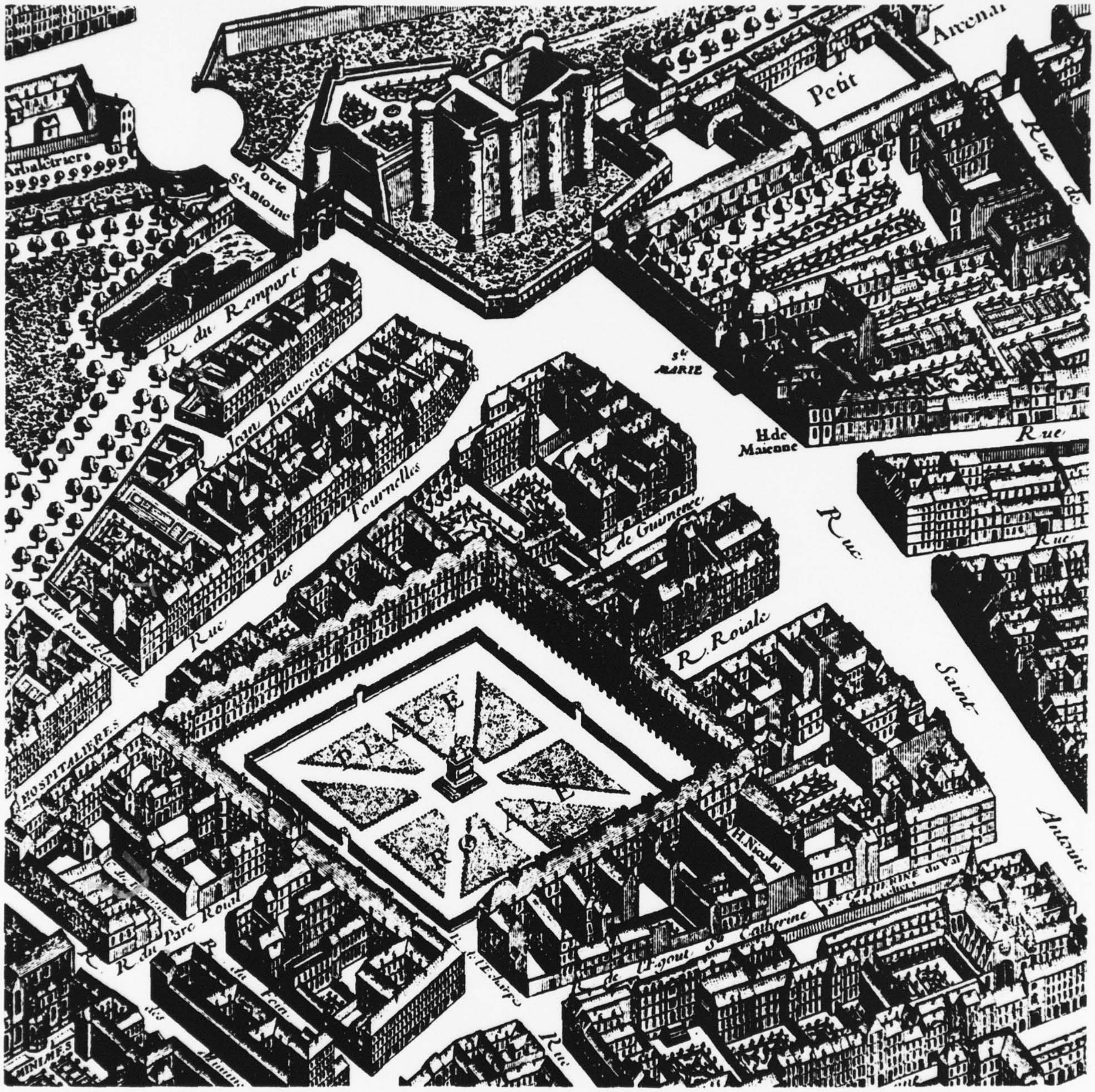
2.14 PLAN/PERSPECTIVE: MEXICO CITY

In this 1556 map, the old Aztec city is shown shortly after its conquest by the Spanish. Elevations and axonometric views of buildings and mountains are superimposed on a plan view of the region. Map reprinted by permission of HISTORIC URBAN PLANS (reproduction), Ithaca, N.Y.



2.15 BRUSSELS

Legible, but rather conventional, this street map uses a simple and effective device to give blocks a three dimensional sense. Two sides of each block are rendered in a heavy line weight, giving a feeling of bulk that in turn strengthens the street system.

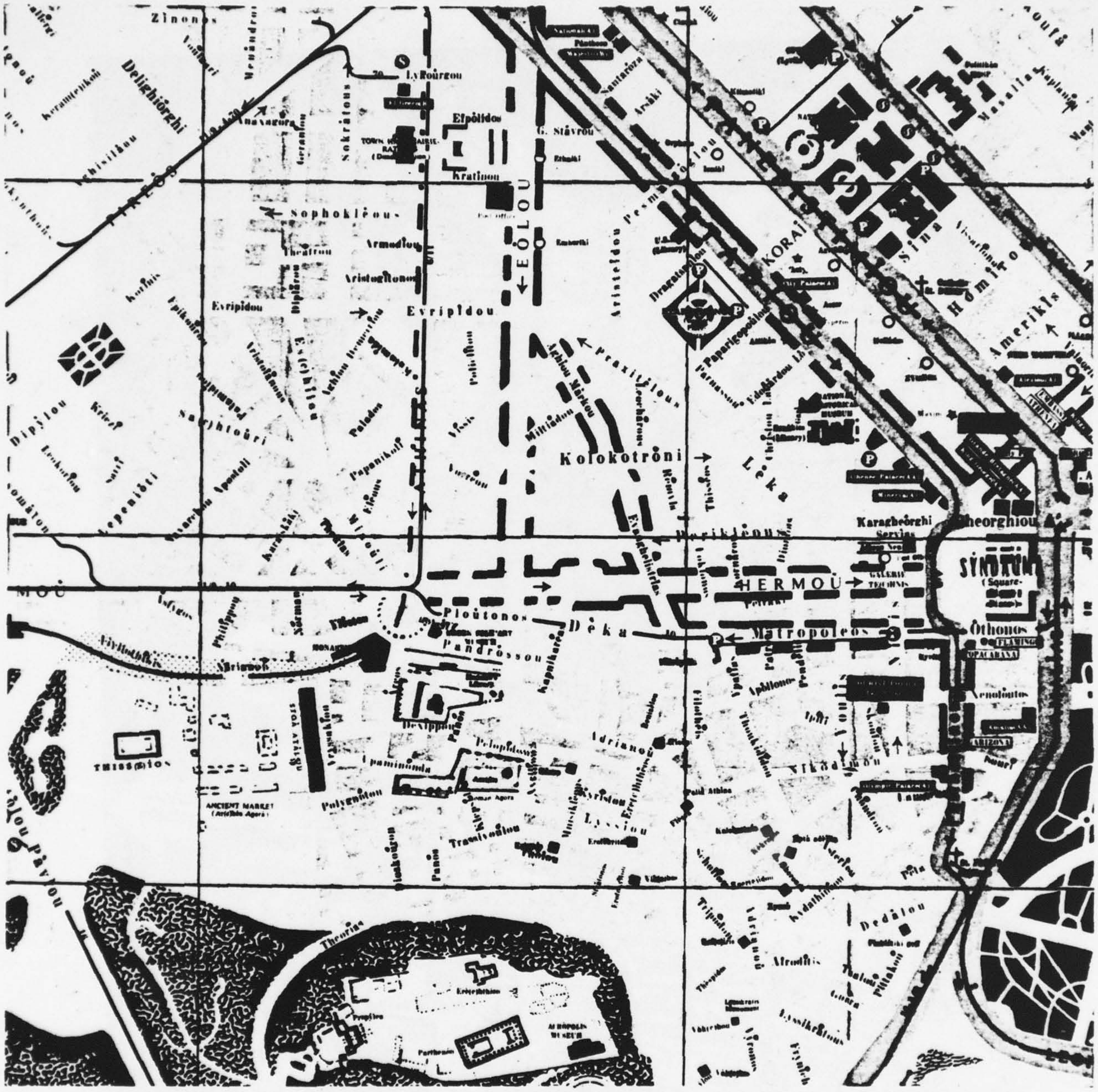


2.16 PARIS: PLAN TURGOT, 1734

Elegance and detail are the outstanding qualities of this 18th century engraved map. Buildings are shown as axonometric projections with correct detail and orientation. Streets, however, are widened so that they don't disappear behind buildings. The map allows study and armchair travel in depth, but it can also be used for real travel. Because of its detail, it is more appropriate for the foot traveler rather than higher speed modes. Map reprinted by permission from Paris au XVIII Siécle; Plan de Paris En 20 Planches. Published by A. Taride, 1908, Paris. Photo courtesy of Harvard College Library.

2.17 AERIAL PHOTOGRAPH: MANHATTAN

Aerial photographs provide a wealth of information and are highly useful for many tasks involving strategy, evaluation, or description. For some uses, the detail is overwhelming, making performance difficult. Shadow patterns can block out large areas of information or some elements may be difficult to interpret due to lack of definition. In general, aerial photos make unsuitable tools for navigation or fast action because they contain too much redundant information. Map reprinted by permission from New York City Planning Commission PLAN FOR NEW YORK CITY: MANHATTAN, Copyright 1969, M.I.T. Press, Cambridge, Ma.

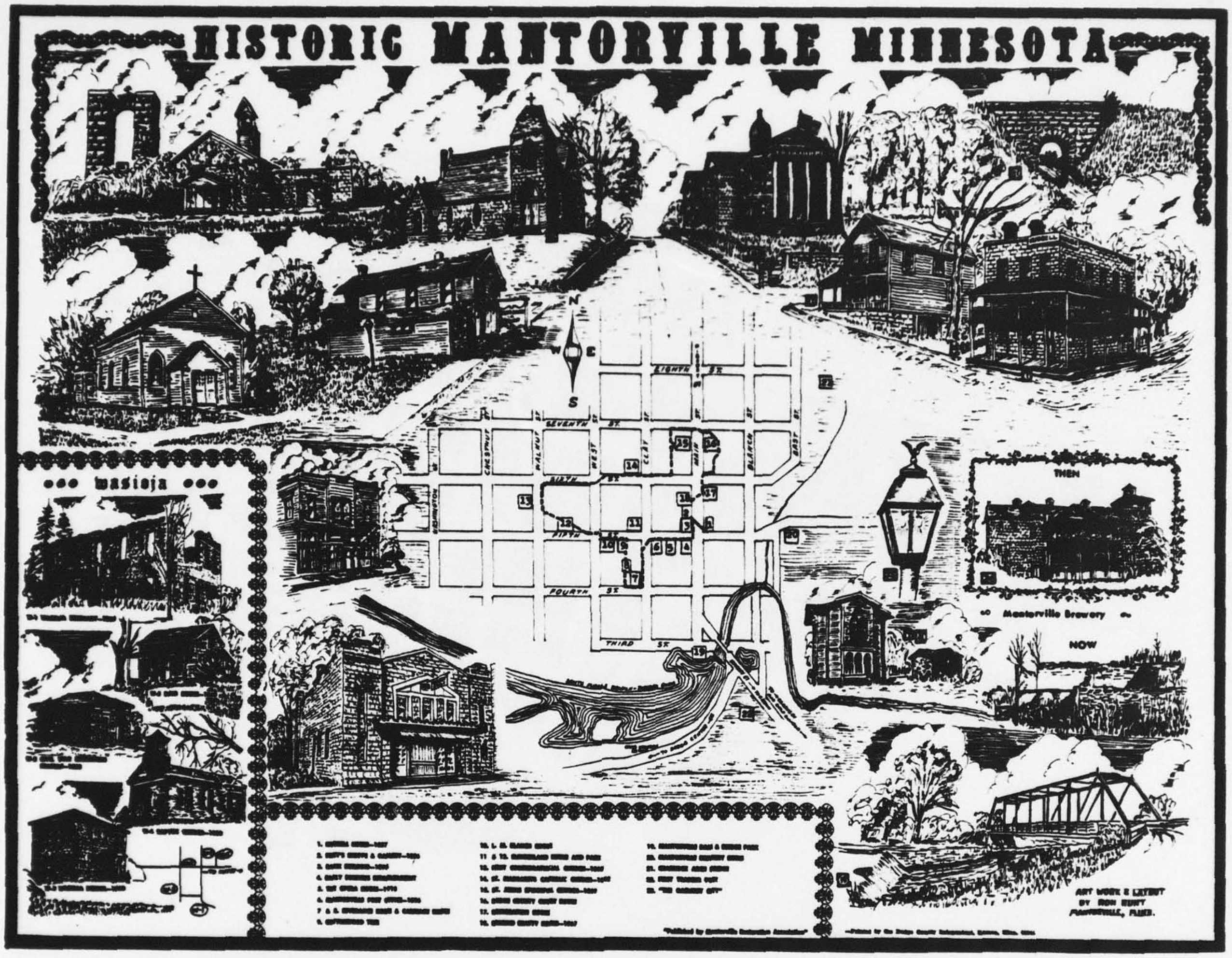


2.18 THE BEST GUIDE MAP OF ATHENS

This map has a unique sense of sytle and unusually good balance between information importance and graphic strength. Plans of major historic sites are shown in some detail; this is useful in many cases such as the temples, where the plan bears a close resemblance to what one sees. Blocks are simple colored shapes with no outline, making street patterns and names quite easy to read. The street trolley network is clearly identified without detracting from other information by an overlay tone of light yellow. Principal shopping streets are clearly shown by red bands on the edges of the blocks. Map reprinted by permission from J. Sakellaridis, Interpress, Athens.

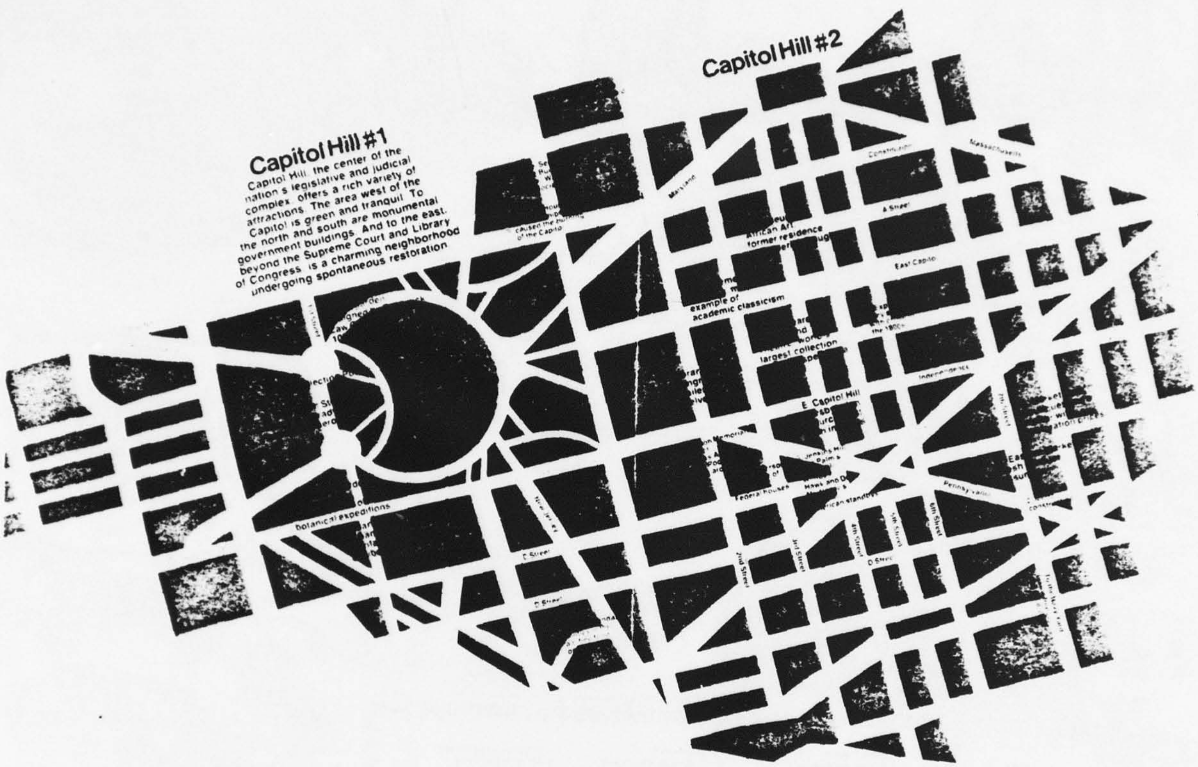
2.19 PICTORIAL LANDMARK MAP: BOSTON 200 DISCOVERY NETWORK

Major historic sites and visitor services are depicted in three dimensions and are annotated with cartoon-style balloons. Minimal symbol learning and index checking is required, making the map suitable for inexperienced map users. The map is designed to guide the typical visitor along a network of pedestrian trails in Central Boston. Landmark buildings are accurately located and oriented, but are somewhat enlarged. The map is part of a larger orientation system found in the city itself consisting of kiosks with district maps, trail blazers, and site markers. Map reprinted by permission. Design and graphics by Michael & Susan Southworth, Boston. Copyright 1975 by City Design Institute.



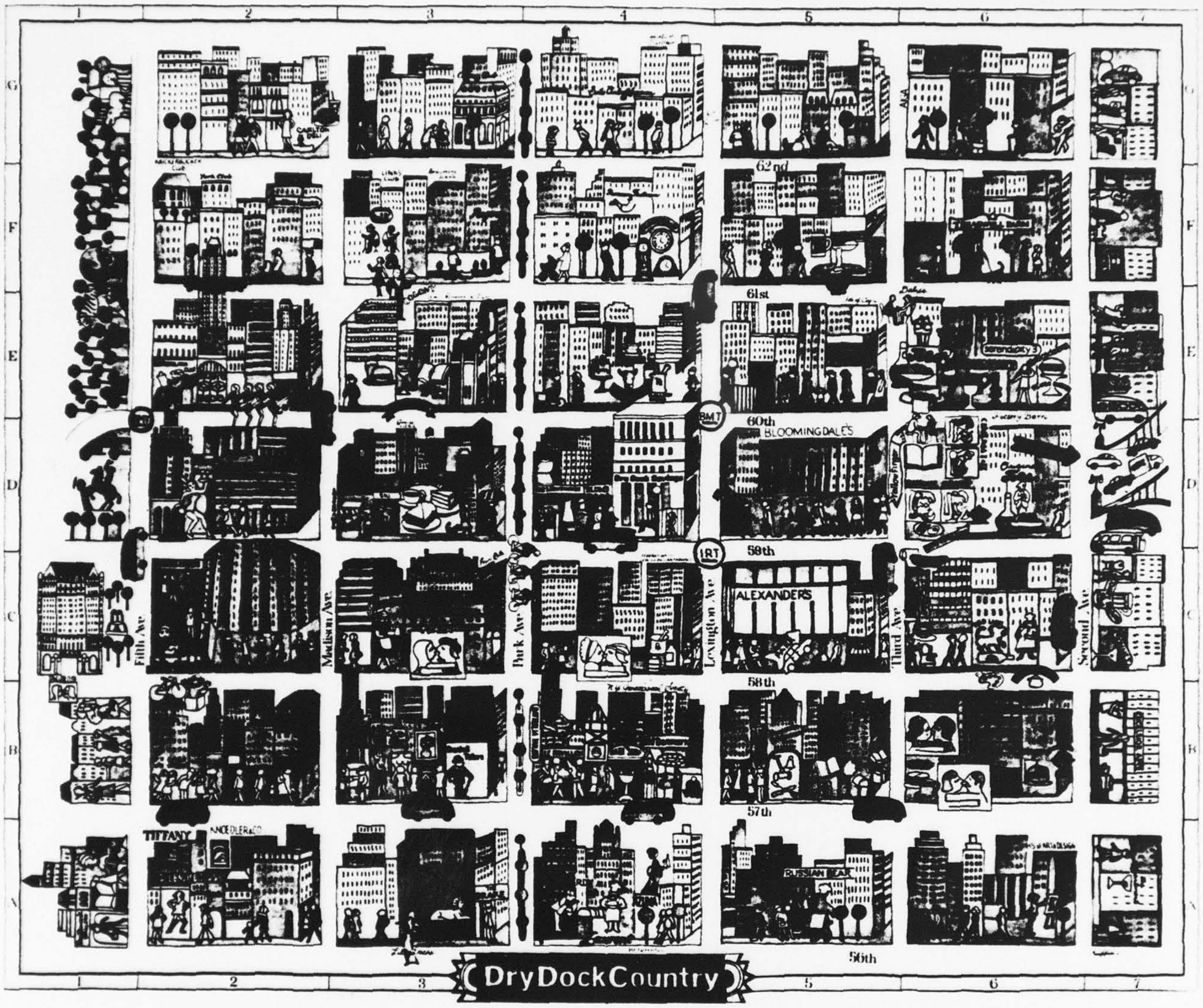
2.20 HISTORIC MANTORVILLE MINNESOTA

A simple street map is made more imageable by surrounding it with sketches of several landmarks which are keyed back into the map. Although this technique requires the user to jump back and forth between the map and the sketches, the map is kept free of distracting information and is easy to use. For large areas with numerous sites, this technique becomes impractical. Map reprinted by permission of Ron Hunt, for Mantorville Restoration Association, Mantorville, Mn.



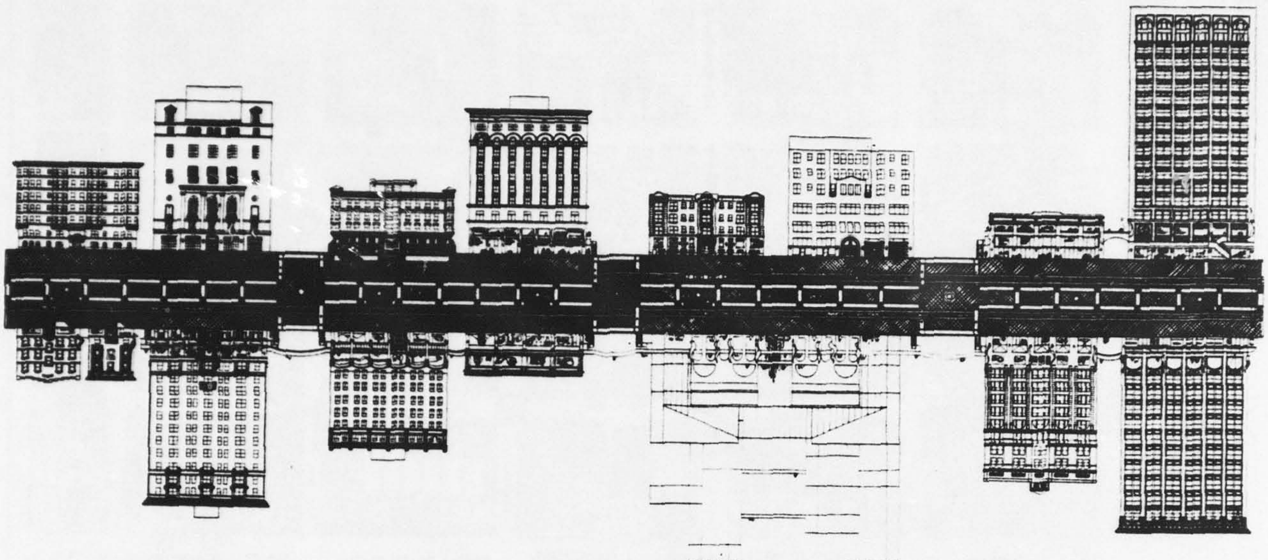
2.21 ANNOTATED SCHEMATIC MAP: WASHINGTON, D.C., CAPITOL HILL

Simplification of reality is essential in making a good map. This map has been reduced to a schematic block pattern shown in solid color. Points of interest and major streets are indicated verbally. Such maps are inexpensive and quickly produced and are suitable for single purpose use. This one is meant to tell visitors about the highlights of Capitol Hill; it is one of a set of maps treating several districts of Washington, D.C. Map reprinted by permission from Richard Saul Wurman, Peter Bradford, Jane Clark, Kay Layne, James Bailey, et al, for the American Institute of Architects, Washington, D.C.



2.22 PICTORIAL MAP: DRY DOCK COUNTRY

Cartoon techniques are used in this pictorial map. Streets are very legible, but the block pattern is distorted to suit the format. Facades, landmarks, signs, symbols, and activity are suggested for each block, but one senses from the graphic style that many liberties have been taken by the designer. The map is fun to look at but would not be the best travel guide. Note that the only facades shown are those facing South, except for Second Avenue and a small part of Fifth Avenue. Map reprinted by permission from Geer, Dubois, Inc., for Dry Dock Savings Bank, New York.

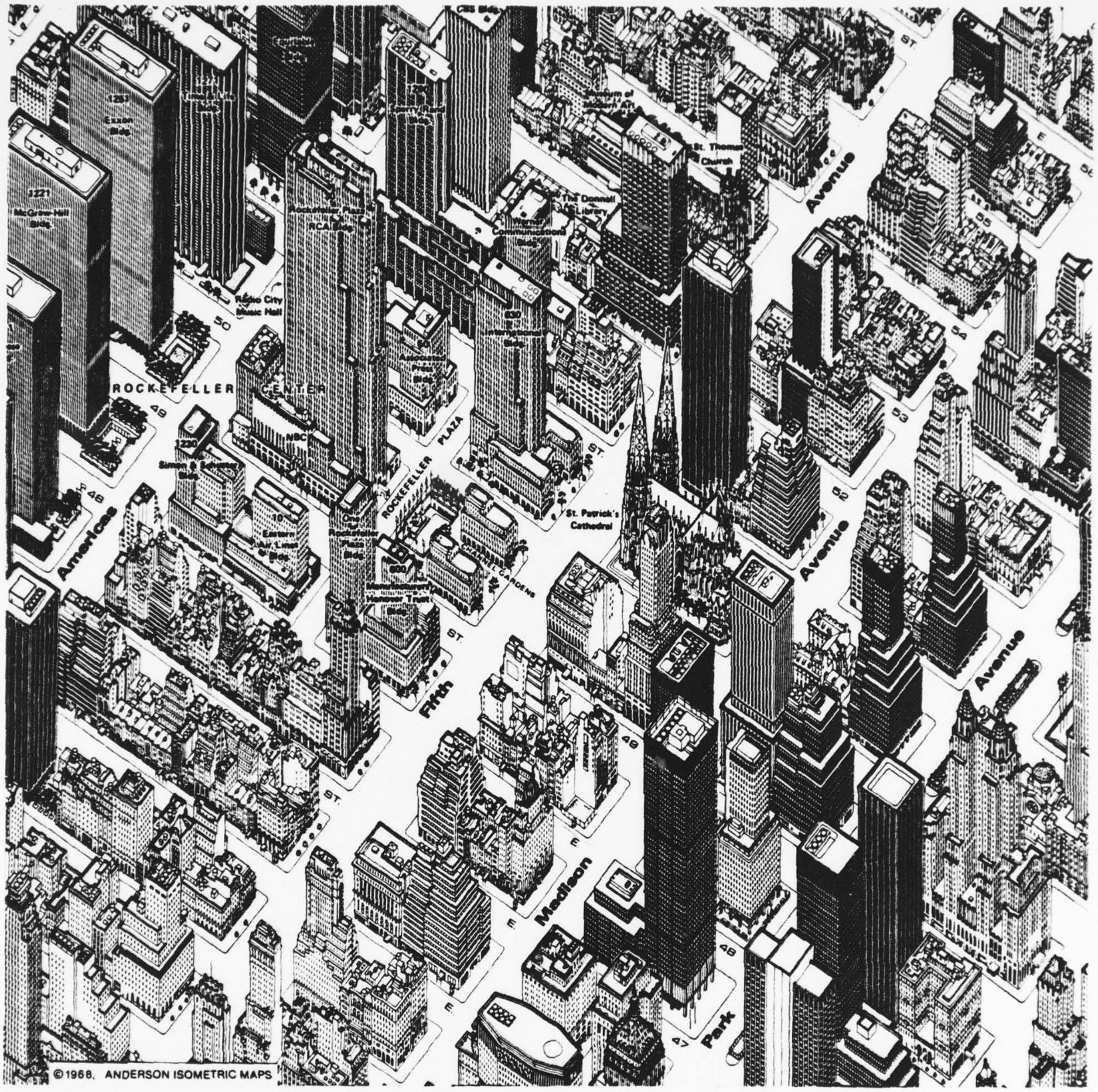


2.23 ELEVATION/PLAN MAP: PARK MALL, DETROIT

To solve the problem of giving detailed architectural and landscaping information on one drawing, building facades were laid flat on both sides of the street plan. The original plan was 16' long, but was reduced to several smaller sizes for a variety of uses. This technique is most appropriate to linear systems such as streets, rivers, or railways; networks or overall areas would be difficult to represent in this way. Map reprinted by permission. Plan and graphics by Michael & Susan Southworth, City Design & Architecture, Boston.

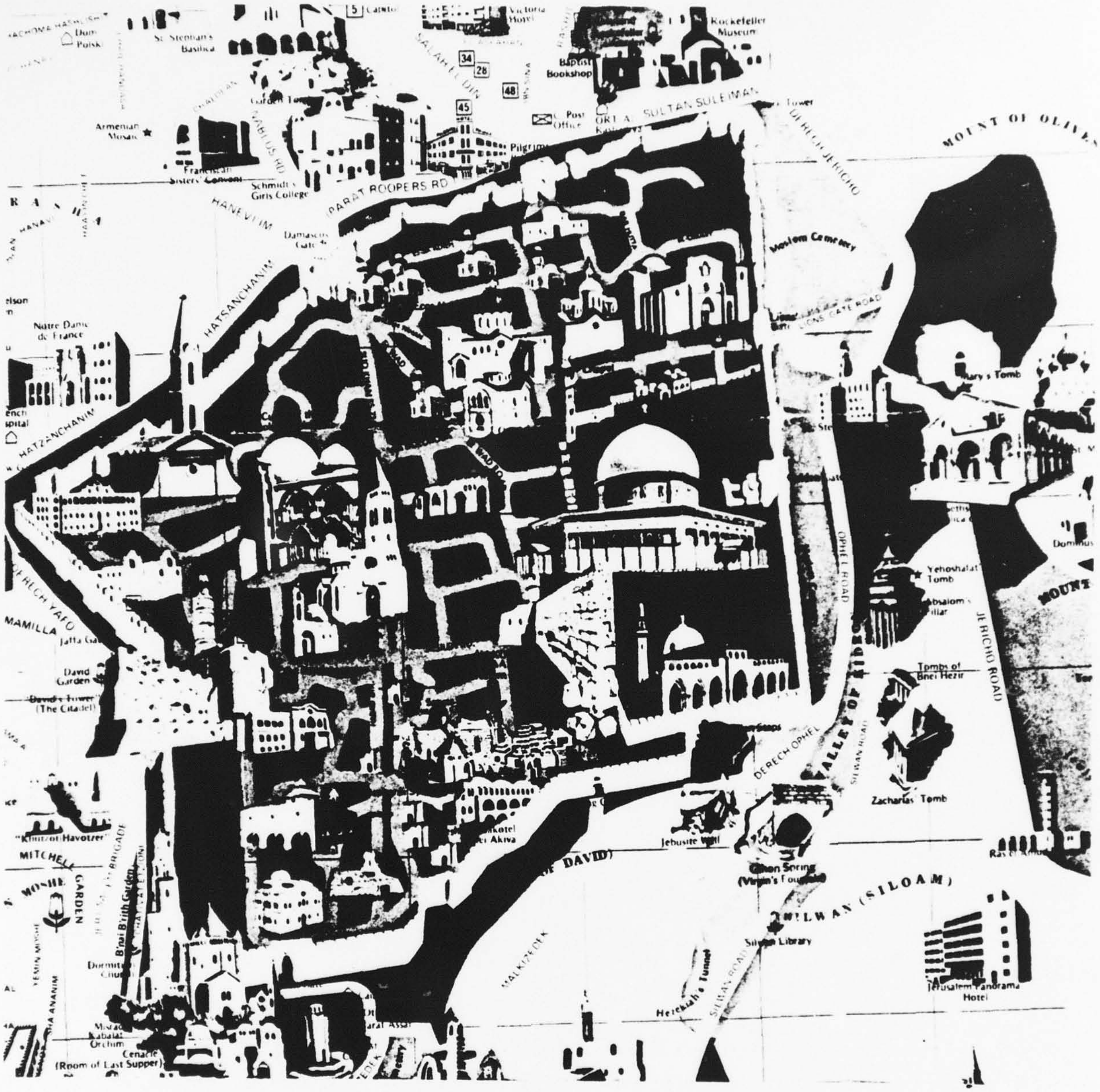
2.24 FLOATING LANDMARK MAP: CAMBRIDGE

The "floating landmark" style is popular for tourist and poster maps. Precise information is unnecessary and distortion is a crucial part of the style. Landmarks are drawn at an enlarged scale and face in any direction without regard for reality. As a result, buildings which are actually quite remote from one another appear to be next door neighbors. Because of the distortions, omissions, incorrect orientation, and misleading juxtapositions, it is not possible to use this type of map for navigation. Rather it serves as a poster, souvenir, or advertisement. Map reprinted by permission from Archar Inc., Scarboro, Ontario, copyright 1977.



2.25 AXONOMETRIC PICTORIAL MAP: MANHATTAN

Buildings are shown with detail and accuracy in this map of central Manhattan. Vertical dimensions are somewhat exaggerated and streets are widened to allow more space for tall buildings. Nevertheless, many street segments are obliterated by skyscrapers. The map is a tour de force in detailed cartography. Enormous amounts of data were collected in the field using photographs and sketches; aerial photos were also essential. Maps such as these are fascinating for study purposes and are useful for small scale travel; for larger scale trips the detail is an impediment to rapid use. Map reprinted by permission of Anderson Isometric Maps, New York City, Copyright 1968.

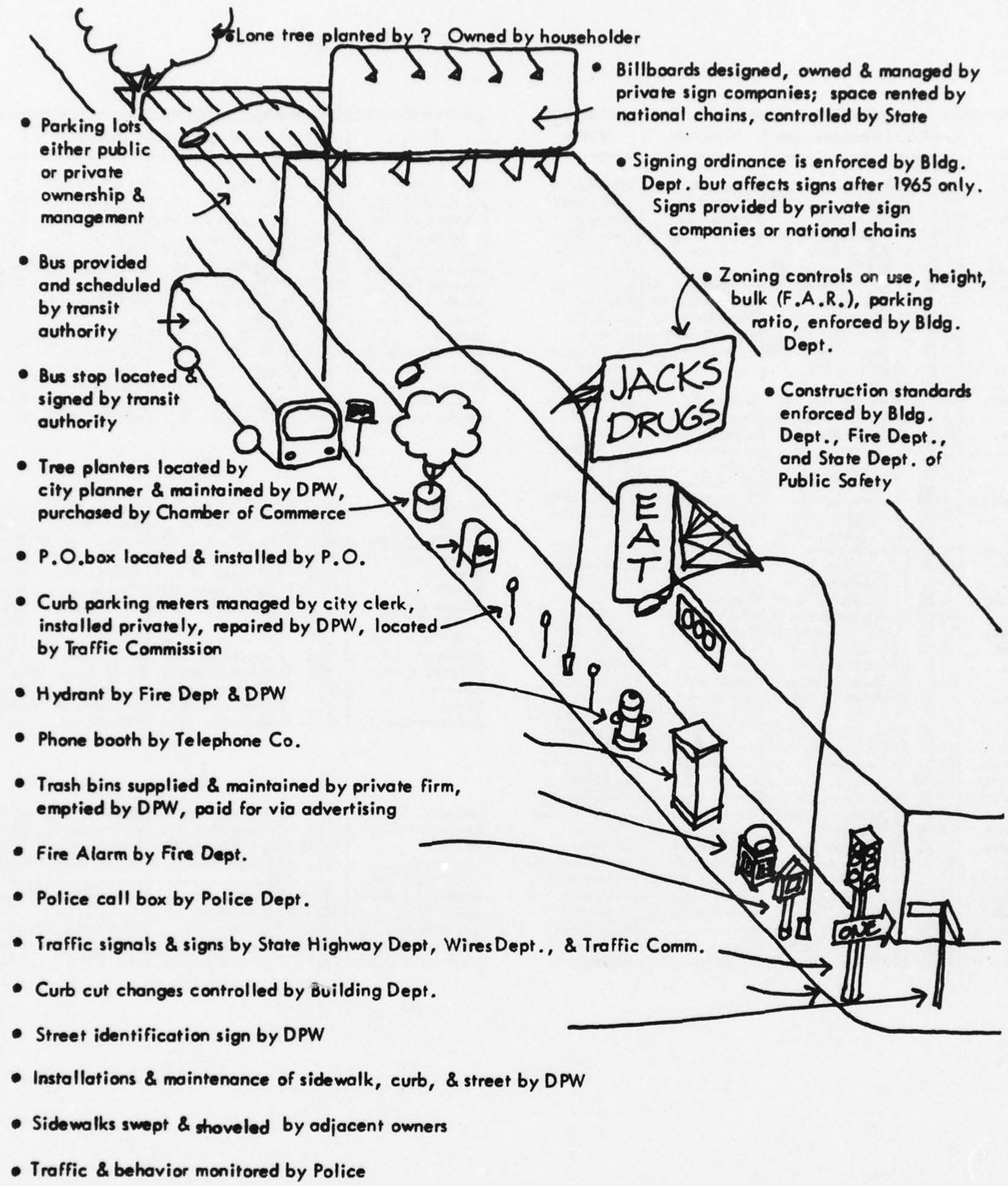


2.26 FLOATING LANDMARK MAP: JERUSALEM

An example of the "floating landmark" approach, this map shows many landmarks pictorially but takes great liberties in orientation and scale. Landmarks often face the wrong direction and are out of proportion to the streets and blocks. As a result, it is difficult to use the map for precise travel, although it is useful for obtaining a sense of distribution and general location of sites. Map reprinted by permission of Amir Publishing Ltd., Tel Aviv, design by I. Blaushild, Artwork by R. Vero; Copyright 1976.

2.27 TOURIST MAP: KÖLN/COLOGNE

Color, typography, and stylized delineation combine to make this a handsome tourist map. Major sites are drawn as simple elevations that lay flat on the plan and are keyed by number to an index. Minor streets appear to have been eliminated. As with many tourist maps, this one is probably more successful in arousing interest than in actually guiding tourists through the city. Map reprinted by permission of Verkehrsamt der Stadt Köln, Unter Fettenhennen 19, 5000 Köln 1, Germany.



2.28 ENVIRONMENTAL CONTROL MAP: MANAGEMENT OF MAIN STREET

This map is not concerned with topographic form but with who controls and manages elements of the environment. It points out that although a street appears simple, a maze of agencies, individuals, and organizations are involved in making it what it is. The technique is most relevant to planning and administration. Map reprinted by permission of Michael Southworth, from DESIGNING AND MANAGING THE STRIP by Michael Southworth and Kevin Lynch, Joint Center for Urban Studies of M.I.T. and Harvard Working Paper No. 29, 1974.

Rues	A	Plan	Commençant	Finissant	Métro
Jos.-Sansbœuf	8	I 12	Pépinière, 6	Rocher, 9	*Saint-Lazare*
Joséphine	18	D 15	Damrémont, 117	en impasse	*Jules-Joffrin*
Josseaume (pass.)	20	N 25	Haies, 67	Vignolés, 72	*Buzenval*
Josset (pass.)	11	N 21	Charonne, 38	av. Led.-Rol. 101	*Ledru-Rollin*
Joubert	9	I 13	Ch.-d'Antin, 35.	Caumartin, 58	*Ch.-d'Antin*
Joudrier (imp.)	11	N 24	bd Charonne, 85		*Bagnolet*
Jouffroy (pass.)	9	J 15	bd Montmart. 10	Gr.-Batelière, 9.	*Rich.-Drouot*
Jouffroy (rue)	17	G 10	bd Péreire, 1	av. Wagram, 80.	*Wagram*
Jour (du)	1	L 16	Coquillère, 2	Montmartre, 9	*Les Halles*
Jourdain (du)	20	I 23	Pyrénées, 336	Belleville, 134	*Jourdain*
Jourdan (bd)	14	V 15	Am.-Mouch. 100	a. Gl-Leclerc 129	*Pte d'Orléans*
Jouvence (imp. de)	14	S 10	Alésia, 245		*Plaisance*
Jouvenet (sq.)	16	Q 3	Jouvenet, 16		*Chardon-Lag.*
Jouvenet (rue)	16	Q 3	av. de Vers., 152	Boileau, 51	*Chardon-Lag.*
Jouy (de)	4	N 18	N.-d'Hyères, 37.	Fran.-Miron, 58	*Saint-Paul*
Jouye-Rouve	20	J 22	Belleville, 60	J.-Lacroix, 66	*Belleville*
Joyeux (cité)	17	D 12	Epinettes, 53	en impasse	*Pte St-Ouen*
Juge (rue)	15	O 7	Viala, 9	Violet, 6	*Dupleix*
Juge (villa)	15	O 7	Juge, 22	villa de Gren., 6.	*Dupleix*
Juges-Consuls (d)	4	M 17	Verrerie, 68	Cl.-St-Merri, 3	*Hôtel-de-Ville*
Juillet	20	K 23	Bidassoa, 44	Bidassoa, 54	*Martin-Nad.*
Juin (cour)	11	N 20	p. Cheval-Blanc.		*Bastille*
Jules-Bourdais	17	F 8	bd Berthier, 134.	a. Brunetière, 31	*Champerret*
Jules-Breton	13	R 18	J.-d'Arc, 172	bd St-Marcel, 37	*Saint-Marcel*
Jules-César	12	O 19	bd Bastille, 22	Lyon, 43	*Arsenal*
Jules-Chaplain	6	Q 13	N.-D.d.-Ch., 60.	Bréa, 21	*Vavin*
Jules-Cheret	20	N 26	Mendelssohn, 11	D^r^-Déjerine, 9	*Pte Montreuil*
Jules-Claretie	16	L 5	bd E.-Augier, 36	Pompe	*La Muette*
Jules-Cloquet	18	D 14	p. Ch.-Alb., 20	bd Ney, 131	*Pte St-Ouen*
Jules-Cousin	4	O 19	bd Henri-IV, 17.	Petit-Musc., 12.	*Sully-Morl.*
Jules-David	20	I 26	Paul-Meurice, 41	Hors Paris	*Pte des Lilas*
Jules-Dumien	20	J 25	Pelleport 108	H.-Poincaré, 3	*Pelleport*
Jules-Dupré	15	T 8	Périchaux, 2	bd Lefebvre, 95.	*Pte Versailles*
Jules-Ferry (bd)	11	K 19	a. République, 13	Fg-Temple, 28	*République*
Jules-Guesde	14	R 12	Vercingétorix, 17	R.-Losserand, 18	*Gaîté*
Jul.-Hénaffe (pl.)	14	U 13	Beaunier, 1	av. Reille, 40	*Pte d'Orléans*
Jules-Janin (av.)	16	M 5	Pompe, 12	Pompe, 32	*La Muette*
Jules-Joffrin (pl.)	18	E 16	Ordener, 82	Mont-Cenis, 77.	*Jules-Joffrin*
Jules-Jouy	18	F 15	Francœur, 16	Cyr.-Bergerac, 3	*Lamarck-Cau*
Jules-Lefebvre	9	H 13	Clichy, 49	Amsterdam, 68	*Liège*
Jules-Lemaître	12	Q 26	bd Soult, 62	V.-d'Indy, 1	*Bel-Air*
Jules-Pichard	12	S 24	Jardiniers, 13	Meuniers, 35	*Pte Charenton*
Jul.-Renard (pl.)	17	G 7	Claude-Debussy	Gouvion-St-Cyr	*Champerret*
Jul.-Sandeau (b.)	16	L 4	Oct.-Feuillet, 2	a. H.-Martin, 101	*La Muette*
Jules-Siegfried	20	K 26	Irénée-Blanc	Paul-Strauss, 32.	*Gambetta*
Jules-Simon	15	Q 7	Croix-Nivert 141	Cournot, 2	*Félix-Faure*
Jules-Vallès	11	N 22	Chanzy, 23	Charonne, 102	*Charonne*
Jules-Verne	11	J 20	Orillon, 21	Fg-d-Temple, 98	*Belleville*
Julia-Bartet	14	U 9	pl. Pte Vanves	bd Ad-.Pinard	*Porte Vanves*
Jul.-Lacroix (p.)	20	J 22	Couronnes, 49	Vilin, 40	*Couronnes*
Julien-Lacroix	20	J 22	Ménilmont., 49	Belleville, 56	*Couronnes*
Julienne (de)	13	S 16	Pascal 62	bd Arago, 45	*Glacière*
Juliette-Dodu	10	I 20	Cl.-Vellefaux, 3.	Gge-a.-Belles, 20	*Col.-Fabien*
Juliette-Lamber	17	F 9	bd Péreire, 36	b. Malesh., 190.	*Wagram*
Jumeau (imp.)	19	F 20	Tanger, 45		*Riquet*
Junot (av.)	18	F 14	Girardon, 3	pl. C.Pecqueur, 1	*Lamarck*
Junot (imp.)	20	I 25	Haxo, 101 *bis*		*Télégraphe*
Jura (du)	13	R 17	bd St-Marcel, 49	Oudry, 10	*Campo-Formio*
Jussienne (de la)	2	K 16	Et.-Marcel, 40	Montmartre, 41.	*Les Halles*
Jussieu (place)	5	P 17	Linné, 24	Jussieu, 19	*Jussieu*
Jussieu	5	P 17	Cuvier, 10	Car.-Lemoine 35	*Jussieu*
Juste-Métivier	18	F 14	av. Junot, 37	Caulaincourt, 56	*Lamarck*
Justice (de la)	20	K 26	Surmelin, 70	bd Mortier, 61	*Pelleport*

K

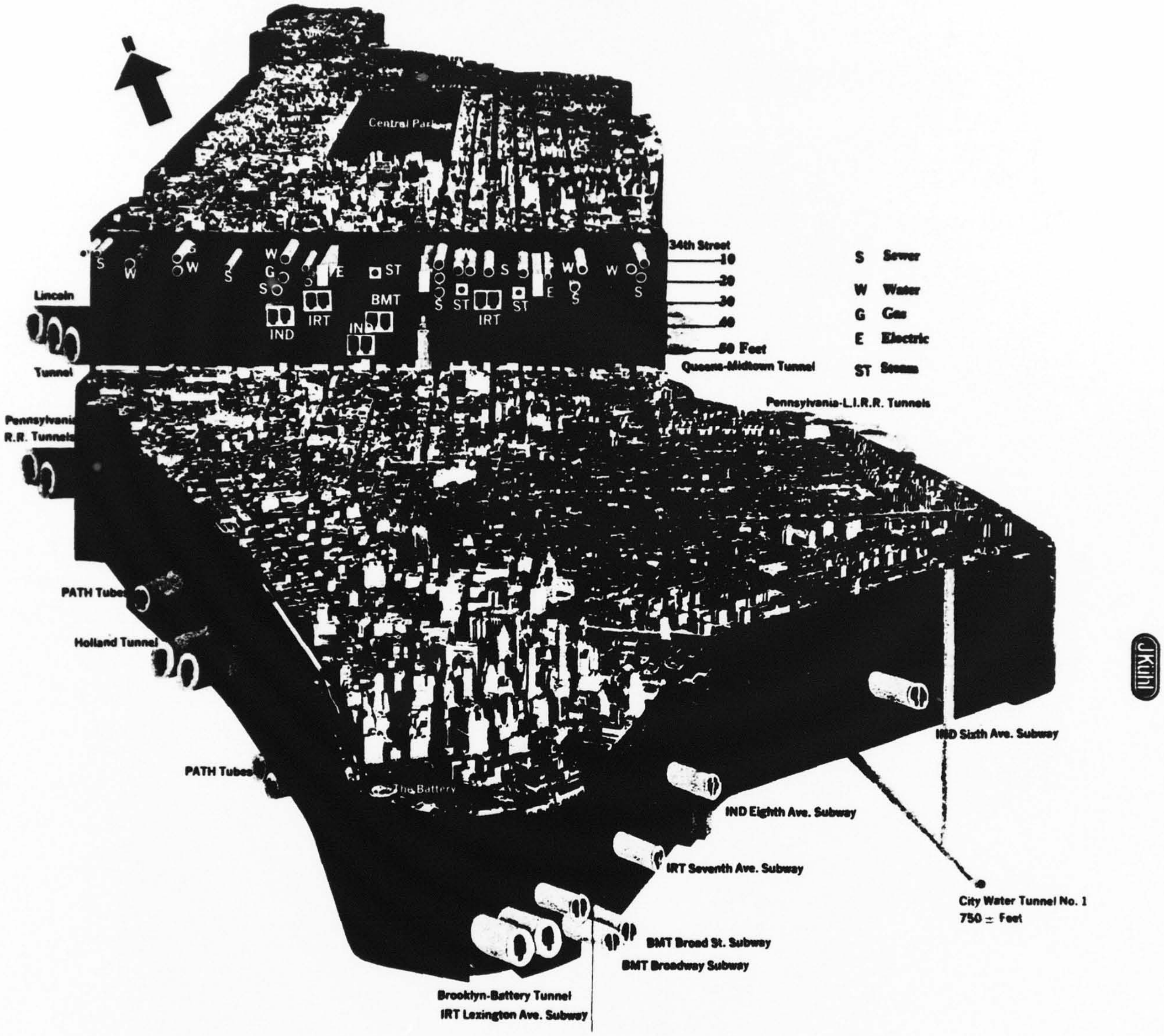
Rues	A	Plan	Commençant	Finissant	Métro
Kabylie (de)	19	G 19	bd Villette, 216.	Tanger, 12	*Stalingrad*
Keller	11	N 21	Charonne, 41	Roquette, 72	*Ledru-Rollin*
Kellermann (bd)	13	V 17	av. d'Italie, 192.	A.-Mouchez, 99.	*Porte d'Italie*
Kellermann (v.)	13	V 18	b. Kellermann 22		*Porte d'Itali*
Keppler	16	J 8	Bassano, 21	Galilée, 40	*George-V*
Keufer	13	V 17	Kellermann, 31.	Max-Jacob	*Porte d'Italie*
Kleber (av.)	16	J 7	pl. Etoile	pl. Trocadéro, 4.	*Etoile*
(N^os^ 39 à 90)		K 7			*Kléber*
(N^os^ 91 à fin)		L 7			*Trocadéro*
Kléber (imp.)	16	J 7	av. Kléber, 62	en impasse	*Boissière*
Kossuth (place)	9	I 15	Chateaudun, 12.	Fg Montmart. 58	*N.-D.-Lorette*
Kracher (pass.)	18	E 16	Clignancourt 137	Neuve-I-Ch., 8.	*Simplon*
Kuss	13	V 17	Peupliers, 36	Bril.-Savarin, 16.	*Maison-Blanc*
Kuszner (pass.)	19	J 21	Belleville, 17	Rébeval, 26	*Belleville*

L

Rues	A	Plan	Commençant	Finissant	Métro
Labat	18	F 16	Poissonniers, 61.	Bachelet, 12	*Marcad.-Pois.*
La Baume (de)	8	I 10	Courcelles, 20	av. Percier, 11	*Miromesnil*
Labie	17	H 7	av. Ternes, 79	Brunel, 46	*Porte-Maillot*
La Boétie	8	I 11	pl. St-August., 3	av. Ch.-Elys., 60	*Miromesnil*
(N^os^ 52 à fin)		J 10			*St-Ph.-Roule*
Labois-Rouillon	19	E 20	Curial, 29	Aubervilliers 164	*Crimée*
Labor (cité)	20	J 22	Couronnes, 55		*Couronnes*
Laborde (de)	8	I 12	Rocher, 11	Miromesnil, 58	*St-Augustin*
La Bourdonnais	7	M 8	quai Branly, 61	pl. Ecole-Milit. 4	*Ecole Militaire*
La Bourdon. (pt)	7	I 7	pt de l'Alma	pont d'Iéna	*Alma-Marc.*

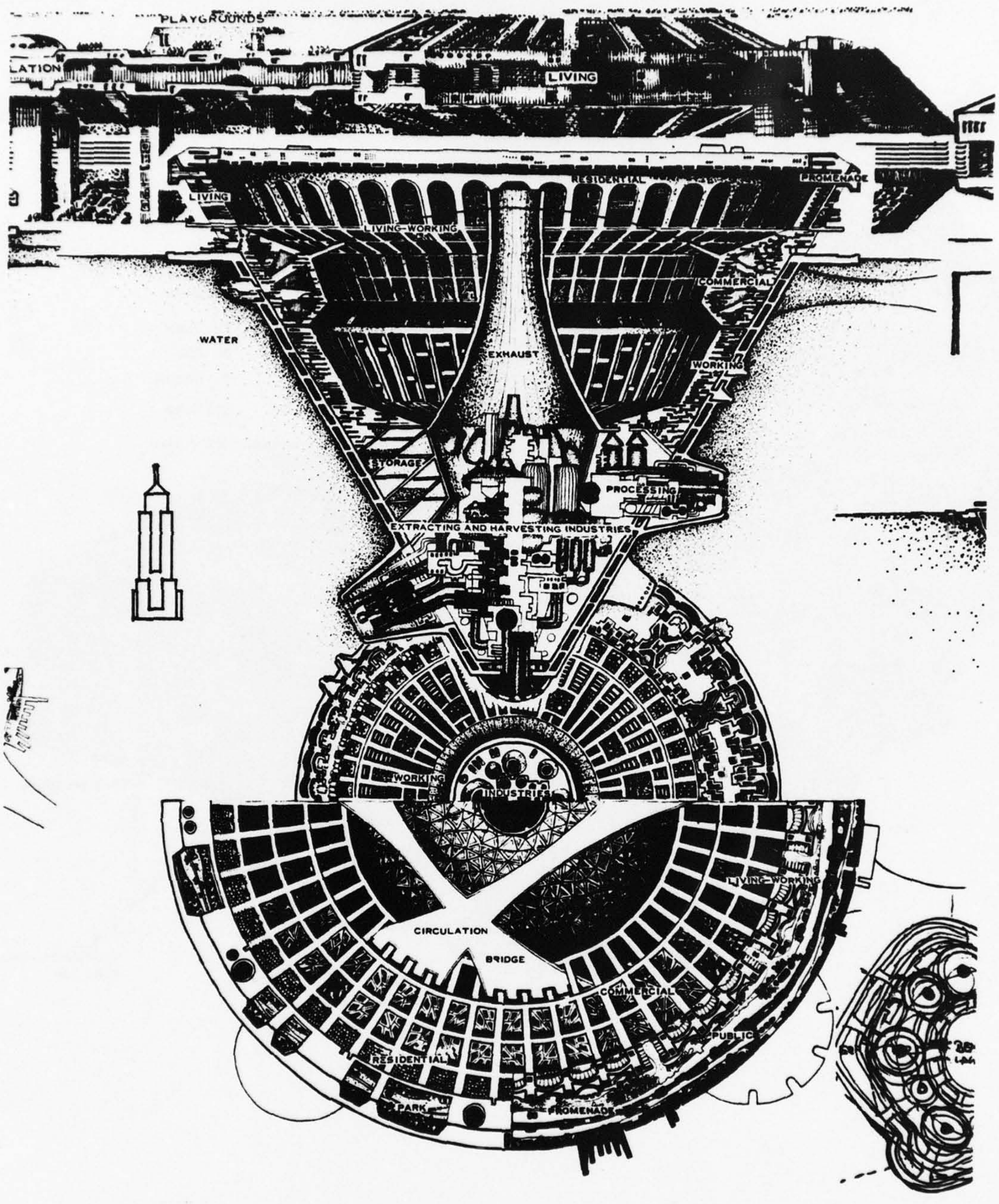
2.29 ADDRESS FINDER: RÉPERTOIRE DES RUES

All streets in Paris are listed alphabetically down the left column in this excellent guide. The number of the district in which the street occurs is in the second column, followed by the letter and number of the corresponding quadrant on the appropriate map. The last three columns list the intersecting streets at the beginning and end, and finally the closest Metro station. The comprehensive nature of the list makes it a valuable tool for a visitor, particularly one using public transit. Map reprinted by permission of Raymond Denaès, L'INDISPENSABLE PARIS PAR ARRONDISEMENT, Paris.



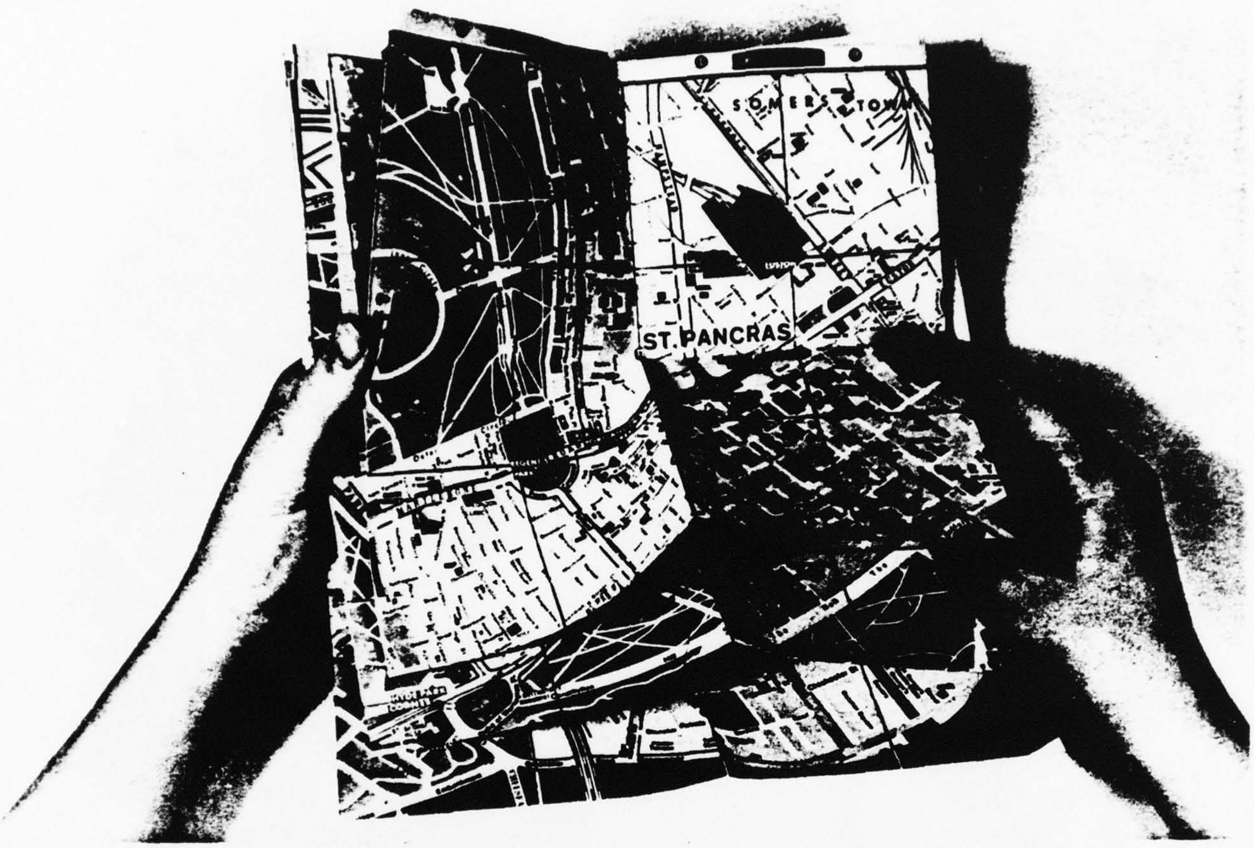
2.30 CROSS-SECTION MAP: NEW YORK UNDERGROUND

In this novel map, Manhattan appears to be carved out of its surroundings to expose the underground network of utilities, and automobile and transit tunnels. Aerial cross-sections are useful for explaining relations between the visible surface and hidden underground; the technique is not particularly effective as a travel aid. Map reprinted by permission.



2.31 SECTION/PLAN MAP: NOVANOAH II

Two different plan levels are shown in cross section, along with a vertical section of this giant futuristic city. The Empire State Building provides scale. Multiple views of a complex environment such as this are often helpful. In this case, the dissimilarity between the different levels suggests that many more plans would be necessary for actual travel due to lack of vertical repetitiveness. Map reprinted by permission of the M.I.T. Press, Cambridge, Ma. ARCOLOGY: THE CITY IN THE IMAGE OF MAN by Paolo Soleri. Copyright M.I.T. 1969.

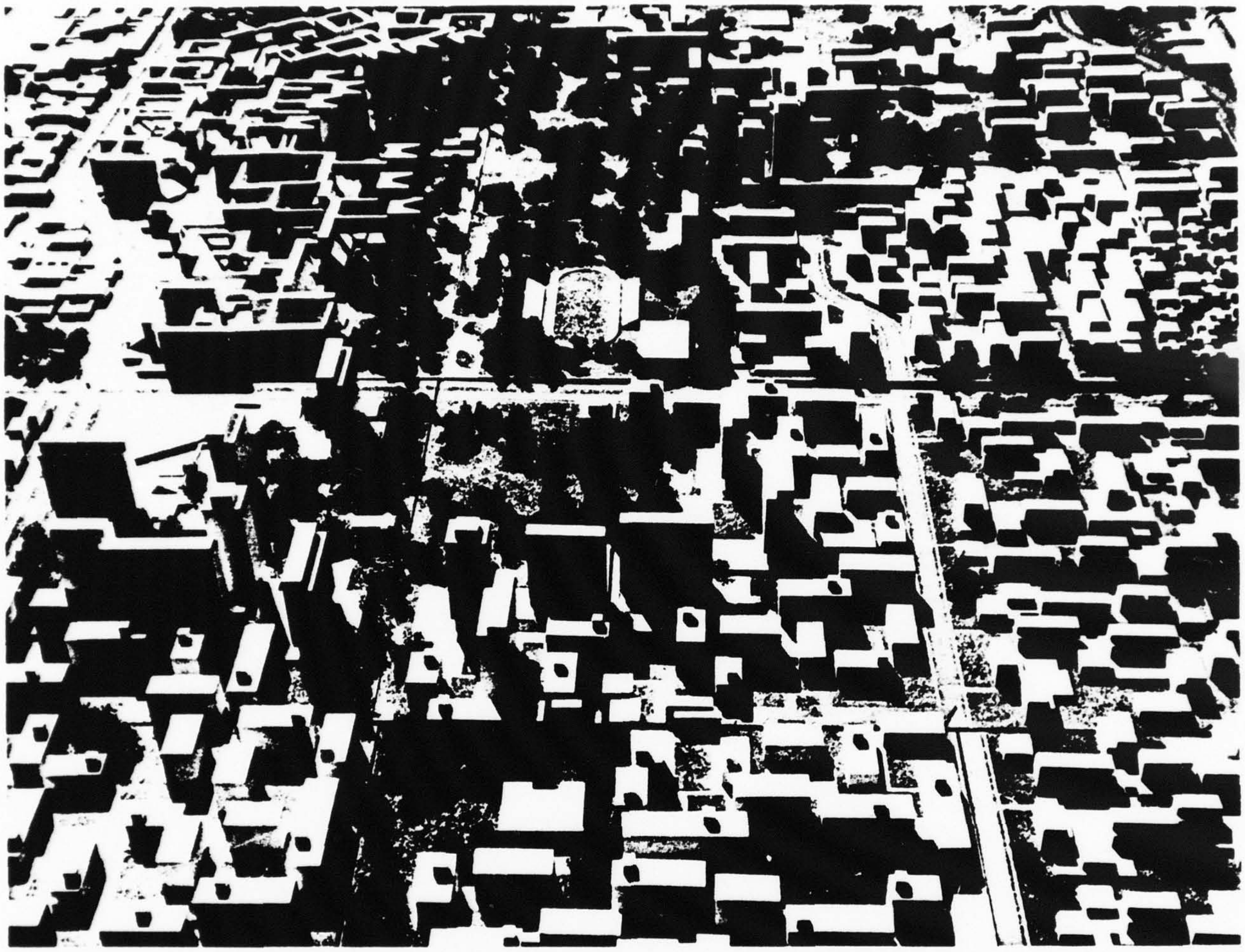


2.32 COMPACT MAP: LONDON

Through a clever trick of folding and cutting a map of London, one can view and use consecutive sections without ever unfolding more than one fold. The map operates first like a conventional book by allowing one to turn to the general area of interest within London. One then flips down the flaps to reveal the partially hidden sections. Strangely, all areas of the map are accessible, unlike conventional map folding which leaves most of the map "inside" and inaccessible. As long as one wants to proceed section by section, the system works well. However, if one wants a large scale view - the whole map at one time - there are problems. Because of the cuts and unusual folding, the map is difficult to open and, once open, is subject to tearing along the slits. Map reprinted by permission of Falk Plan Publishing, London. Copyright by Falk-Verlag, Hamburg, Germany.

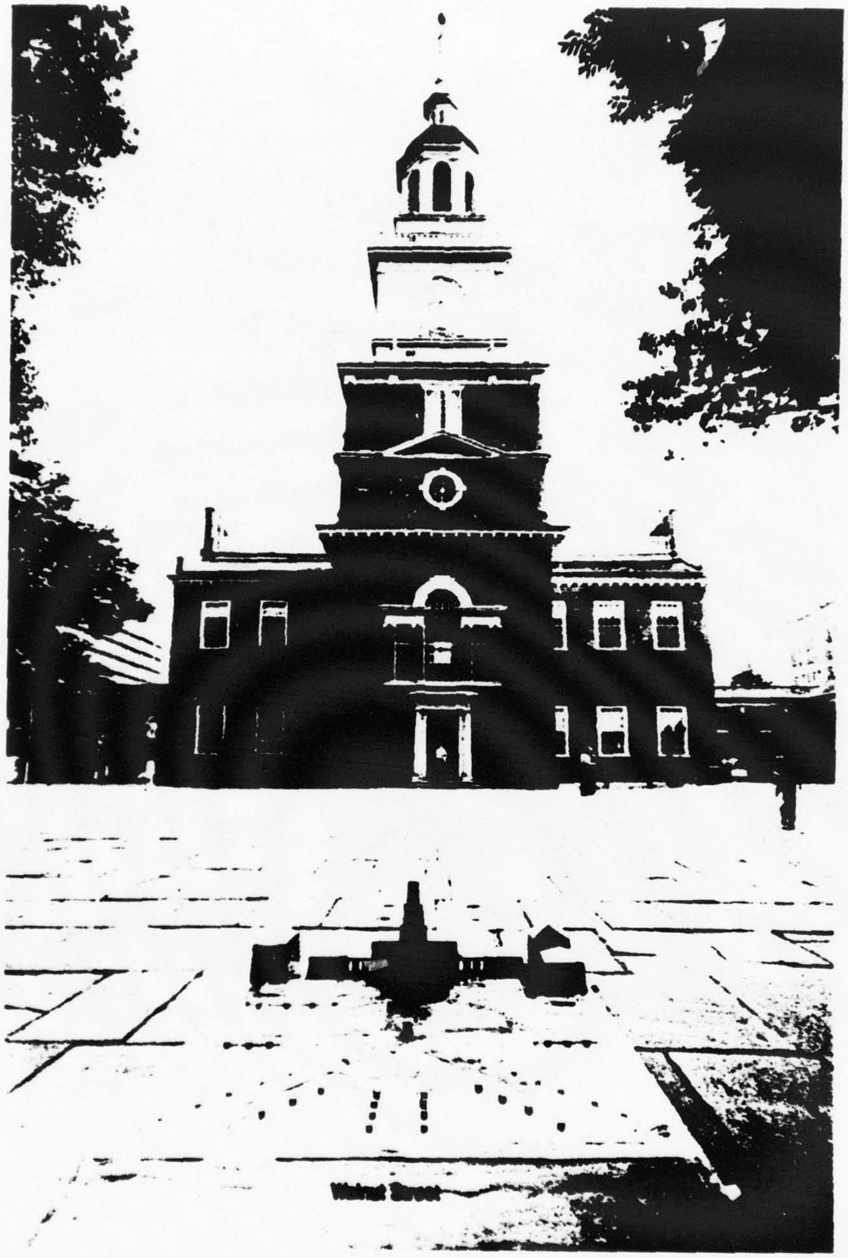
2.33 POP-OUT MAP: YELLOWBIRD MIGRATION GUIDE, BOSTON

Storing the bulk of a paper map can be a problem. Complicated folds leave one wondering how to open or refold a map. Although this map is uninformative, it addresses itself to the folding problem by using the pop-out technique. Clever folding allows one to open or close the map in one motion. The technique is appropriate only for small maps such as this (8¼" x 10"). Courtesy of Delta Air Lines.



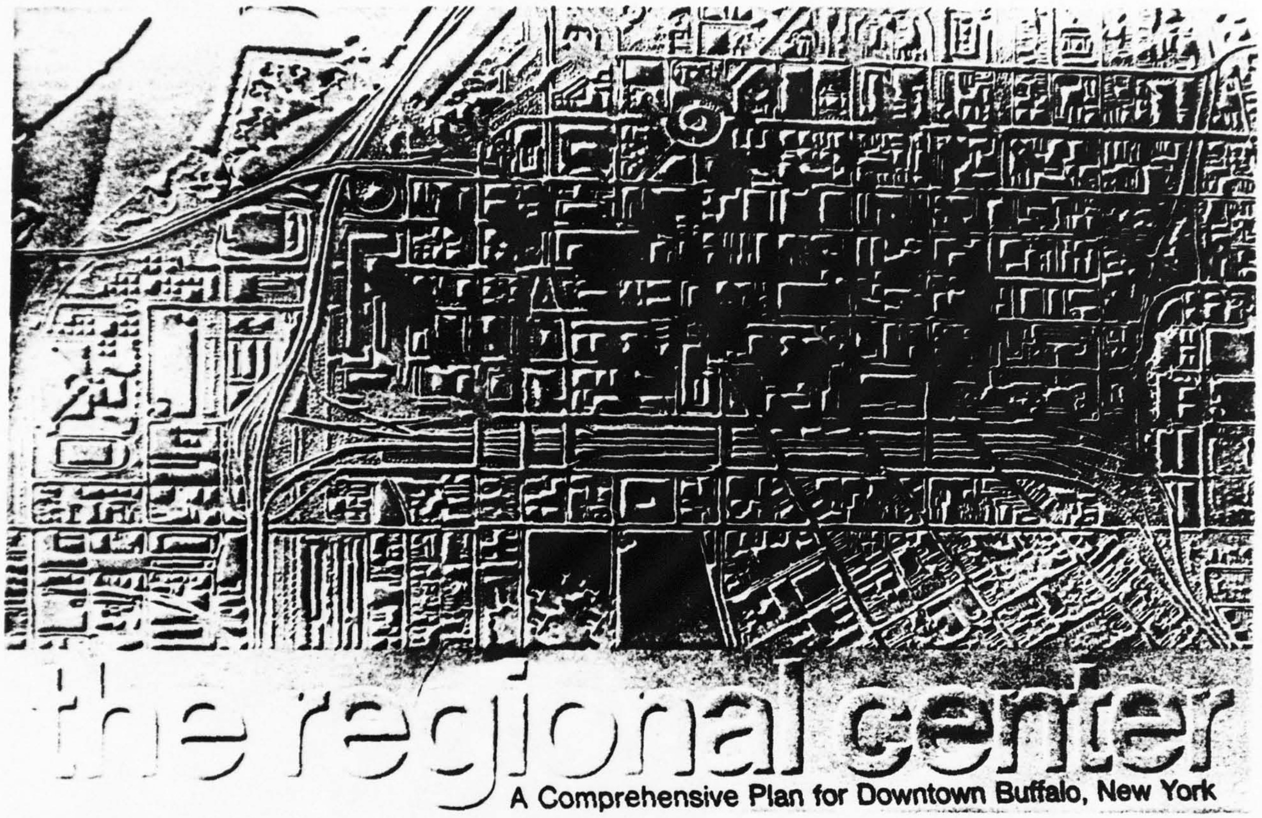
2.34 MODEL: DETROIT

Three dimensional models can provide convincing and easy-to-understand information about environments. However, they tend to be cumbersome and expensive, making them generally unsuitable for travel. They are one of the ideal techniques for representing the actual experience of a real environment, especially when used in conjunction with optical devices that simulate being in and moving about the environment. Thus, models are useful for a variety of training, strategy, and planning purposes. For those who cannot read two-dimensional maps, they are invaluable. Map reprinted by permission of Detroit City Planning Commission, 1964.



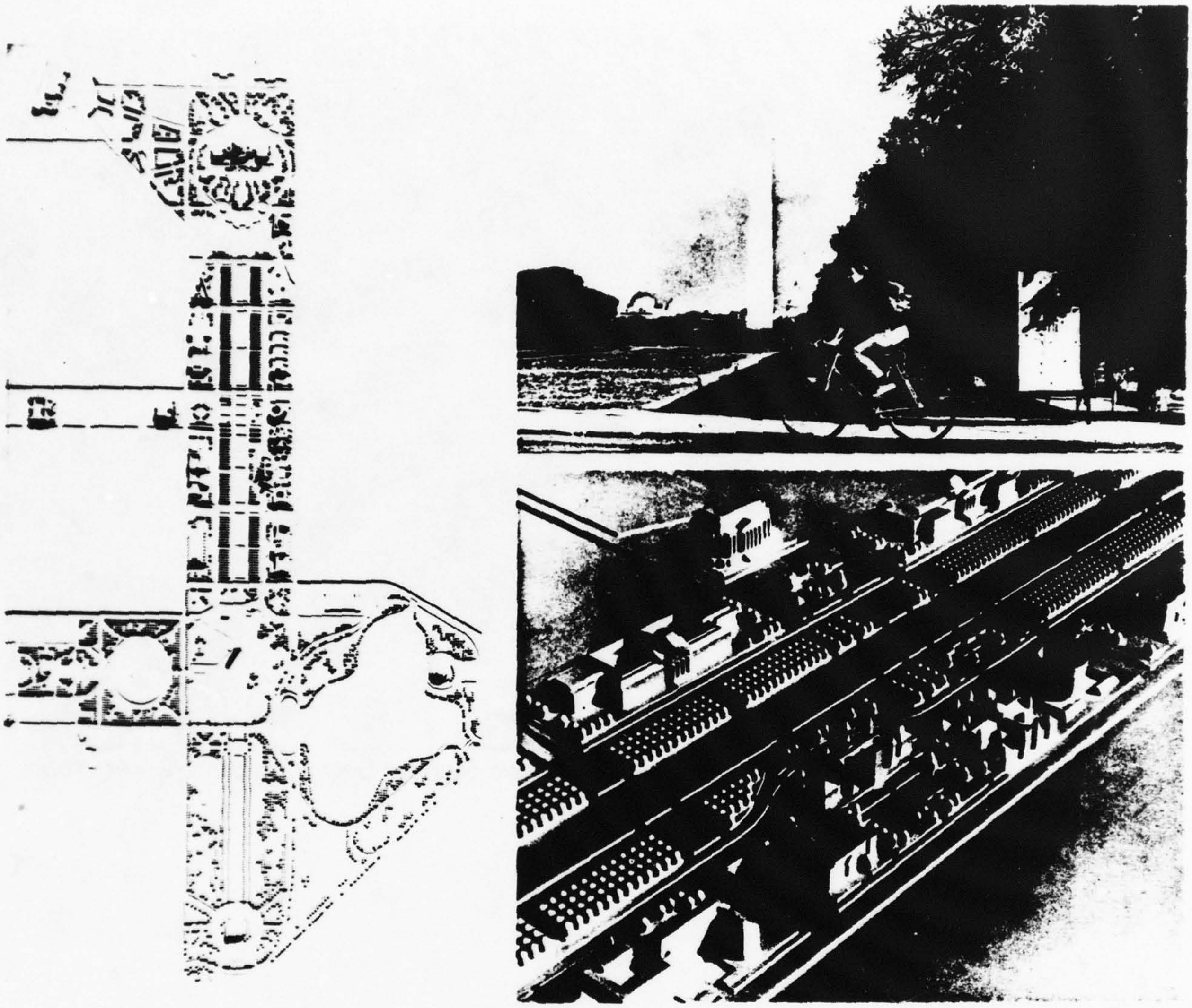
2.35 MODEL FOR THE BLIND: PHILADELPHIA, INDEPENDENCE HALL BLOCK

This model was developed to communicate the form and pathways of the Independence Hall area to the blind. Surface textures are emphasized in the model and are keyed in the legend. Braille information is included on the model. The model was developed in clay and cast in fiberglass. Map reprinted by permission. Richard Saul Wurman, et al; photograph by Joel Katz and Scott Miller.



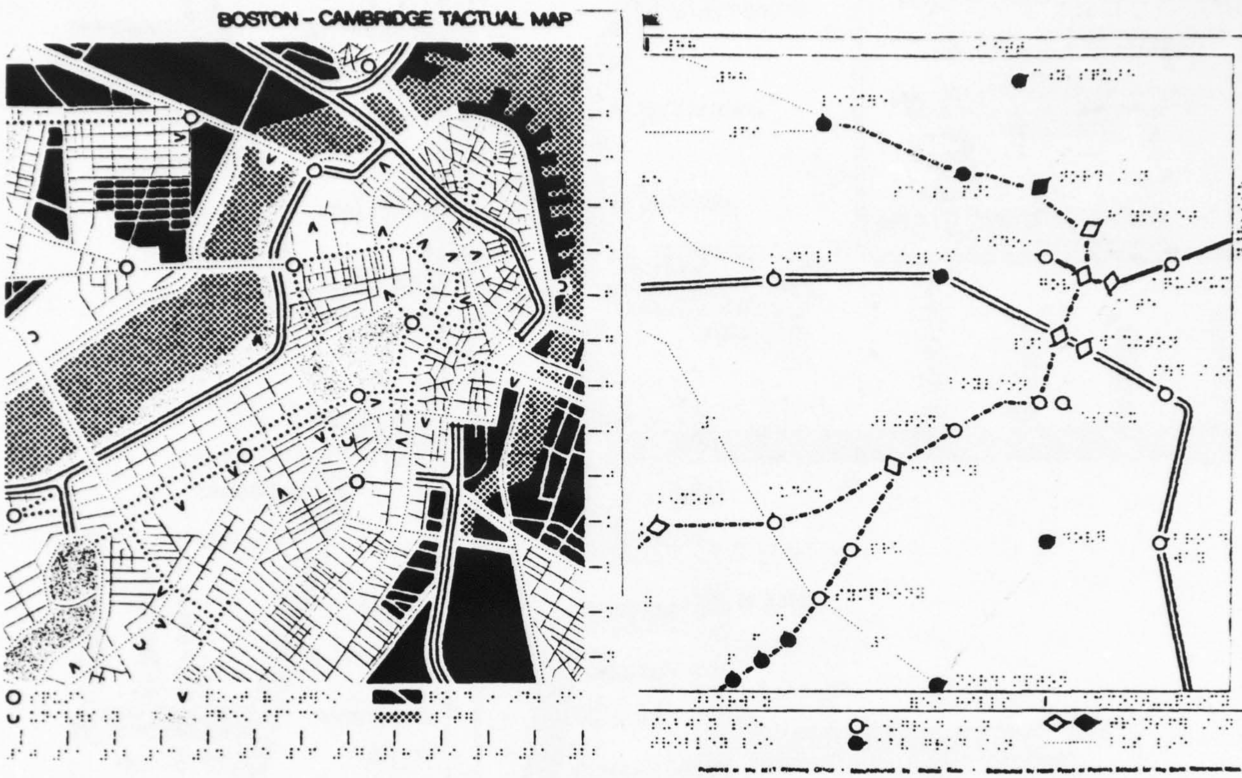
2.36 EMBOSSED MAP: BUFFALO

A low relief representation of Buffalo is achieved by embossing a map pattern on heavy-weight paper. In this case, it is not high enough relief to be of much use to the blind and is intended for the sighted. The technique is attractive but not entirely practical. The embossing process is expensive and, when done on paper, is subject to damage. The advantage is that it can communicate three dimensional form of buildings or topography more directly than a drawing. Map reprinted by permission of Wallace, McHarg, Roberts & Todd, THE REGIONAL CENTER: A COMPREHENSIVE PLAN FOR DOWNTOWN BUFFALO, 1971.



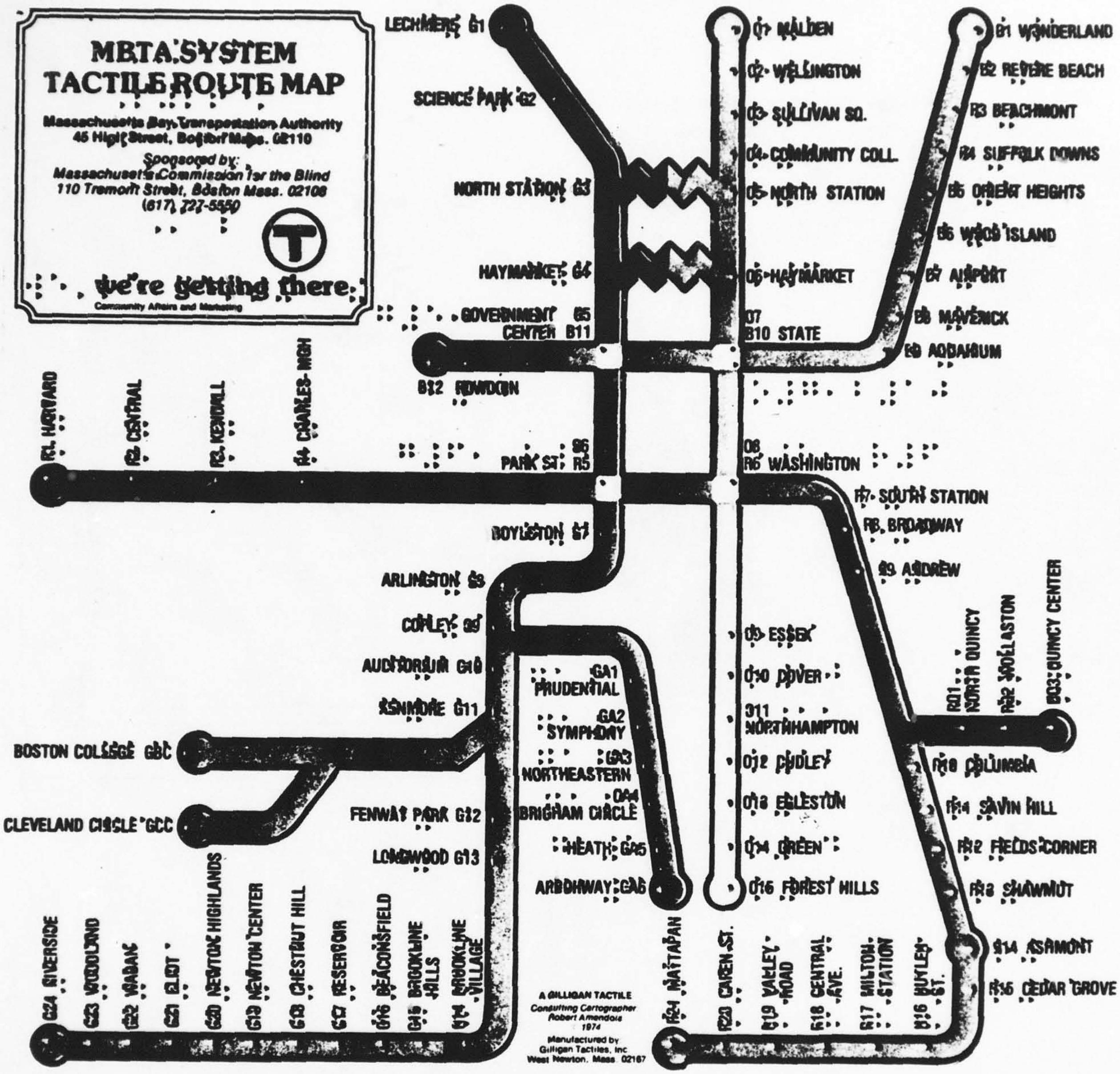
2.37 RELIEF MAP: WASHINGTON MALL

The Washington Mall, and its associated landmark sites and institutions, are attractively modelled in high relief of white plastic. Trees and streets are differentiated from flat grassy lawns through various relief patterns. On each side of the Mall, pictograms relate to the institutions and introduce verbal descriptions of adjacent sites. The whole map is mounted in enclosed kiosks at various points along the Mall. Map reprinted by permission. Wyman and Cannan Co. (New York) for Smithsonian Institution, National Park Service, the Capitol, National Gallery of Art, and the National Archives. Susan Hamilton, Project Director.



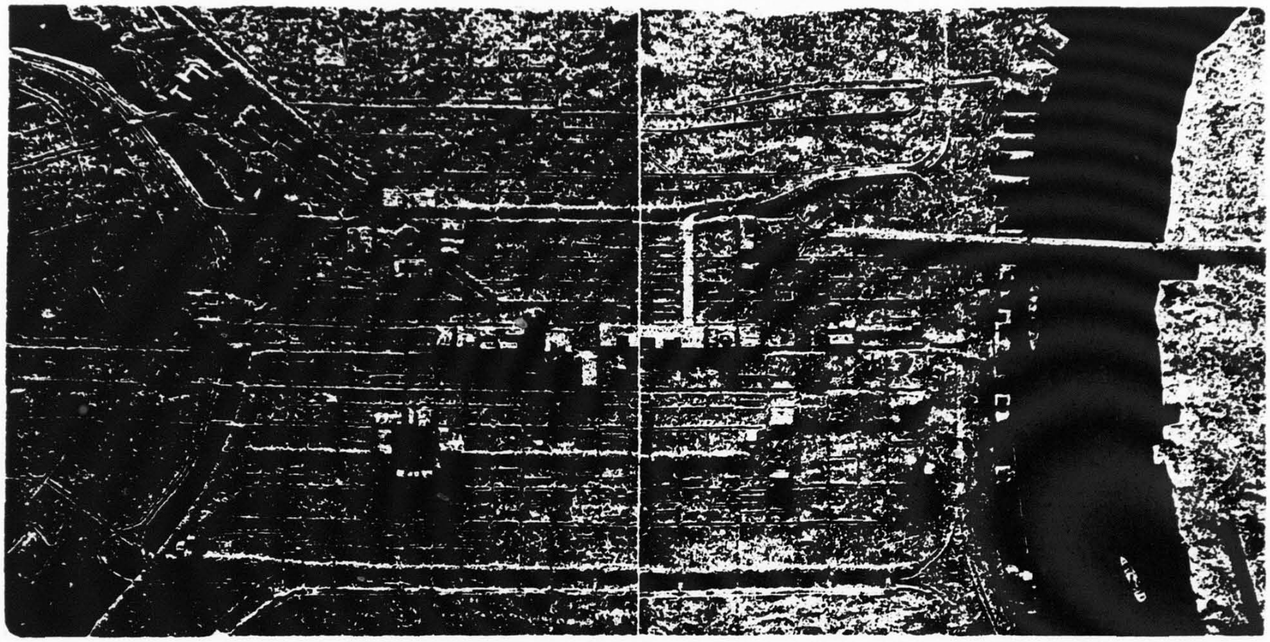
2.38 BRAILLE/TACTILE MAP: BOSTON-CAMBRIDGE

Maps for the blind, a fascinating branch of cartography, also have implications for the sighted. Buildings and pathways are embossed in low relief, creating a map that is in many ways more concrete and intelligible than most printed maps. For the blind, special attention is given to navigation aids and problems; for example, curbs and other barriers or hazards are tactually emphasized, as are guidance cues such as paving texture, fences, or walls. Map reprinted by permission. Prepared by MIT Planning Office, manufactured by Ithamai Kutai, distributed by Howe Press of the Perkins School for the Blind, Watertown, Mass.; Copyright 1973 by MIT.



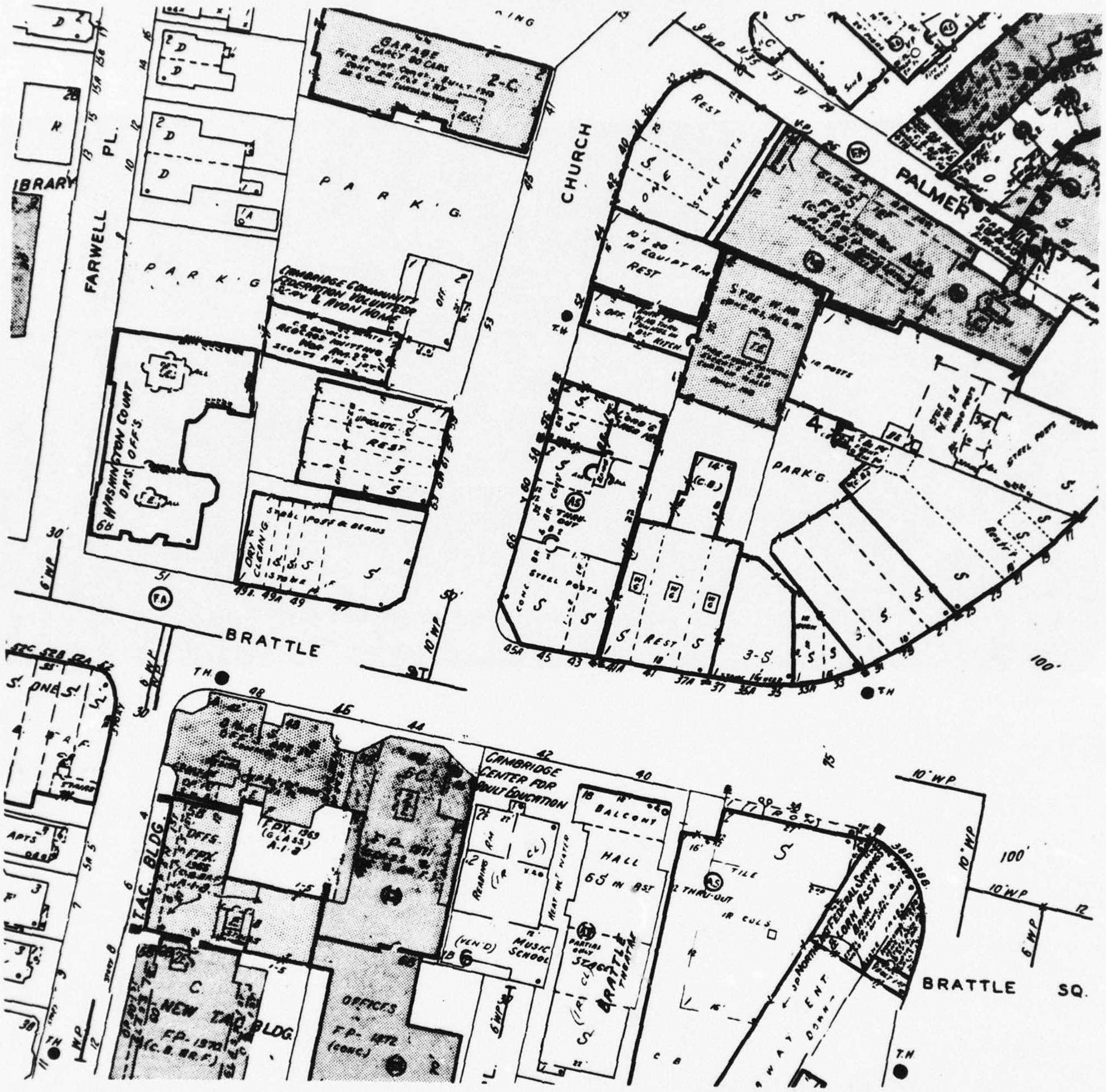
2.39 BRAILLE MAP: MBTA SYSTEM TACTILE ROUTE MAP

The Braille map of the Boston subway system presents the route diagram with raised ridges defining the lines, station names in Braille, and a raised dot on the line for each station location. The routes are also printed in color; and station names are printed in English, allowing for interaction with the sighted. Additional information is keyed into the map from several attached sheets in Braille. Relative distance between stations is distorted in the diagram, which may present planning problems. Map reprinted by permission. Robert Amendola and Gilligan Tactiles, Inc. for Massachusetts Commission for the Blind and Massachusetts Bay Transportation Authority, Boston, MA., Copyright 1974.



2.40 RELIEF MAP: PHILADELPHIA

Essential features of cities are reduced to the simplest elements in clay relief models. Models were made of fifty cities, all at the same scale, thus facilitating comparative study. Size ranged from one to twelve 8" x 8" modules. A texture screen was used in the photographic process to create more graphic consistency in the final product. The technique is simple and creates an easily understood and appealing prepresentation of a place. Map reprinted by permission. Richard Saul Wurman, et al. CITIES: COMPARISONS OF FORM AND SCALE, Raleigh, N.C., 1974.

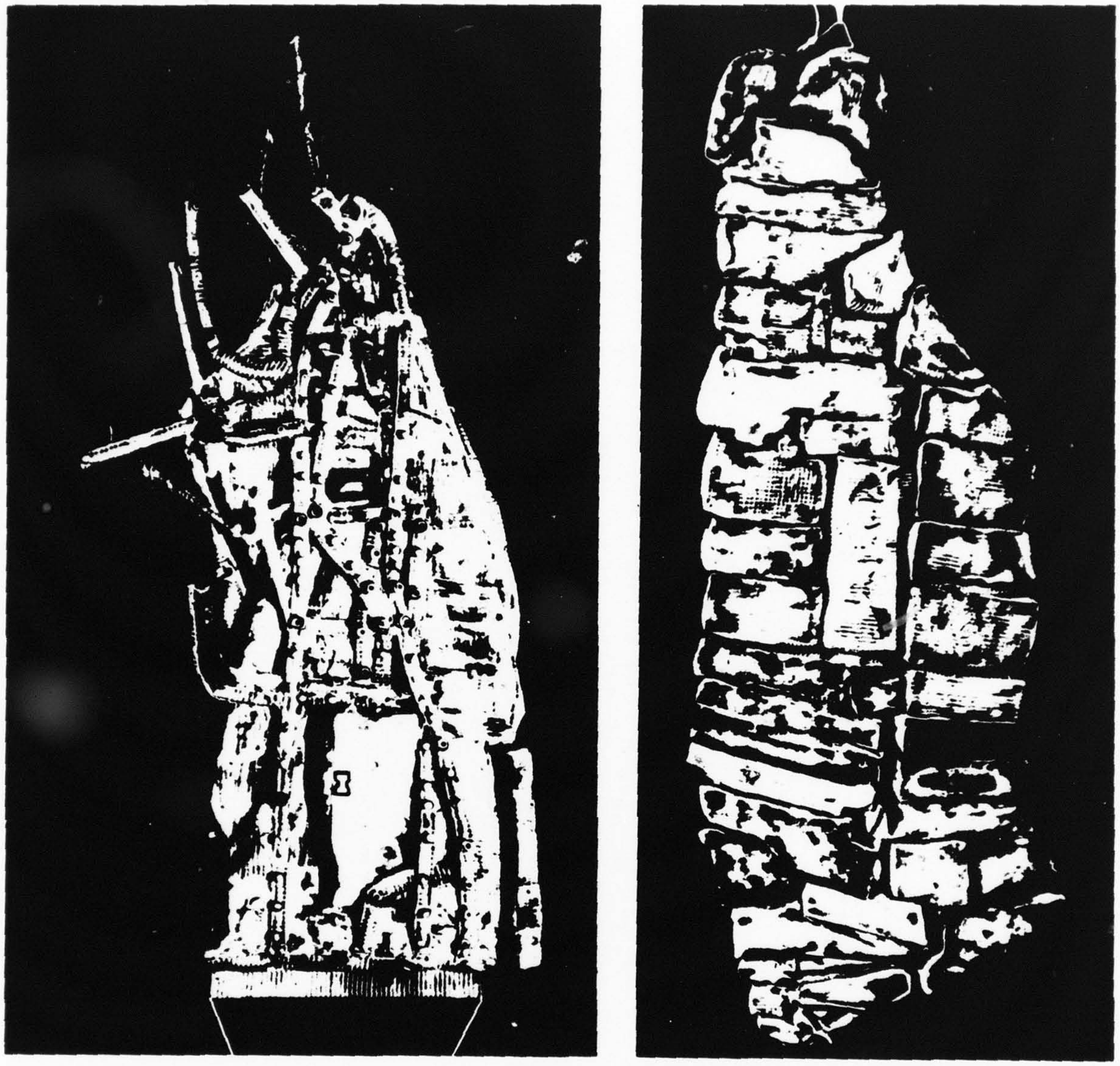


2.41 SANBORN INSURANCE MAPS

Developed for insurance purposes, the Sanborn maps are the only readily available source of detailed building information in the U.S. Building shape, construction type, address, property lines, streets, underground utilities, and land use information are given. The maps are periodically updated. They are useful in planning and construction but are too detailed for general use. Maps reprinted by permission of Sanborn Map Company, Pelham, N.Y.

2.42 LOWER MANHATTAN PLAN

Shadows are used to create a very comprehensible but detailed plan view of Lower Manhattan. Every building is shown. It closely resembles an aerial photograph but simplifies and adds emphasis, eliminating non-essential details such as rooftop equipment or vehicles. Such maps can be useful for planning or local travel but are too detailed for quick reference or regional travel. Map reprinted by permission. New York City Planning Commission, PLAN FOR NEW YORK CITY: MANHATTAN, Copyright 1969, M.I.T. Press, Cambridge, Ma.



2.43 SOFT MANHATTAN I & II

An amusing interpretation by an artist, here Manhattan becomes soft sculpture. Bags or pillows represent zip code zones; conduits represent subway lines. The soft maps are made of fabric stuffed with kapok. Map reprinted by permission. Claes Oldenburg. Soft Map I courtesy of Albright-Knox Art Gallery, Buffalo, New York; Gift of Seymour H. Know. Soft Map II in CLAES OLDENBURG by Barbara Rose, Museum of Modern Art, New York, 1970.

292 *Route 42.* VENICE. *c. Canal Grande.*

LEFT.

Pal. Loredan (17th cent.), residence of Don Carlos.

Pal. Balbi-Valier (18th cent.).

Pal. Manzoni-Angaran, in the style of the Lombardi (15th cent.).

Steamboat-station *Accademia* (Pl. E, 6), see p. 261.

RIGHT.

in the Piazza di San Marco), by *Gius. Vissotto-Alberti* and *Vinc. De' Stefani* (1897).

Pal. Curtis (formerly *Barbaro*), in the pointed style of the 14th century.

Pal. Franchetti (formerly *Cavalli*), in the pointed style of the 15th cent. (restored), with fine windows and a handsome new staircase by *Camillo Boito*.

Church of *San Vitale* (p. 316).

Ponte di Ferro or *Ponte dell'Accademia* (Pl. E, 6; p. 283), constructed in 1854, between the *Campo della Carità* and the *Campo San Vitale*.

LEFT.

Accademia di Belle Arti, see p. 283.

Palazzi Contarini degli Scrigni, one by *Scamozzi* (1609), in the late-Renaissance style, the other Gothic (15th cent.)

Pal. Loredan or *dell' Ambasciatore*, 15th cent. (restored in 1900), with two statues on the façade ascribed to Pietro Lombardo (German embassy in the 18th cent.).

***Pal. Rezzonico** (now *Browning*), built by *Bald. Longhena* (1680), with a top story by *G. Massari* (1745). This is the house in which Robert Browning died in 1889, and is now occupied by his son. Memorial tablet on the wall facing the side-canal. It contains celebrated ceiling-paintings by *Luca Giordano* and *G. B. Tiepolo* (usually open 9-4; 1 fr.).

Two *Palazzi Giustiniani*, in the Gothic style (15th cent.). In the first of these Mr. Howells wrote his 'Venetian Life'.

***Pal. Foscari** (called *Pal. Giustiniani* before the addition of

RIGHT.

Pal. Levi (formerly *Giustiniani-Lolin*), of the 17th century.

Pal. Falier (Gothic; 15th cent.), occupied for some time by Mr. W. D. Howells.

Cà (i.e. Casa) del Duca, a plain house on the grand foundations of a palace begun for Francesco Sforza, Duke of Milan, but left unfinished by order of the Republic.

Pal. Malipiero, rebuilt in the 17th century.

Campo San Samuele, with a church of that name.

Pal. Grassi, by G. Massari (1705-45), restored by the late Baron Sina. Frescoes on the staircase by *P. Longhi*.

c. Canal Grande. VENICE. *42. Route.* 293

LEFT.

the upper story by Doge Francesco Foscari), pointed style of 15th cent. (restored in 1867), situated at the point where the Canal turns to the E., containing the Scuola Superiore di Commercio.

Pal. Balbi, late-Renaissance, by Aless. Vittoria (1582-90), now occupied by Guggenheim, the dealer in antiquities (p. 265).

Pal. Grimani (a San Tomà), late-Renaissance.

Steamboat-station *San Tomà* (Pl. E, 5); see p. 261.

Pal. Persico, in the style of the Lombardi (16th cent.).

Goldoni (1707-93), the writer of Italian comedies, was born in the interesting Gothic house (good staircase) behind this, at the corner of Ponte S. Tomà (bust and inscription).

Pal. Tiepolo-Valier (15-16th cent.).

***Pal. Pisani** *a San Polo*, in the pointed style of the 15th century.

Pal. Barbarigo della Terrassa, by Bern. Contino (1568), now the mosaic shop of Rigo & Co.

Pal. Cappello-Layard, at the corner of the side-canal Rio di S. Polo, the residence of Lady Layard.

It contains an interesting collection of pictures, including specimens of Ercole Grandi, Savoldo, Cosimo Tura, Moretto, Buccaccino, Giov. Bellini, Carpaccio, Cima da Conegliano, Gentile Bellini (portrait of Sultan Mahomet II.), and others (visitors not always admitted).

Pal. Grimani-Giustiniani, in the style of the Lombardi (16th cent.).

Pal. Bernardo, Gothic (15th cent.), now the mosaic factory of A. Salviati & Co.

Pal. Donà, Romanesque (12th cent.).

Pal. Papadopoli, formerly

RIGHT.

Pal. Moro-Lin (Pl. E, 5; now *Pascolato*), a late-Renaissance edifice by Seb. Mazzoni of Florence (16th cent.).

Pal. Contarini delle Figure, early-Renaissance (1504), with trophies on the walls.

Pal. Mocenigo, three contiguous palaces, that in the centre occupied by Lord Byron in 1818. The second and third of these palaces date from 1580.

Pal. Garzoni (Gothic; 15th cent.), now the French consulate.

Steamboat-station *Sant' Angelo* (Pl. F, 5), see p. 261.

***Pal. Corner Spinelli**, early-Renaissance by *Moro Coducci*, in the style of the Lombardi.

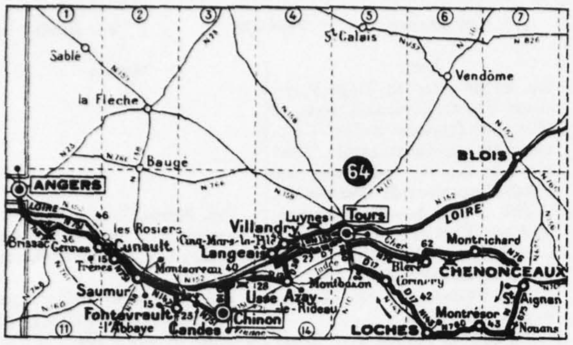
Pal. Cavalli, Gothic style of 15th century.

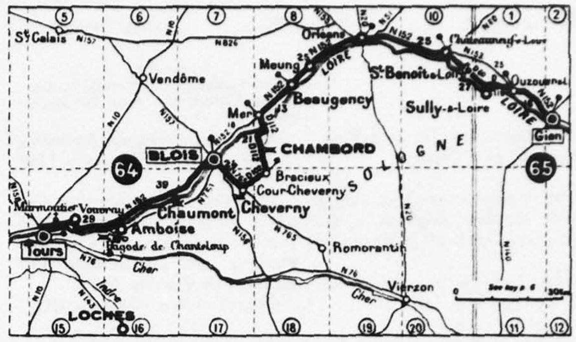
3.1 VENICE: A TRIP DOWN THE GRAND CANAL

A trip down the Grand Canal is verbally presented, using a double columned format, with the sequential views on the left and right differentiated. Although this is constructed with one direction in mind and is easiest to use that way, the agile reader can take the route backwards. Either forward or backward, the problem in this kind of mapping of very similar, undifferentiated events is that one might misidentify just one site and from then on be 100% incorrect without knowing it. Use of reference addresses, unique and identifiable passing events, or pictures of landmarks would help keep one on the track. The system is suited to any pathway, from hiking trail to train route or highway. Map reprinted by permission. Karl Baedeker, ITALY: HANDBOOK FOR TRAVELLERS, PART I, Charles Scribner's Sons, New York, 1903.

PROGRAMME FOR 5 DAYS

Angers–Gien or Gien–Angers





ANGERS ↓ — Details of each day — ↑ **ANGERS**

1st Day / **5th Day**

Angers–Chinon or vice versa

55 miles and 6½ hours sightseeing

Lunch at Gennes or at Saumur / *Lunch at Saumur*

Angers*** (2 hours), the capital of Anjou, has remarkable buildings and tapestries.

Before you reach Gennes a short detour will enable you to see the château of Brissac* (¾ hour).

Between Gennes, a picturesque little place, and Candes the road follows the Loire; it is a charming drive. In passing you will see the fine church of Cunault** (½ hour) and the tower at Trèves.

Saumur** (2½ hours) is the great riding-school and centre for sparkling wine; its château contains interesting museums.

You should make the small detour that leads to the Abbey of Fontevrault** (½ hour—do not arrive after 6.30 p.m. in summer or after 4.30 p.m. in winter). The Plantagenets have lain for six centuries in the great domed church; among the buildings is a Romanesque kitchen unique in France. Passing in front of the château of Montsoreau you will reach Candes** with its fine fortified church.

Between Candes and Chinon you will follow the pretty valley of the Vienne.

2nd Day / **4th Day**

Chinon–Tours or vice versa

47 miles and 3½ hours sightseeing

Lunch at Azay-le-Rideau / *Lunch at Azay-le-Rideau*

Chinon** (1½ hours) is one of the places of Touraine famous for its extraordinary picture of the Middle Ages and its delightful views of the Vienne.

Next, the trip includes Ussé**, the château of the "Sleeping Beauty", Azay-le-Rideau*** (½ hour), a jewel of the Renaissance, and Villandry** (½ hour) with its wonderful gardens.

Villandry and Tours are linked by the direct road following the Cher valley. This road may be used on Mondays, when Langeais** is closed. On other days you should make a detour to see this château (¾ hour), which is remarkable. Its furnishing offers a picture of family life among the nobility on the eve of the Renaissance.

Between Langeais and Tours you will follow the picturesque bank of the Loire, overlooked by the Château and Pile de Cinq-Mars and the tall towers of the castle of Luynes*.

3rd Day / **3rd Day**

Tour starting from Tours

92 miles and 3 hours sightseeing

Lunch at St-Aignan / *Lunch at St-Aignan*

The road runs along the Cher valley from Tours to St-Aignan. The valley is not as spacious as that of the Loire, but it offers smiling and varied scenes. It makes a charming drive. The wonderful château of Chenonceaux*** (¾ hour), built astride the Cher, and the old town of Montrichard* are on this run.

The church and château of St-Aignan* stand in picturesque surroundings.

Between St-Aignan and Loches the interest of the tour is heightened by a visit to Montrésor* (½ hour), which is proud of its castle and its church.

Loches*** (1¾ hours) is dominated by an impressive fortified castle. It is a great sight.

Between Loches and Tours most of the road follows the cultivated valley of the Indre, which is more intimate than that of the Cher.

↓ Details of each day ↑

4th Day / **2nd Day**

Tours–Blois or vice versa

42 miles and 3¾ hours sightseeing

Lunch at Amboise / *Lunch at Amboise*

Tours** (1 hour), the capital of Touraine, has interesting buildings and a picturesque old quarter.

Between Tours and Blois the road follows the right bank of the Loire. This is a wonderful spectacle at any season: sky, trees and old houses harmonise delicately. It would be difficult to find a scene more typically French in its grace, delicacy and proportion.

Marmoutier has the remains of an old abbey.

Vouvray, of Bacchic fame, nestles against a ridge honeycombed with caves in which people live.

The historic castles of Amboise** (½ hour) and Chaumont** (1 hour) are both perched on heights from which their massive shapes dominate the Loire. There are magnificent views from their terraces.

A short detour from Amboise leads to the curious pagoda of Chanteloup (½ hour).

The Gothic, Renaissance and Classical château of Blois*** (1 hour) is one of the great sights of the Loire valley.

5th Day / **1st Day**

Blois–Gien or vice versa

94 miles and 4½ hours sightseeing

Lunch at Beaugency / *Lunch at Orleans*

Between Cheverny and Chambord this trip includes a run through the Sologne with some characteristic features, a fast stretch of road from Mer to Orleans and pleasant views of the Loire at Orleans, St-Benoît, Sully and Gien. The trip is of first-class architectural and historical interest. You will see:

Cheverny** (½ hour), a Classical building with sumptuous decoration and furnishings dating from the 17th century;

Chambord*** (¾ hour), the magnificent creation of François I, surrounded by the largest park in France;

Beaugency** (½ hour), a delightful little town, picturesque and with fine architecture;

Meung*, an old town with fine promenades in which the church and the château make a pretty picture;

Orleans* (1 hour), the city of Joan of Arc;

the basilica of St-Benoît** ½ (hour), one of the finest Romanesque buildings;

the feudal castle of Sully** (½ hour);

the church and castle of Gien*, in which an interesting Museum of Hunting and Falconry has been installed (¾ hour).

GIEN / **GIEN**

3.2 VERBAL ROUTE PROGRAM: ANGIERS-GIEN OR GIEN-ANGIERS

The text sets forth the route program with accompanying map segments. As the margin arrows indicate, the program is designed to work either forward or in reverse. However, it is more laborious to read upwards, skipping one paragraph at a time. This is a good example of the possibilities of verbal mapping at the regional scale. Orientation directions are not generally given, however. The map segments are a support to the verbal mapping, helping people to organize visually the itinerary and keep on the route. Map reprinted by permission. Michelin, CHATEAUX OF THE LOIRE. The Dickens Press, London, Copyright 1964.

Quai de Montebello.—From this quayside and particularly from the little square René-Viviani, the **view***** of Notre-Dame is very beautiful.

The Pont au Double retains its name from an older toll-bridge, charge of which was a " double ", a small coin of the time.

Quai de la Tournelle.—The perspective of the Seine and the very old quay (1380), enhanced by its many picturesque old houses, is enchanting.

The **Musée de l'Assistance publique** is at No 47. Its collection comes from the Hospitals of Paris, and consists of documents, works of art, furniture and pharmaceutical equipment, some dating from the Middle Ages. *It is open every day except on Tuesdays and Public Holidays, from 10 a.m. to 12 and from 2 to 5 p.m. Admission: 1 F, free on Sundays.*

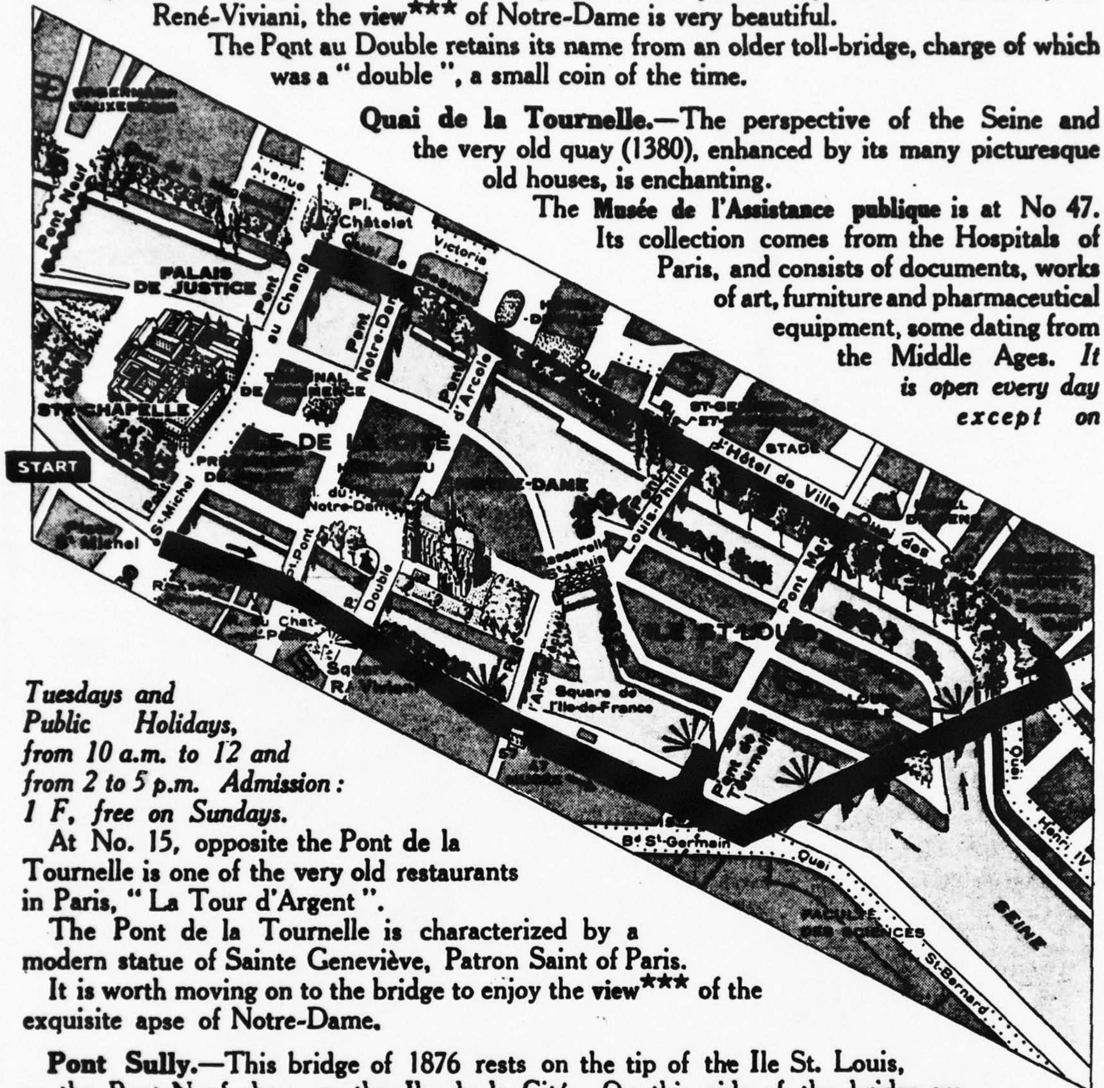
At No. 15, opposite the Pont de la Tournelle is one of the very old restaurants in Paris, " La Tour d'Argent ".

The Pont de la Tournelle is characterized by a modern statue of Sainte Geneviève, Patron Saint of Paris.

It is worth moving on to the bridge to enjoy the **view***** of the exquisite apse of Notre-Dame.

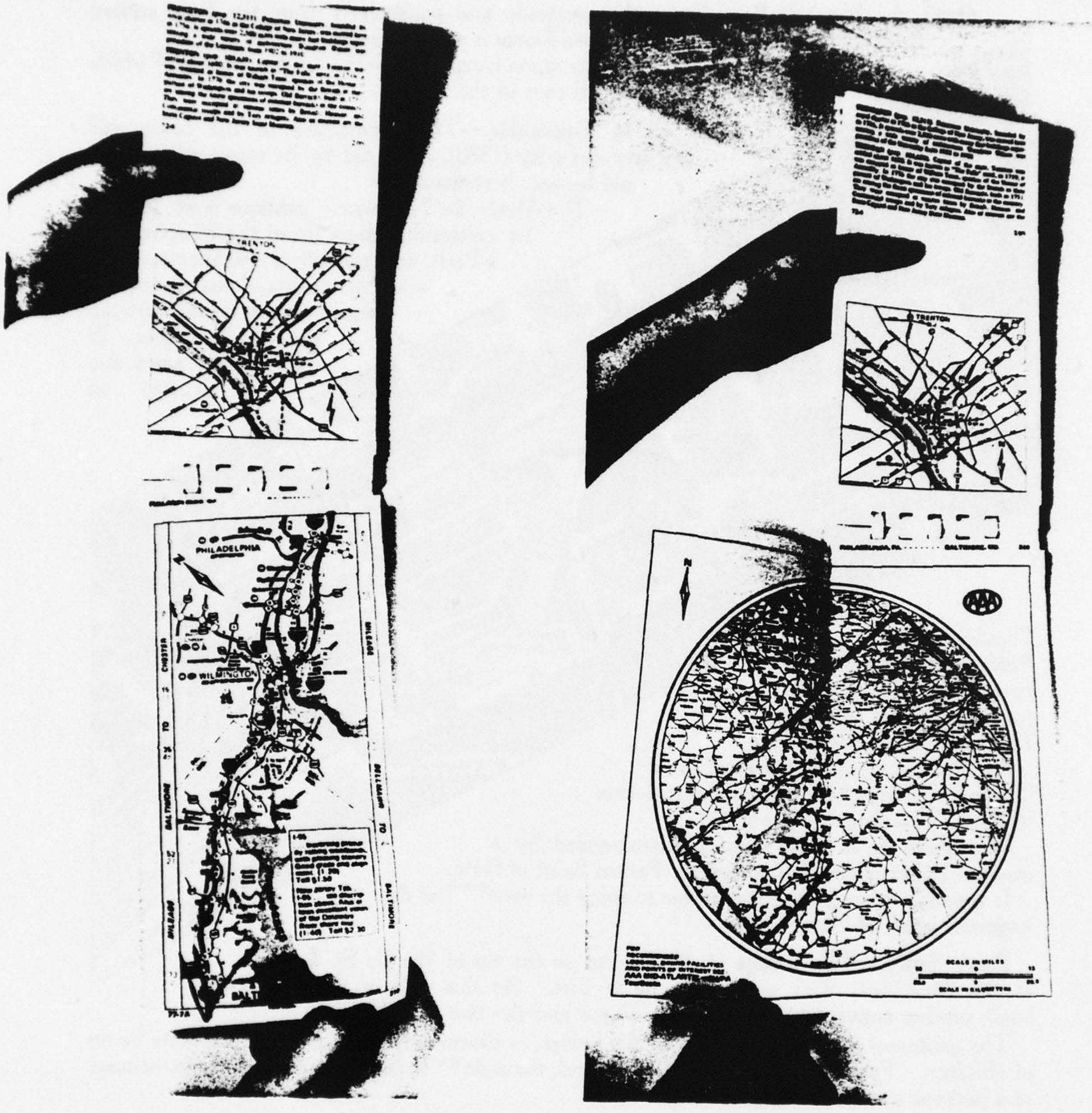
Pont Sully.—This bridge of 1876 rests on the tip of the Ile St. Louis, as the Pont Neuf does on the Ile de la Cité. On this side of the bridge we have another superb **view**** of Notre Dame and the two islands.

The garden of the island, crossed by the bridge, is charmingly wooded and a favourite haunt of children. From the other side of the island, the **sight**** is in a different key, more intimate and perhaps more delightful.



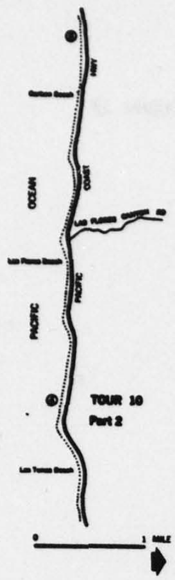
3.3 ROUTE: PLACE ST. MICHEL TO THE PONT SULLY

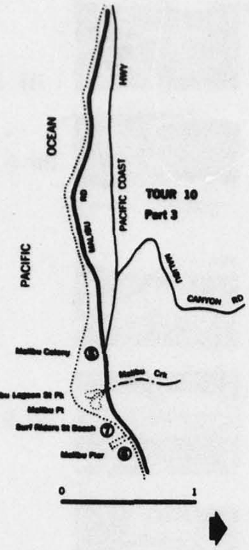
This map suggests a sight seeing route (shown in red) and shows major landmarks in pictorial terms. Major vantage points are indicated by the fan-like symbol. Map reprinted by permission. Michelin, PARIS AND PRINCIPAL SIGHTS NEAR BY, Paris, 1967.

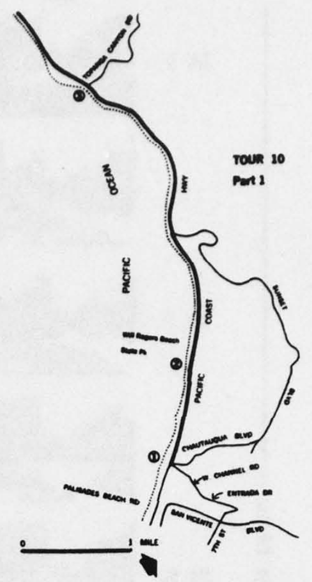


3.4 TRIP TIK: BOSTON TO WASHINGTON, D.C.

TRIP TIKs are personalized route maps prepared by the American Automobile Association. Given any origin and destination in the U.S., AAA uses standardized maps of route segments to prepare a strip map of the entire itinerary. The recommended route is marked in felt marker; the route proceeds sequentially from front to back of the booklet. Detailed maps and verbal descriptions of metropolitan areas are included for each segment of the route. The system is valuable for the motorist and could be adapted to other forms of transportation. Map reprinted by permission of American Automobile Association. Copyright AAA.







UP THE COAST TO MALIBU

LENGTH: *26 miles round trip*
TERRAIN: *Mainly flat*
TRAFFIC: *Medium to heavy*
BEST RIDDEN: *Any time of the year*

The ride from Santa Monica to Malibu on Pacific Coast Highway has a great sense of distance and place, despite its reasonable length. You leave the big city behind, pedal steadily on through vast, scenic spaces, and finally arrive at a quaint village with beautiful and distinctive inhabitants. It is sort of cross-country touring in miniature, a foreign experience in your own backyard. Pacific Coast Highway is a fast road, with a goodly amount of car and truck traffic, particularly in summer. But there are marked shoulder lanes on both sides, so that the cyclist is removed somewhat from the main stream. In addition, motorists are more used to seeing bicycle riders on this stretch of open road than elsewhere, and tend to give them wide berth. En route, we have plenty of time to take in the various features of the seaside environment: the eroded palisades, the mountain canyons running into the ocean, the shifting sands, the offshore reefs, and the way the coastline is formed into numerous small bays. The breeze usually blows directly offshore, cleaning the air without really slowing our progress in either direction. Each season has its own pleasures on the beach, from the refreshing swims of summer to the envigorating air and churning seas of winter. Having sampled one, the cyclist will want to explore them all.

Along the Way

1. Our sea ride begins on the Pacific Coast Highway at the mouth of Santa Monica Canyon, where Chautauqua Boulevard meets West Channel Road. Will Rogers Beach has ample parking; but on summer weekends, the lots fill up early, so an early start is best then. The cozy eateries and drinkeries in the Canyon offer a stirrup cup of various kinds to the dauntless rider.

2. Will Rogers Beach State Park stretches for over three miles of coastline to Castle Rock at the city limits. The large and good-looking apartments that have been built against the palisades are probably the wave of the future — a compromise between those who want to live at the beach and those who want to use it.

3. Around Topanga Canyon Boulevard we encounter the older type of oceanfront development: rows of shoulder-to-shoulder homes, cottages, apartments, and clubs, which barricade the beach quite effectively against the public. Access ways have now been opened by the County at several points, and cyclists will be pleased that the days of such completely selfserving land use are probably over.

4. The scalloped beaches just west of Topanga have close-in reefs which attract many fish, as well as the favorite game of skin divers — the California Spiny Lobster. We may meet some of the wet-suited hunters on shore, or see their red and white flag bobbing on the waves.

5. We approach Malibu along a continuous line of dwellings, punctuated by quick food stands, shops, gas stations, and whatall, most with giant overhead signs. Not a great deal of respect has been shown here to our splendid Riviera.

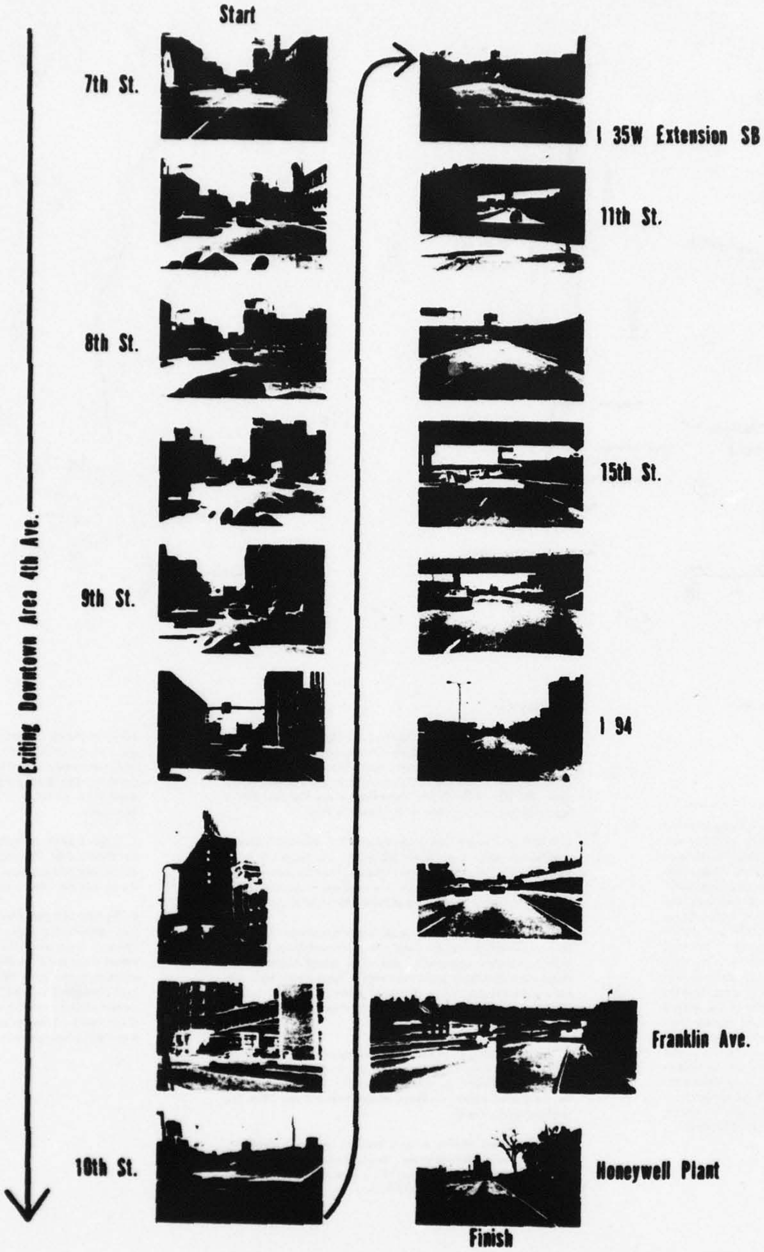
6. Malibu Pier is a properly salty collection of seafood restaurants and fishing supply shops. Locals drop their lines from pierside, while others take the sports fishing boats which leave from pier's end for cruises up the coast. A good place to relax for a while over a soft drink, a beer, or a hot cup of coffee, depending on you and the season.

7. Gidget is alive and well at Surf Riders State Beach, just west of the Malibu Pier. This portion of surf line has been reserved for the hot-doggers and hang-tenners, and one can see them hard at it whatever the weather or time of day.

8. We bear left onto Malibu Road, which carries us two-and-a-half miles further along the shoreline, beside some of Malibu Colony's finest and most interesting beach houses. Spare and simple Hunt house, at 24514 Malibu Road, has received special commendation; it was designed in 1955 by Craig Ellwood. The road runs into the Coast Highway near Solstice Beach, and here we turn around to retrace our route back to Santa Monica Canyon. Don't worry, the ocean views are never the same twice, and the way back proves just as intriguing as the way out.

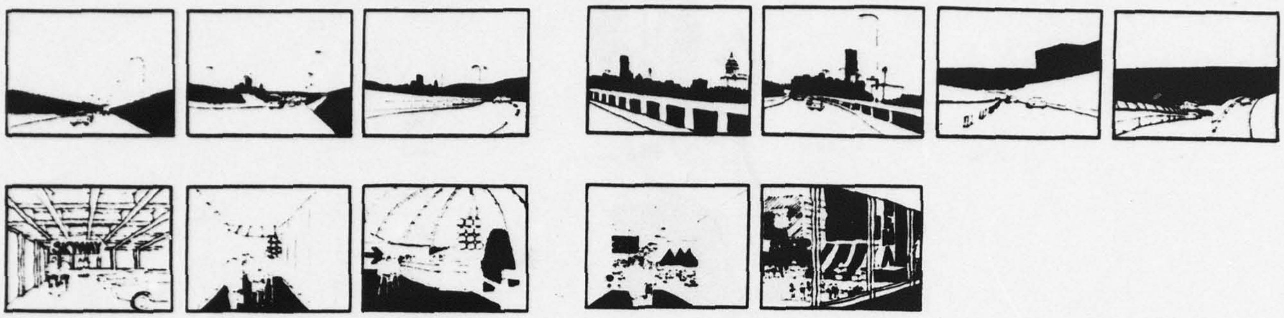
3.5 VERBAL ROUTE GUIDE: UP THE COAST TO MALIBU

Verbal maps, in addition to being comprehensible to those who have problems with conventional maps, can provide more information and a stronger environmental sense. This bicyclists' guide from Santa Monica to Malibu evokes, in a few words, strong pictures of the landscapes, people, and activities one can expect to find along this section of the Pacific Coast Highway. Each route begins with an abbreviated assessment in terms of length, terrain, traffic, and recommended season or time, followed by a description of the whole experience in general terms. Next, points of interest are described, with special attention to comforts and interests of the cyclist. These are keyed into a skeletal reference map. Maps reprinted by permission. Gershon Weltman and Elisha Dubin, BICYCLE TOURING IN LOS ANGELES, Ward Ritchie Press, Los Angeles. Copyright 1972 by the authors.



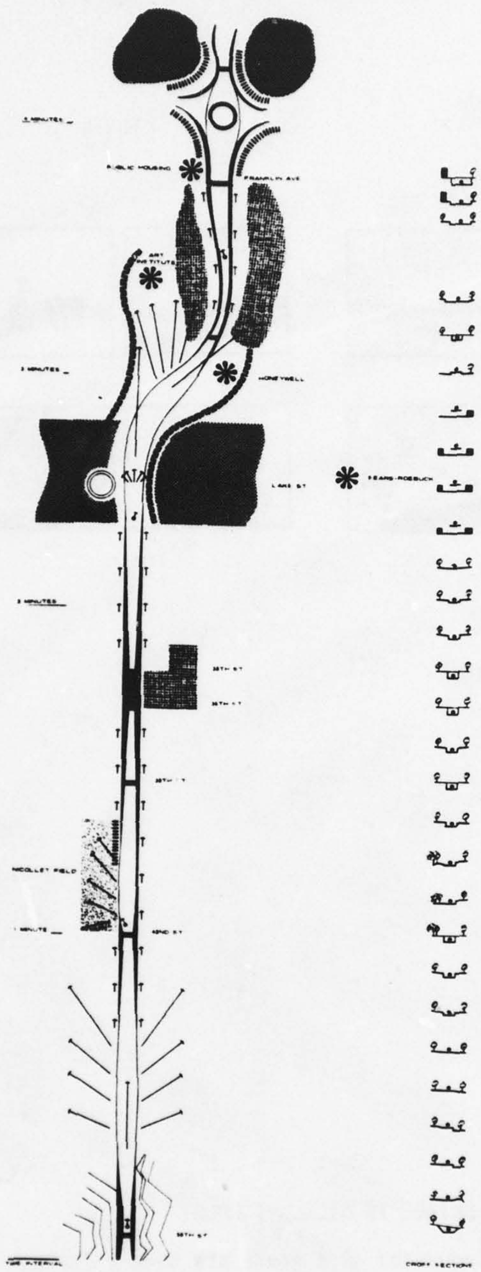
3.6 PHOTO ROUTE SEQUENCE: EXITING DOWNTOWN AREA VIA FOURTH AVENUE, MINNEAPOLIS

Route sequences of still photos or film are useful in environmental analysis and design and can also be effective in route learning. In still photo sequences, it is important that each photo contain a repetition of some identifiable element from the previous photo so there is no confusion about the relations between photos. The eighth photo down on the left indicates that one is going to turn a corner. Although photo sequences provide good route information, there is no sense of what is outside the picture frame. In addition, they normally have to be annotated with such information as street names and addresses which normally are not dominant enough in a photograph. Map reprinted by permission of Department of Planning & Development, City of Minneapolis, 1969.



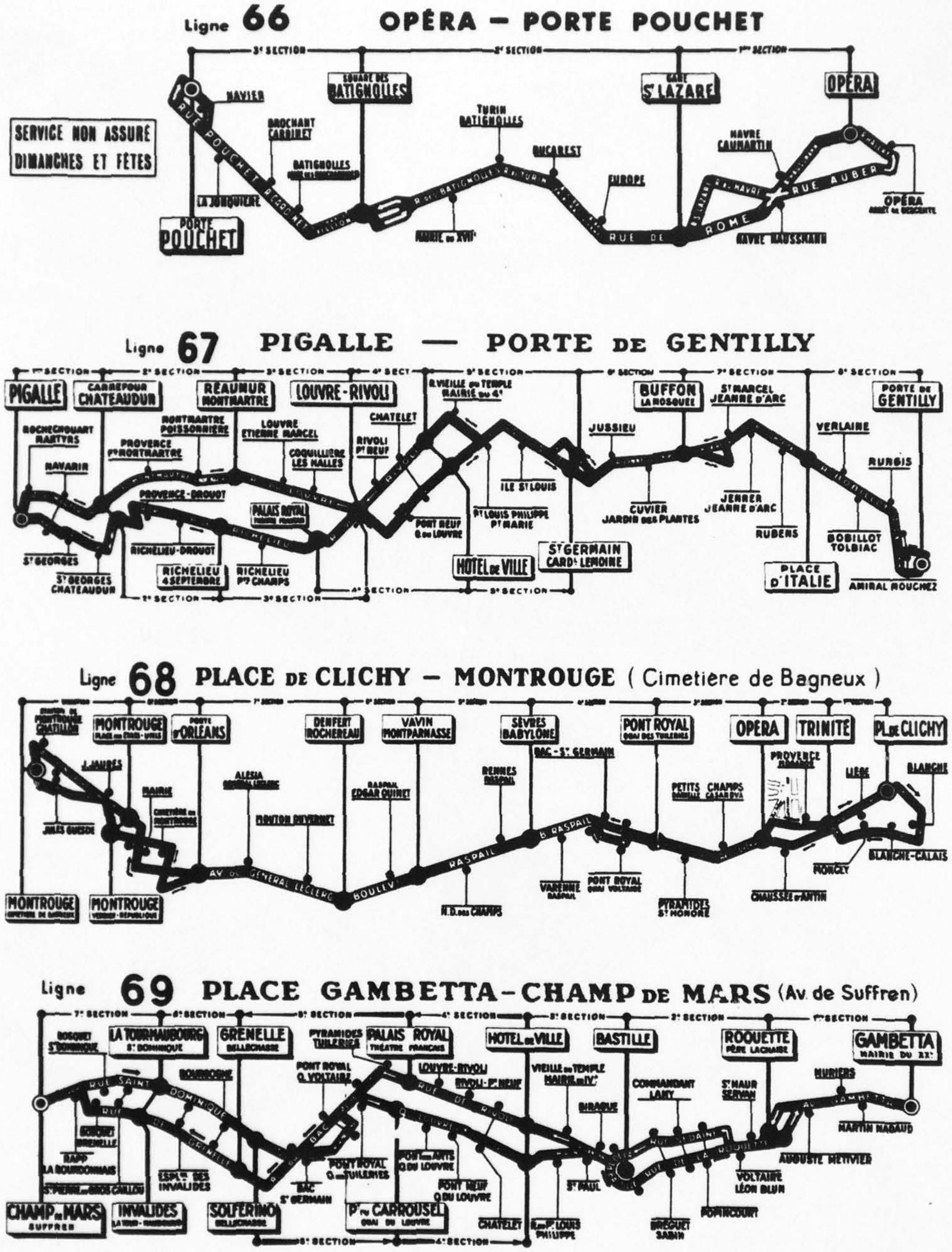
3.7 SEQUENCE FROM I-35W BRIDGE TO NICOLLET MALL

In many respects, sketch sequences of a route are more effective than photo sequences because they allow emphasis and editing. What is most important can be highlighted, and what is not informative or merely distracting, eliminated or simplified. Since the interpretive element is strong, caution must be taken so style does not predominate over information. Sketch sequences, in addition to having low production costs, are useful in simulating the visual impact of proposed environmental changes as perceived from a highway or street. Map reprinted by permission of Department of Planning & Development, City of Minneapolis, 1970.



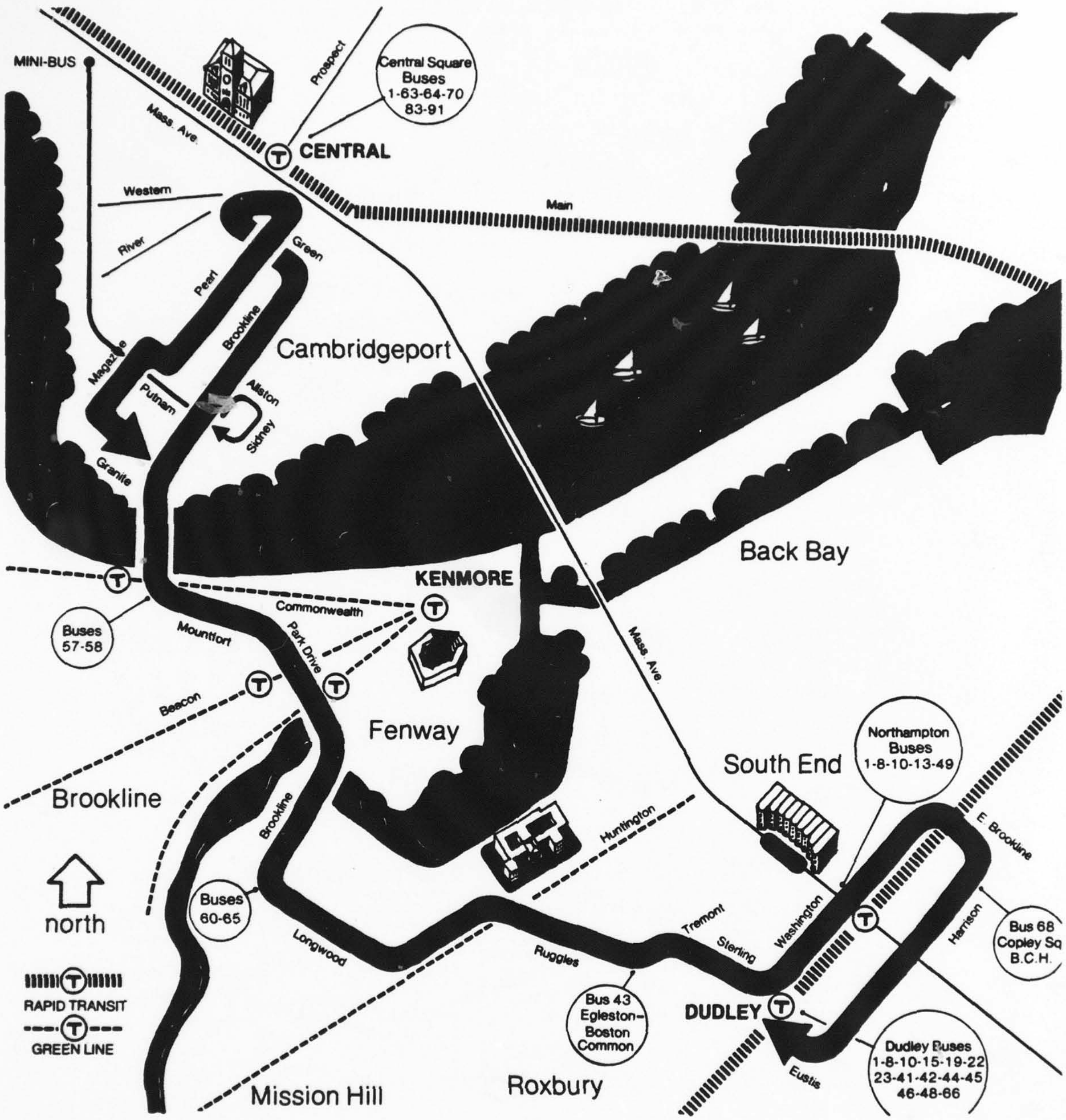
3.8 MINNEAPOLIS: PROPOSED IMAGE STRUCTURE FOR A HIGHWAY

Visual experience along a highway is symbolized here. Landmarks are shown by asterisks, open fields of view by long arrows, enclosures and tunnels by heavy black. Diagrammatic sectional views accompany the route on the right. The map is to be read from the bottom up; time distance intervals are given for each minute of travel. Perceptual maps such as this have been useful in highway design and evaluation. Map reprinted by permission of Department of Planning & Development, City of Minneapolis, 1969.



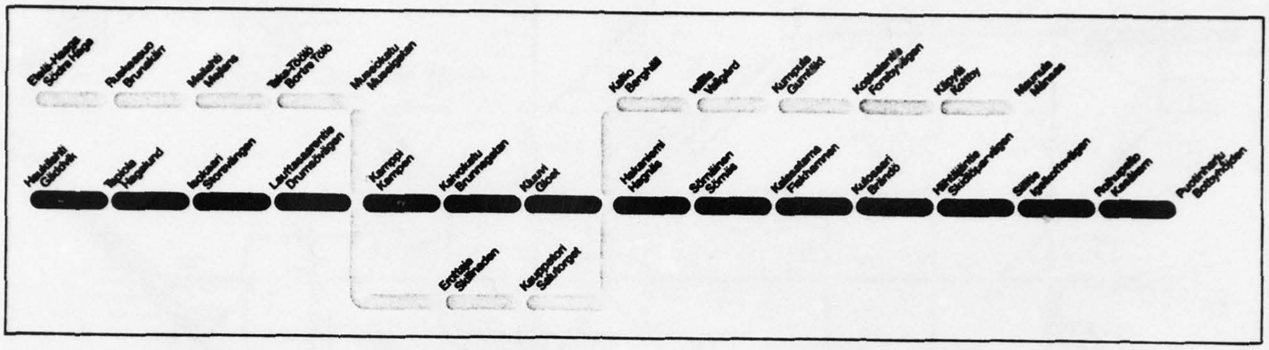
3.9 BUS ROUTES: TRACÉS DÉTAILLÉS DES LIGNES D'AUTOBUS

These bus route maps provide the names of major stops and Metro connections, as well as fare divisions for Paris bus lines. The routing directions, turns, etc. are approximately correct, but no distracting information about intersecting streets or buildings is included. The user must know where he is going in terms of the major stop names in order to use the maps. No information about specific sites is included except indirectly, as in the use of the "Hotel de Ville" Metro station as a major stop. Presenting the bus lines individually, as this collection does, makes them easier to follow than the difficult untangling which a single mapping of complex interwoven bus lines can involve. Map reprinted by permission. Raymond Denaès, GUIDE GÉNÉRAL DE PARIS, Editions L'Indispensables, Paris.



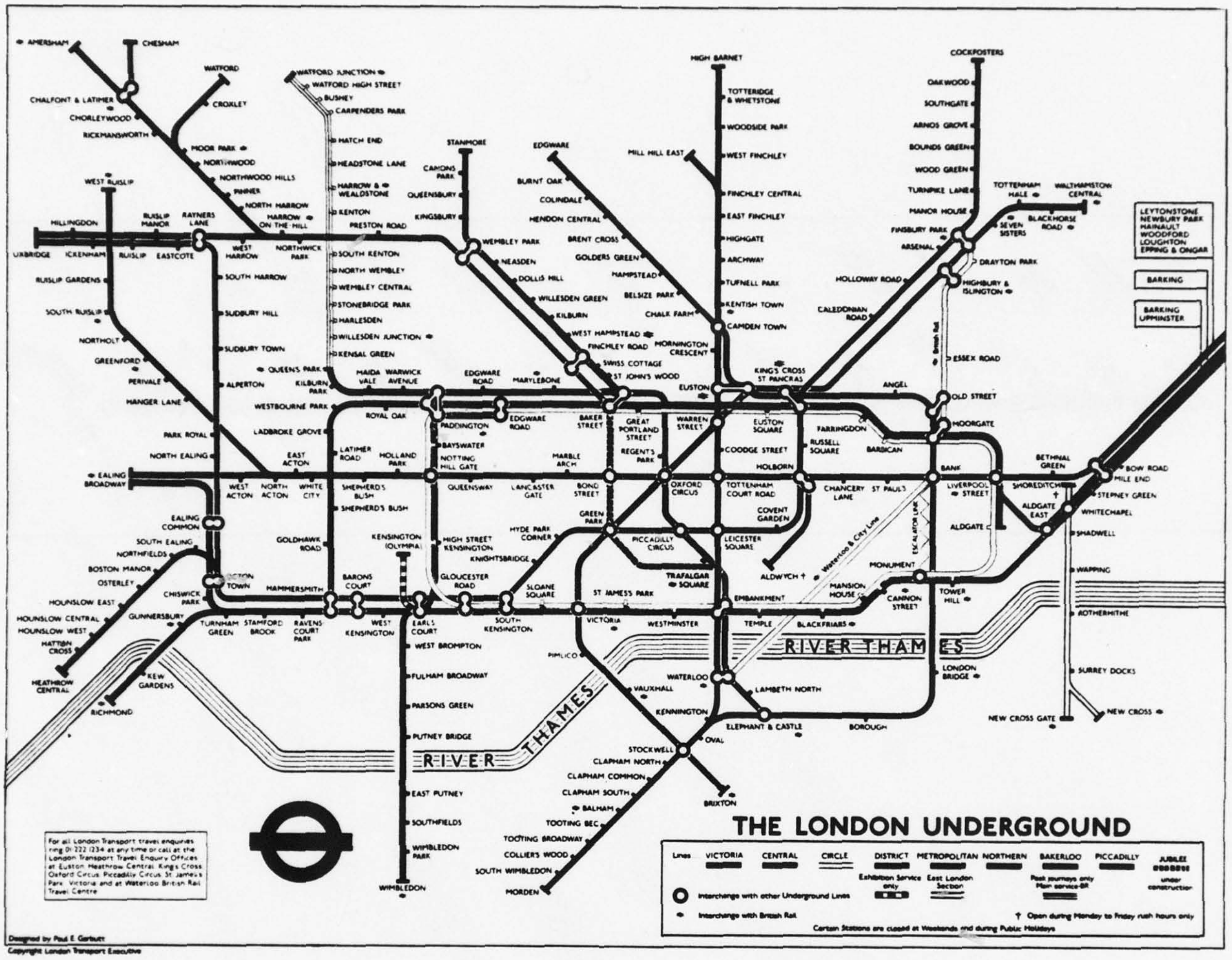
3.10 PICTORIAL BUS ROUTE: BUS 47

Communicating essential route information without confusion is a problem because of the wealth of information available. This map eliminates all but the essential information. The route itself is given visual dominance by increasing its width and printing it in color. Intersecting bus and subway lines are indicated to aid trip planning. Bus schedules are printed on the reverse side of the folder. Major recognizable landmarks on or near the route are shown in pictorial terms. The pictorial technique was used to make the maps readily usable by the general public. Over 150 of Boston's bus routes have been mapped this way. Map reprinted by permission. Michael & Susan Southworth/City Design & Architecture, for Massachusetts Bay Transportation Authority, Boston.



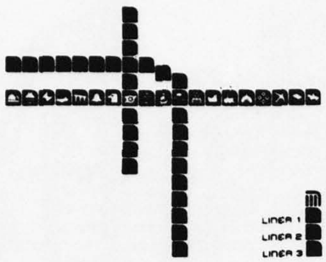
3.11 LINE DIAGRAM FOR HELSINKI SUBWAY

A graphic alternative to the London Underground approach, the Helsinki subway system looks like a string of sausages. Stations are emphasized by breaks in the route. Map reprinted by permission. Ola Laiho, Esko Miettinen of G4 Designers, Helsinki.



3.12 LONDON TRANSPORT UNDERGROUND SYSTEM

The London Underground Map is considered a classic diagrammatic system map and has been the model for numerous subsequent maps in other cities. The system portrayed is extensive and complex, so that focus on its key components - stations and routes - is helpful. The different lines are color coded to make it easier to follow an individual line from beginning to end without getting tangled in the other lines. Easily identifiable symbols are used for stations and interchanges. Unfortunately, light yellow was chosen for the Circle Line, making an outline necessary. As a result, graphic treatment of this line is inconsistent with the rest of the map. The inherent problem in showing a system in a void is that it doesn't answer questions about where one is or where the line is going. Map reprinted by permission of London Transport Executive.



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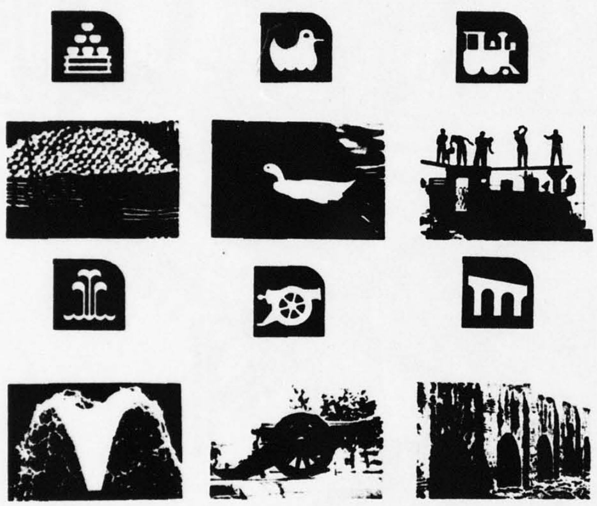
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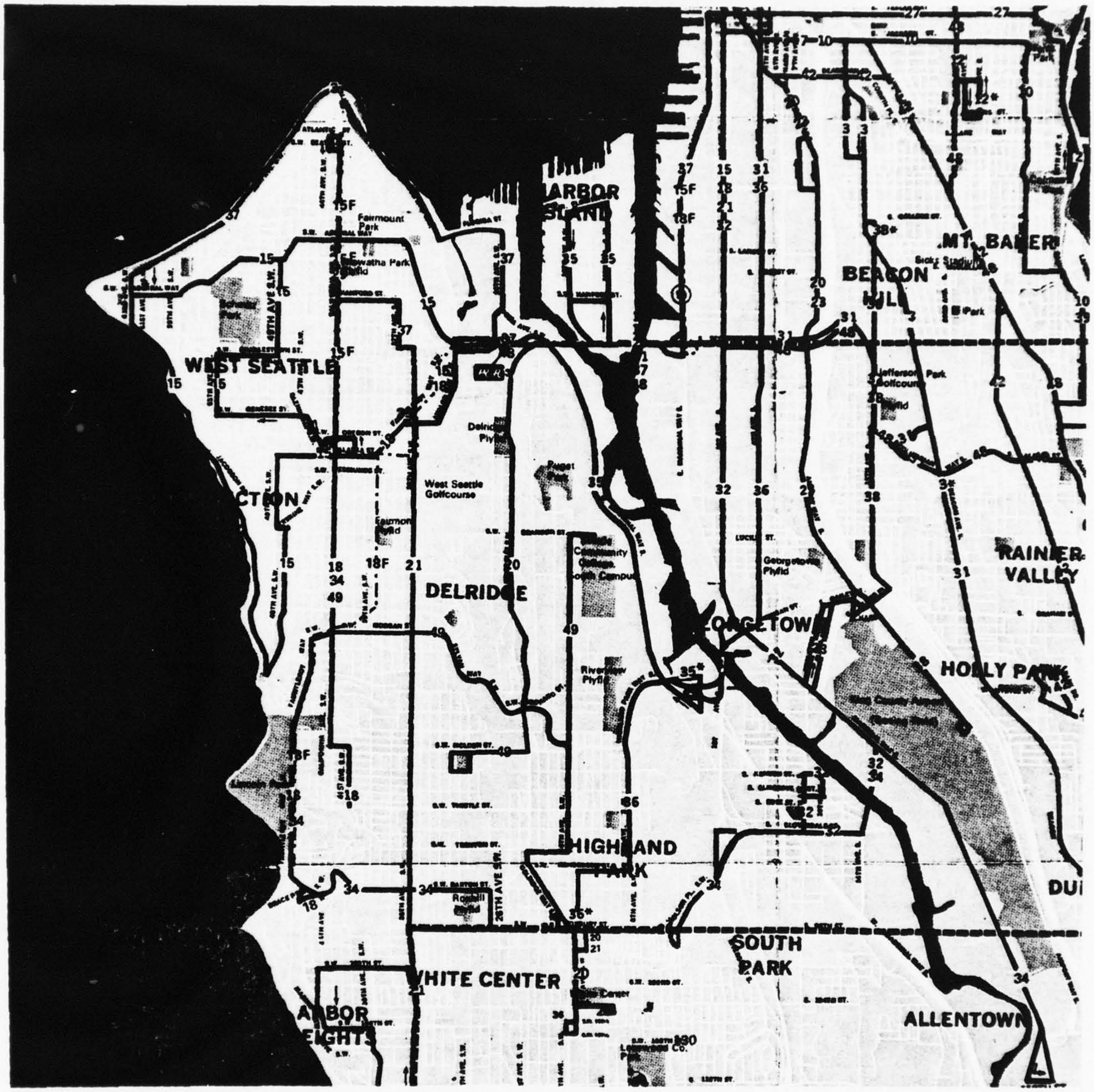
3.13 PICTOGRAPHIC MAPS: MEXICO CITY METRO & NATIONAL ZOO

Pictographs were developed to symbolize landmarks located near each station of the Mexico City metro system. The pictographs have been arranged to represent the order of stations and the overall pattern (1). Sources for several pictographs are illustrated (2). As long as the pictograph suggests the correct destination to most users, the graphic system is easy and direct to use. Pictographs also can be very useful in guiding large crowds of people efficiently. Pictographic signing for the National Zoo is illustrated in (3) and (4). Stylized heads and footprints of animals are used to guide visitors through the zoo. Map reprinted by permission. Mexico City Metro graphic design and photography by Lance Wyman. National Zoo map and graphics program by Wyman and Cannan, New York.

3.14 MANHATTAN BUS GUIDE

This rather successful bus map uses four colors - red, orange, blue and green - to distinguish Northbound, Southbound, Westbound, and Eastbound buses. Buses are identified by numbers inside circles along routes. The light gray street pattern base helps make the map intelligible, but only streets traversed by buses are named. As with the New York subway map, district names and more landmarks would make the map more useful. Map reprinted by permission. New York City Transit Authority, Copyright 1974.

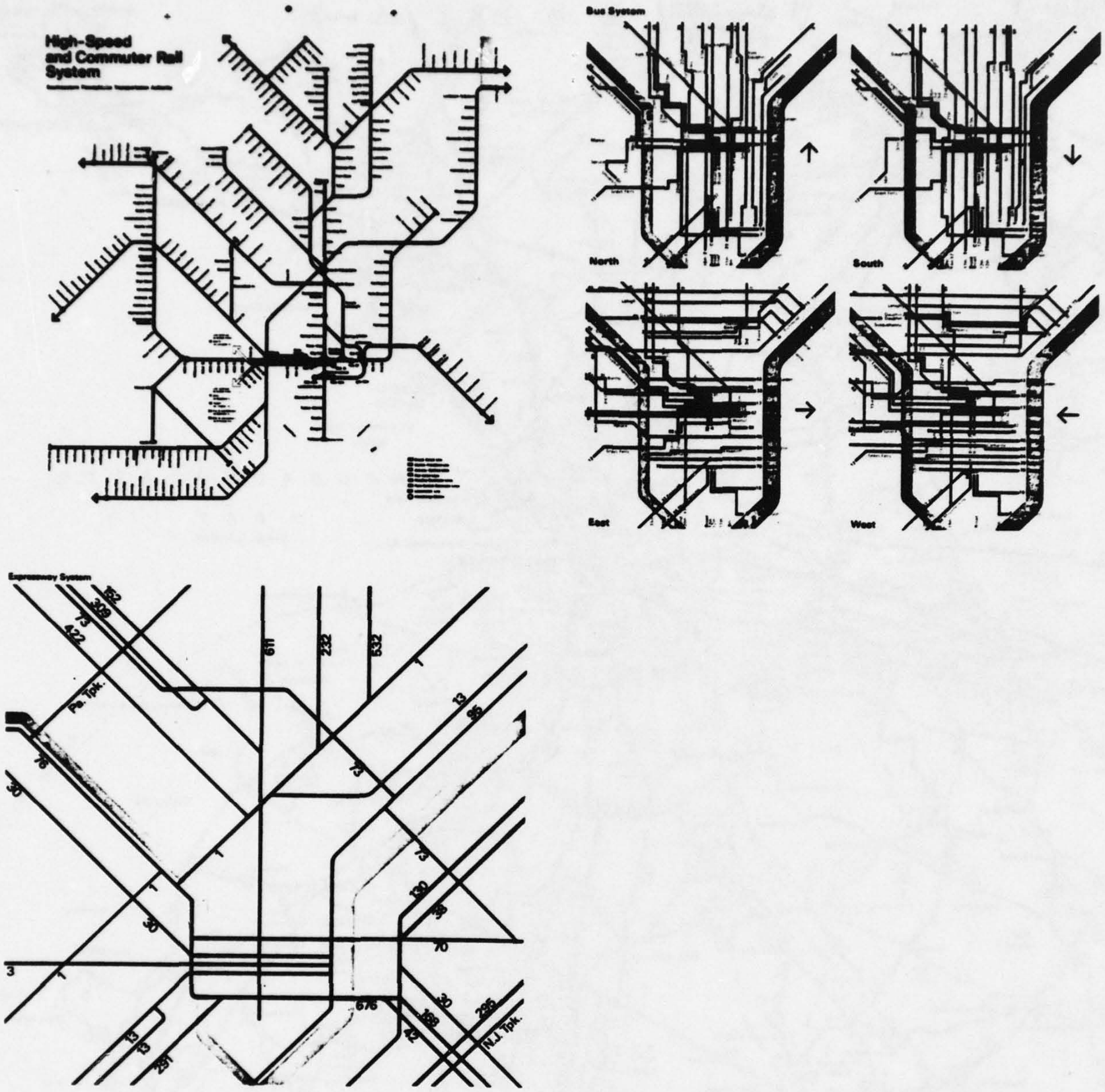


3.15 RIDER MAP: SEATTLE/KING COUNTRY BUS ROUTES

One of the more successful solutions to the problem of bus system mapping, Seattle shows the entire geographic context and street system in pale background tones. To avoid information overload, only major streets are named. Routes are identified by frequently spaced large numbers. Unfortunately, there is occasional overprinting of route numbers and street names. Supplemental street maps are needed for detailed street finding, but transfer from this map to a street map is made relatively simple by the undistorted street grid used as a base. Map reprinted by permission of Metro Transit, Seattle, 1975.

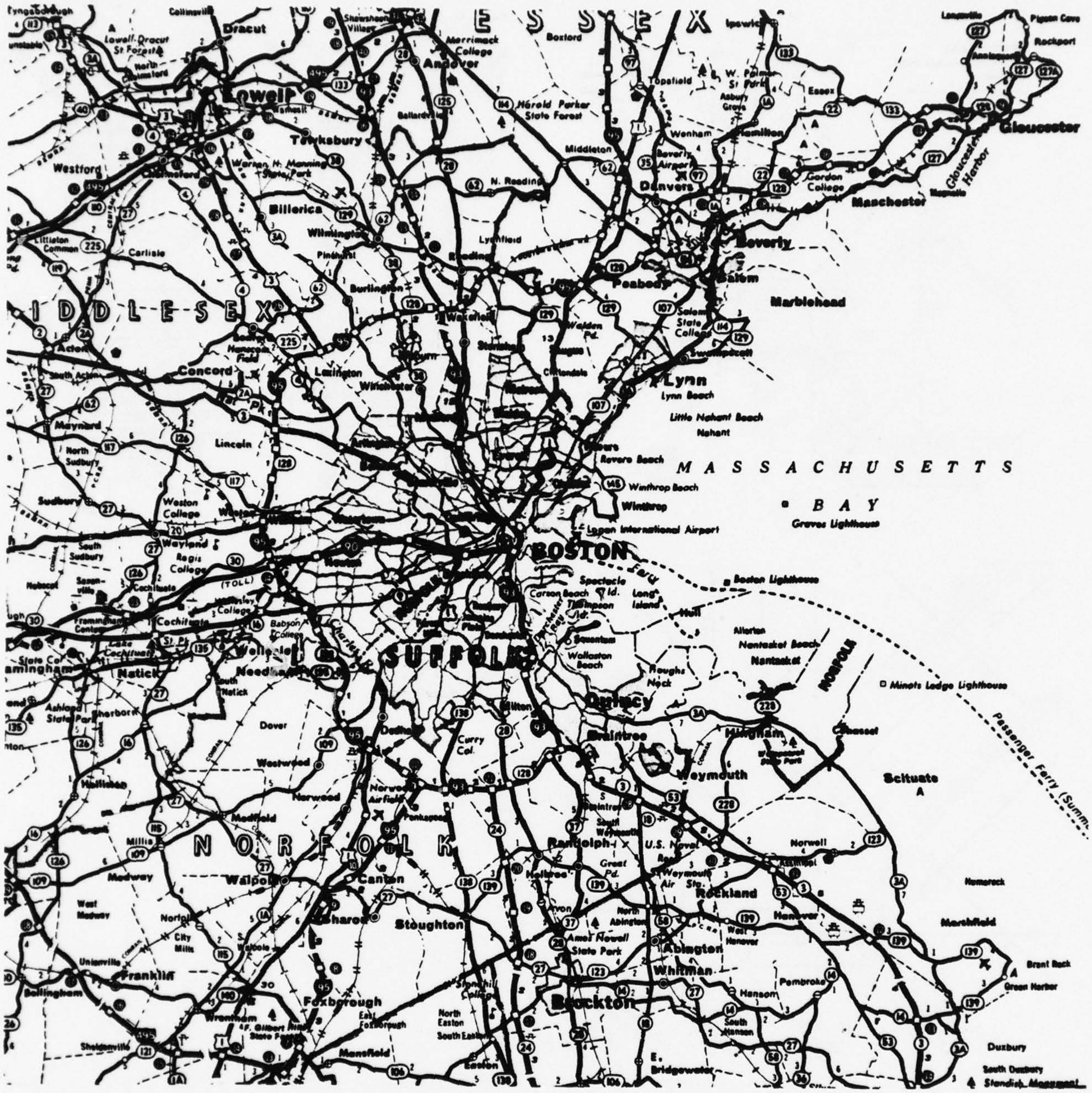
3.16 PROPOSED NEW YORK SUBWAY MAP

This map, still in the experimental stage, attempts to solve many of the problems of using earlier New York subway maps. Care has been taken to give many geographic references, including streets, street names, and several landmarks and points of interest. The Manhattan street pattern has been distorted, however, to accommodate the complexity of the subway network. Different lines are identified by numbers or letters at stations and along routes. This facilitates reproduction of the map in a variety of media and color formats and eliminates the need for color discrimination. The map is being tested extensively before final delineation. Map reprinted by permission of Metropolitan Transportation Authority, New York City, 1978.



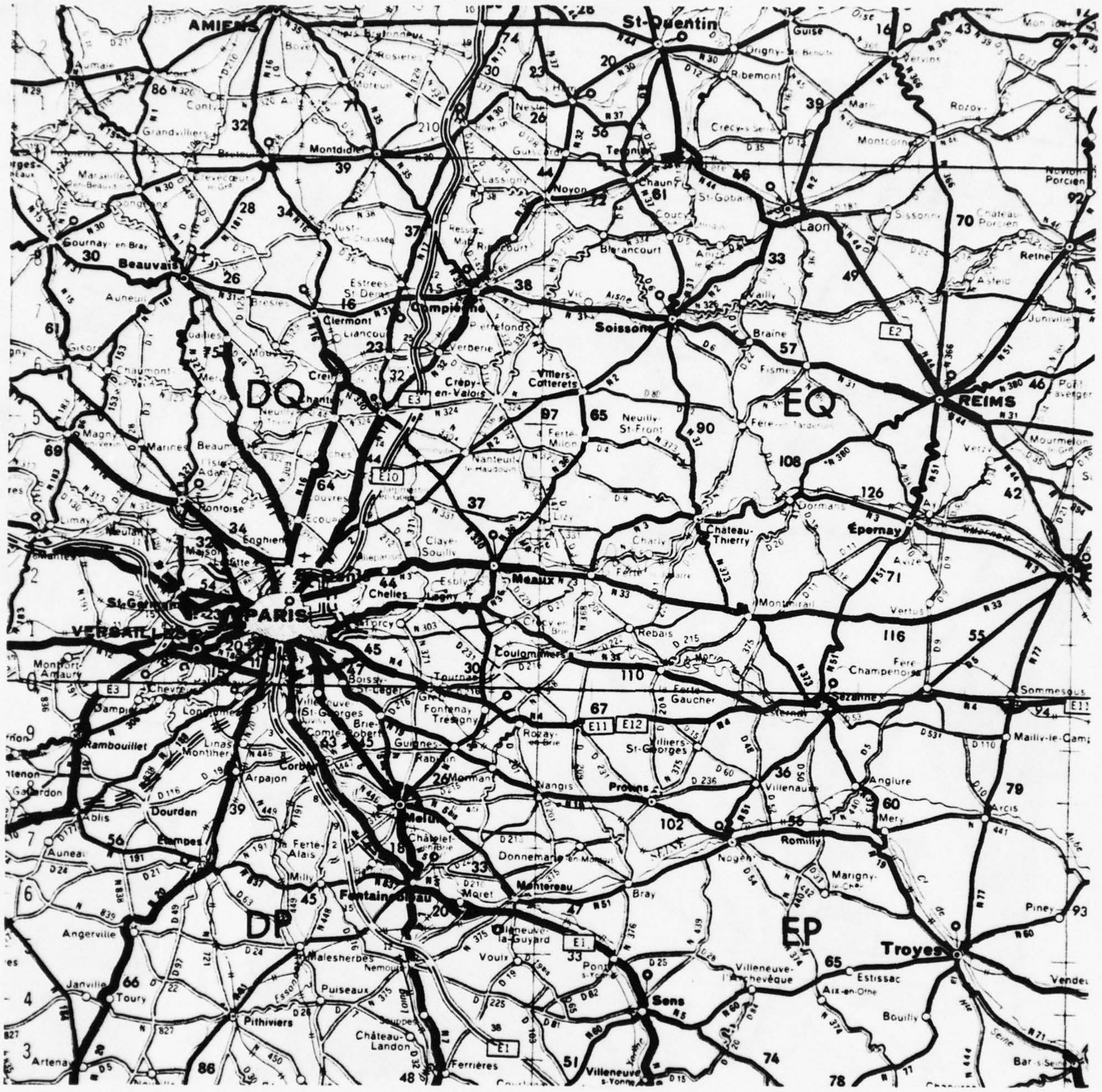
3.17 SUBWAY, BUS, AND EXPRESSWAY MAPS: PHILADELPHIA

Dissection, distortion, and simplification have helped make the Philadelphia transportation system more understandable. The subway map uses the skeletal system approach. Routes are regularized and simplified, and station names are emphasized. Only the rivers are shown for geographic orientation. No other landmark data is given, making routes appear to exist in a vacuum. While comprehension of the subway system is made simple, relating that system to the rest of the city is difficult for strangers. Other maps, including mental maps, must be used in conjunction with system maps such as these. The bus system map uses similar principles. To simplify the system, North/South and East/West buses have been shown on two separate maps. Map reprinted by permission. Richard Saul Wurman and John Andrew Gallery, MAN-MADE PHILADELPHIA, A GUIDE TO ITS PHYSICAL AND CULTURAL ENVIRONMENT, MIT Press, Copyright GEE! 1972



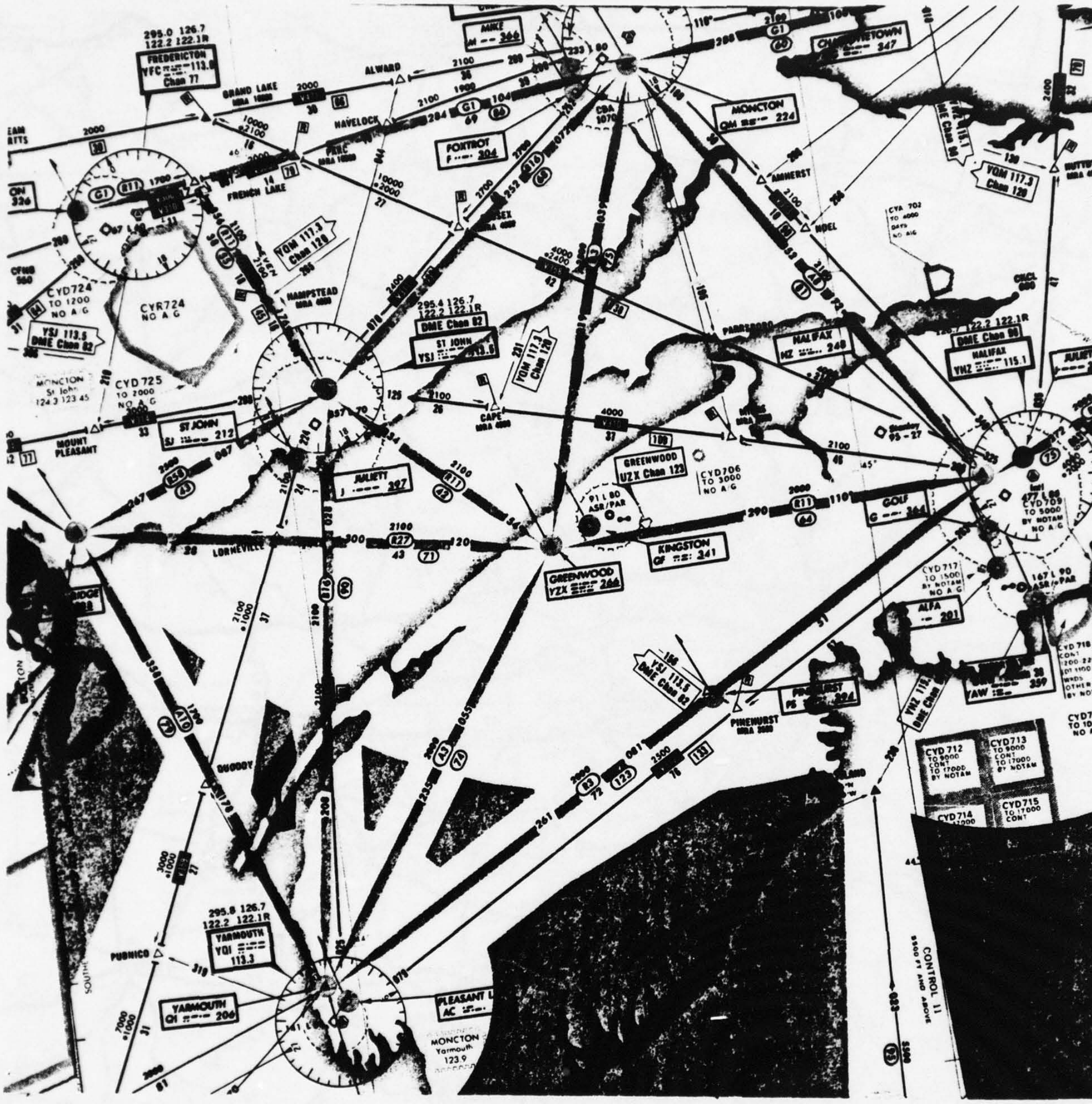
3.18 BOSTON ROAD MAP

Neither innovative nor graphically exciting, conventional road maps concentrate on the circulation system and place names. Roads are graphically coded by type. Little information is given on topography and landmarks. No attempt has been made to make the map more attractive and legible by streamlining the road network through elimination of meaningless curves and bends, as done in the London Underground and many other public transit maps. Nor have other approaches to graphic simplification, such as separation of different systems into separate maps, been employed. Map reprinted by permission of the Commonwealth of Massachusetts, Department of Public Works. OFFICIAL TRANSPORTATION MAP OF MASSACHUSETTS. Copyright 1977.



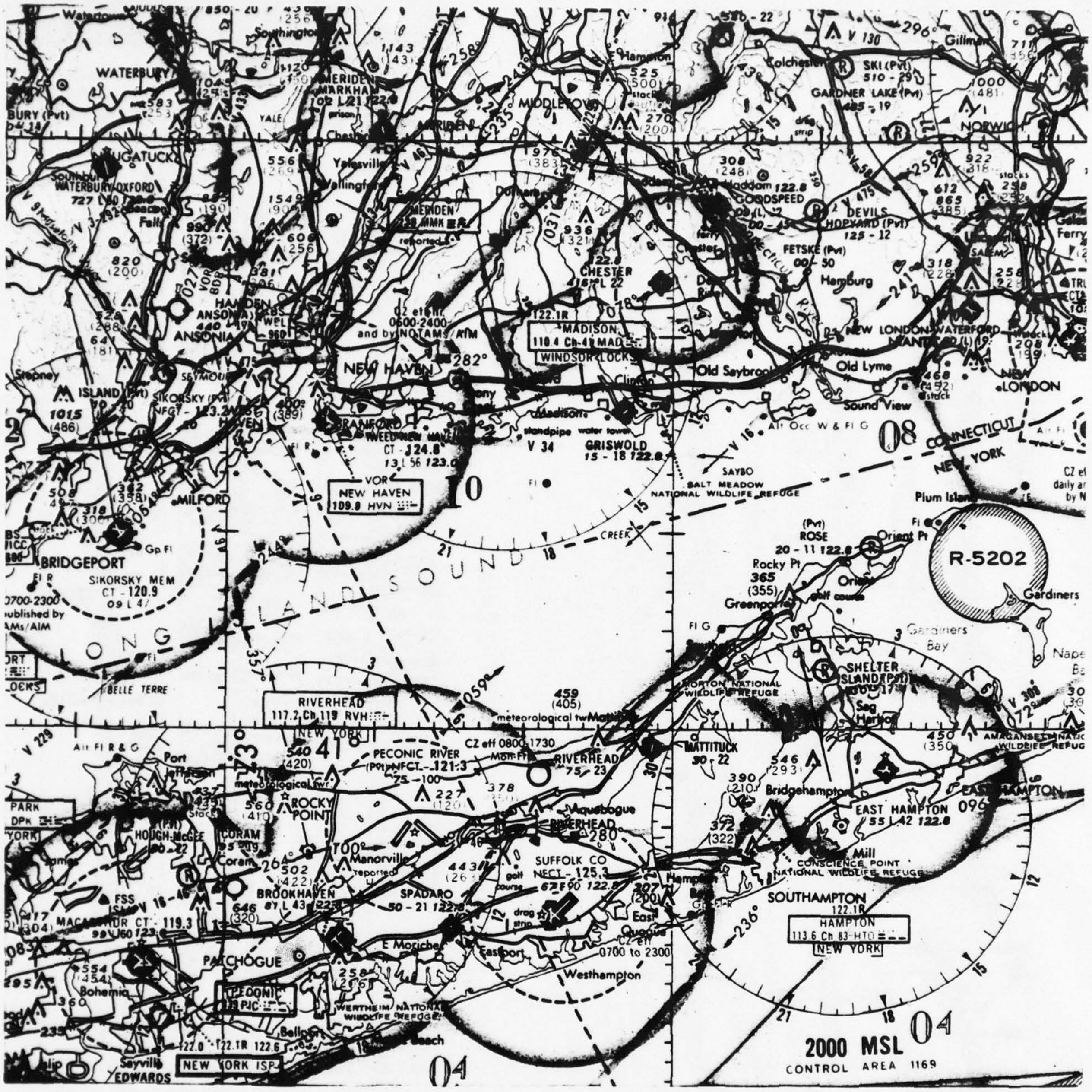
3.19 GERMANY AND CENTRAL EUROPE: OFFICIAL ROAD MAP FOR ALLIED FORCES

Excellent information on road types and conditions is provided on this military map. Color is the primary means for communicating tnese data. In addition, the map emphasizes national boundaries. Note that no topographic data is given. For its purpose--travel by highway--the map is very successful. Map reprinted by permission of USAREUR, Engineer Topographic Center, Washington, D.C.



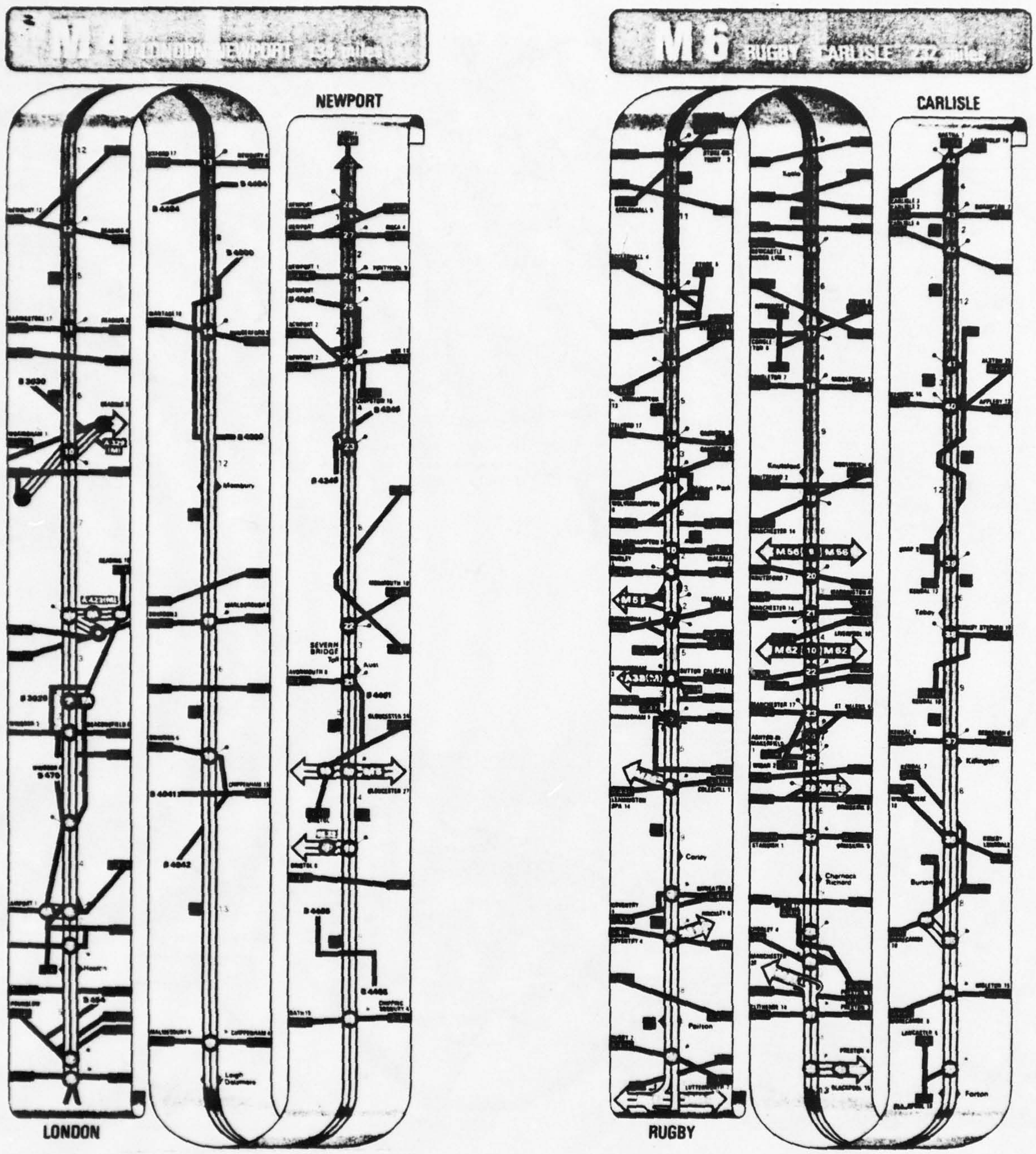
3.20 NEW ENGLAND: FLIGHT INFORMATION PUBLICATION

For the layman, this flight map of the Northeast U.S. is a maze of unintelligible symbols. Place names and faint coastline markings are the only commonly understood ground references. Routes radiate from compass roses giving exact directions for each airway. *Much of the map data concerns radio aids to navigation.* Map reprinted by permission of Defense Mapping Agency Aerospace Center. Published in accordance with Inter Agency Air Cartographic Committee Specifications and Agreements approved by Department of Defense, Federal Aviation Administration and Department of Commerce.



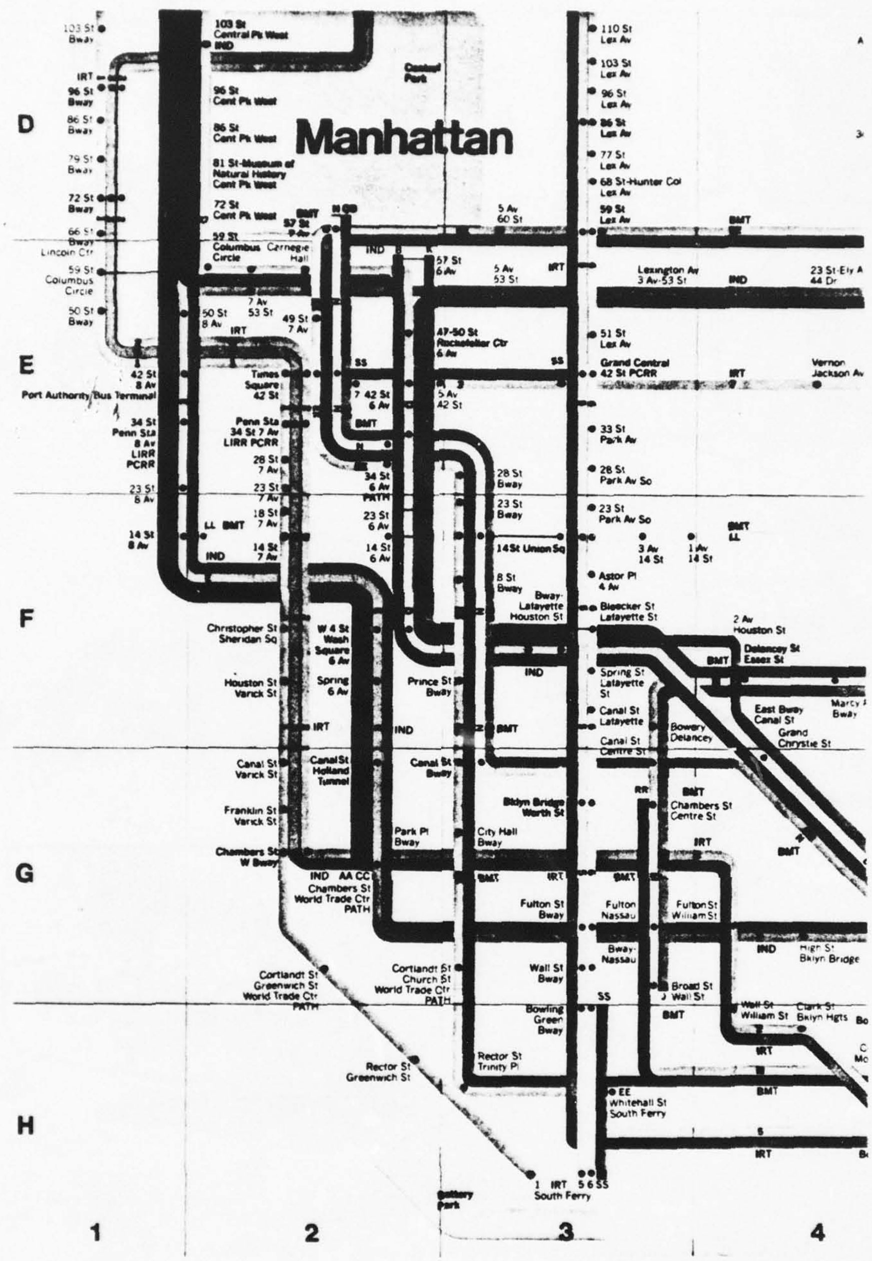
3.21 NEW YORK FLIGHT MAP: SECTIONAL AERONAUTICAL CHART

This flight map shows extensive ground information. Air fields are classified by type, using symbols that require learning. Boundaries of controlled airspace are shown by vignette bands. In addition, information is given on radio aids, special airways, parachute jumping areas, obstructions, and beacons. The problem is that graphic dominance does not correlate with information priorities; for example, highways in dark blue dominate the map, while low altitude Federal airways are in faint blue bands. Map reprinted by permission of National Oceanic and Atmospheric Administration, Rockville, Maryland, 1976.



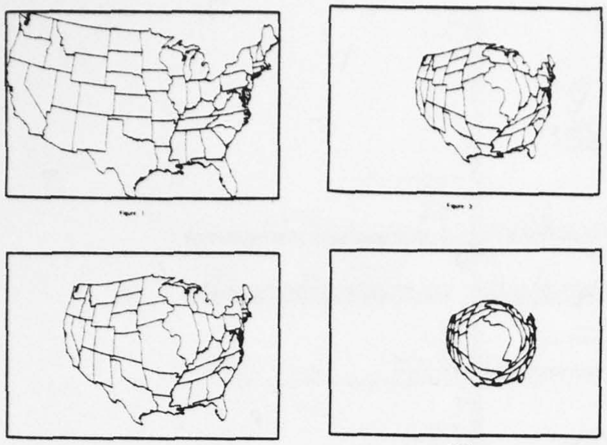
3.22 ROUTE/INTERSECTION MAPS

Entries, exits, and intersections are the main sources of confusion on highways. Thus, these strip maps give detailed information for each decision point. Intervening segments of highway are compressed. Note that the entire route is represented as a straight line, ignoring any curves, since these are not particularly important in highway orientation. Little information is given about the environs; without environmental back-up information, one must know exactly which intersection is needed. Map reprinted by permission of The Reader's Digest Association Limited, London. READER'S DIGEST: A NEW BOOK OF THE ROAD. Copyright 1975.



3.23 NEW YORK SUBWAY GUIDE

The complex New York subway system, a maze of intersecting and overlapping routes, is simplified into handsome diagrams of color coded route lines in the manner of the London Underground map. Distances are distorted for the sake of clarifying the diagram. Streets and some landmarks are named to provide orientation, but more orientation cues such as district names would be helpful. Color coding is useful when no more than a handful of readily distinguished colors is necessary. Color discrinimation of the general public is not adequate for coding of more than five or six variables. Map reprinted by permission. New York City Transit Authority, Copyright 1974.



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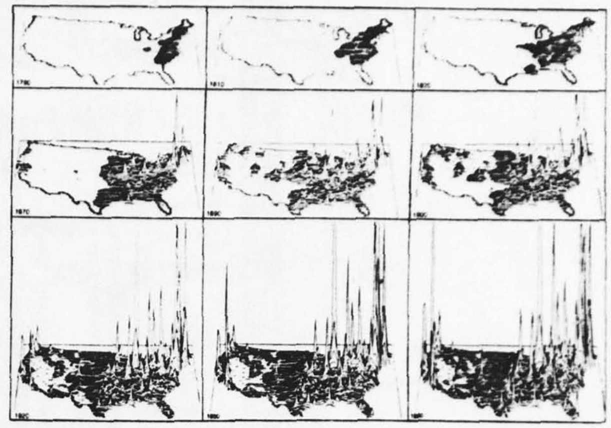

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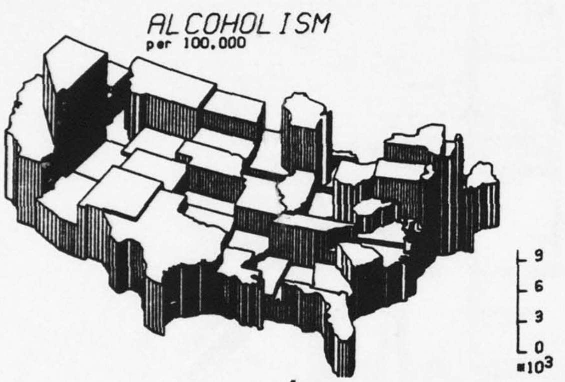

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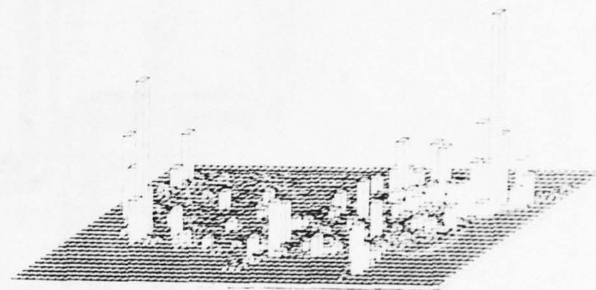

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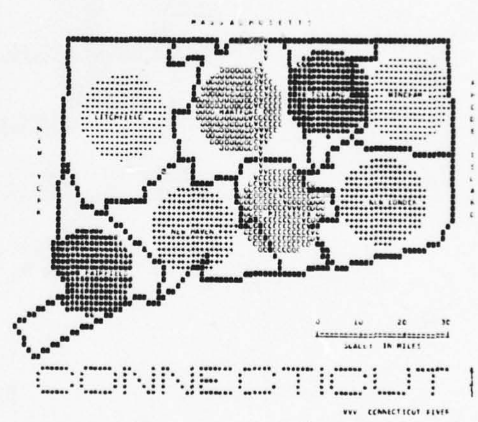

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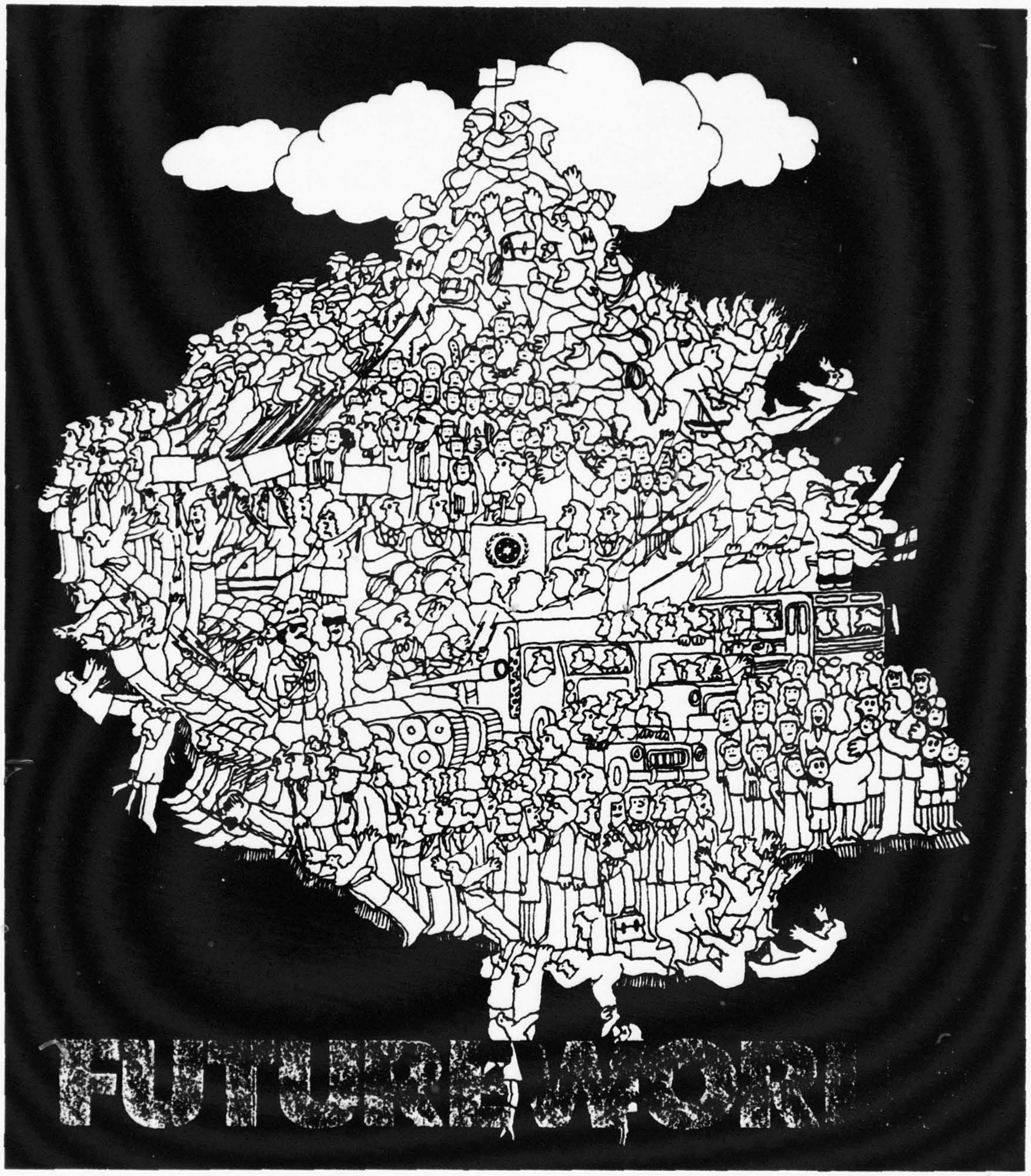
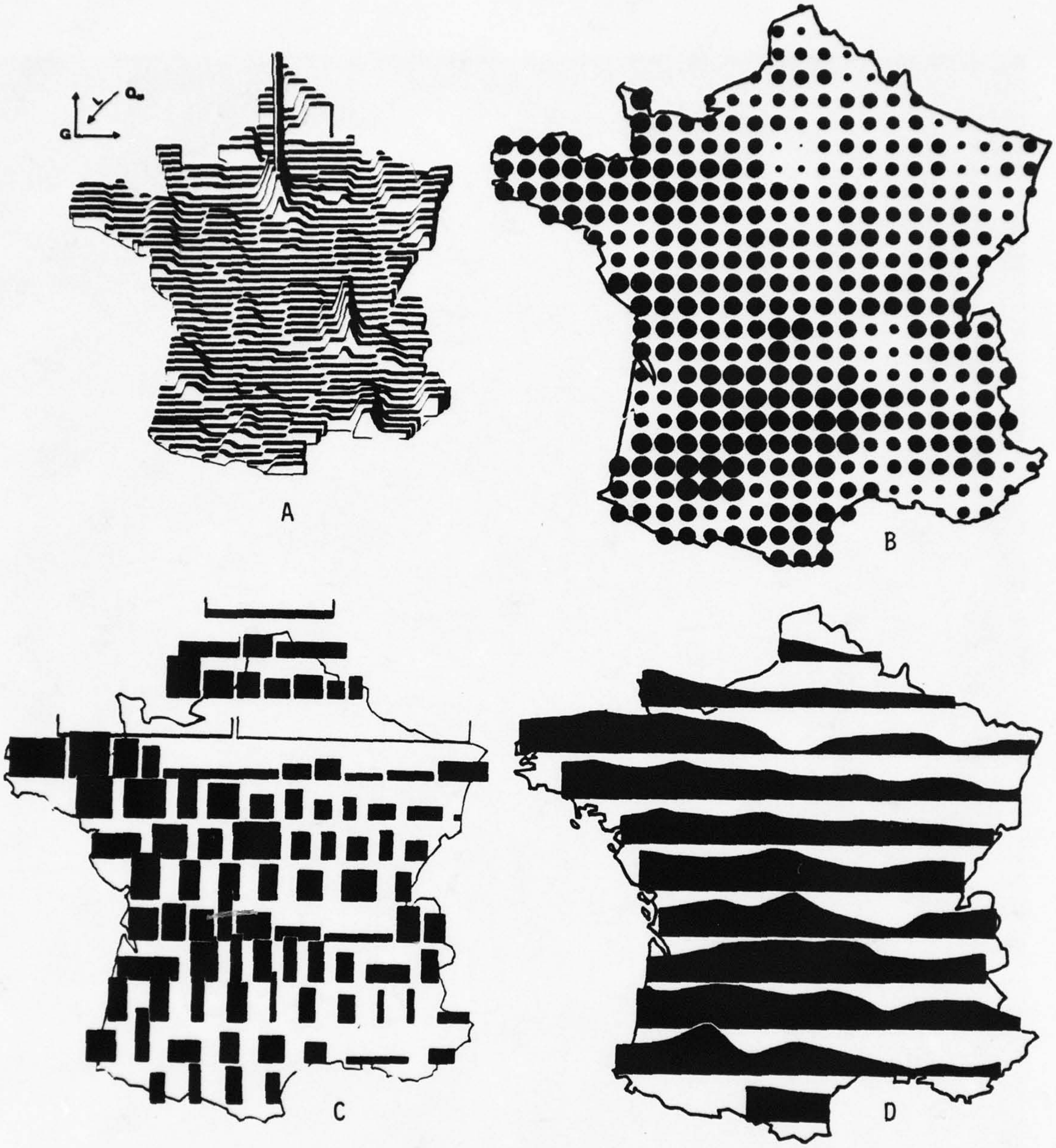
4.1 COMPUTER GRAPHICS: MANIFESTED DESTINY, TRIDIGRAM, SYMAP, PRISMAP, & ODYSSEY

The mapping techniques illustrated by this set of computer generated maps are: (1) Manifested Destiny. Contour lines dramatically convey U.S. population growth at 9 points in time, from 1790 to 1960. (2) TRIDIGRAM. Another technique for representing population, the country is divided into equal cells; height of each column is proportional to population within that cell. (3) SYMAP. Area textures progress in density to represent varying percentage of structures build after 1950. (4) PRISMAP. Amount of alcoholism per 100,000 population in each state is proportional to the height of prismatic projection of the state. (5) ODYSSEY. A map of the U.S. is computer transformed to represent distance from St. Louis, Mo. in terms of long distance telephone rates, rather than miles. Map reprinted by permission of Laboratory for Computer Graphics and Spatial Analysis, Harvard University.



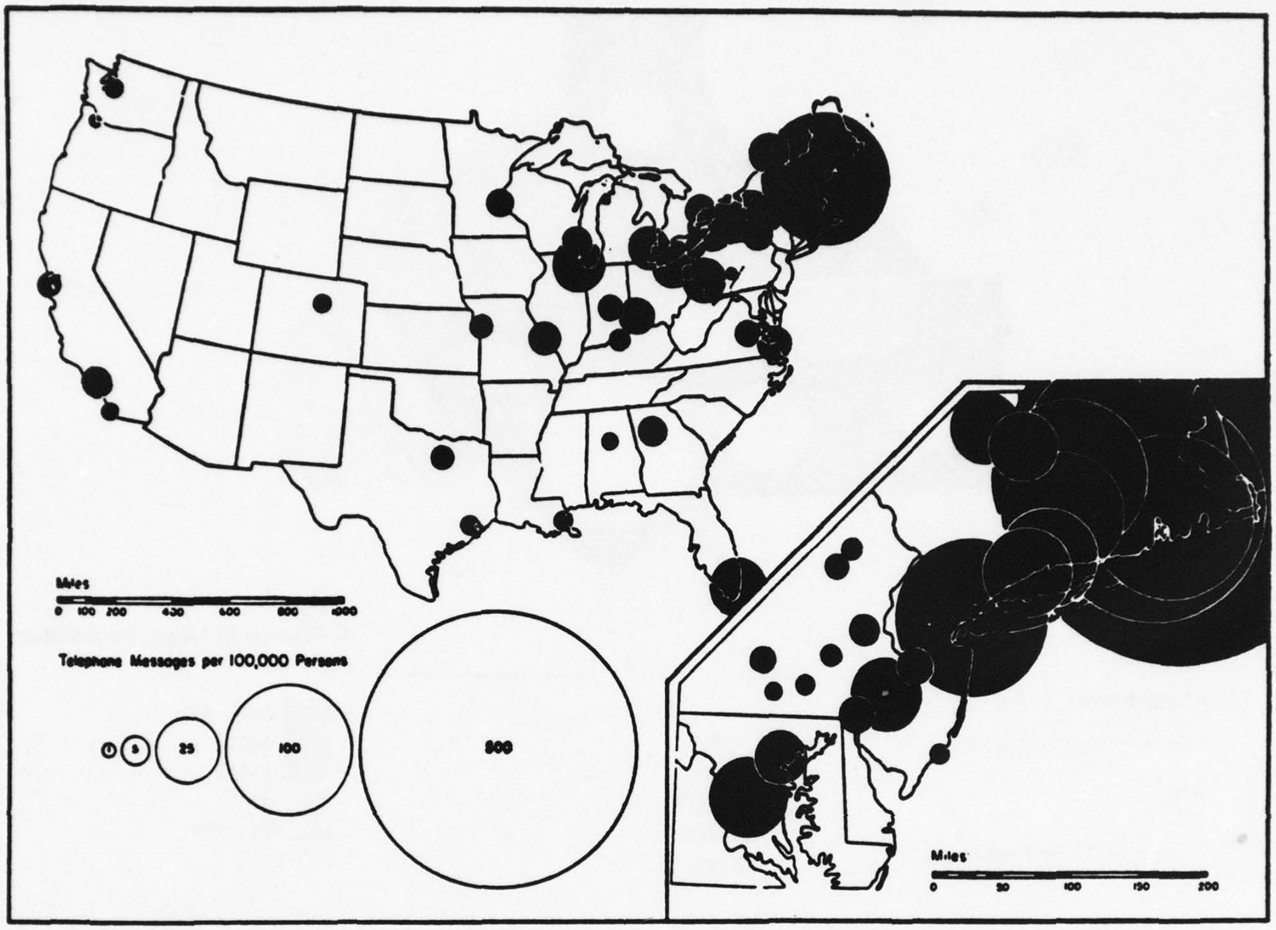
4.2 CARTOON MAP: FUTURE WORLD

The population problem is emphatically expressed in this cartoon map showing great piles of people on North America. No explanation or key is necessary to communicate the intended point to any age group. The idea of showing quantity through exaggerated representations of the actual unit overlaid on the geographic territory is useful. Obviously, the technique is not precise and can treat only relative distribution. Map reprinted by permission of Hal Aber, Dale Moyer; "Headline Focus Wall Map 18", SCHOLASTIC MAGAZINES, INC., Dayton, Ohio, Copyright 1976.



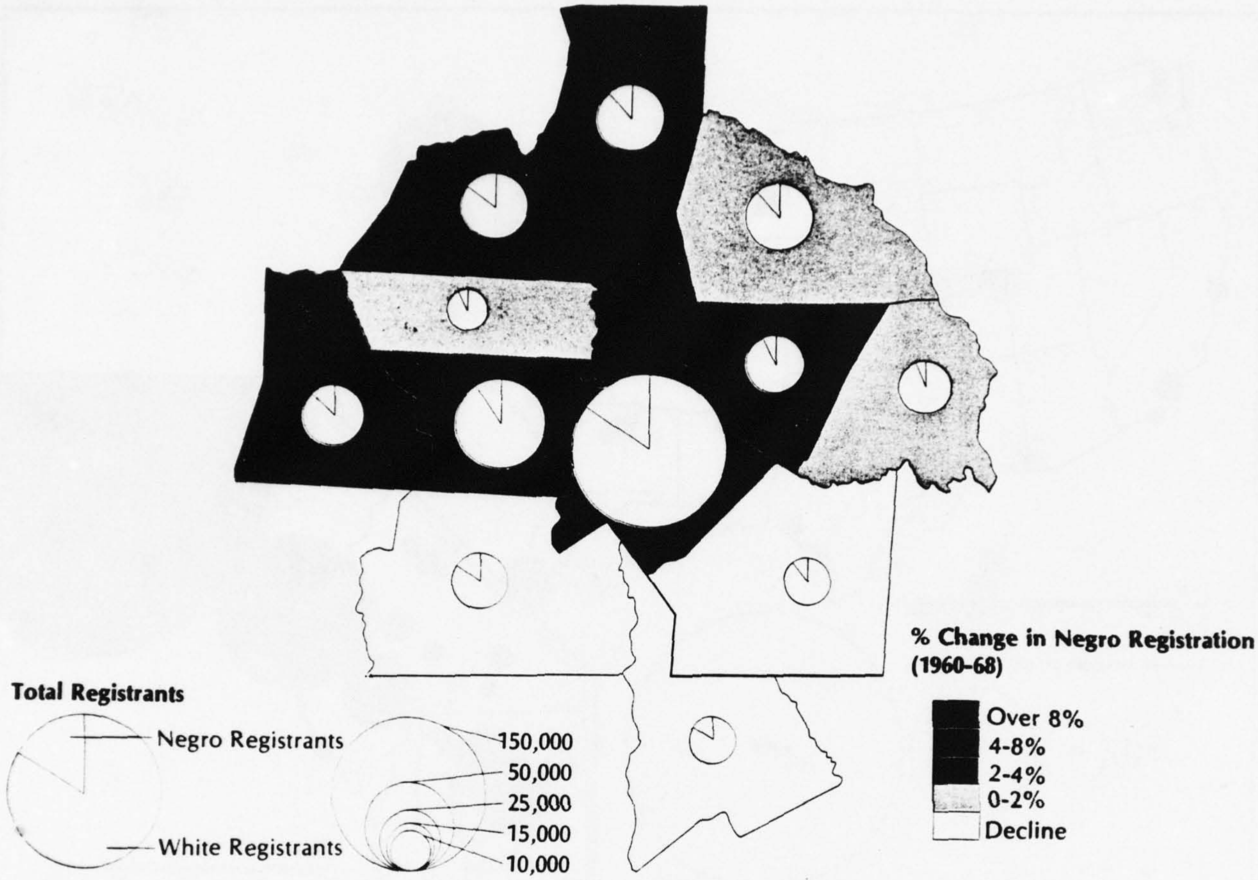
4.3 SELECTED TECHNIQUES FOR COMMUNICATING QUANTITY, DENSITY, AND PERCENTAGE

Techniques for illustrating density, quantity, and percentage are seen in these maps of France. In "A," percentage is shown by a series of equidistant horizontal contour bands. The blacker a region is, the more of a certain quantity it possesses. "B" communicates percentage by dots of variable size spaced on a grid. In "C," both absolute quantity and percentage are given by département. Each département has its own rectangle, with the length of the base proportional to population within the district. Height of the rectangle is proportionate to the percentage of quantity "x" in the district. Thus, the total area of each rectangle is proportional to the absolute quantity of "x." "D" represents quantity or density by means of equally spaced horizontal contour lines. Map reprinted by permission of Jacques Bertin, SEMIOLOGIE GRAPHIQUE, 1967.



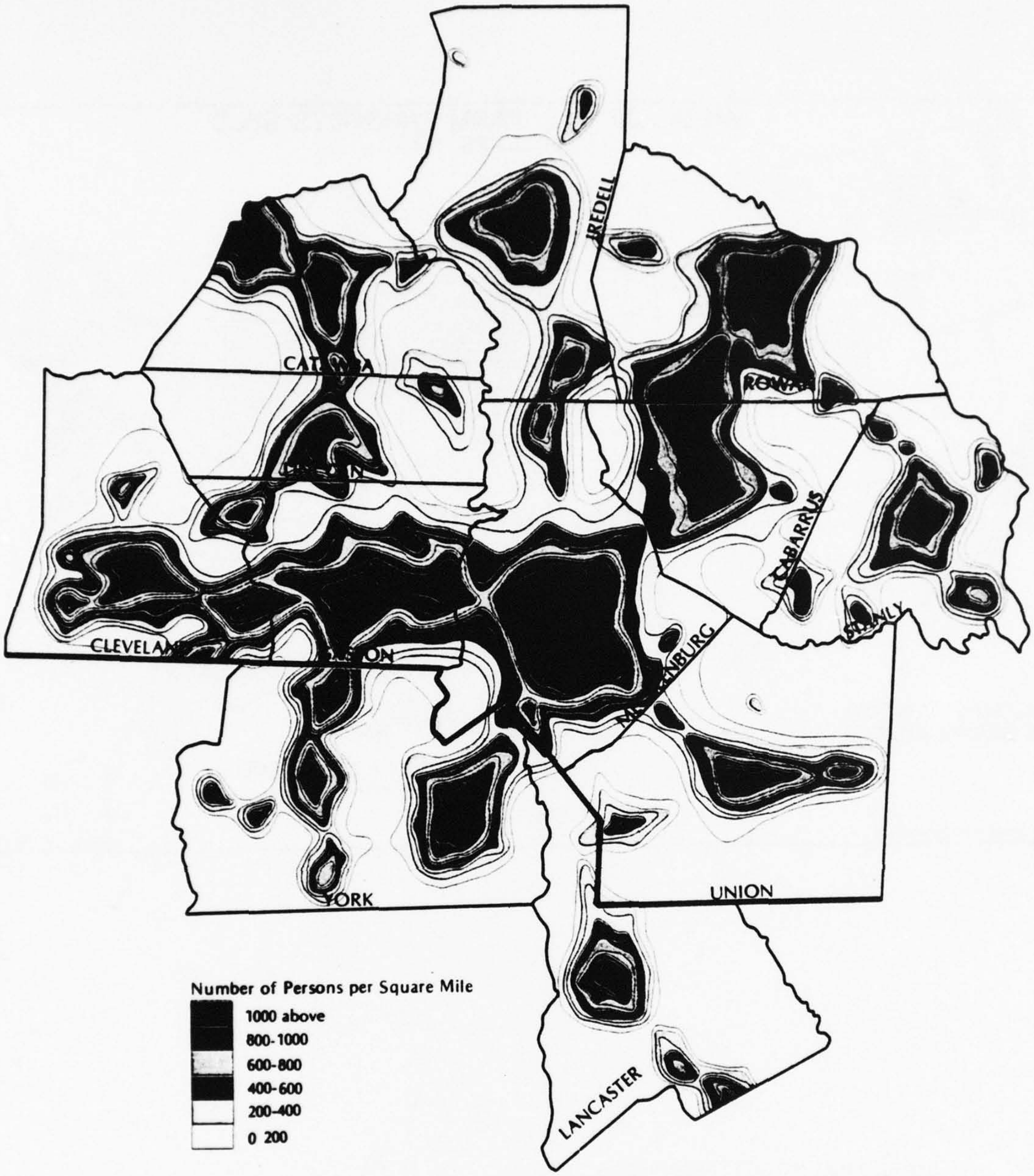
4.4 CIRCLE MAP: AVERAGE NUMBER OF DAILY TELEPHONE MESSAGES PER 100,000 PERSONS BETWEEN BOSTON AND SELECTED CITIES FOR APRIL 1958

Black circles of varying sizes indicate quantity of events taking place at a given time. Overlapping patterns of circles leave one unsure of what quantity is where, since geographic references are obscured by the black circles. Map reprinted by permission. Neil C. Gustafson in MEGALOPOLIS by Jean Gottmann, MIT Press, Cambridge, MA. Copyright 1961 by The Twentieth Century Fund, Inc., New York.



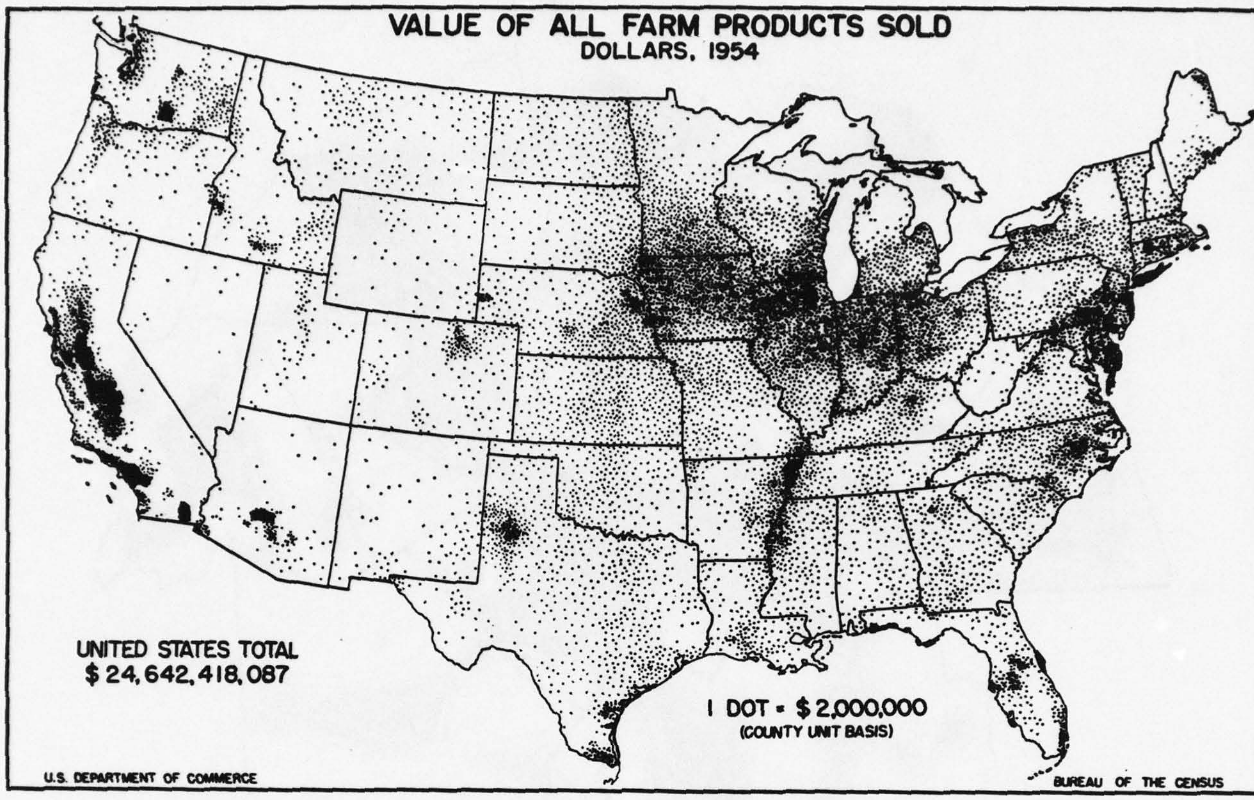
4.5 PIE MAP: POTENTIAL VOTERS BY RACE IN METROLINA, 1968

The "pie circle," a conventional technique and not very exciting graphically, shows both quantity and percentage in this map. Size of pie is proportional to population, while the size of the wedge indicates percentage of registered Negro voters. Thus, the biggest pieces of pie indicate the largest number of potential Negro voters. A further layer of information is given by color of state, telling percent change in Negro registration between 1960-68. Map reprinted by permission. Jefferson L. Simpson in METROLINA ATLAS by James W. Clay and Douglas M. Orr, Jr., University of North Carolina Press, Chapel Hill, Copyright 1972.



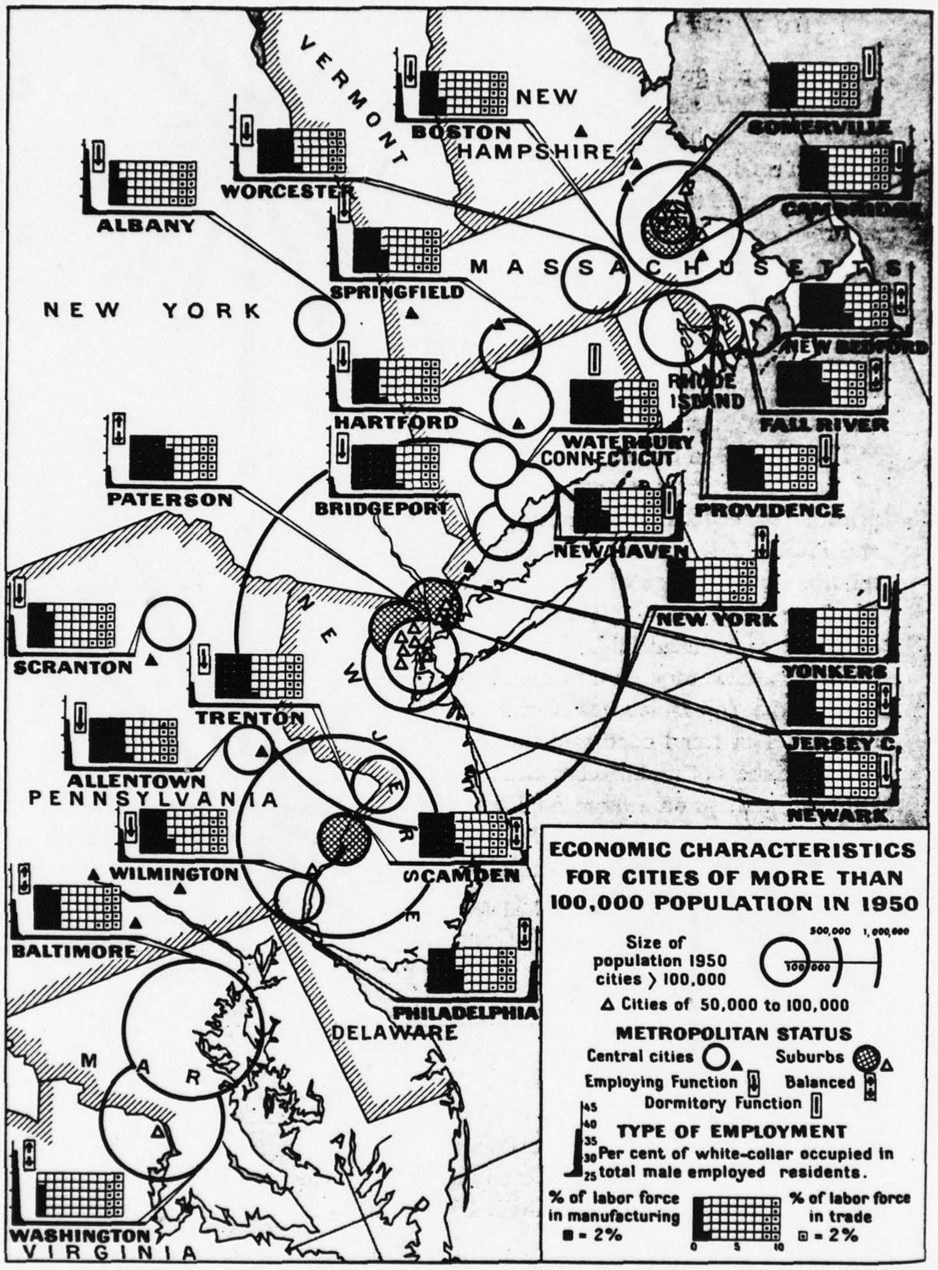
4.6 METROLINA POPULATION DENSITY PATTERN

An alternative to the dot map, color/texture mosaic, or graph map for representing density and distribution, is this variation of the standard method of indicating topography. Highest population densities occur at "peaks" and lowest in "valley." Color is not essential, but aids rapid interpretation of levels. Map reprinted by permission. Jefferson L. Simpson in METROLINA ATLAS by James W. Clay and Douglas M. Orr, Jr., University of North Carolina Press, Chapel Hill, Copyright 1972.



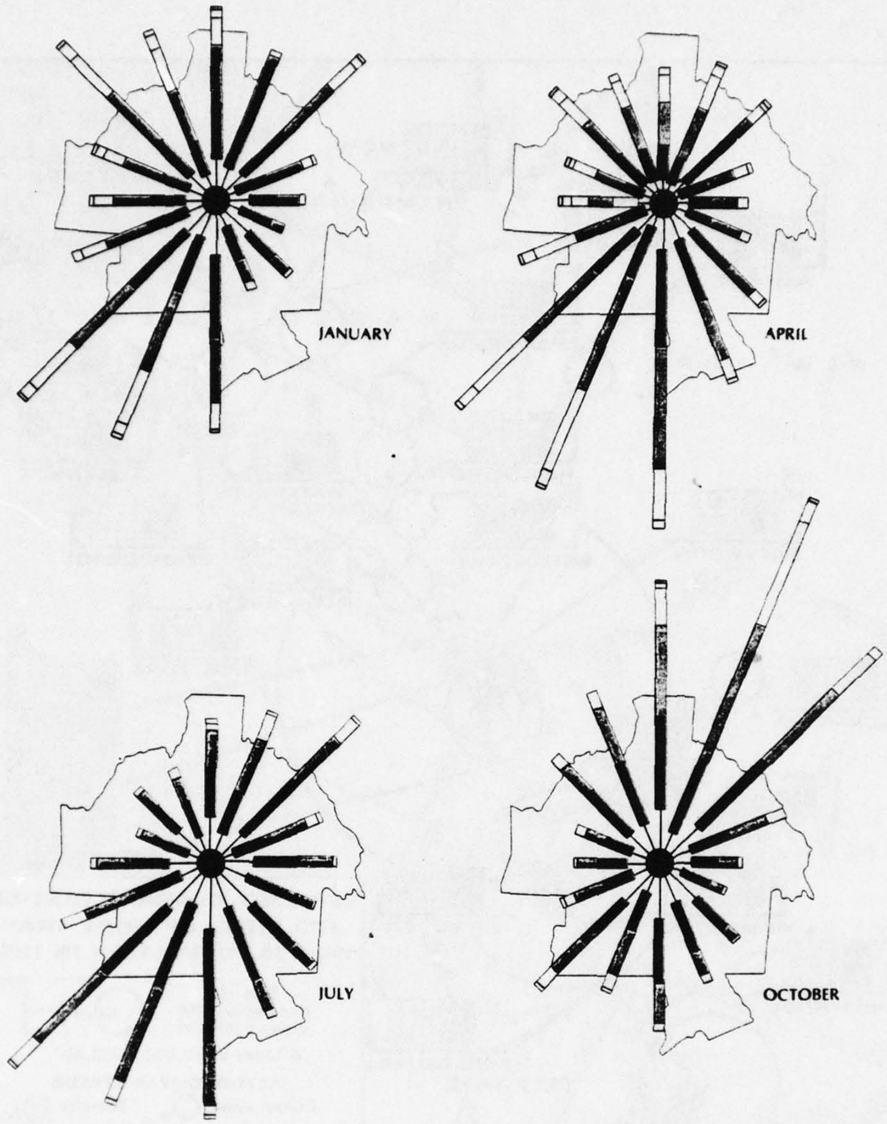
4.7 DOT MAP: VALUE OF ALL FARM PRODUCTS SOLD

Dots are used to indicate high and low concentrations of quantities, in this case, dollars in sales of farm products. This technique is simple and direct and, therefore, understandable to a wide audience. Without looking at the key, it is apparent where concentrations and scarcities exist. This is an important aspect of quick comprehension mapping. The technique is old and still usable because the symbol - the dot - has a minimal number of distracting features. This kind of map is often done with concentrations indicated by the build up of complex symbols, which become more attention demanding than the patterns of concentrations and scarcity. Map reprinted by permission. U.S. Bureau of the Census, in MEGALOPOLIS by Jean Gottmann, MIT Press, Cambridge, MA. The Twentieth Century Fund, Inc., New York. Copyright 1961.



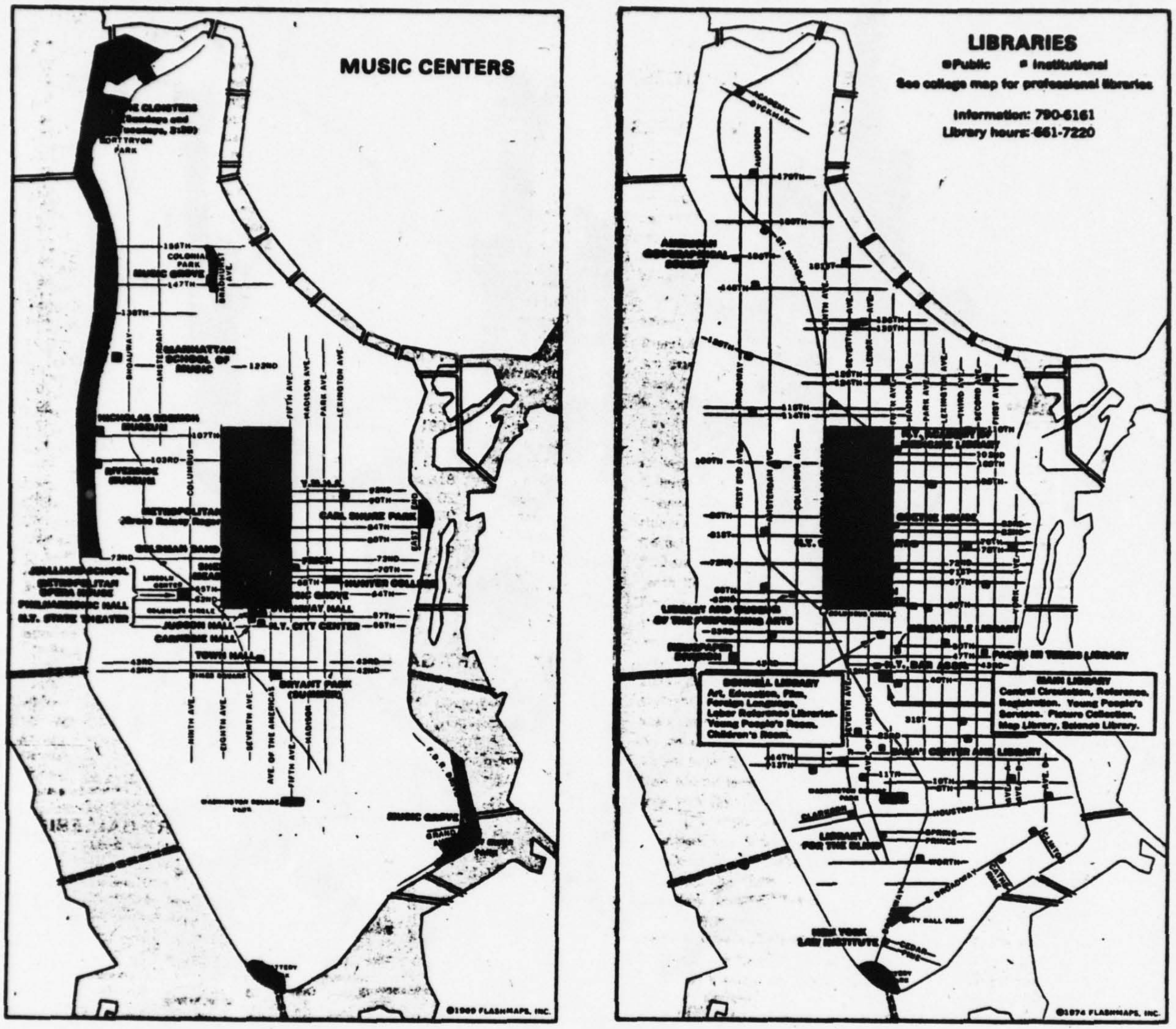
4.8 GRAPH MAP: ECONOMIC CHARACTERISTICS FOR CITIES OF MORE THAN 100,000 POPULATION IN 1950

Graphs and maps can be combined. Employment characteristics are charted individually for a number of locations, and then the graphs are visually distributed to conform to the geographic relationships. Size is indicated through the varying circumferences of concentric circles superimposed on top of the location. Symbols identify metropolitan status. Map reprinted by permission. Jean Gottmann, MEGALOPOLIS. The Twentieth Century Fund, Inc., New York. Copyright 1961. Figure 60, page 212, based on data and classification in Municipal Yearbook: 1959.



4.9 BAR MAP: AVERAGE METROLINA WIND DIRECTION AND SPEED

A variation of the bar graph, the wind rose gives direction, duration, and speed of wind. Length of bar segments is proportional to percentage of time that wind of varying velocities occurs for each of 16 directions, averaged over 3 month periods. The technique is appropriate only for data that involve directional movement such as weather, transportation, migration, or trade. Map reprinted by permission. Jefferson L. Simpson in METROLINA ATLAS by James W. Clay and Douglas M. Orr, Jr., University of North Carolina Press, Chapel Hill. Copyright 1972.



4.10 FLASH MAPS: NEW YORK/MUSIC CENTERS & LIBRARIES

The concept of flash maps is appropriate for complex environments with diverse user needs. Map making and using are simplified by presenting only one category of information at a time. Thus, one must consult several maps during a typical day of travelling; for example, shopping, restaurants, transportation, theaters, and parks would be on separate maps. While a single map with all the information would be nearly useless because of information overload, a series of simple maps are understandable. Map reprinted by permission. FLASHMAPS--NEW YORK by Toy Lasker, Jean Paul Tremblay (Cartographer). Copyright by FLASHMAPS, Inc.

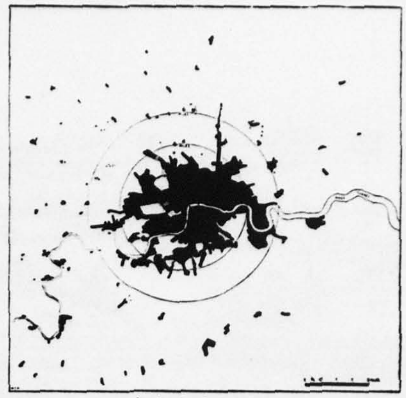
4.11 THREE DIMENSIONAL PICTOGRAPH: THE BALANCE OF POWER, 1914

Three dimensional pictographs standing on a map of Europe and Russia convey population, number of soldiers, battleships, submarines, quantity of steel production and railway mileage, and other power-related factors. The resulting map is simple, attractive, and understandable to most people. Map reprinted by permission. Bruce Robertson, HISTORY OF THE TWENTIETH CENTURY, Purnell Reference Books.

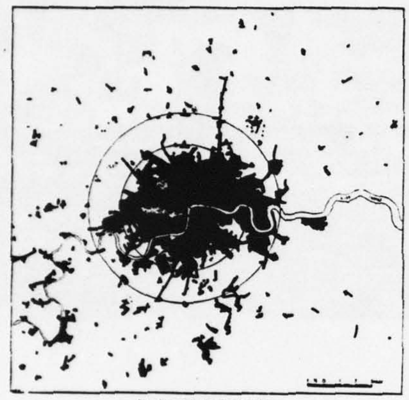
5.1 SYNCHRONOLOGICAL MAP: A CHRONOLOGICAL CHART OF ANCIENT, MODERN AND BIBLICAL HISTORY

This map depicts the time and place of major milestones in history, from the dawn of civilization to modern times. Sebastian Cabot Adams (1825-1898), a pioneer Oregon educator and minister, developed the map and first issued it in 1871. The stream of time is represented by the long black line extending from left to right. Each hundred years is marked by an upright black pillar and every ten years is indicated by a red pillar. Flowing with the stream of time are colored areas which show the world's geo-political structure for any given period. Time lines are amplified with notes and illustrations. The map is about fifteen feet long. Map reprinted by permission. By Sebastian Cabot Adams. Copyright Samuel J. Ferelli, 1978 and Copyright Alan J. Schmid 1973.

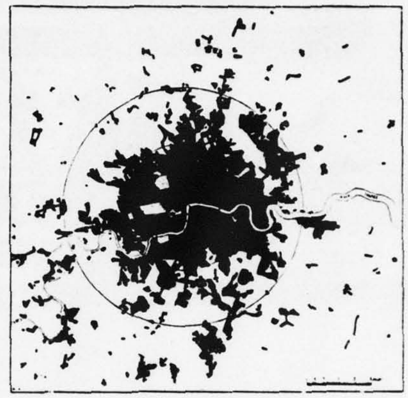
London: Area built over 1840



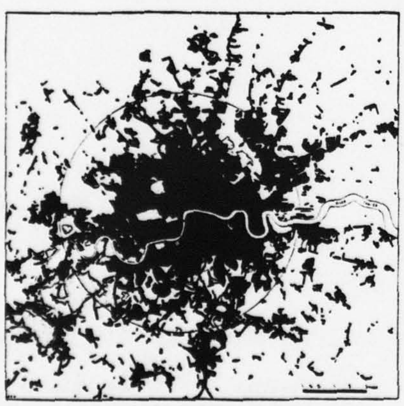
London: Area built over 1860



London: Area built over 1880



London: Area built over 1900

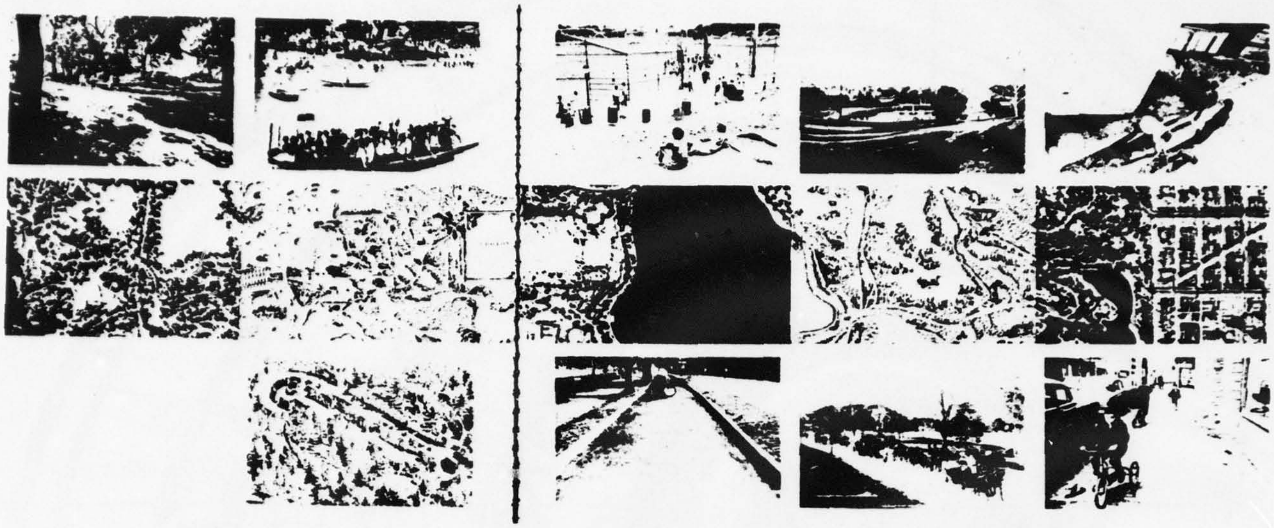


London: Area built over 1914

London: Area built over 1929

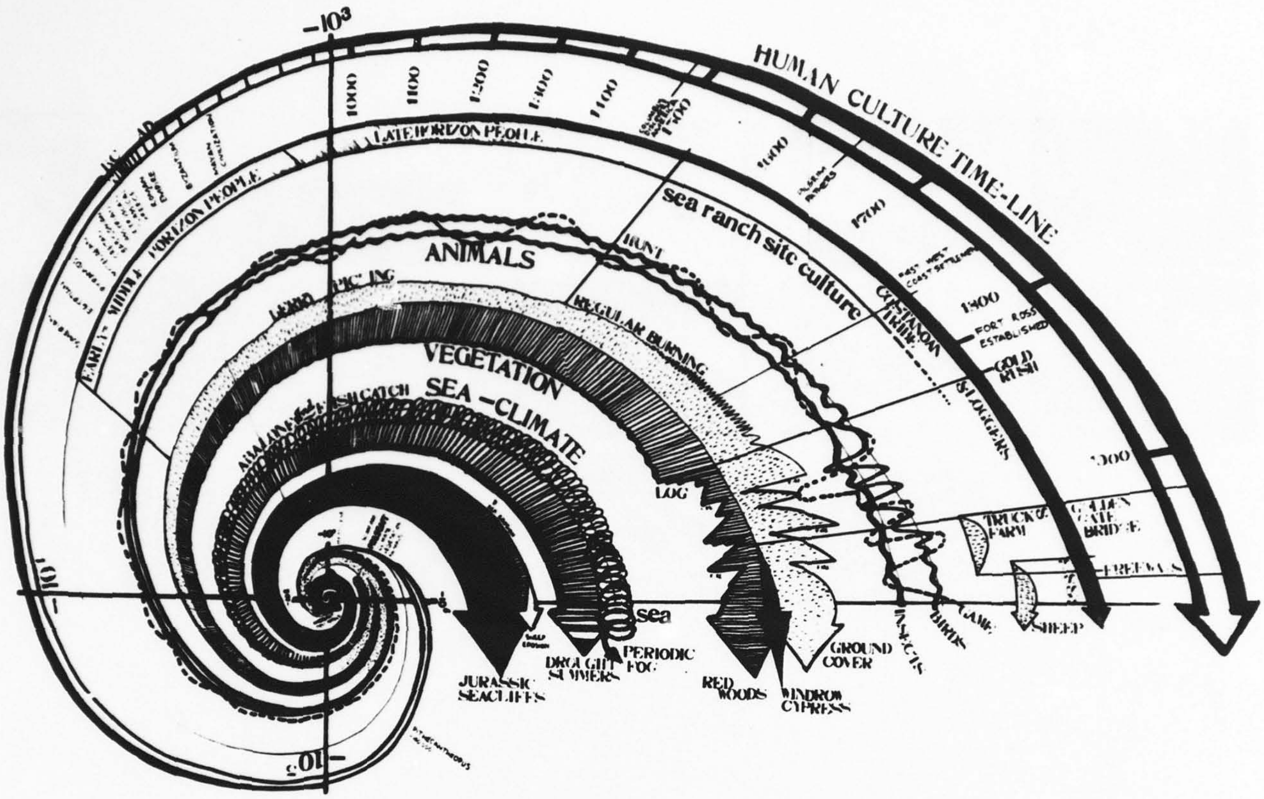
5.2 GROWTH & CHANGE: LONDON/AREA BUILT OVER 1840, 1860, 1880, 1900, 1914, 1929

Consecutive mapping of the same geography over time can be used to compare any aspect of growth, consumption, production, etc. which is linked to geography. This series shows the growth of London between 1840 and 1929. The simple graphic presentation is highly effective. Map reprinted by permission. Steen Eiler Rasmussen, LONDON: THE UNIQUE CITY, Copyright 1934 by Steen Eiler Rasmussen, MIT Press, Cambridge.



5.3 TIME LAPSE, MIXED MEDIA MAP: A SLICE THROUGH CENTRAL PARK, 1870 and 1970's

This slice through Central Park is a collage of three pieces of a recent aerial photograph and two pieces of a nineteenth century engraving, fitted together to create a single image, and printed in different colors to differentiate the time shifts back and forth. The strip is surrounded by seven views of areas of the park shown in the slice, similarly color-keyed. Map reprinted by permission. Richard Saul Wurman, Alan Levy, Joel Katz, THE NATURE OF RECREATION, MIT Press, Copyright 1972 by The American Federation of Arts and GEE! Group for Environmental Education, Inc.

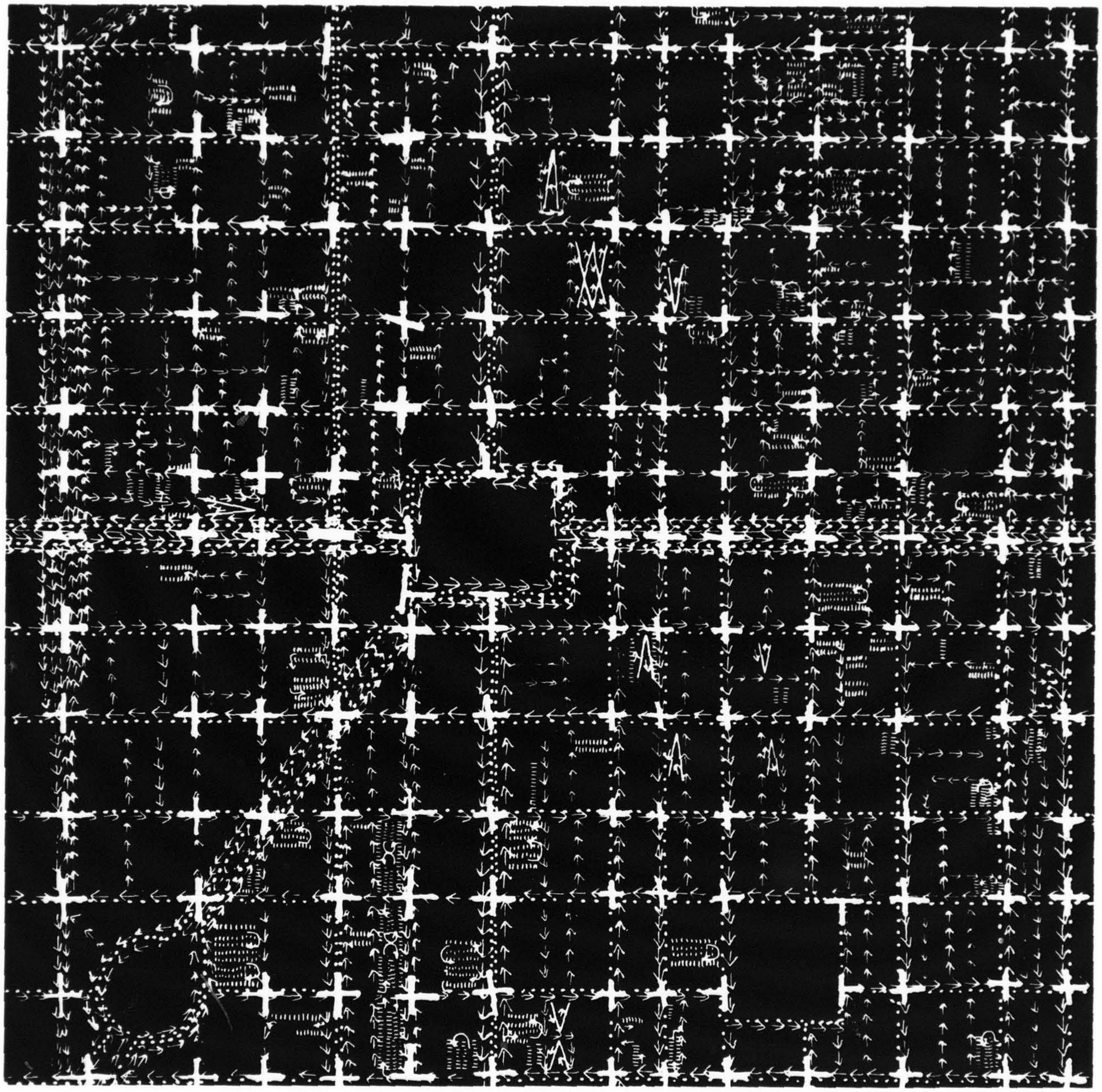


5.4 TIME LINE

The evolution of Sea Ranch and its environs are mapped as a time spiral. Beginning at the primeval core, the spiral progresses and expands through time quadrants, from 100 million years ago, 10 million, and so on down to 100 years ago. As modern times approach, the spiral expands and detail increases. The time spiral presents 4 aspects of the area's evolution: sea-climate, vegetation, animals, and human culture. The same information could have been shown as well in a straight line, although the spiral is space-saving. Map reprinted by permission. Lawrence Halprin, RSVP CYCLES: CREATIVE PROCESSES IN THE HUMAN ENVIRONMENT, George Braziller, Inc., 1969.

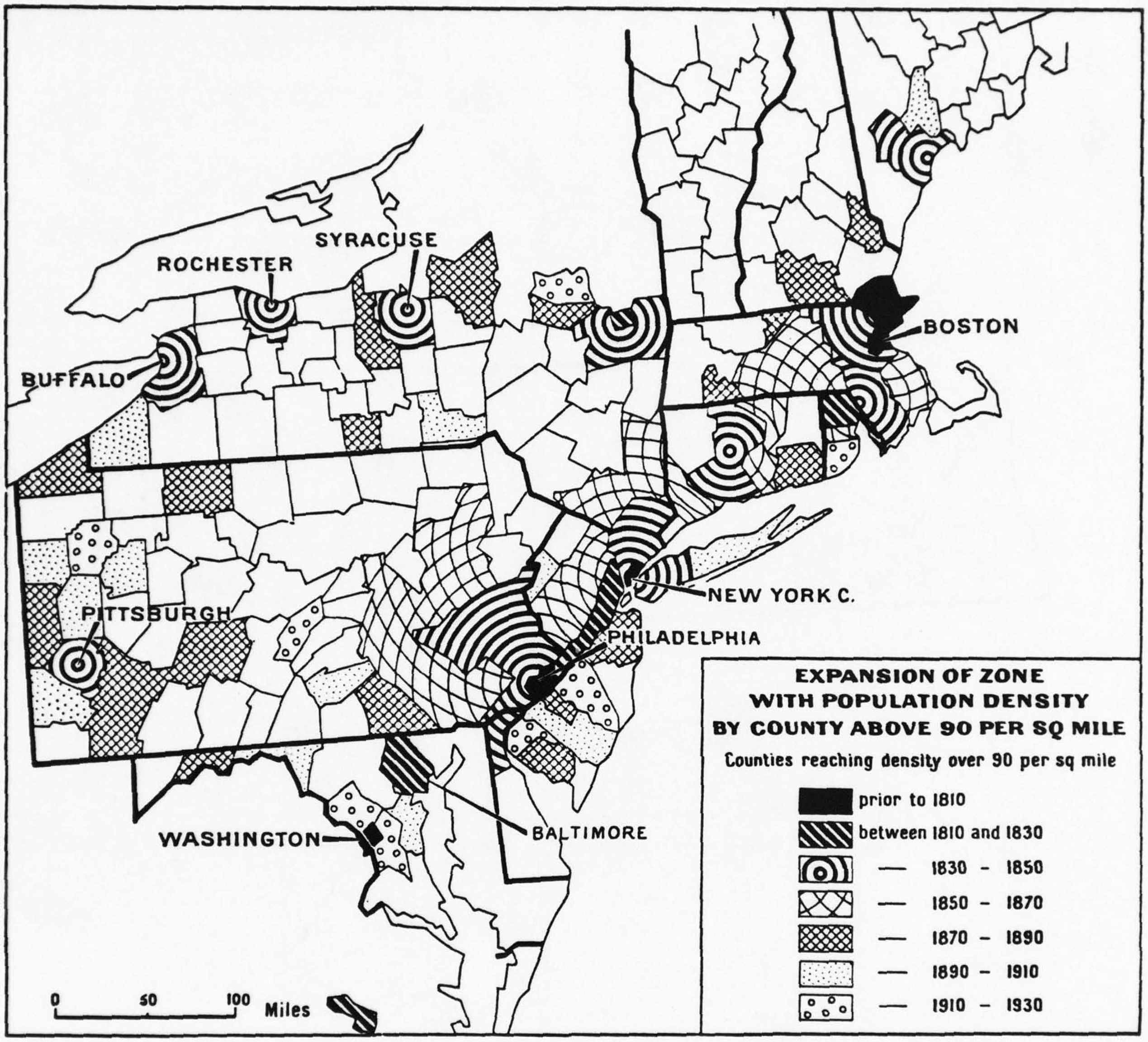
5.5 MIGRATION MAP: FRANCE

Population migration in and out of French cities is shown by means of arrows. Size of arrows is proportional to number of people migrating. Map 1 shows migration into cities throughout France, Map 2 shows migration from these cities into Paris, and Map 3 is a composite of 1 and 2. The technique is graphically elegant and easy to interpret. Map reprinted by permission. Jacques Bertin, SEMIOLOGIE GRAPHIQUE, Editions Gauthier-Villars (Paris), Mouton Publishers (Paris, New York, The Hague), Ecole des Hautes Etudes en Sciences Sociales (Paris).



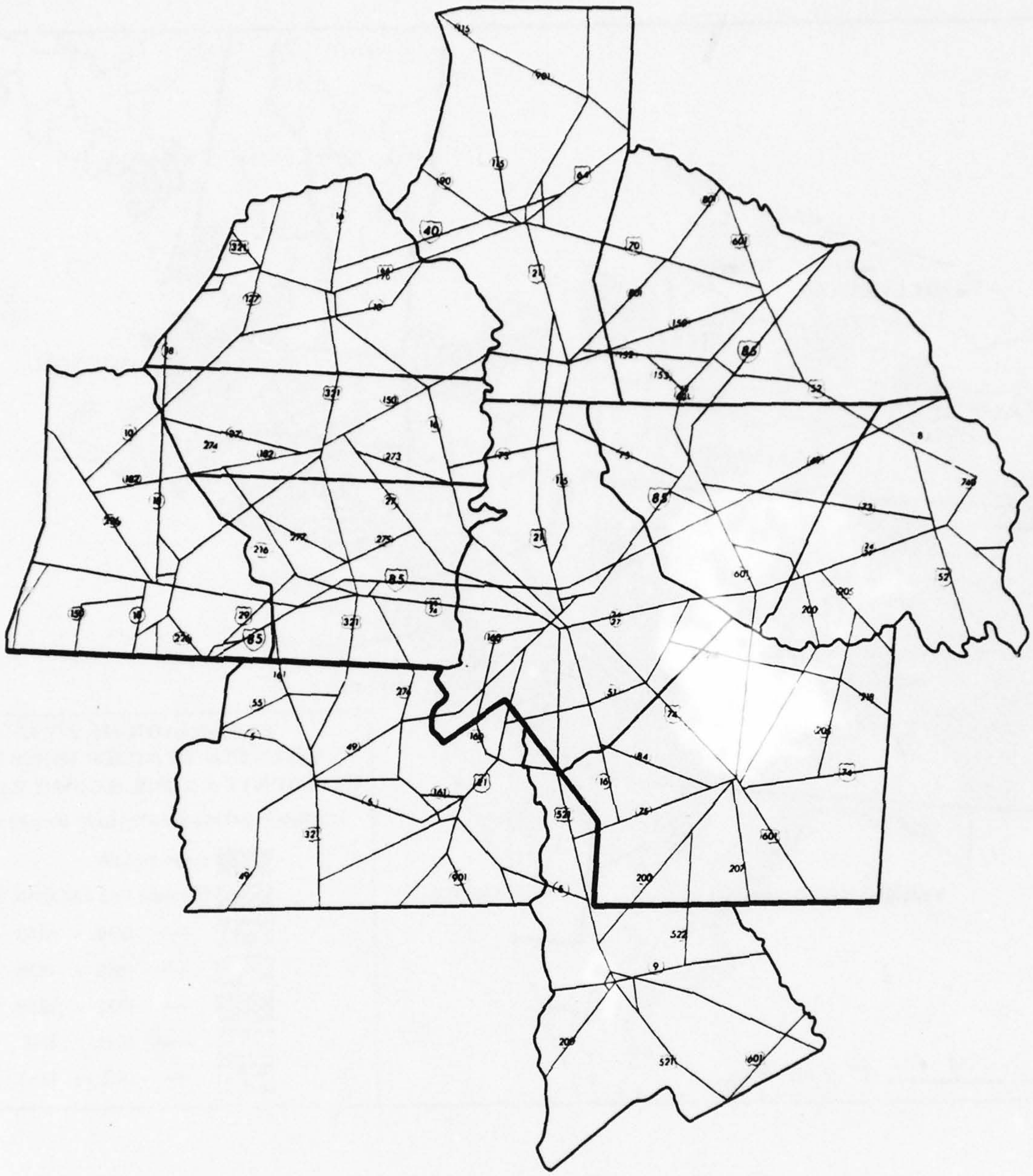
5.6 TRAFFIC MOVEMENT AND VEHICLE STORAGE, PHILADELPHIA

One aspect of city form, the circulation system, is expressed in terms of moving and parked vehicles. Arrows symbolize both direction and relative density of moving vehicles. Short lines indicate parked cars. The technique is direct and understandable, as well as graphically exciting. Map reprinted by permission. Louis I. Kahn, THE NOTEBOOKS AND DRAWINGS OF LOUIS I. KAHN, Richard Saul Wurman and Eugene Feldman, editors and designers, The Falcon Press, Copyright 1962.



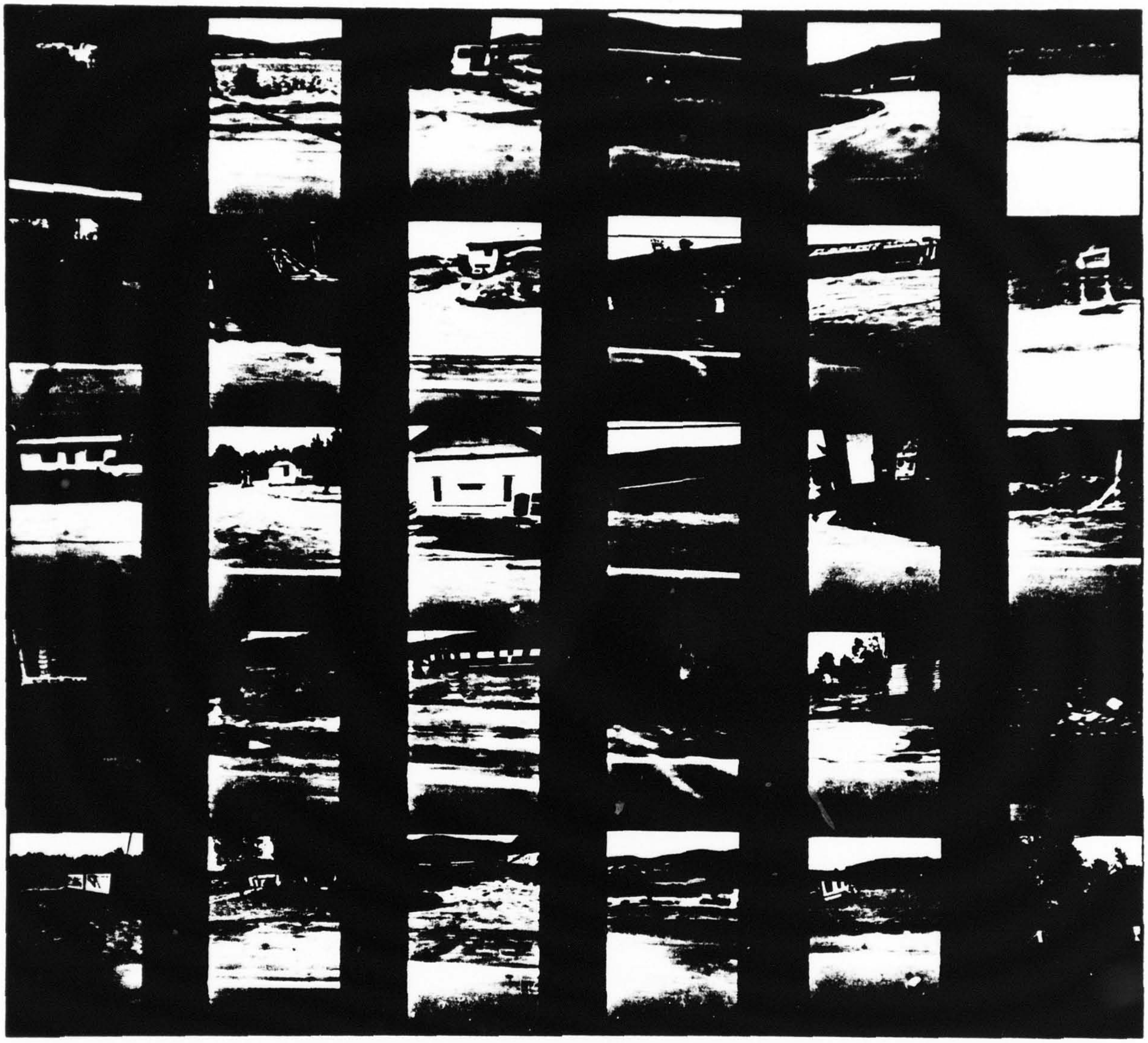
5.7 CHANGE MAP: EXPANSION OF ZONE WITH POPULATION DENSITY BY COUNTRY ABOVE 90 PER SQUARE MILE

Graphic patterns are intended to represent population expansion in ten year increments, starting with 1810. Regrettably, the varying patterns are at war with one another. Two of the patterns are almost indistinguishable from each other. Some are very dynamic, suggesting growth from a center, while others representing equal periods of time are recessive and static. The result is more confusion than communication. Nevertheless, the idea is a useful one, that is, change is communicated through expressive graphic patterns. Map reprinted by permission. Jean Gottmann, MEGALOPOLIS. The Twentieth Century Fund, Inc., New York. Copyright 1961.



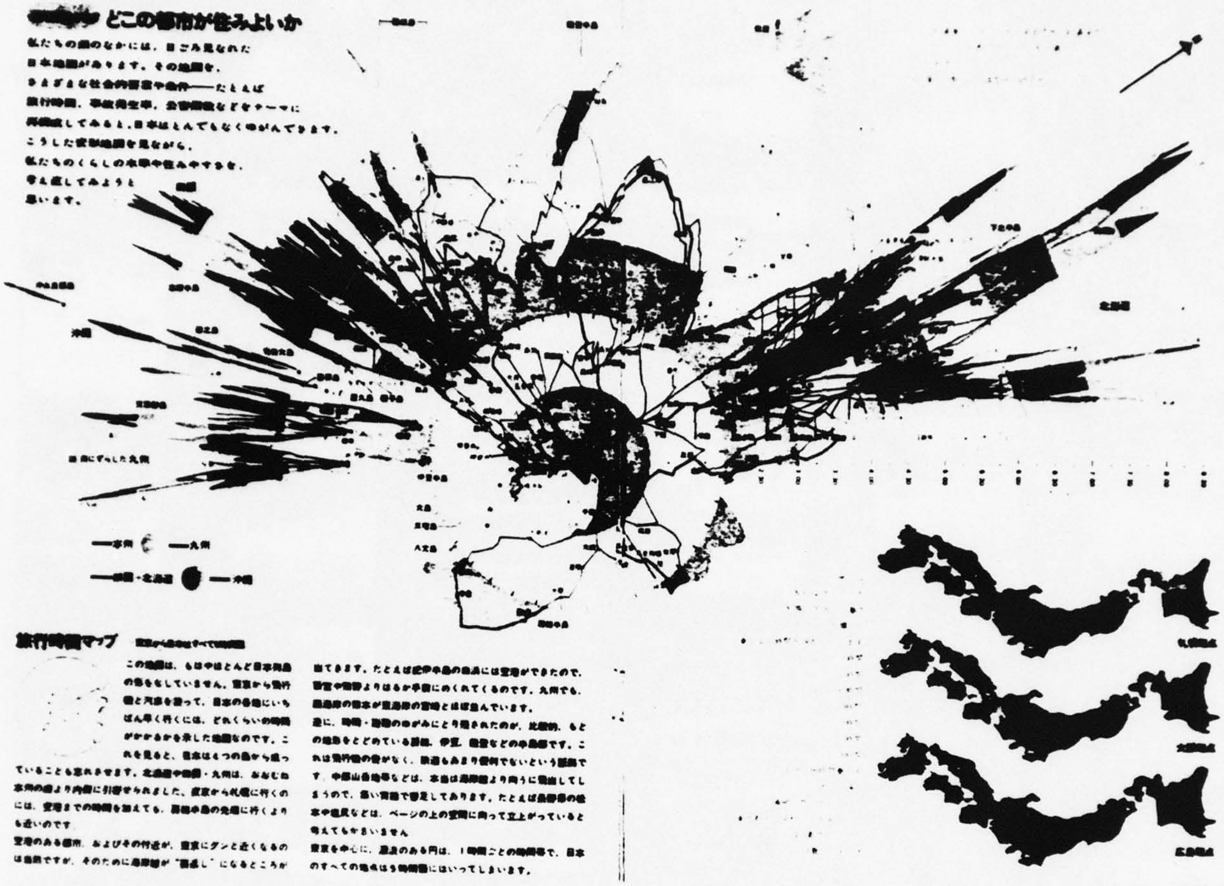
5.8 VEHICLE TRAFFIC VOLUME IN METROLINA

One effective and commonly used techniquc for representing intensity or volume of movement, traffic in this case, is found in this regional map of Charlotte, North Carolina. Bands, proportional in width to the amount of traffic, are superimposed on the highway network. One drawback of the approach is the difficulty of working with dense networks where there is no space to put the bands. Map reprinted by permission. James W. Clay and Douglas M. Orr, Jr., METROLINA ATLAS, University of North Carolina Press, Copyright 1972.



5.9 PHOTOGRAPHIC TIME LAPSE: THE AMERICAN ROAD EDGE

The road edge from Philadelphia City Hall to Buffalo City Hall is documented in this novel and highly specialized map. Using time lapse photography, a frame was shot every 30 seconds, resulting in a total of 1700 frames, each frame covering approximately one-half mile. The technique is useful for studying changes over a large territory. Map reprinted by permission. Joel Katz, 1974.

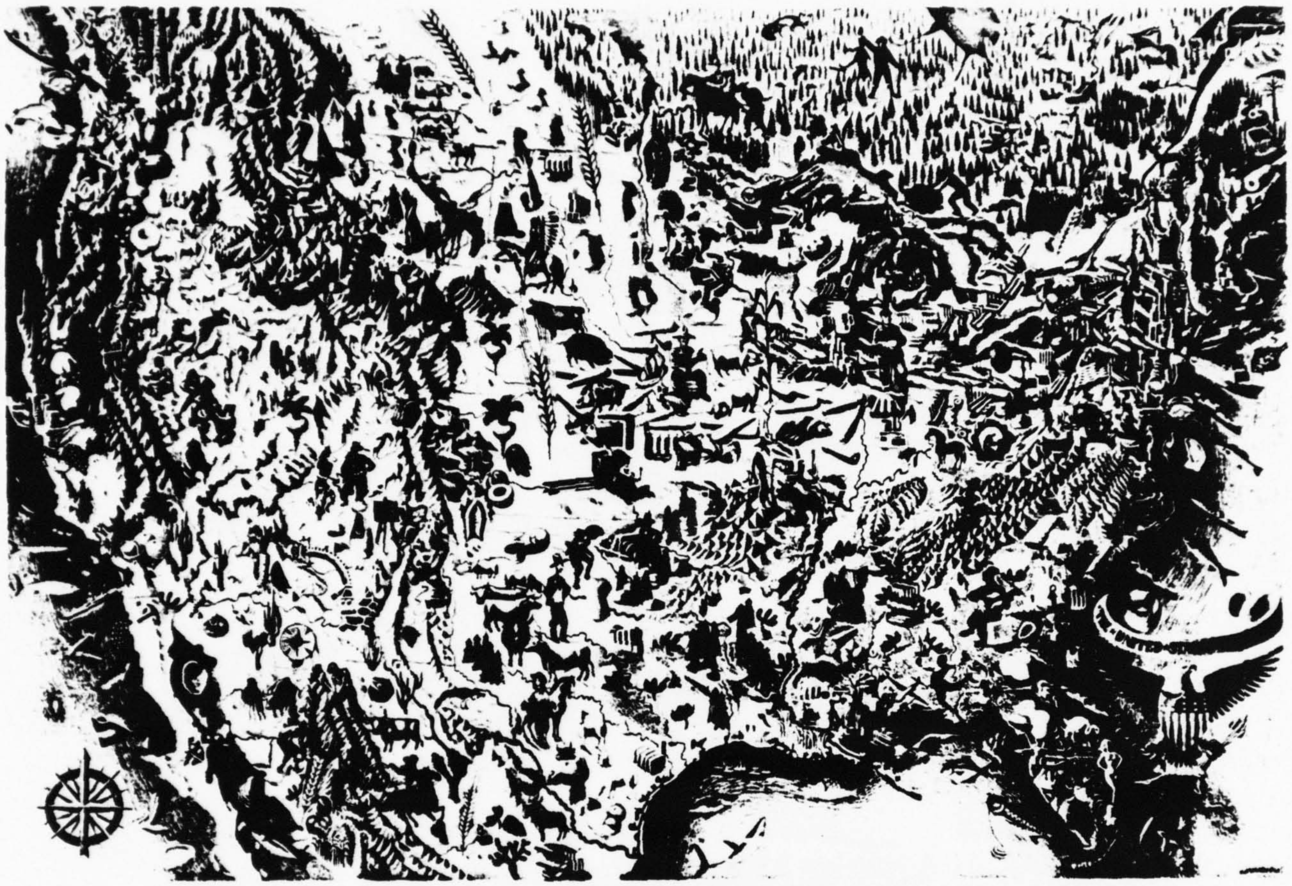


5.10 TIME-DISTANCE MAP: TRAVEL TIME, JAPAN

In this unusual map, the configuration of Japan is warped according to travel time rather than distance from Tokyo. Thus, a near point that takes a long time to reach appears farther away from Tokyo than another point that can be reached more quickly. The bands of concentric circles represent the time frames for location of the various points. The time distance represents the shortest travel times via airplane and train, as found in time tables. Map reprinted by permission. Cho Shinta et al, SHUKAN ASAHI (Magazine), Tokyo, May 9, 1969.

5.11 PHOTOGRAPHIC TIME-LAPSE: A DAY IN THE LIFE OF THREE PERSONS AND TWO SPACES AT HOURLY INTERVALS

Time Lapse photographs map changes in activity and space. By photographing various spaces and individuals in a school at hourly intervals between 1 PM and 5 PM, the life of the school is illustrated non-verbally. This technique is useful for quick in-depth descriptions of an environment and its users. The technique has also been applied to career counseling; time lapse photos of people doing different jobs give a much better sense of what is involved in that job than job descriptions. The essential ingredient of the technique is the rigid schedule of photos. Map reprinted by permission. Richard Saul Wurman & Joel Katz in OPT, Copyright 1973 by GEE!

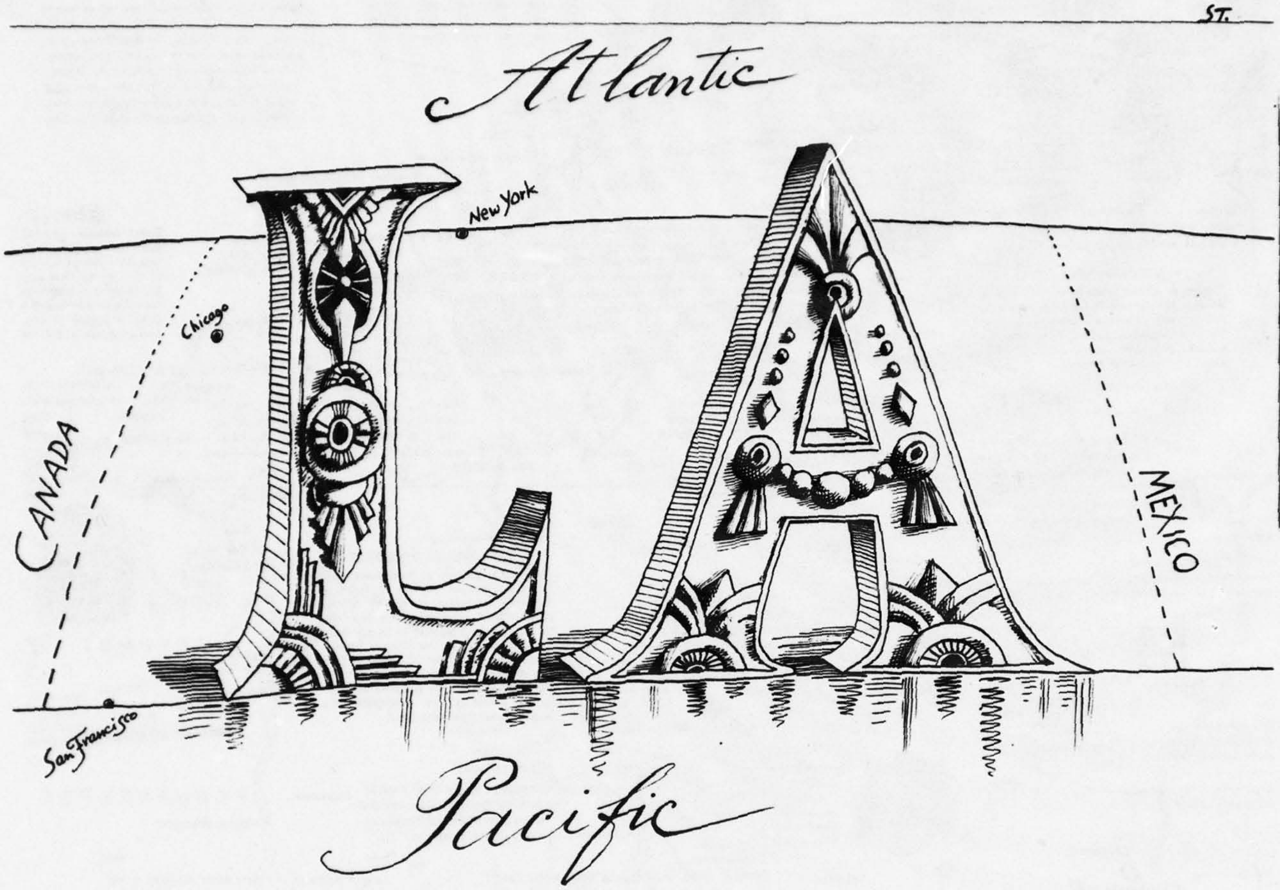


6.1 PICTORIAL MAP: COVARRUBIAS' AMERICA

Miguel Covarrubias' fascinating impression of America, a mural created for the Golden Gate International Exposition in San Francisco, in 1939-40, has influenced many a school child's image of the country. Pictographs were painted in Covarrubias' unique style to epitomize each region. Hollywood has glamorous movie stars, Texas has oil wells, and Boston has beans. The result is very personal and also very dated, but all of this makes it more evocative, and perhaps nostalgic, to viewers 40 years later. Map reprinted by permission. Miguel Covarrubias, Copyright 1942 by Associated American Artists, New York City.

6.2 ANNOTATED ARCHEOLOGICAL MAP OF MIDDLE AMERICA

Descriptive paragraphs combined with illustrations present the archeological sites of Central America. Interesting as an armchair guide and useful as a sightseeing reference, the annotation technique combines the depth of information one obtains from an article with the geographic sense provided by a map. The overlay of archeological material leaves room for only the basic geographical points necessary for reference; the map cannot function as a primary transportation tool. Map reprinted by permission. National Geographic Society, NATIONAL GEOGRAPHIC MAGAZINE, October 1968, Copyright by National Geographic Society.



6.3 IMAGE MAP: LOS ANGELES

Mental maps tend to focus on one's own region, exaggerating its size and importance, while dropping detail and shrinking other areas. In this amusing cartoon of a mental map, Los Angeles looms large as a billboard, with Chicago the only reference point between the Atlantic and Pacific. U.S. boundaries reduce to a simple block shape. Everything beyond L.A. looks dull and uninviting, incapable of competing with glittering L.A., yet no environment is evoked by the symbolic letters. The well-known New Yorker's view of the U.S., also by Steinberg, is in marked contrast. Manhattan is represented as a real place, with streets, buildings, and activity. The great barren plains of the Midwest begin just across the Hudson River and are shortly terminated by the Pacific Ocean. Map reprinted by permission. Saul Steinberg, THE INSPECTOR, Penquin Books, New York, Copyright by Saul Steinberg.

6.4 ANTHROPOMORPHIC MAP: MANHATTAN

The streets of Manhattan are given human form and personality in what might be called an anthropomorphic map. Broadway is a rough, ill-kept, shirt-sleeved character in racy tie, barrelling unexpectedly through a sedate Fifth Avenue and young 23rd Street, with 24th toddling behind. The ruffian is heading for City Hall, according to his balloon. In the second drawing, the Grande Dame Fifth Avenue parades slowly past well behaved little 90's until a sudden character change occurs at 97th Street, where we have little ruffians with a tin can hurtling straight at the dignified eminence of Park Avenue as she sails uptown like an enormous yacht. Map reprinted by permission. Saul Steinberg, THE INSPECTOR, Penguin Books, Copyright 1973.

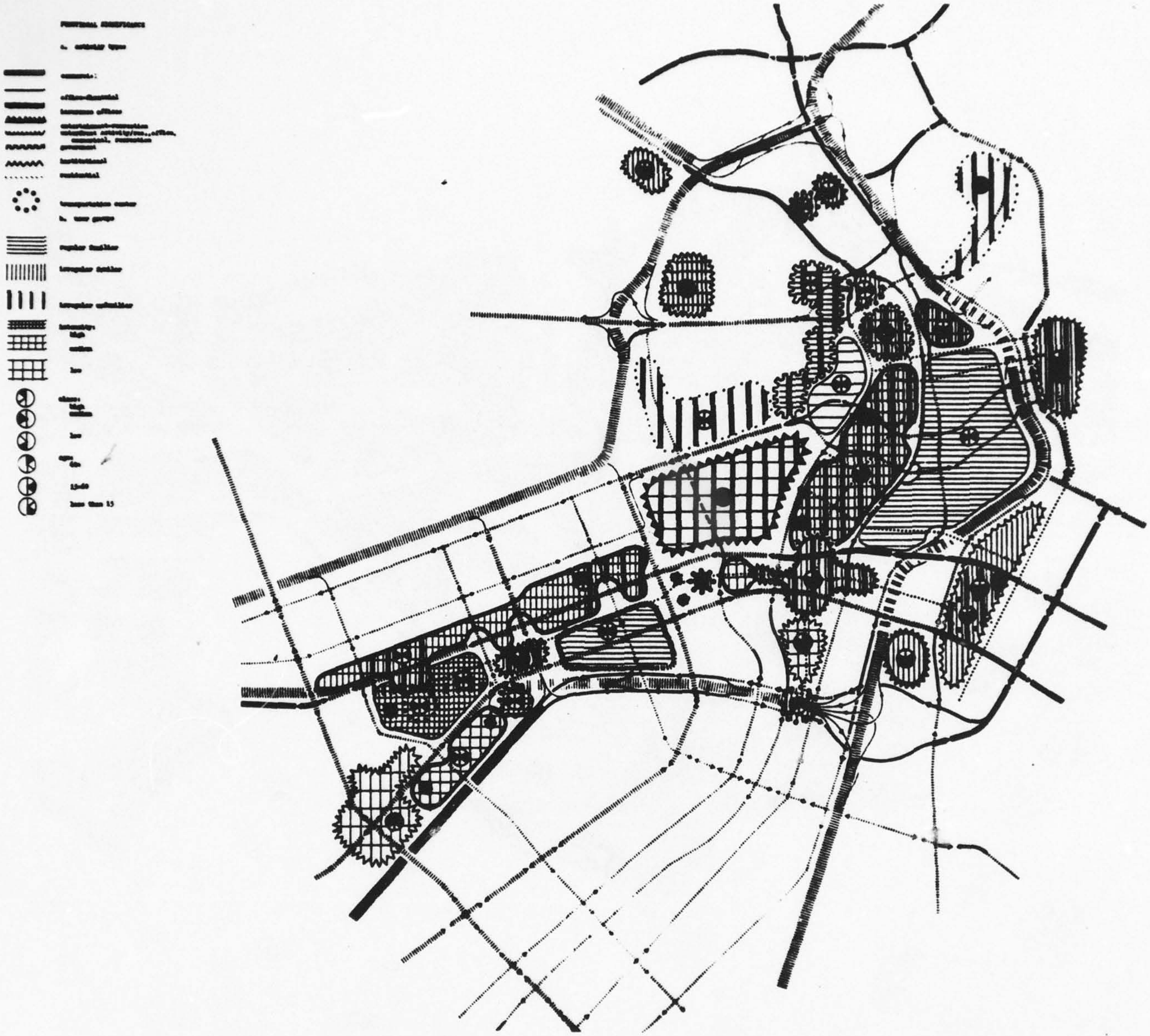
Gateway To Orient Denny Mt. Rainier Hills
Mountains Rainfall Overcast Sunsets Mist
American Dream Outdoors Puget Sound
Waterways Cascades Perimeter Mountains
Sailboats Madrona Trees Fog City of Hills
International Commerce Mt. Baker Potlatch
Family Life Historical Boldness Middle-Class
Seaport International Fountain Mild Climate
Pike Street Sawmills Waterbound City Fish
Wood Houses Monorail Winter Roses Alki
Rhododendron Gardens Water Gold Rush
The Good Life Salmon Canal Olympics Firs
Foliage Pioneer Spirit Chief Seattle Boeing
Wholesome Surroundings Cultural Heritage
Seafair Airplanes Great Northwest Chinook
University of Washington Floating Bridge Ships
Salt Water Education Theater Homes Views
Pioneer Square First Avenue Sports Ferries
Aurora Houseboats Fireboats Gray Seagulls
Front Lawns Deck Great Outdoors Huskies
Skiing Sails Waterways Home Ownership
Queen City Green Hilly University District
Ballard Pier 91 Frederick and Nelson Ridges
Valleys Skid Road Alaskan Way Portage Bay
Highway 99 Ship Canal Leschi Greenlake
Totem Poles Alaska Trade Leisure Drizzle
Mercer Girls Market Harbor Island Nature
The Downtown Timber Sea-First Arboretum
USS Decatur Bardahl Denny Regrade Wawona
Alaska Yukon Exposition Ivars Forward Thrust
World's Fair Montlake Fill Evergreens Cedar
Smith Tower Duwamish Waterway Indians
Salt Water 1869 Alaskan Way Space Needle
747 Seattle University Dexter Horton Metro
Schooner Exact B-17 'Doc' Maynard Bell Town
Pleasure Craft City Light Central District 1851
King County Shilshole Pioneer Building Port
Fire of 1889 The Freeway King Street Station
Pike and Pine Lakes Northgate Elliott Bay 5th Ave

6.5 WORD COLLAGE/MAP: SEATTLE

Place names, slogans, and other imageable words, printed in an overall undifferentiated pattern, characterize Seattle, creating a verbal poster of city souvenirs. One can dive in at any point and come up with suggestive verbal pictures. It is unnecessary to read the entire "map" as one would a book. Rather, one scans and lands on "Wood Houses/ Monorail/Winter Roses," for example. It can be looked upon as a straight list of attractions in the conventional sense, and thus can provide destinations for the stranger; but it is more successful as a suggestion of the impressions the city gives. The "map" is not an operational orientation device for planned movement through the environment; location of verbal names of sites bears no relation to their position in the landscape. Map reprinted by permission. Department of Community Development, SEATTLE URBAN DESIGN REPORT, Seattle, 1971.

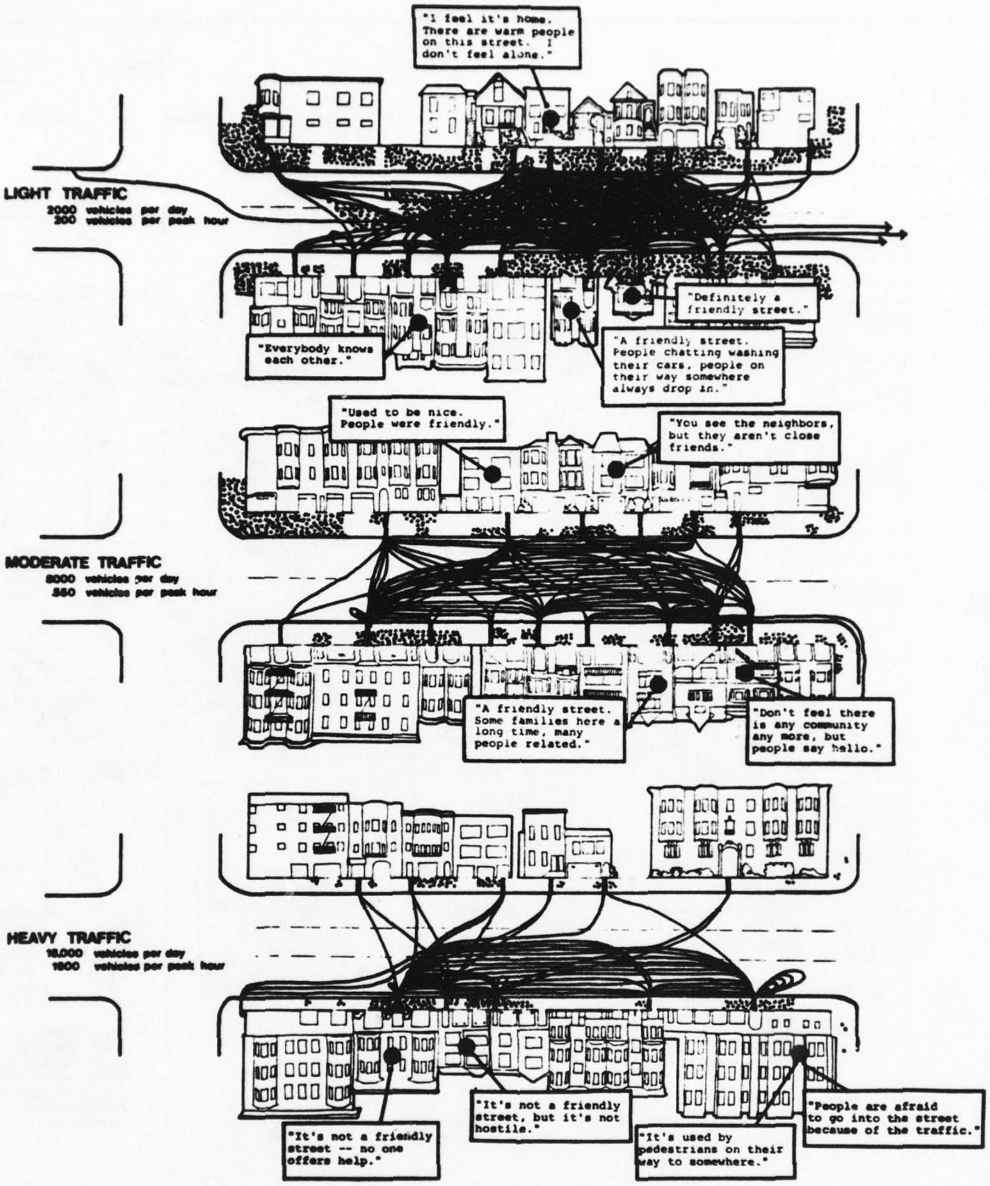
6.6 WORD MAP: SEATTLE

This unusual verbal map does, in fact, locate activities and sites in the geography. In theory, one could navigate with it, but its primary value is in its ability to evoke place-related imagery. Words and phrases are located at the point they refer to and follow topographic contours and streets. Street names are given, as well as such descriptive terms as "water tower/asphalt/driftwood/picnics/small homes/moorage sail boat races". In some ways, this might prove to be a most useful map for a stranger to Seattle, but it does take time and close attention to "read." For the armchair traveler who never gets to Seattle, it is a rich source of impressions of the city. Map reprinted by permission of Department of Community Development, SEATTLE URBAN DESIGN REPORT, Seattle, 1971.



6.7 ACTIVITY MAP

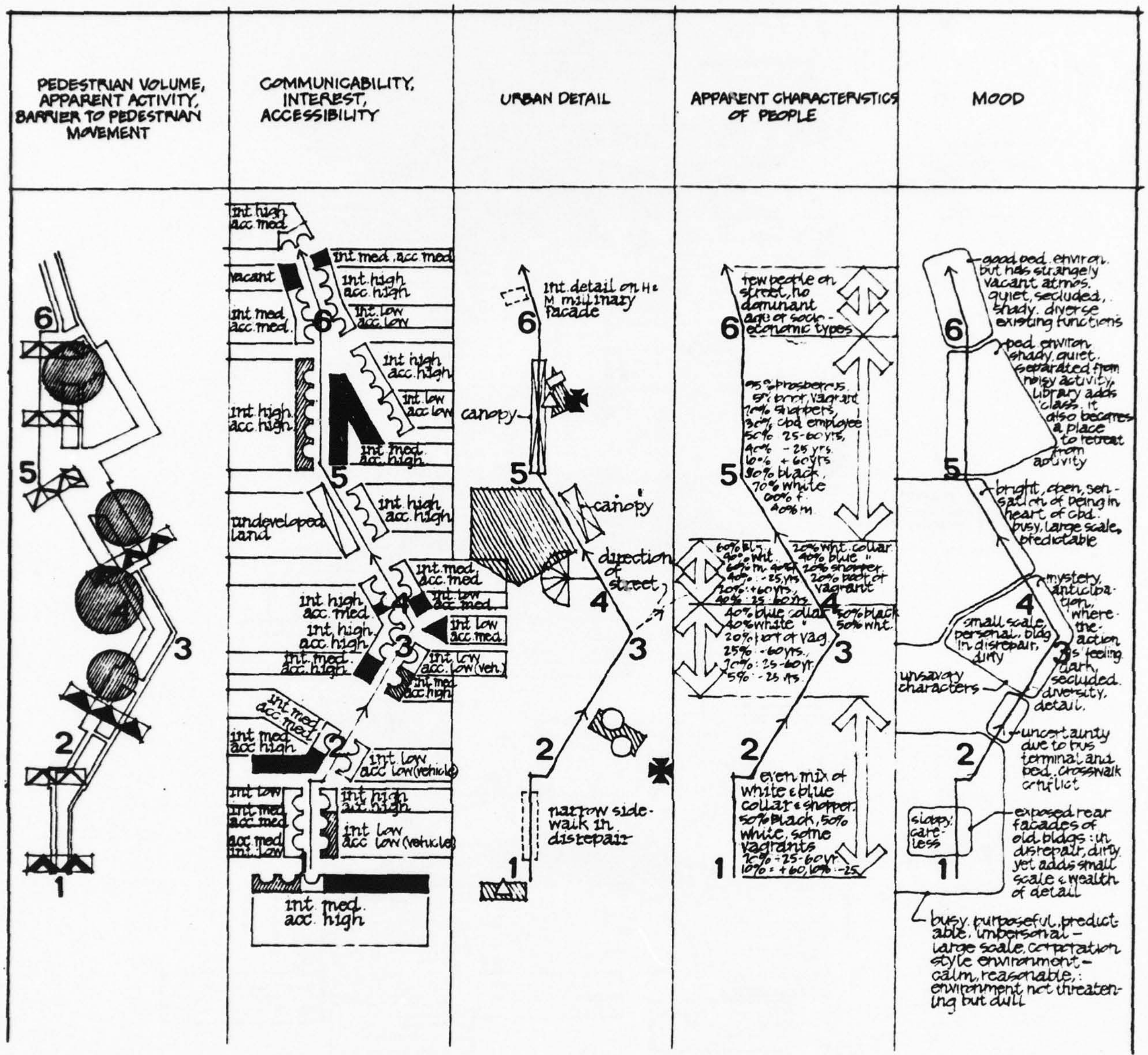
Several graphic techniques are employed to express information about activity types and their users in various city districts. Boundary patterns symbolize activity type, e.g. insurance offices, entertainment, government. Vertical and horizontal lines relate to regularity of use patterns and familiarity of users with the area, while density of cross-hatched lines expresses intensity of use or number of users. "Pie" graphs, divided into halves, communicate social class and age of users. Although symbolic techniques can encode a lot of information, one must learn the language to interpret them. Map reprinted by permission. Donald Appleyard and Michael Southworth, General Motors Urban Transportation Project, Unpublished.



NEIGHBORING AND VISITING

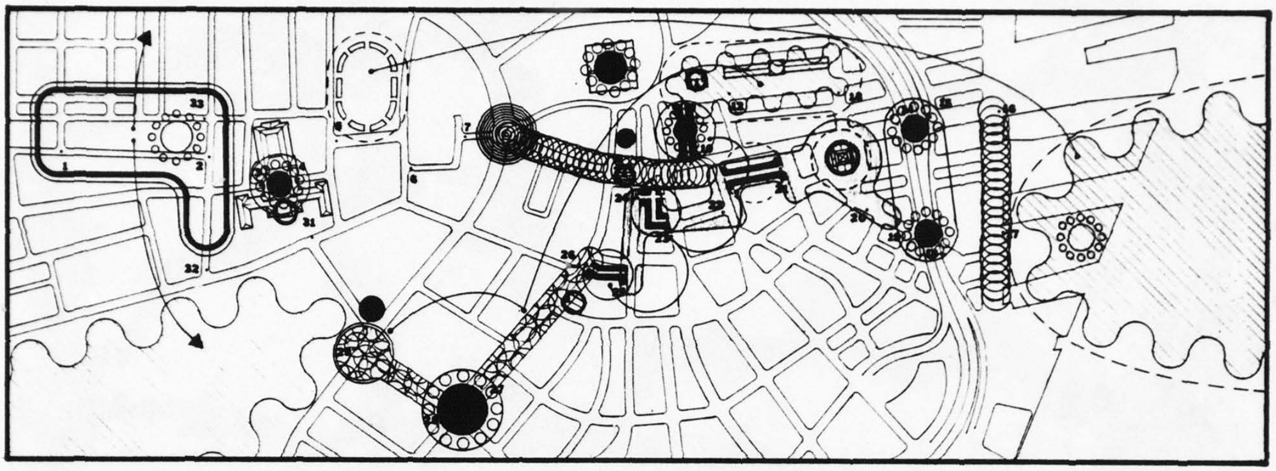
6.8 NEIGHBORING AND VISITING: SAN FRANCISCO

Study of this innovative social interchange map suggests that heavy traffic is detrimental to neighboring and visiting. Patterns of neighboring and visiting are represented by the lines connecting buildings on three different streets. The amount of friendly social encounters is proportional to the number of lines, the largest number of encounters occurring on the street at the top. The dots on the sidewalks represent intensity of sidewalk social activity. The opposite facades of each block are shown in sketch terms on each side of the street. Typical comments from residents of each street reinforce the social picture of the streets. The technique makes social data, normally presented in a dry engaging manner, meaningful to almost anyone. Map reprinted by permission of San Francisco Department of City Planning, Donald Appleyard, Consultant, STREET LIVABILITY STUDY, San Francisco, 1970.



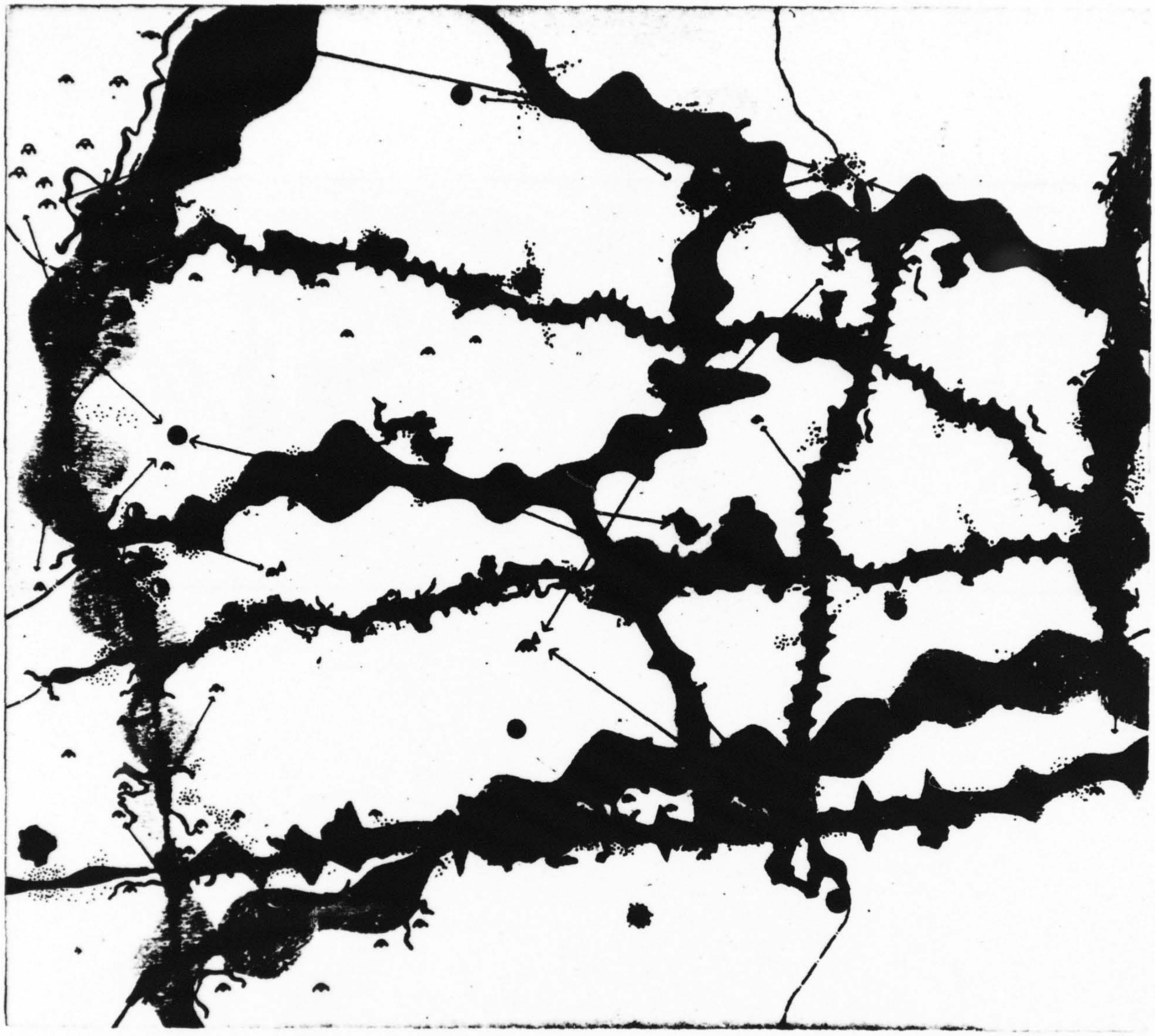
6.9 STREET ANALYSIS: DETROIT

Analysis is one important function of maps in planning and strategy. Here a city street is evaluated in terms of several qualities, including pedestrian volume, barriers to movement, accessibility, detail, apparent characteristics of people, and mood. Independent of content, the format used here is valuable. By separating analyses into separate, but adjacent maps at the same scale, comparison and comprehension are facilitated. Map reprinted by permission from Detroit City Plan Commission, Urban Design Division, CENTRAL BUSINESS DISTRICT STUDY, Unpublished, 1970.



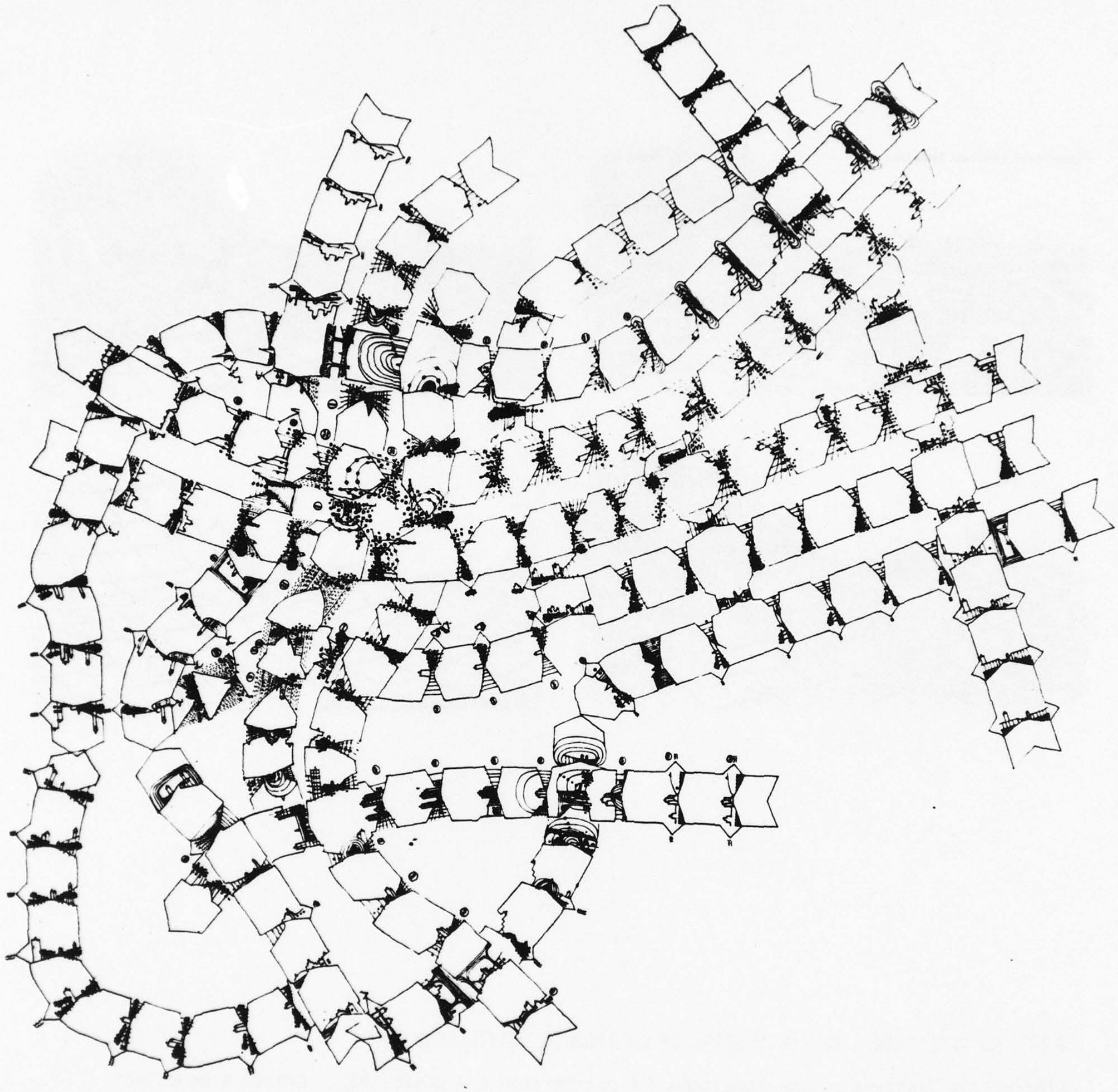
6.10 EVALUATION OF THE SOUNDSCAPE: BOSTON

A composite view of the variety of city sounds, as perceived along a sequence of streets in Boston by numerous subjects, is graphically represented in map form. Symbols were developed to represent qualities of sounds as much as possible, e.g. soft, intense, muffled, sharp, echoing, expansive. Nevertheless, a legend is still needed to fully understand the map. Map reprinted by permission from Michael Southworth, THE SONIC ENVIRONMENT OF CITIES, Unpublished M.I.T. Thesis, 1967.



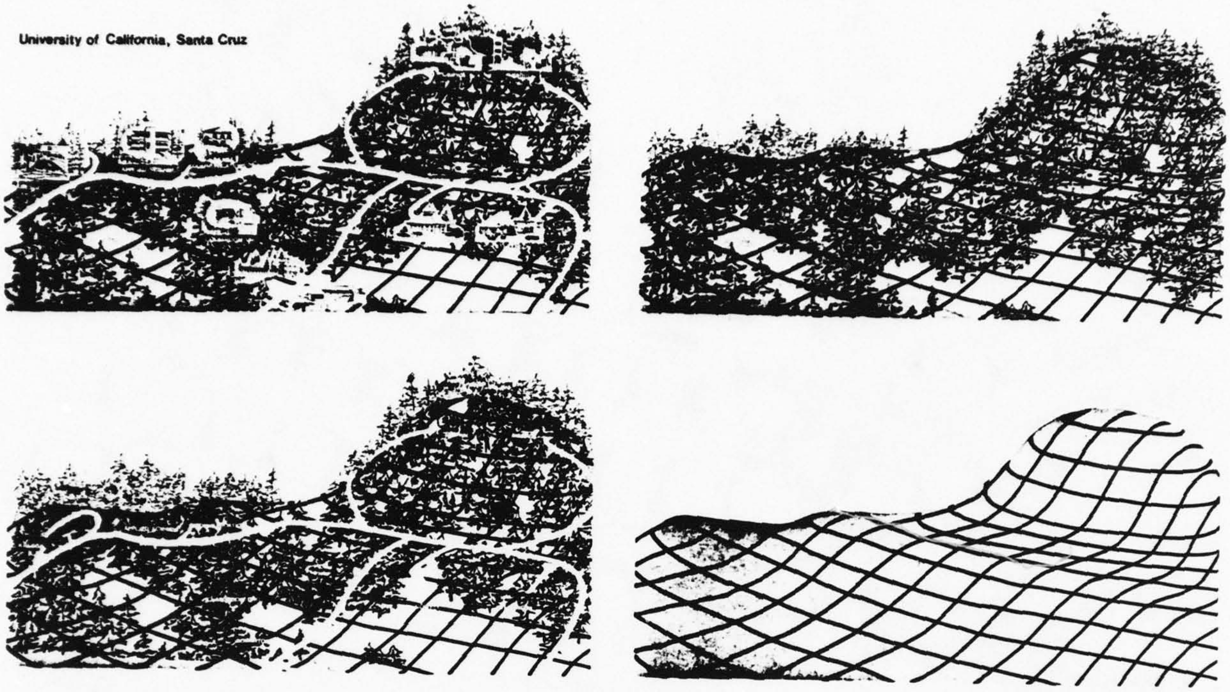
6.11 MOTION-SEQUENCE MAP: VISUAL CHARACTER OF A HIGHWAY NETWORK, WESTERN METROPOLITAN SECTOR OF BOSTON

The experience of vision and motion along a highway network is represented in this map used in highway planning and design. Qualities of the highway experience, such as spatial containment, views, sense of motion, and field of view, are represented. Although economical, the technique requires far more imagination and interpretation from the user than simulation techniques such as models or film. Map reprinted by permission. M.I.T. Student Project, Department of City Planning, 1966.



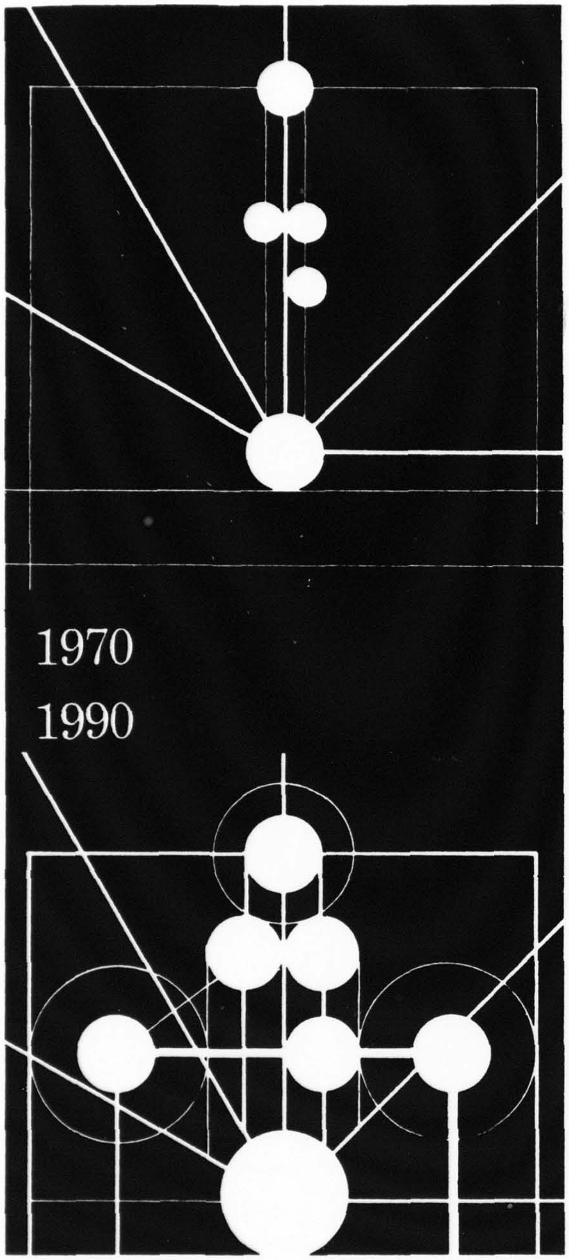
6.12 VIEW SEQUENCE ALONG MAJOR STREETS: BOSTON

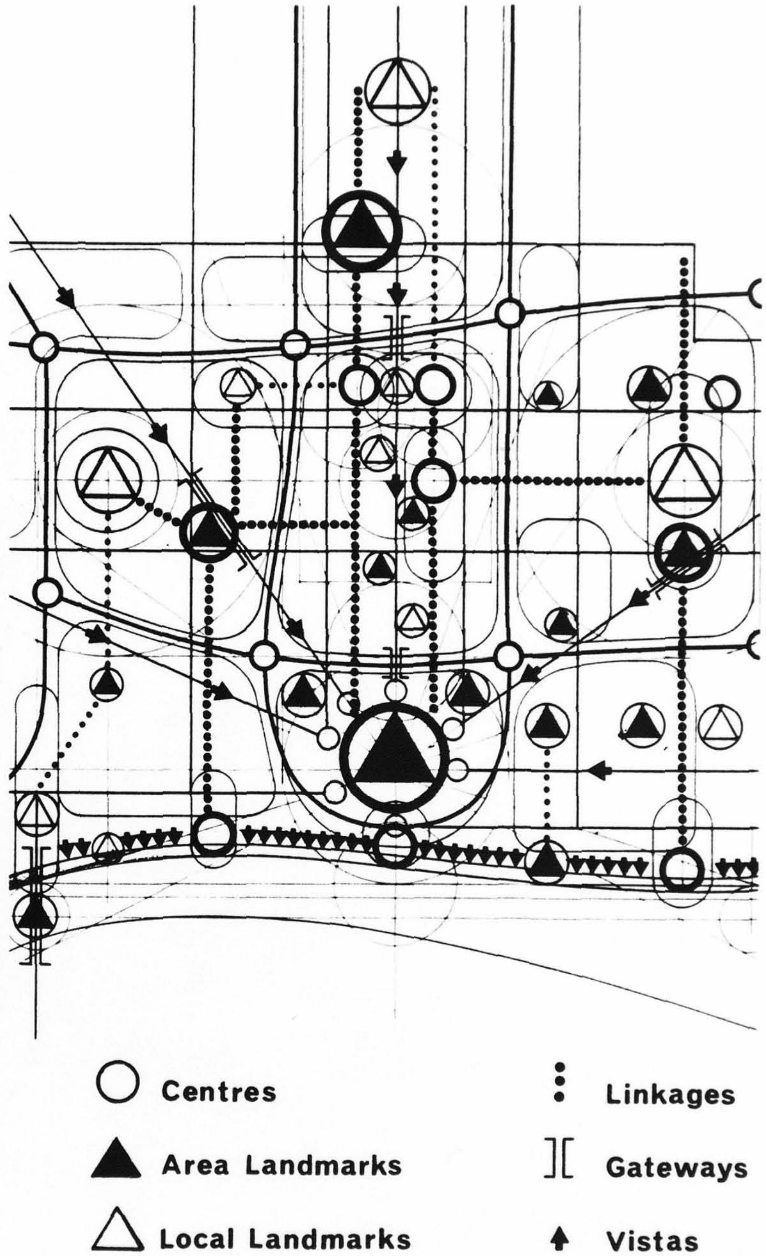
The changing views seen by drivers are shown in map form by connecting individual views along routes into a chain. Activity and form are shown schematically. This technique is useful in highway design and analysis. However, routes can be travelled in only one direction. Street networks must be widely enough spaced to accommodate the view chains. Map reprinted by permission. Donald Appleyard, Michael Southworth; General Motors Urban Transportation Project.



6.13 SUPERFEATURE MAP: UNIVERSITY OF CALIFORNIA, SANTA CRUZ

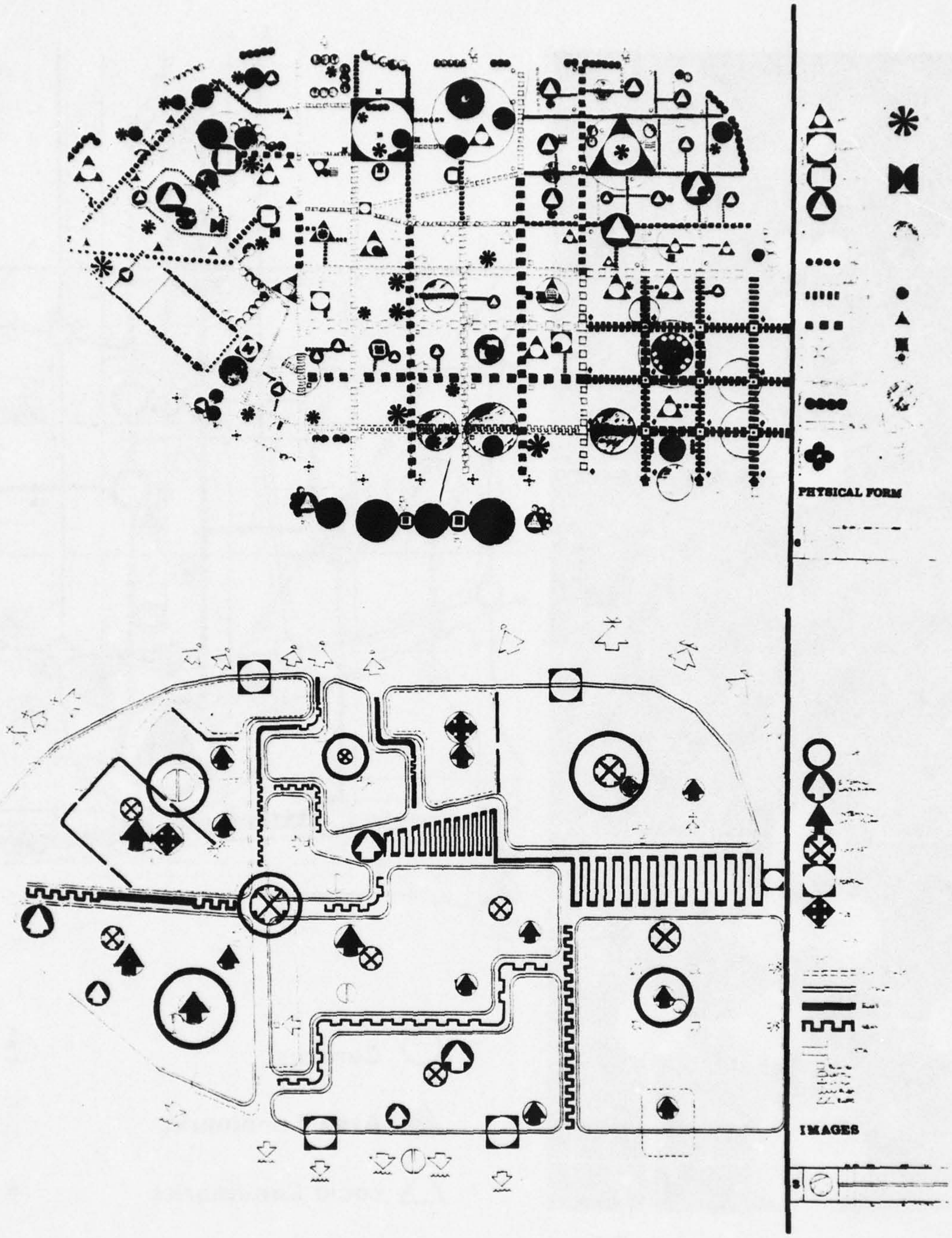
Distinctive features of the landscape are exaggerated and distorted to create a composite "superfeature" that will be recognized by most people. The graphic result resembles cubist art. The Santa Cruz campus is particularly difficult to map and to orient oneself in because it is heavily wooded, highly dispersed, and hilly. Topography is communicated by means of a warped grid. A transparent forest overlay texture was developed to allow visibility of the terrain grid. Four stages in the development of the map are illustrated: topography, circulation, buildings, and vegetation. This technique is not appropriate where quantifiable, accurate information is required, as in navigation or construction. It is particularly useful to the unfamiliar user who knows nothing about the area he is about to explore. Map reprinted by permission from Dana Charlene Cuff and Kristina Hooper, University of California, Santa Cruz.





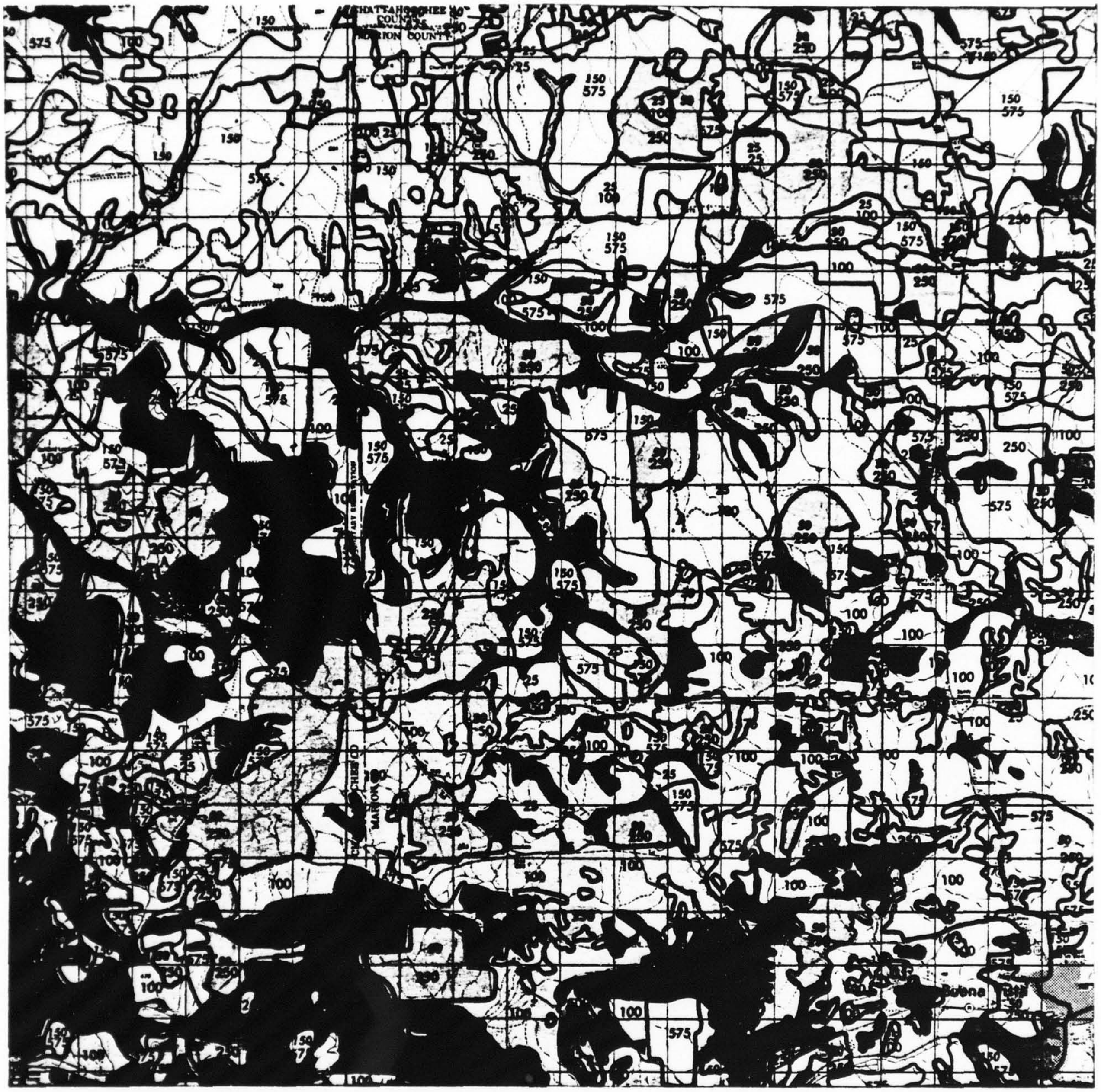
6.14 SYMBOLIC DIAGRAMS: DETROIT--CHARACTER, 1970 & 1990

Diagrams represent symbolically the preceived character of the city in the present and as proposed in the future. Elements of the construct include districts, centers, landmarks, major routes, gateways, and vistas. The large map details the anticipated future image. Symbolic diagrams can powerfully convey concepts that would be lost in the detail of conventional maps, but their meaning is often not apparent without study. Map reprinted by permission. Detroit City Plan Commission, Urban Design Division, DETROIT 1990, Detroit, 1969.



6.15 SYMBOLIC MAPS: IMAGES AND PHYSICAL FORM, ST. PAUL

Another example of symbolic mapping, these maps treat "images" and "physical form" in a redevelopment plan. The problem of symbols is particularly apparent in the second example. Although a rather delightful abstraction is created, it is meaningless without careful cross-referencing with the legend. Unfortunately, the symbols used bear little relation to the qualities being represented. In general, it is wise to attempt developing symbol systems that evoke the qualities represented to achieve greater intelligibility.

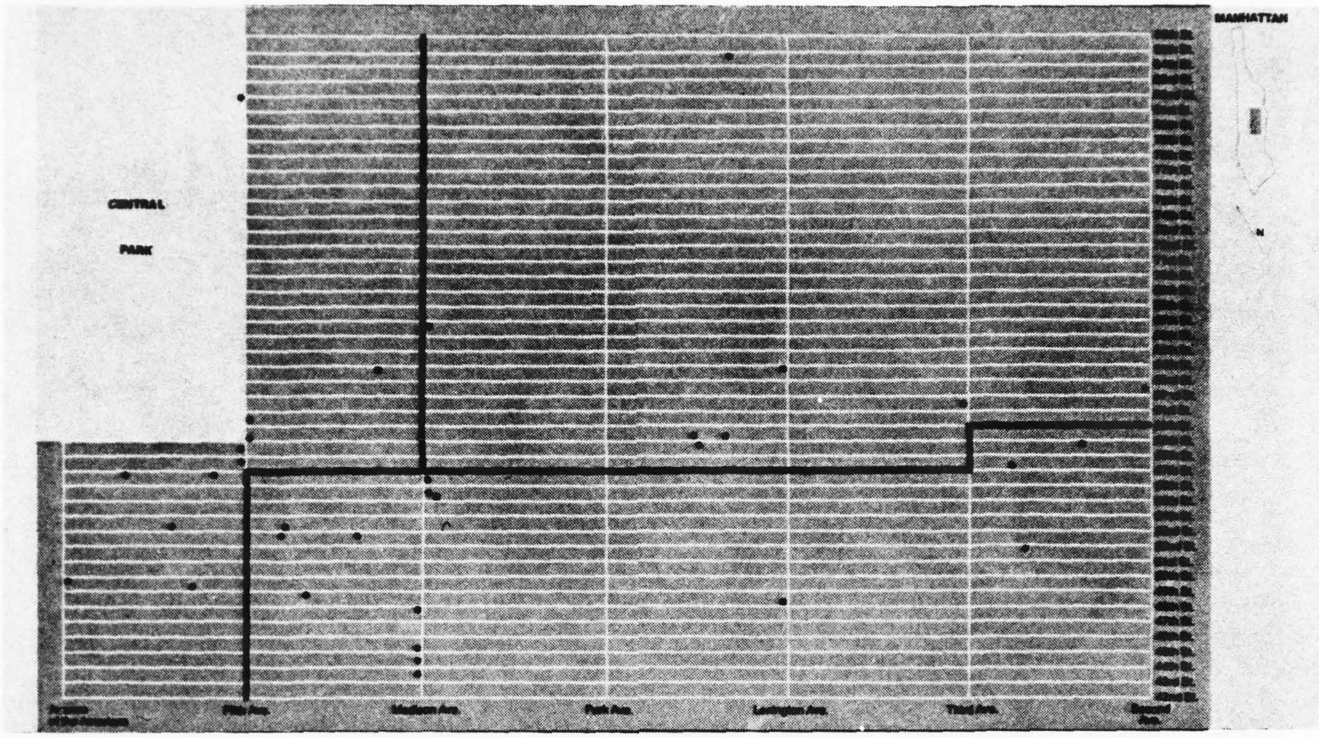


6.16 PROBABILITY OF AERIAL DETECTION, HORIZONTAL VISIBILITY, AND FIELDS OF FIRE

Color and value correlate with degree of concealment from aerial observation, with the darker green areas offering the most concealment and white areas offering the least. Superimposed numbers express maximum horizontal visibility in meters. Red dot patterns indicate areas with restricted fields of fire, and superimposed red numbers show the depth of the field in meters. Tones and the dot pattern work well to communicate these data, but color is not essential. The overlayed numbers are less effective, being hard to read, especially through the dots; the two sets of numbers are differentiated only by color. If numbers are necessary, they should be bolder and differentiated by type face or perhaps by outline frames. Map reprinted by permission. Experimental Map, U.S. Army Topographic Command, Washington, D.C.

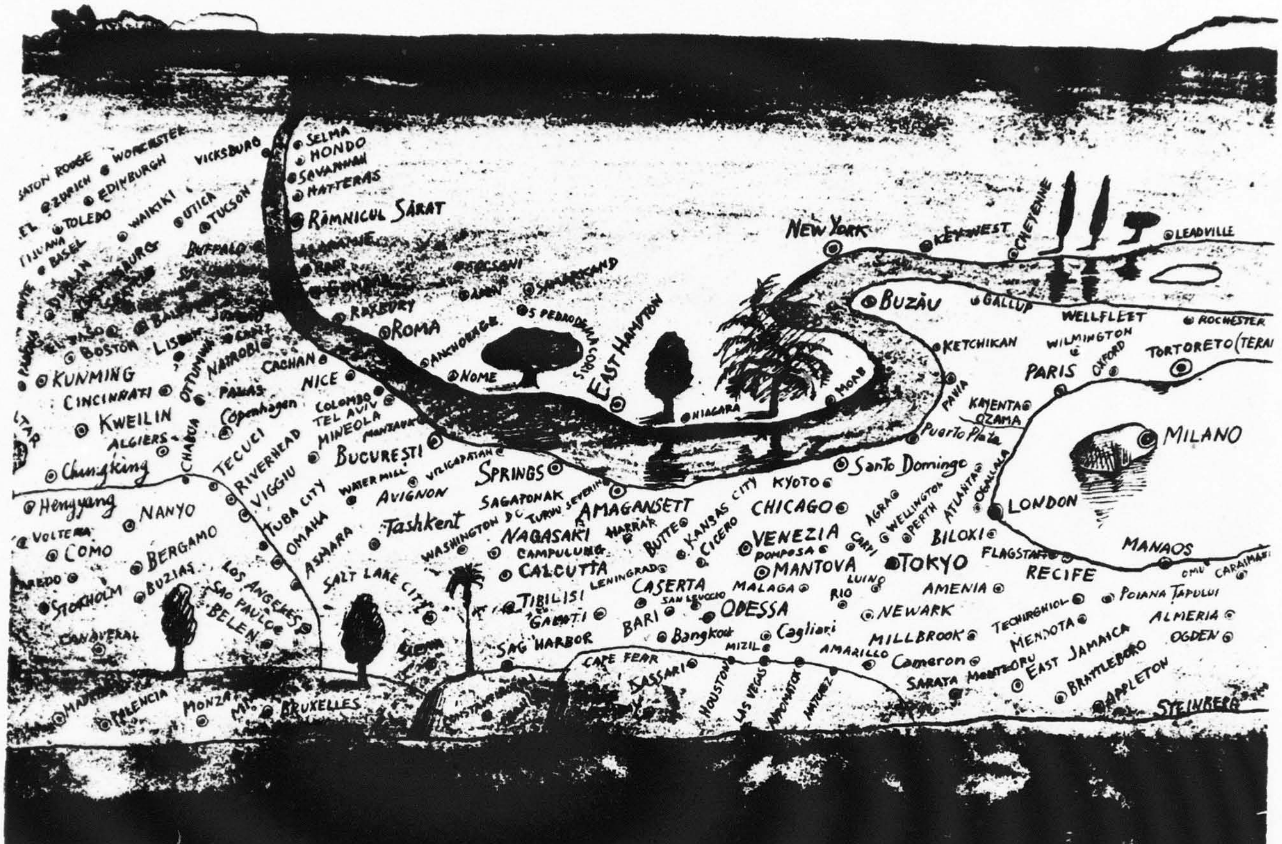
6.17 EYE LEVEL PHOTO GRID MAP: CENTRAL BOSTON

Central Boston was arbitrarily divided into a grid of small, equal size cells about 150' by 150'. A single character photograph was then taken from one point within each cell. Photos were mounted in the same pattern as the cell grid, creating a photo montage map. The technique provides a strong sense of the character of city districts but cannot be used for orientation. It is most useful when overlayed with a transparent street grid to provide reference points. Map reprinted by permission. Carl Steinitz, CONGRUENCE AND MEANING, Unpublished M.I.T. Dissertation, 1967.



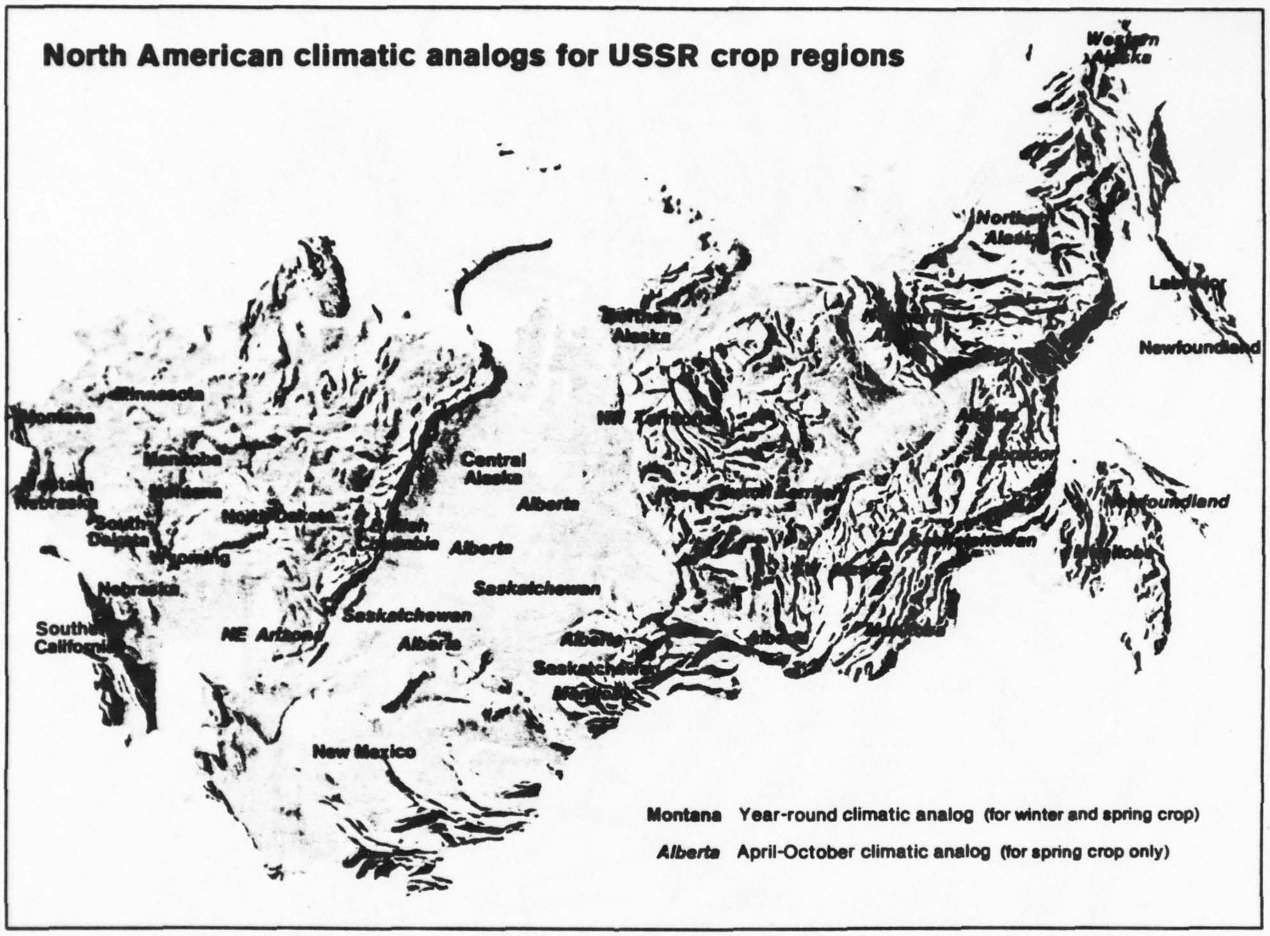
6.18 COUNTER INTUITIVE MAP: HARD-TO-FIND QUALITY SHOPS, MID-TOWN MANHATTAN

Alerting prospective shoppers to the hidden quality shops located just off the main shopping streets is the purpose of this map and the accompanying set of 36 slides. Commonly known shops and landmarks are ignored in favor of little known but worthwhile places. The shopper first views slides of store fronts in rapid succession before leaving on a shopping trip. He retains the image of facades that interest him and is alerted to look for them. The map's continuous line indicates the primary shopping street. The small circles located off these streets correspond to the hidden or difficult-to-find shops. The long Manhattan block has been intentionally distorted to an even more elongated shape to represent the way it is perceived on the street. Similarly, block lengths are shown as equal, even though they are, in fact, unequal. Map reprinted by permission of Craig Fields. Graphics by Rand McNally. Unpublished.



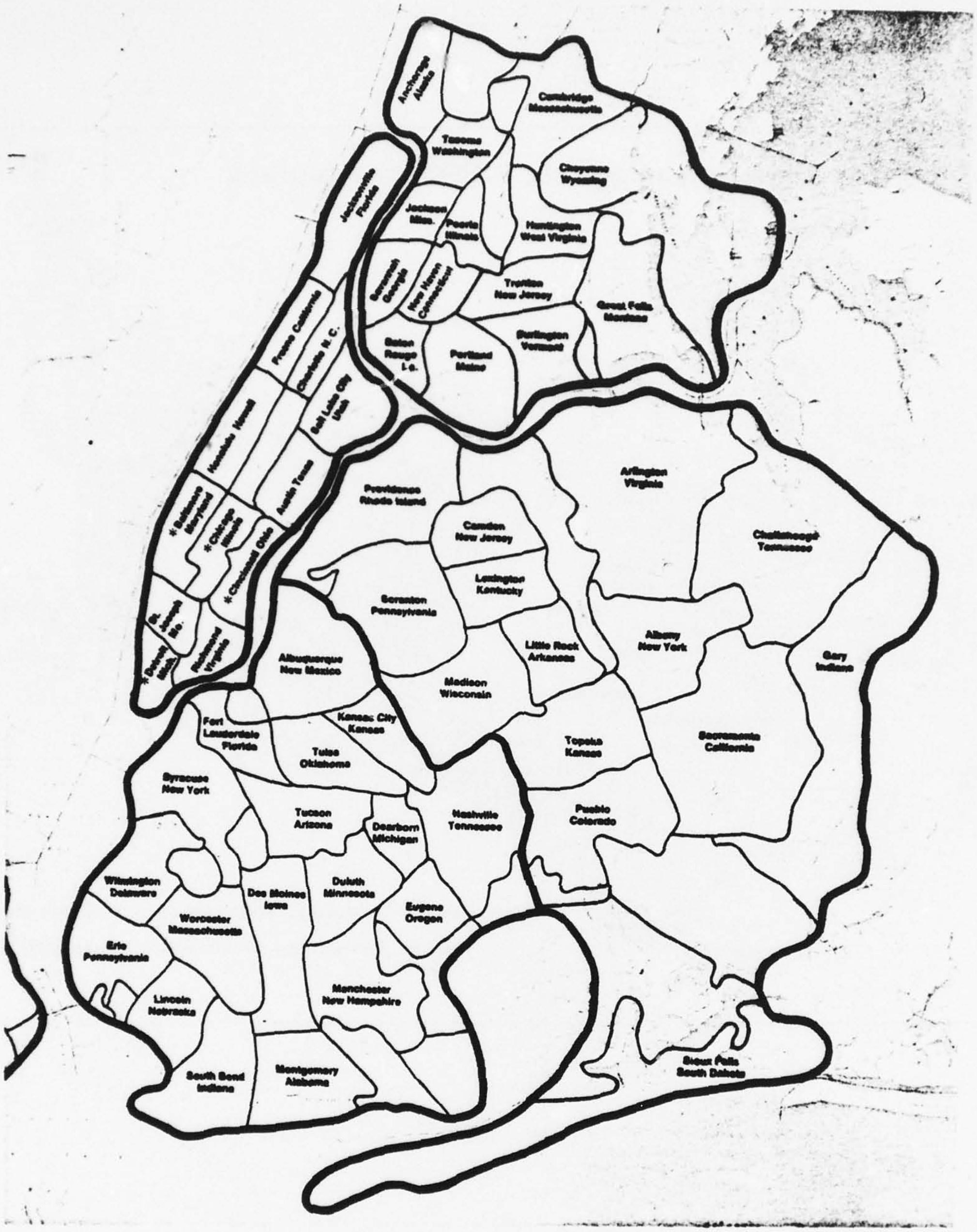
6.19 FANTASY MAP

Real name places are arranged in fantastic juxtapositions on a landscape view. Venezia is between Chicago, Pomposa, Cicero, and Tokyo, while Roma has Anchorage and Roxbury as its neighbors on a river bank. Milano appears to be located on top of a rock in the middle of a lake. The map's use is entirely imaginary--a fantastic trip of the mind--imagining opposites as near neighbors and then pursuing some of the resulting implications. Map reprinted by permission. Saul Steinberg, THE INSPECTOR, Penguin Books, New York, Copyright 1973.



7.1 NORTH AMERICAN CLIMATIC ANALOGS FOR USSR CROP REGIONS

To communicate rather technical information about crop regions in Russian, North American places having equivalent climates have been labeled on the map of the Soviet Union, creating some odd conjunctions. Imagine how Montana would feel to wake up and find itself south of Moscow! But precisely this startling impact is helpful in making the point. To make the unfamiliar country less strange, familiar equivalents are used to describe it, and do so more effectively and quickly than technical terms. Obviously, the technique depends on use of equivalents familiar to the map user. The second example compares the area and latitude of the Soviet Union with the U.S. by superimposing one on the other. Thus, the comparison becomes vivid and direct. Map reprinted by permission. Central Intelligence Agency, USSR AGRICULTURE ATLAS, 1974.

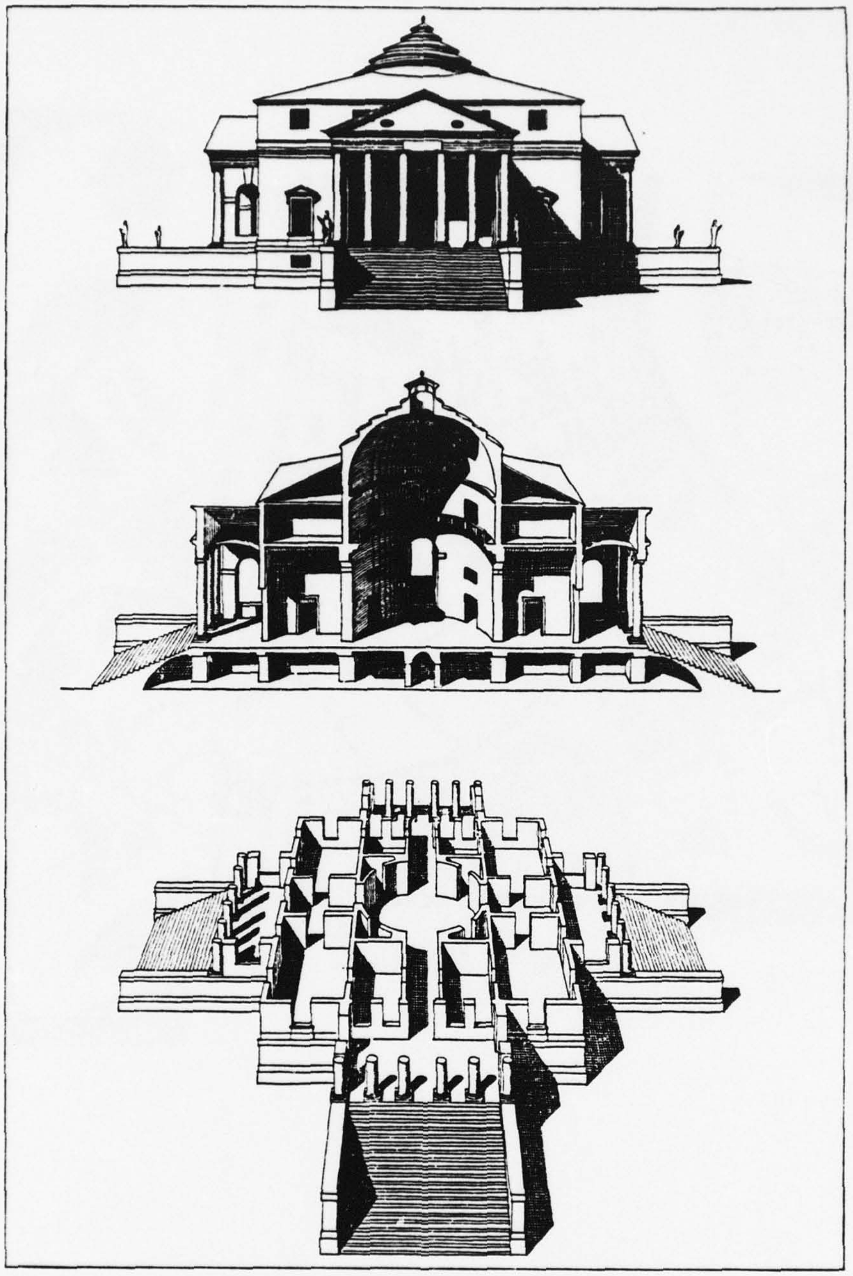


7.2 COMPARATIVE MAP: NEW YORK = 62 CITIES FROM 50 STATES

To make the immense population of New York City and its neighborhoods more concrete, it has been divided into areas identified by other familiar cities in the U.S. having equivalent populations. Such comparisons are very helpful in conceptualizing the population size and density of New York, since large numbers and statistics often mean little to most people. In any situation where large numbers are to be communicated, this technique might be effective. Map reprinted by permission of New York City Planning Commission, PLAN FOR NEW YORK CITY, Volume 1, Copyright 1969.

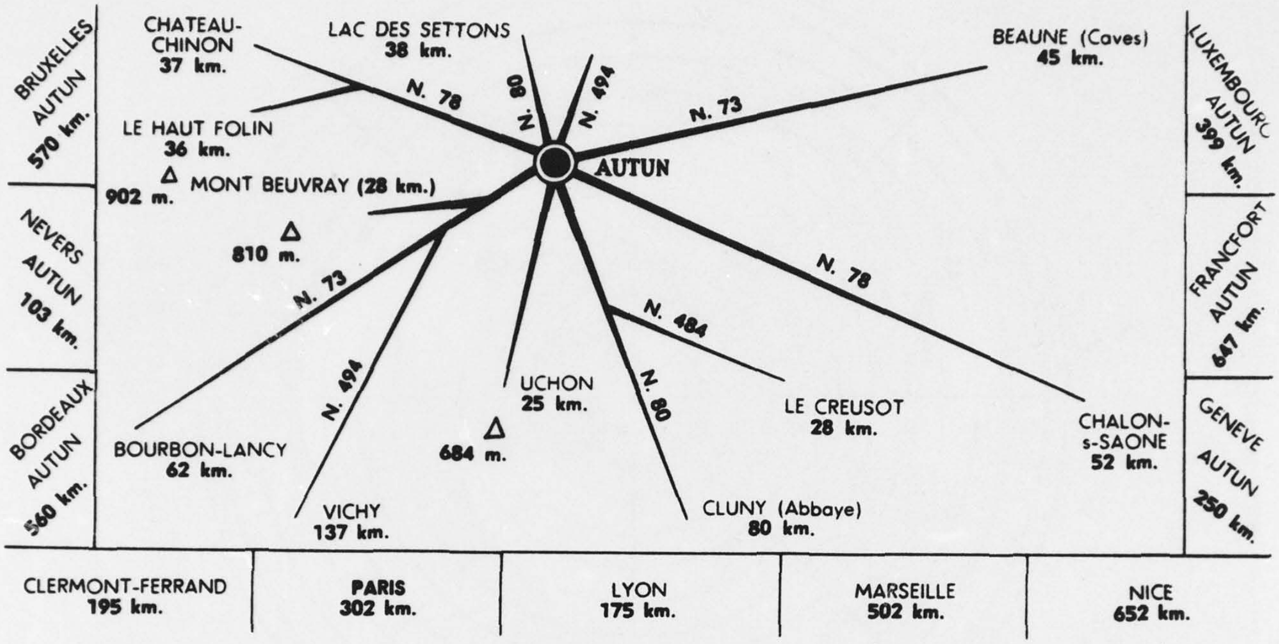
7.3 OPTICAL ILLUSION/MULTI-POINT OF VIEW MAPS: UP AND DOWN AND PRINT GALLERY

Escher, master of the graphic illusion, made these two impossible "maps." The first makes "up" become "down" and vice versa; the second melds interior views with exterior views. Whether such techniques have values for the cartographer beyond those of visual delight remains to be seen. Map reprinted by permission. M.C. Escher, THE WORLD OF M.C. ESCHER, Abrams, New York, Copyright 1971. Courtesy of the Escher Foundation -- Haags Gemeentemuseum-- The Hague.



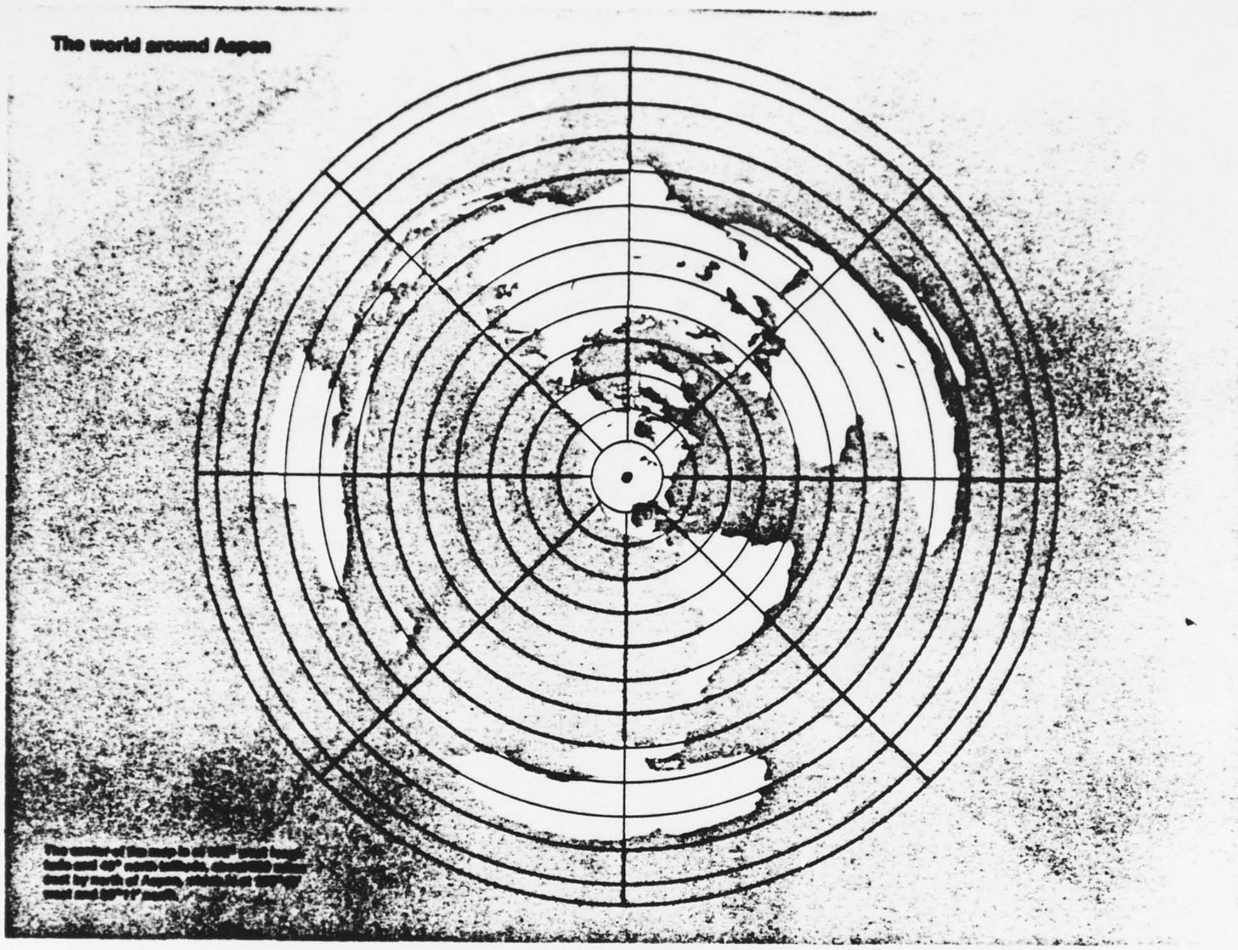
7.4 MULTIPLE VIEWPOINTS: FACADE, SECTION, AND PLAN PERSPECTIVES

Because any single view gives only partial information about a building, Rasmussen shows three views of the same thing: a traditional facade view of the outside front, then a cutaway section showing half of the interior, and finally, a cutaway plan/perspective showing the walls, columns and spaces they form inside and outside. The multiple points of view technique is also appropriate to mapping of non-architectural, large scale environments. Map reprinted by permission. Steen Eiler Rasmussen, TOWNS AND BUILDINGS, M.I.T. Press, Cambridge, MA., 1969. Copyright 1949 and 1951 by Steen Eiler Rasmussen.



7.5 DISTANCES FROM AUTUN TO OTHER POINTS IN FRANCE AND EUROPE

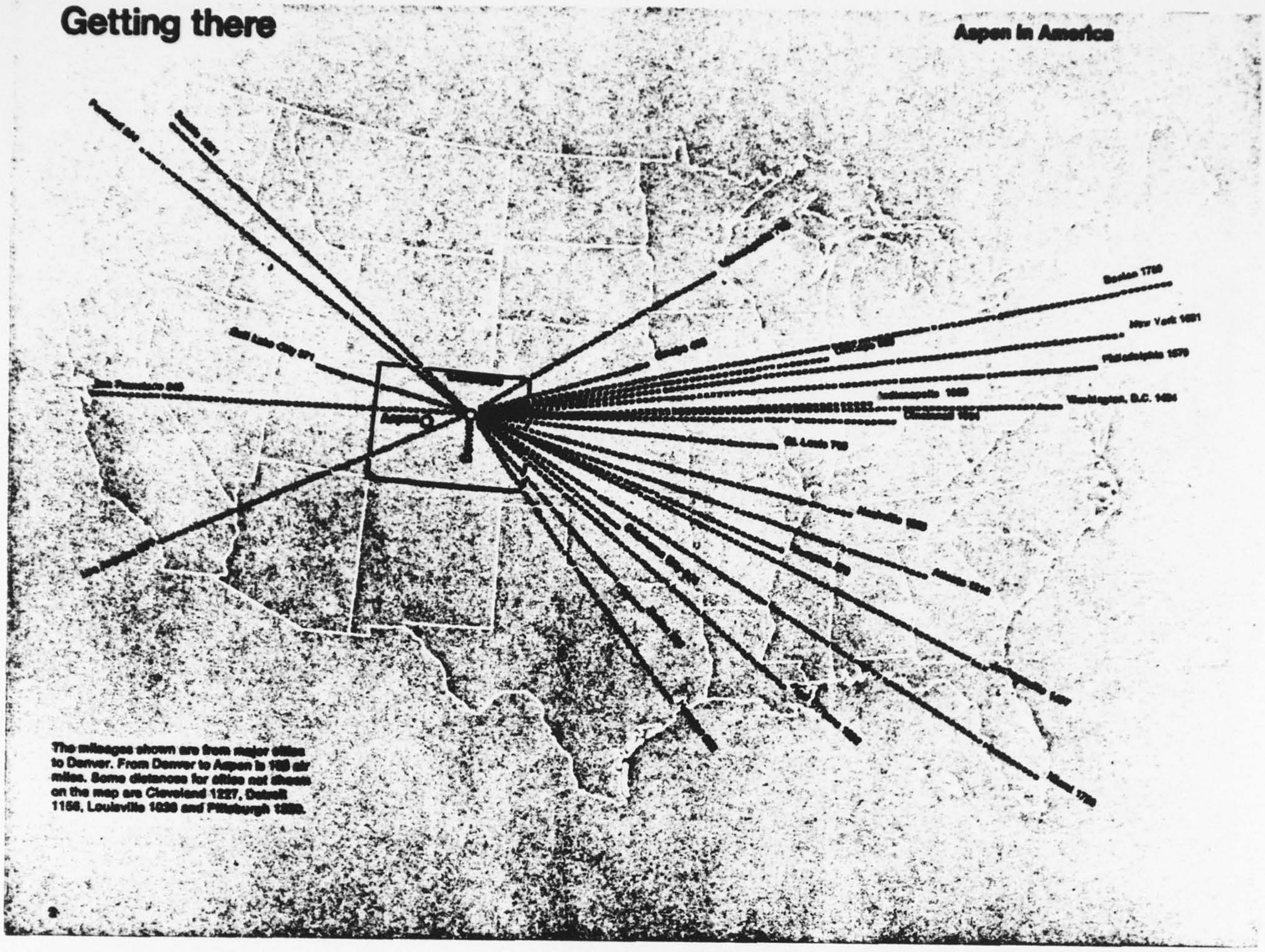
A highly simplified spider diagram presents relative distances from Autun to several regional destinations. Only the road numbers and altitudes are indicated as additional information. In a geometric band around the perimeter, the distances from Autun to various prominent French and European cities are listed. The whole diagram is highly stylized and selective, with no descriptive verbal back-up.

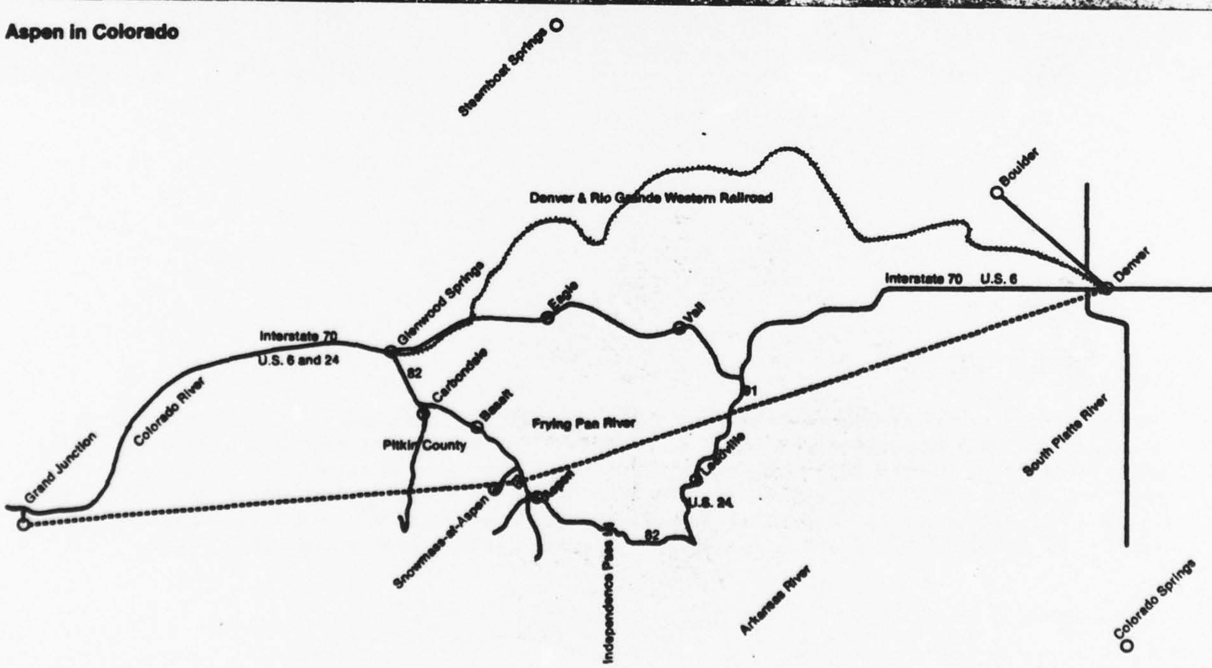


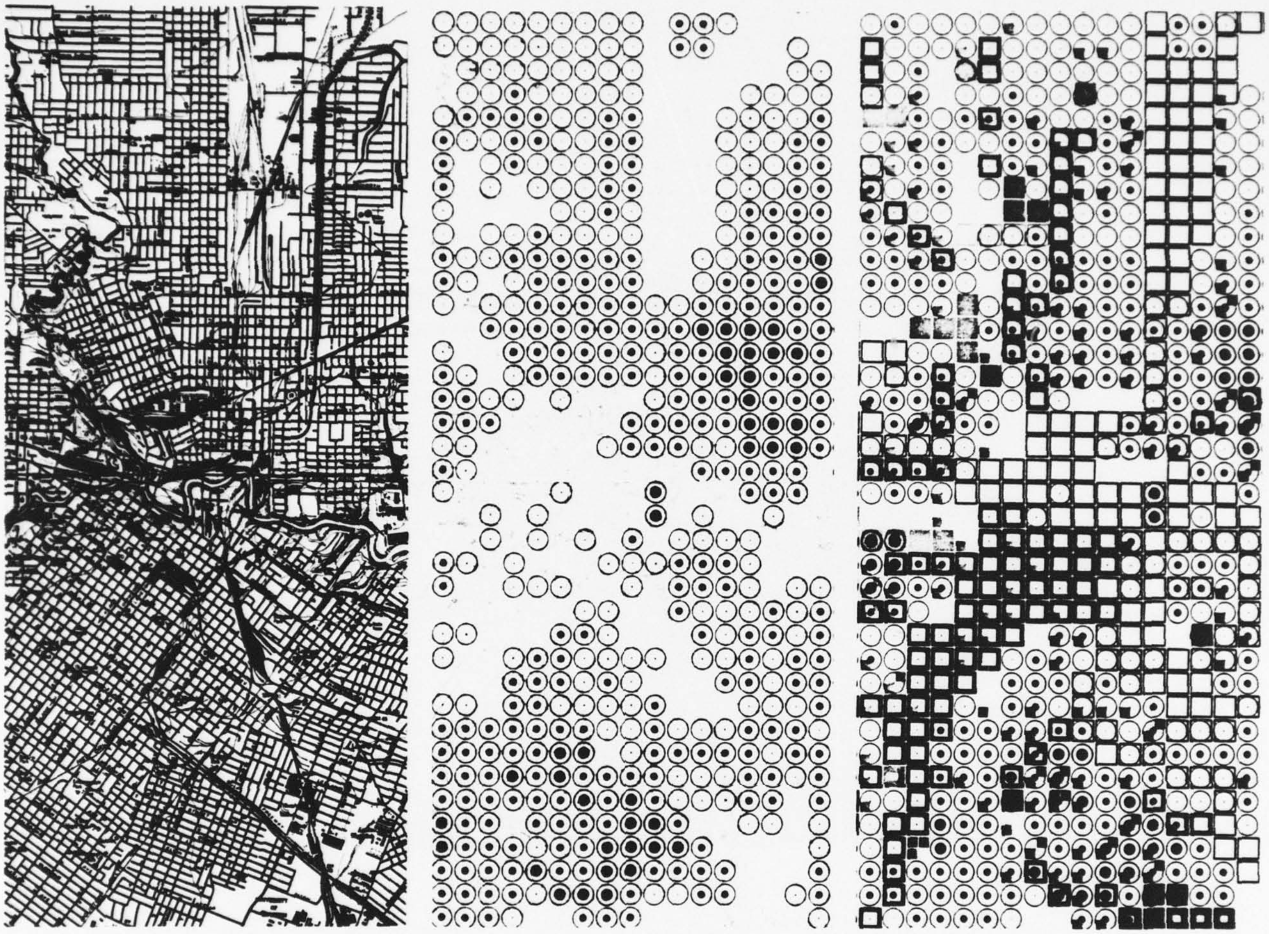
7.6 ZOOM MAPS: ASPEN, COLORADO

By means of a series of maps, one has the effect of zooming in from the scale of the earth, through the country and state, down to the small town of Aspen. All of the maps are drawn with Aspen as the central focus. Map reprinted by permission. Joel Katz and Richard Saul Wurman of Murphy, Levy, Wurman, ASPEN VISIBLE, Aspen International Design Conference, Copyright 1972 by IDCA.

Getting there

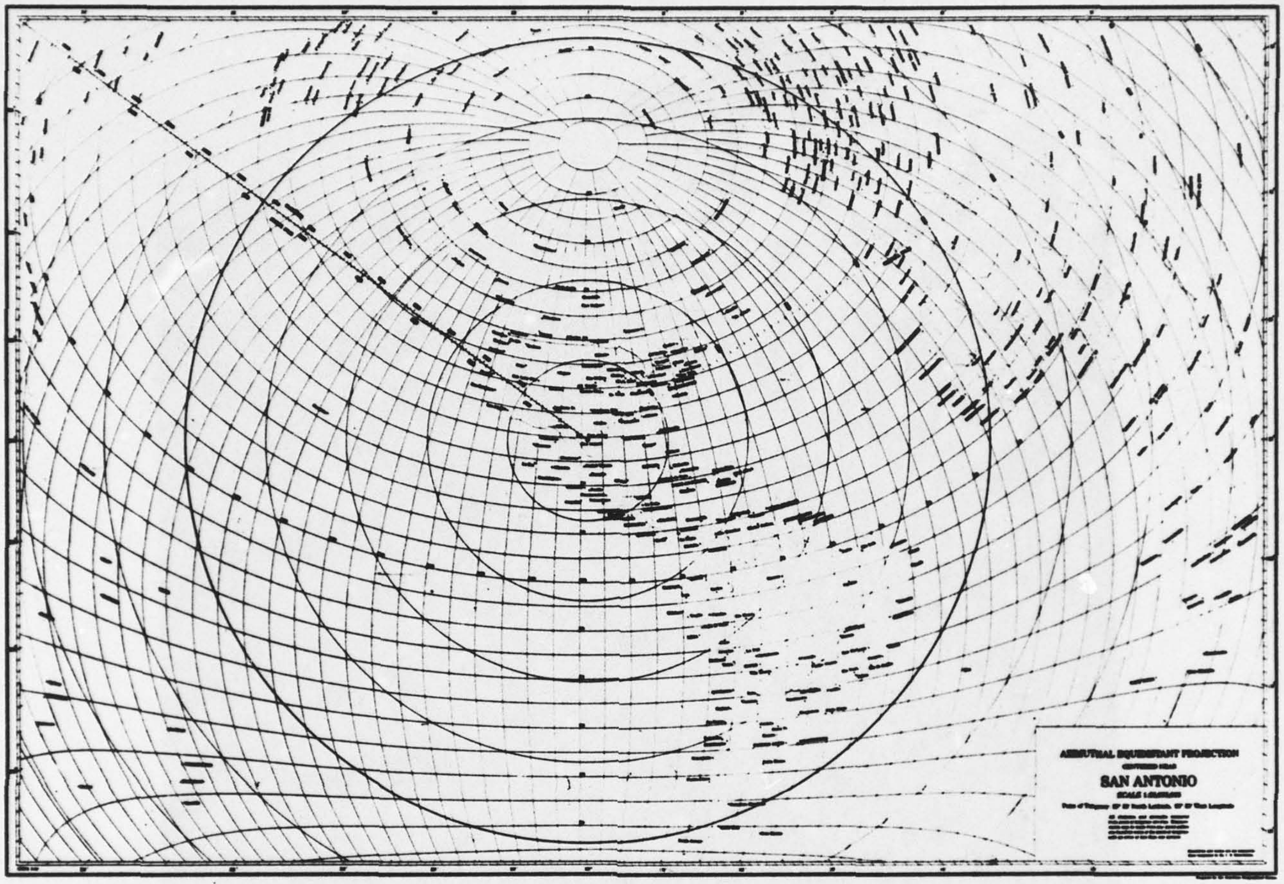






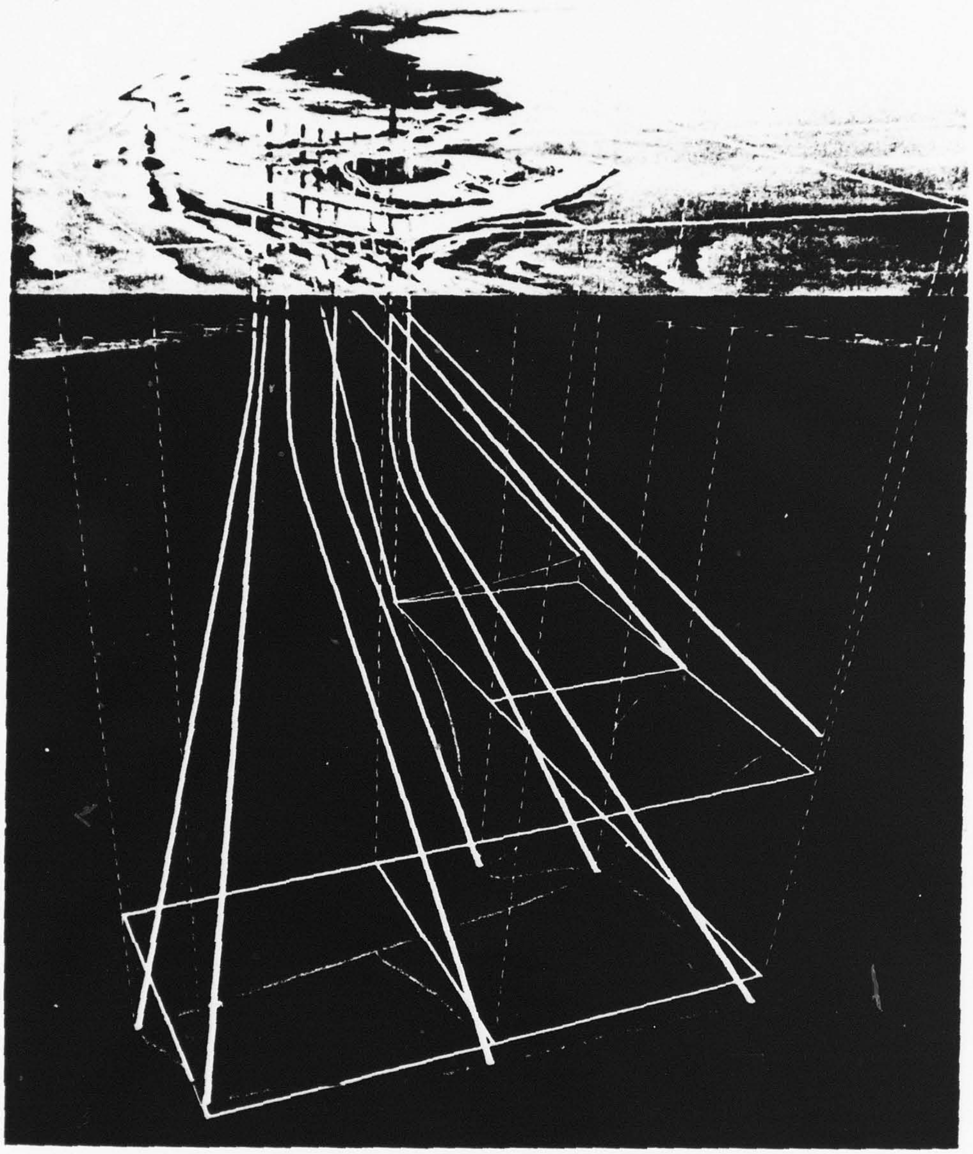
7.7 MAP OF LAND USE

Twenty cities are presented at the same scale in terms of land use. The unique value of these maps is the opportunity to compare different cities against the same variables. Data were mapped in a system that potentially could be automated. Although the majority of the maps are large--17½" x 17½"--the most interesting maps are the small maps at the end of the Atlas. Map reprinted by permission. Joseph R. Passonneau and Richard Saul Wurman, URBAN ATLAS: 20 AMERICAN CITIES, M.I.T. PRESS, Copyright 1968 by Passonneau and Wurman.



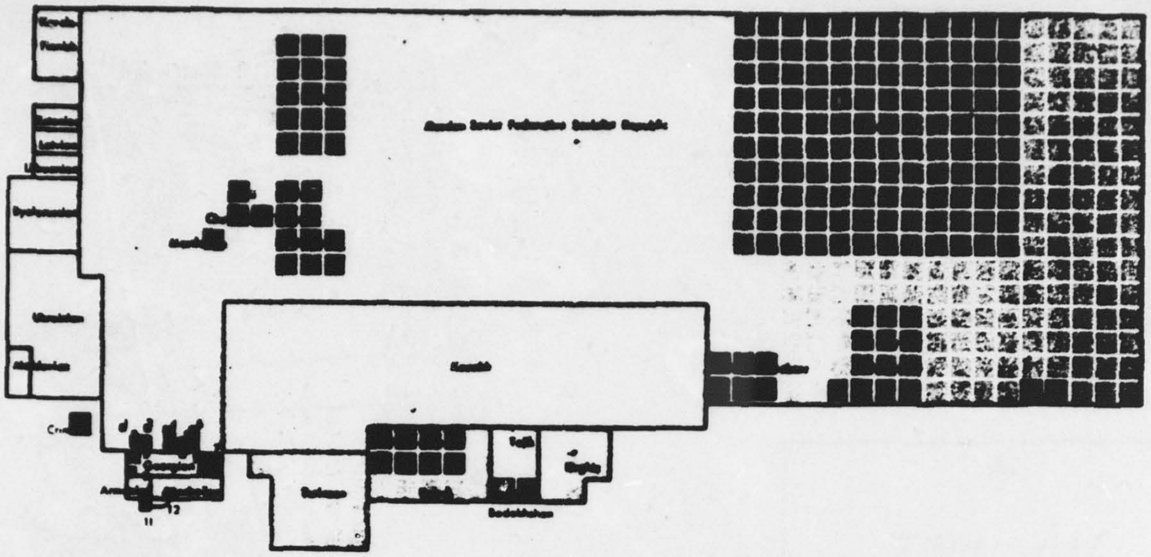
7.8 POINT OF VIEW: AZIMUTHAL EQUIDISTANT PROJECTION CENTERED NEAR SAN ANTONIO

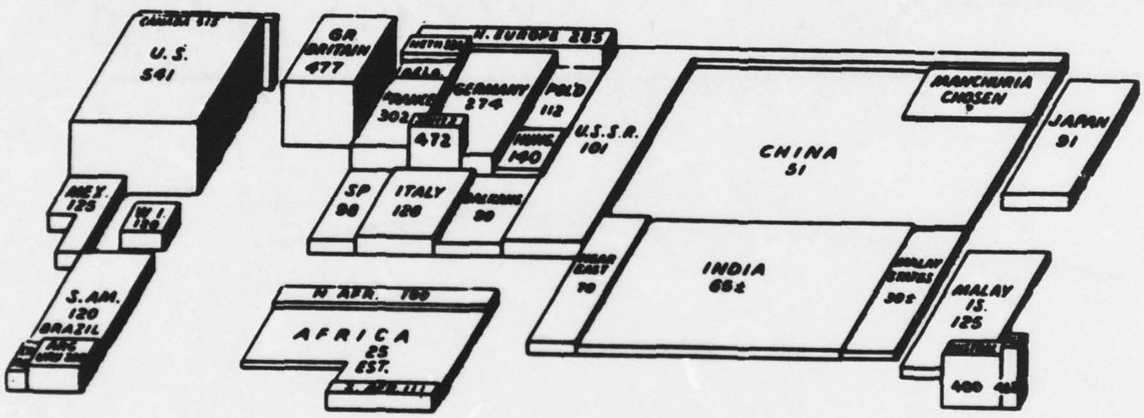
The world is seen in a different perspective when an unusual center is used, San Antonio in this example. All distances and azimuths measured from point of tangency are true. Measurements may be made from any point, within one hundred miles of the point of tangency, with an error of less than one percent. Map reprinted by permission. Based on the material of the American Geographical Society.



7.9 PERSPECTIVE-SECTION: DIAGRAM OF AN OIL PROSPECTING PROGRAM

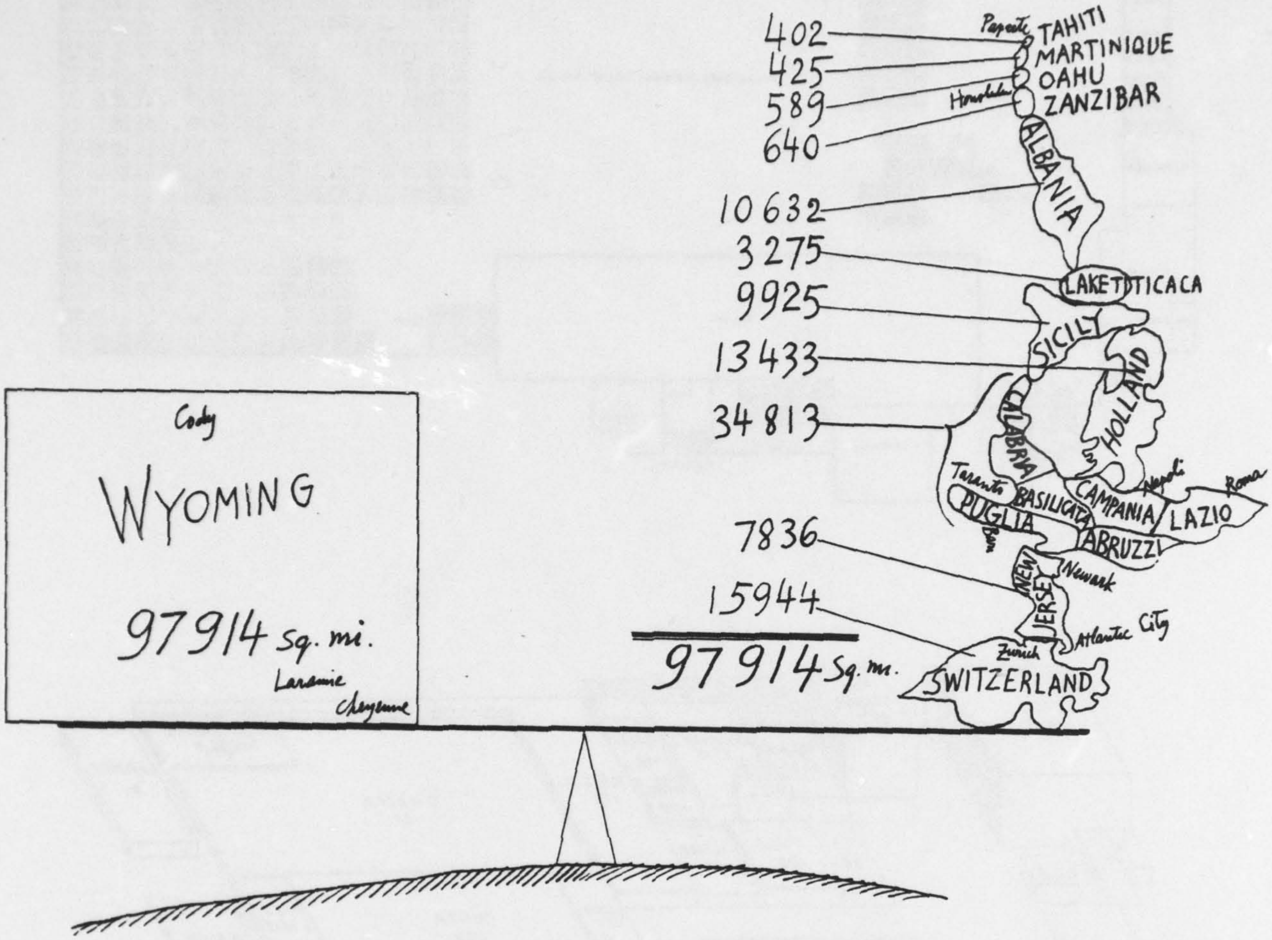
By combining a diagrammatic section with an aerial perspective above the sea landscape, the relationships between the surface and undersea activities are established. Map reprinted by permission. Tanguy de Rémur, Pétrole Progrès, Esso Standard S.A.F. (France).





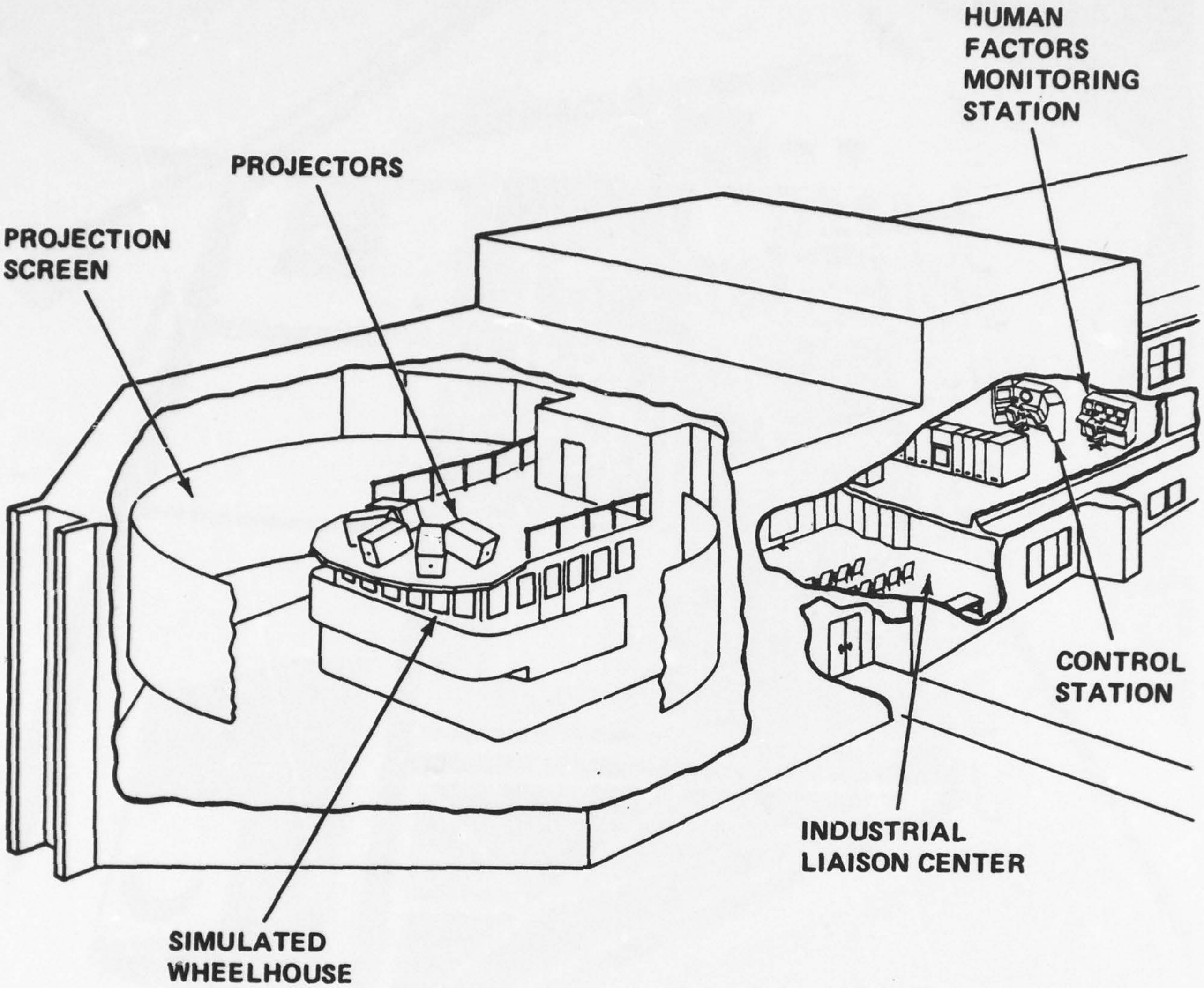
7.10 COMPARATIVE MAPS: SIZE OF MAIN REGIONS OF THE SOVIET UNION, WORLD MAP OF POPULATION AND INCOME

In map "a", the Soviet Union is converted to rectangular shapes to facilitate comparison of administrative regions in 1944. By converting all irregular geographic boundaries to the same shape, comparison becomes easier. Map "b" a map of the world, converts countries to blocks, with areas proportional to population and heights proportional to per capita income. Thus, the volume of each block represents gross national product. The technique is extremely effective for a variety of comparative studies. Maps reprinted by permission. (a) Arthur Lockwood, DIAGRAMS, Watson Guptill, N.Y., Studio Vista, London, Copyright 1969. (b) Erwin Raisz, GENERAL CARTOGRAPHY, McGraw-Hill, 1948; adapted from Colin Clark, THE CONDITIONS OF PROGRESS, 1940.



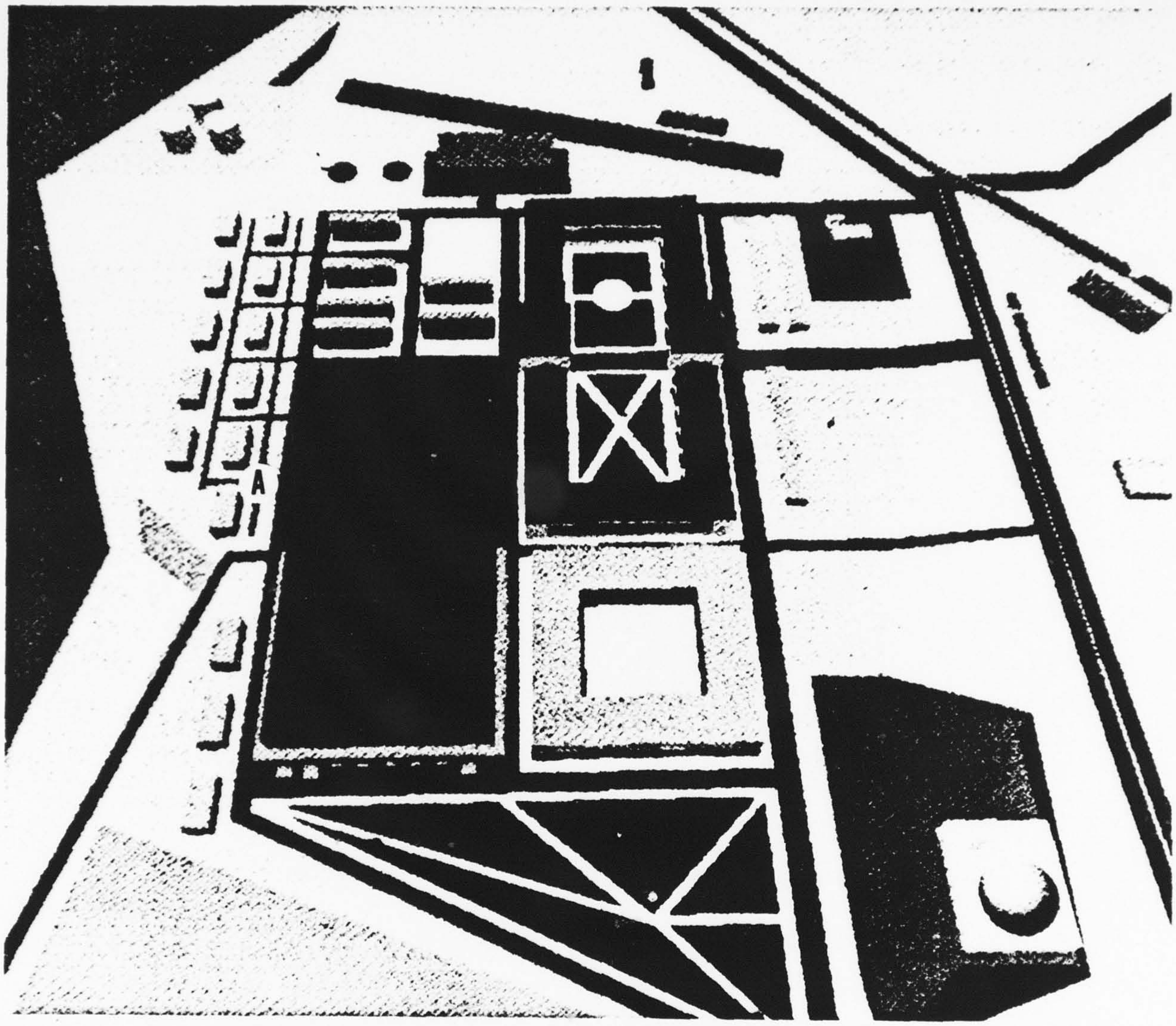
7.11 COMPARATIVE MAP: WYOMING

Wyoming balances as a block of square mileage equal to the sum of a number of small and variously exotic areas--Tahiti, Albania, Martinique, New Jersey, and others. Nevertheless, the technique is essentially concerned with making large numbers--in this case the square mileage of Wyoming--a more meaningful quantity. The surprising contrast between Jerusalem and the others with Wyoming is the attention-getting feature. We come away with the feeling that Wyoming is very large indeed despite its paucity of images. Map reprinted by permission. Saul Steinberg, THE INSPECTOR, Penguin Books, New York, Copyright 1973.



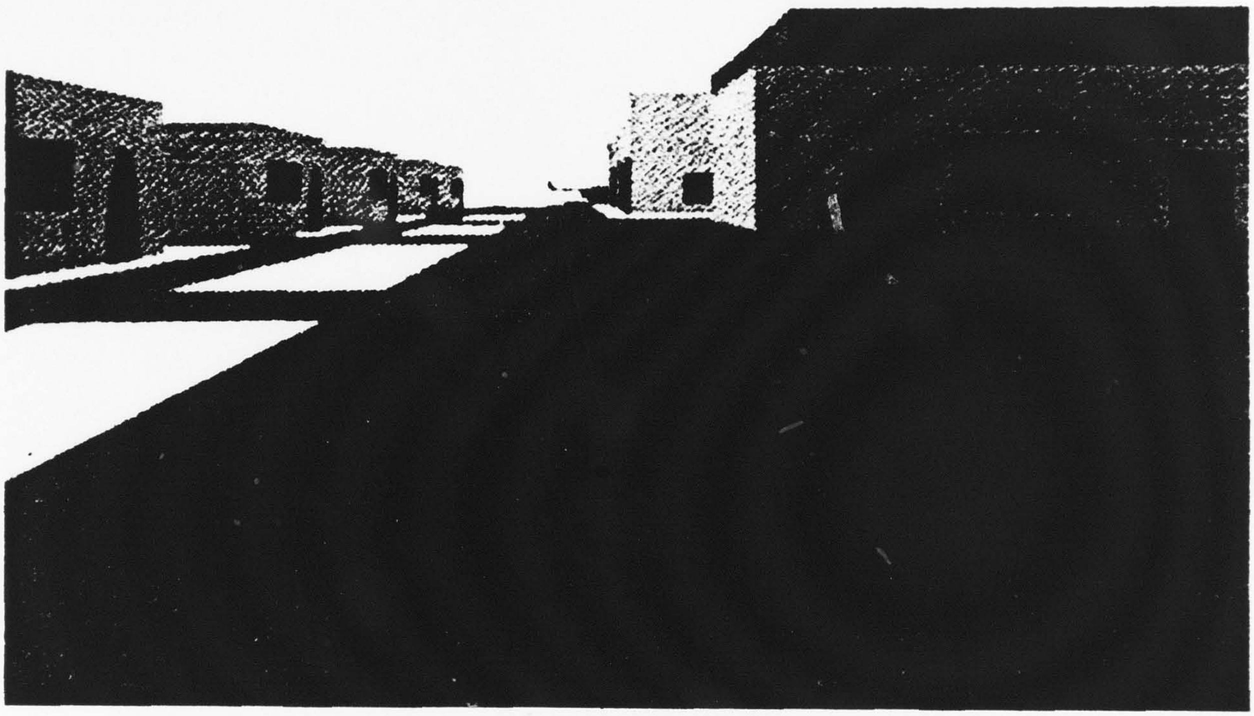
8.1 CAORF NAVIGATION SIMULATOR

The CAORF simulator recreates with considerable realism the feeling of navigating a ship through a busy harbor. A 125 foot cylindrical screen portrays ships and shorelines, navigational aids and docking areas, bridges, and buildings as full-color TV pictures. Six moving ships can be displayed at once, with the scene changing in real time in response to its own and other ship's movements. Illumination from daylight to moonless night, passing ship and harbor lights, haze and fog can all be simulated. Any geographic area, any port, any ship can be generated by a computer with a data base of three-dimensional coordinates and characteristics. As the ship handler changes course or speed, the 240-degree visual scene automatically changes, and CAORF radar and instrument readings adjust accordingly. Map reprinted by permission of Captain H.O. Travis, National Maritime Research Center, Kings Point, New York, N.Y. 11024.

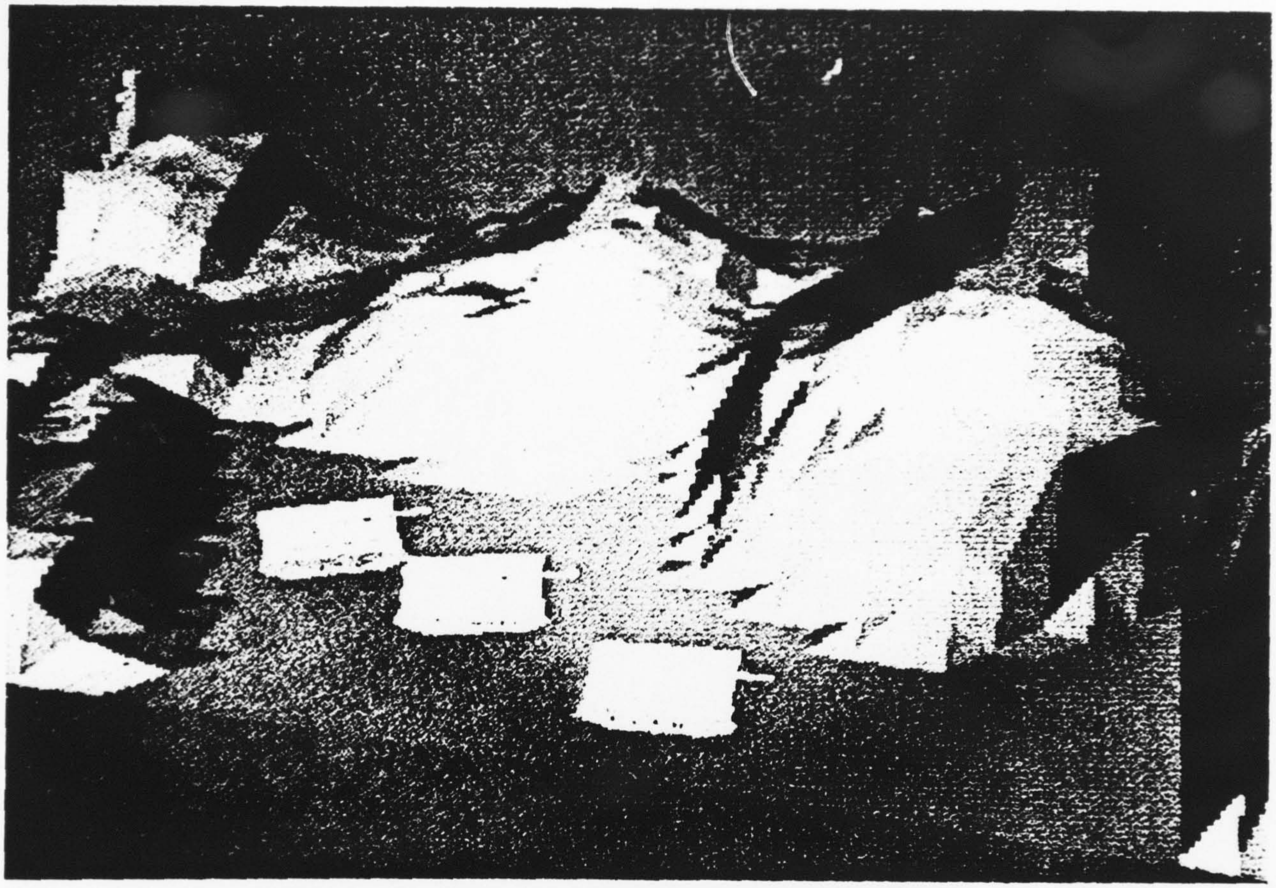


8.2 COMPUTER MOVIE MAP: DAR-EL-MARA

Realistic three-dimensional views are generated by computer from a digital data base which describes the geographical terrain, its vegetation, and its cultural features, such as buildings, roads, landmarks, etc. The left-hand example is an oblique view from above of Dar-El-Mara, a fictional middle eastern town designed by Perceptronics, Inc. for a set of evaluation experiments. The picture itself was photographed directly from a computer-driven CRT display. Once the digital data base is established, the computer can with equal ease generate views from any vantage point--ground level as well as elevated. A closely-spaced series of views, presented on film, videotape, or videodisc, and with narrative

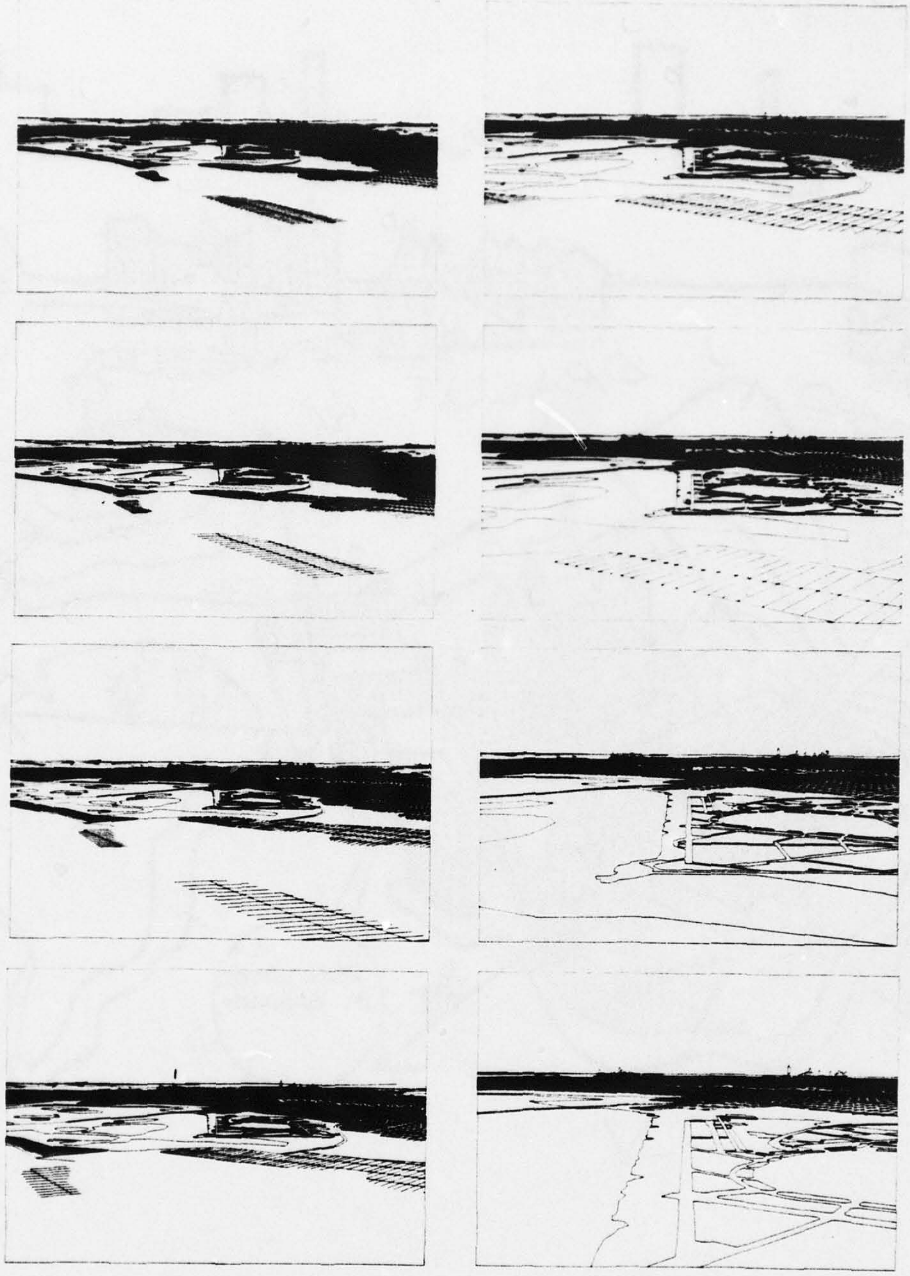


added, becomes a "computer movie map" which gives the viewer the illusion of driving or flying through the mapped locale. The right-hand example is a representative scene from a movie map of Dar-El-Mara. It is a gound level view from the point marked A in the overview scene. The movie map is in essence a guided tour through a region. It provides a stronger sense of place than that provided by conventional maps, and leads to markedly better map performance. The computer technology for producing such realistic views and tours is improving rapidly, and one can expect an increasing utilization of this mapping approach.



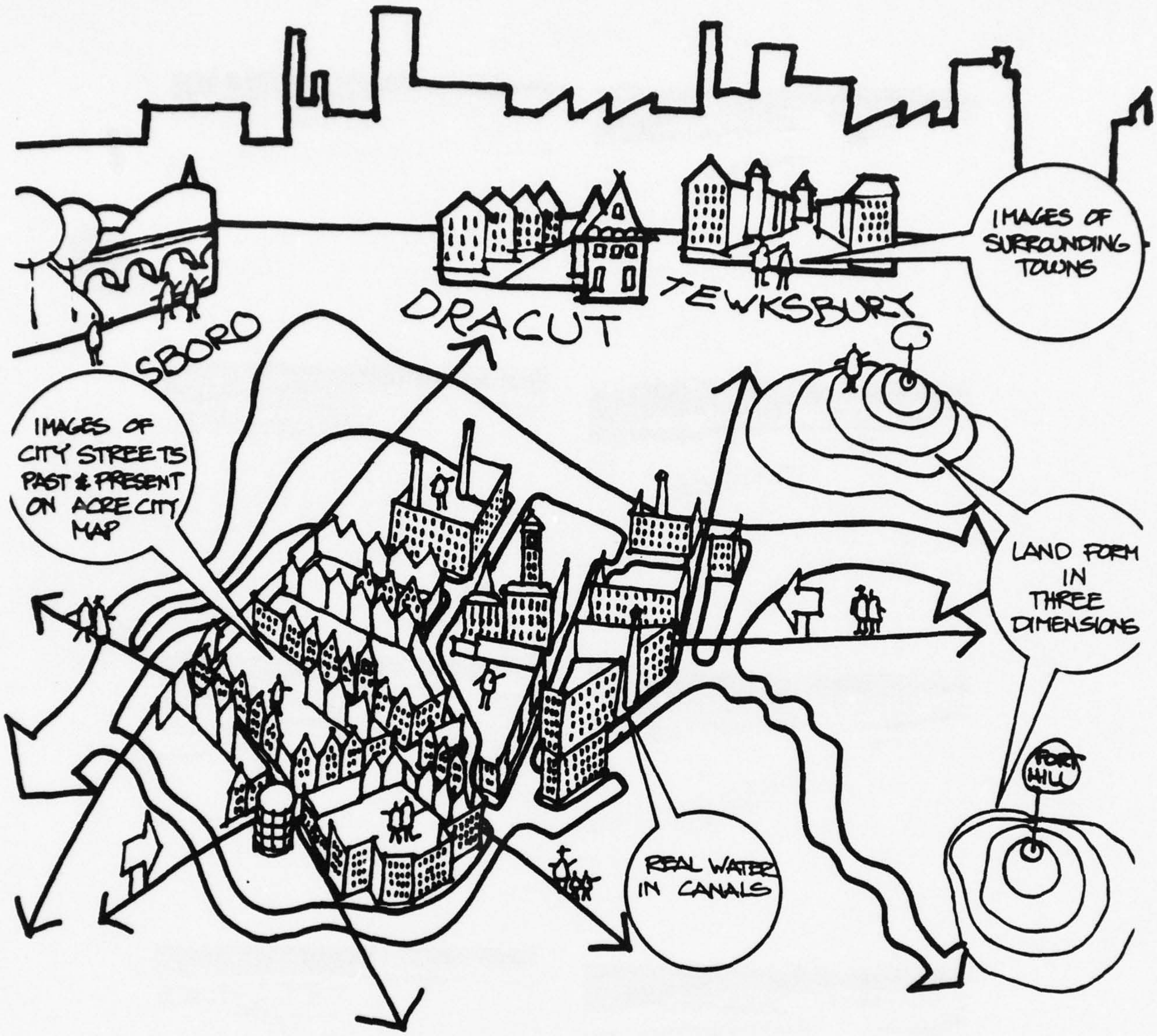
8.3 COMPUTER SIMULATION

Tanks and terrain were constructed mathematically using a computer and the Synthavision system developed by MAGI. This example has three dimensional qualities but is a static simulation. Map reprinted by permission. Mathematical Applications Group, Inc., Elmsford, N.Y. 1974.



8.4 COMPUTER REPRESENTATIONS OF AIRPLANE LANDINGS

Landing at an airport is simulated by a computer generated film of the sequence. This is a useful training or planning tool, allowing one to move through an important sequence ahead of time. It has particular value in simulating motion experiences that cannot be easily practiced in reality, e.g., many military operations or pilot training. Whether or not films of route views are faster than conventional maps in teaching a route to a stranger is not clear, but they would be useful in museums, shopping centers, or cities in response to the ubiquitous "How do I get to...?" Map reprinted by permission. William Fetter in MAKING THE CITY OBSERVABLE by Richard Saul Wurman, Walker Art Center and M.I.T. Press, Copyright 1971 by Walker Art Center.

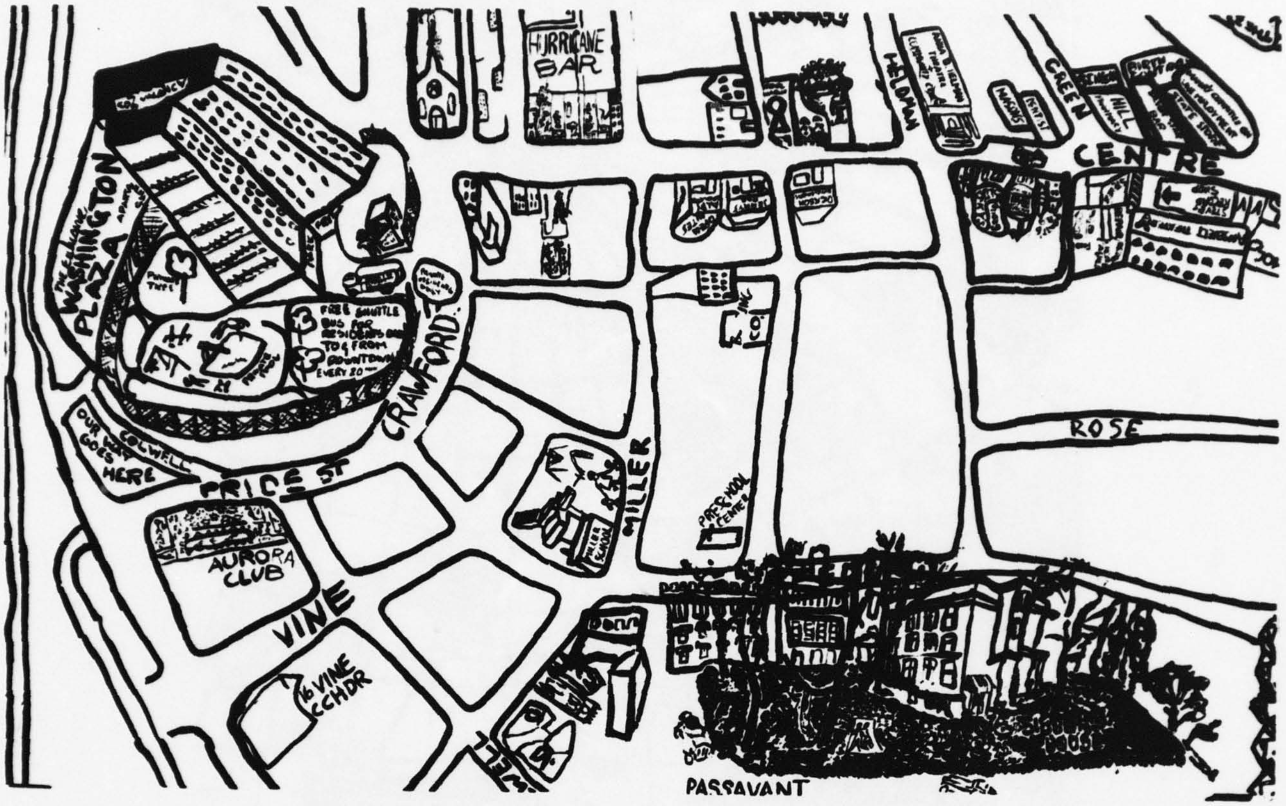


8.5 WALK-THROUGH MAP OF LOWELL

This design proposal for an outdoor museum of the city is a schematic walk-through model of the streets and major sites on a one-acre plot. Intended as an educational tool for use by school children and tourists, it allows quick conceptualization of a large area in very real experiential terms. Map reprinted by permission. Michael & Susan Southworth, City Design & Architecture, Boston, Massachusetts.

8.6 WALK-THROUGH GLOBE: MAPPARIUM

The Christian Science Mapparium allows one to walk on a bridge through the center of a giant, illuminated, stained glass globe, 30 feet in diameter, and to look at it from the inside out. Peculiar acoustic properties result from the spherical space. Oddly, continents are represented as one would see them on the outside of a globe. The major value of the technique is for education and exhibition. Map reprinted by permission. The Christian Science Publishing Society, Christian Science Center, Boston, Ma.



8.7 PARTICIPATORY MAP: COMMUNITY MAP, HILL DISTRICT, PITTSBURGH

Rarely does one encounter such a large map--25' x 40'. Produced piece by piece by community residents in a Pittsburgh neighborhood, it is a walk-on map. The intention was not precision but identification and expression of resources, problems, and attitudes in the neighborhood; it is filled with judgment, preferences, and omissions. The participatory development and large scale of such maps make them valuable tools in community planning and education. Map reprinted by permission. Community Design Associates: Troy West, Douglas Cooper, Jay Greenfield, Chuck Culbertson, Richard Ridley, Ed Goff, Chucky Dial, et. al., Pittsburgh.

8.8 DISTORTED MODEL: RUCKUS MANHATTAN

An artist's conception of Lower Manhattan, this topsy-turvy model rises to a height of 30 feet. Although based on real buildings, simplification, distortion, and selection result in a surreal or cartoon sense of the city. The section illustrated is the World Trade Center. Materials are wood, steel, and plastic. Map reprinted by permission.

Red Grooms and The Ruckus Construction Company; Photograph by Robert Mates and Gail Stern; Courtesy Marlborough Gallery, New York.

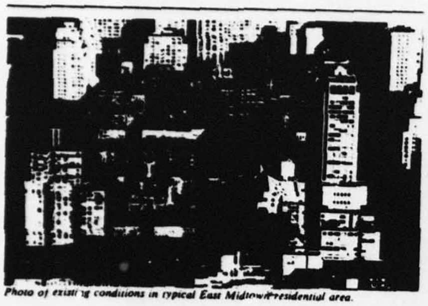
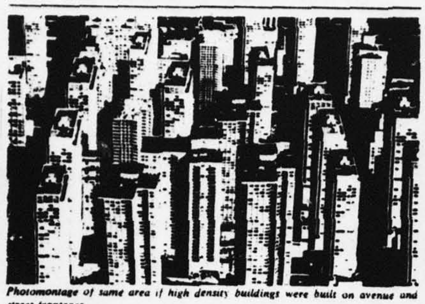


Photo of existing conditions in typical East Midtown residential area.

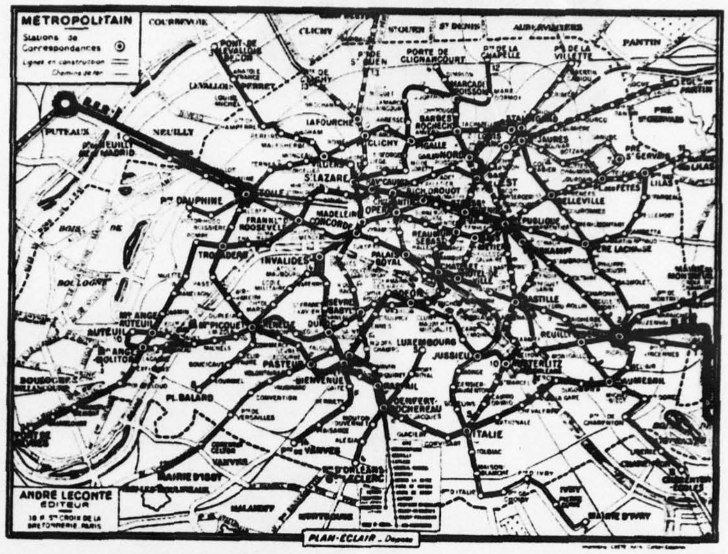


Photomontage of same area if high density buildings were built on avenue and street frontages.

Photomontage of same area with brownstones protected on street frontage and high density residential buildings on avenue frontages.

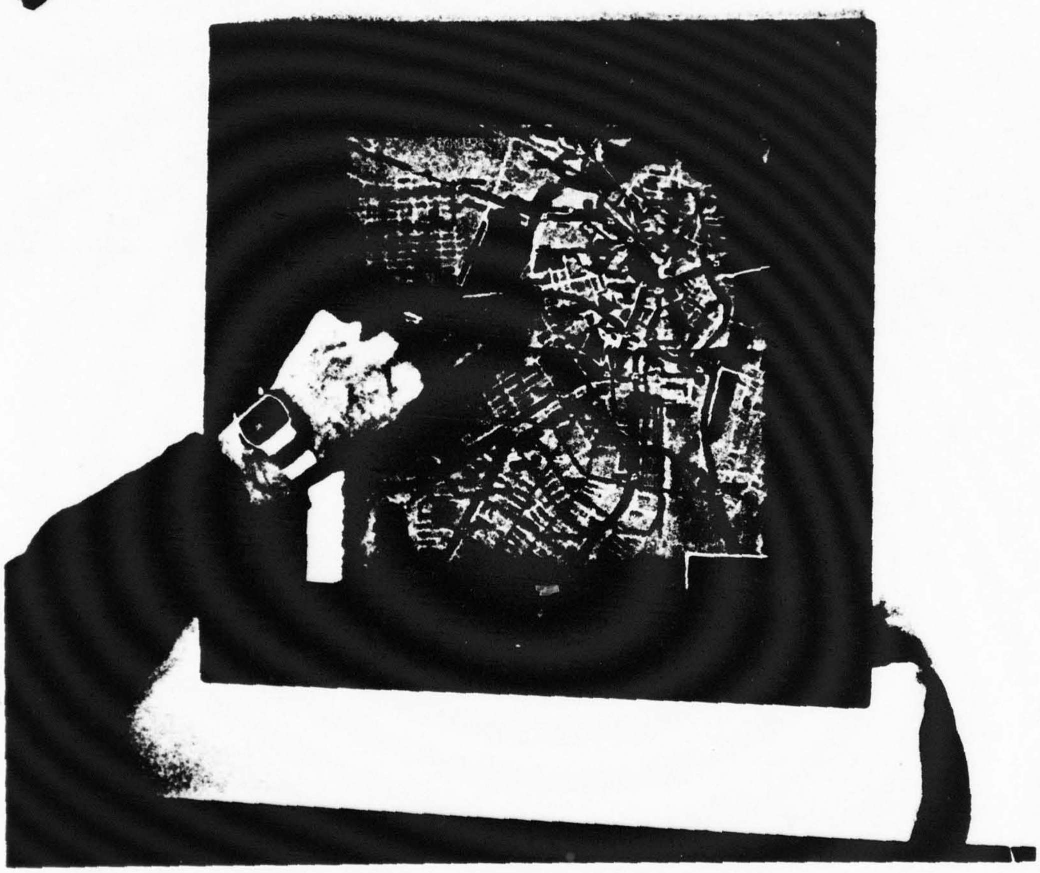
8.9 PHOTO MONTAGE: HOW MUCH HIGH DENSITY DEVELOPMENT SHOULD BE PERMITTED IN MIDTOWN RESIDENTIAL AREAS?

Photomontage techniques can create convincing representation of future possibilities. Here we see three views of Midtown Manhattan. On the left is an actual photograph; in the middle is a photomontage of the same area as if it were covered with high rise buildings, and on the right is a photomontage of the same area, with high rise buildings built only along the avenues. The technique creates a feeling of reality and is valuable for testing hypotheses or the impact of alternative policies. Map reprinted by permission from New York City Planning Commission, PLAN FOR NEW YORK CITY: 1969/Manhattan, M.I.T. Press, Cambridge, Ma., Copyright 1969.



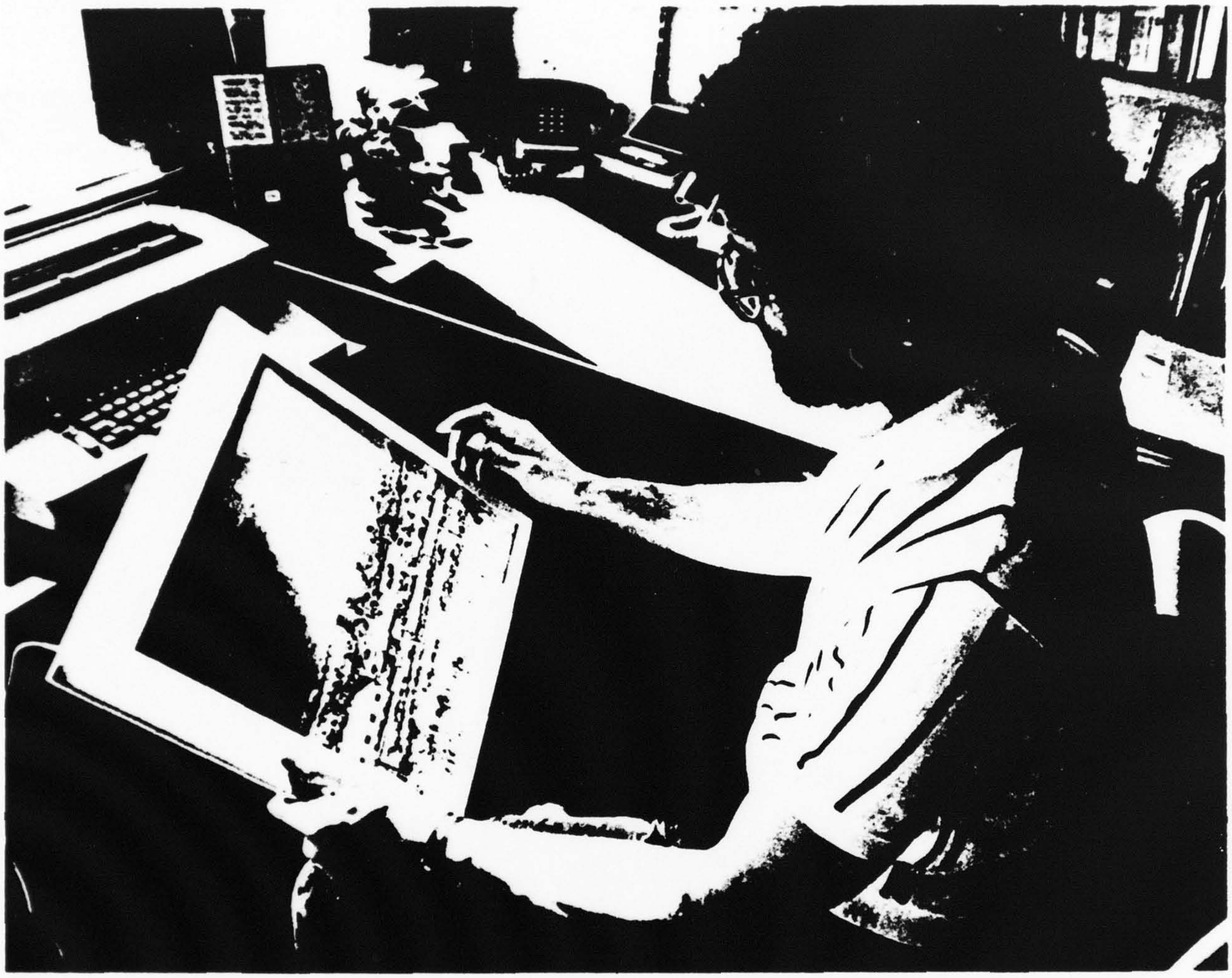
8.10 PARIS METRO LIGHT-UP ROUTE MAP

For the Paris Metro system, the most extensive subway system in the world, the light-up electric map is a very useful device. Most destinations can be reached by at least two routes from any given starting point; several transfers are often necessary. Finding the most efficient route could be a time consuming effort. Using the electric map, a rider simply pushes his destination on the panel below the map. His destination and the most efficient route then light up. Such systems are applicable to any transportation system: bus, airplane, train, highway, as well as subway. It is also useful in complex office buildings, art museums, or college campuses. Computer technology can make electronic routing maps far more sophisticated by allowing route selection by criteria other than efficiency, e.g. the most scenic route, etc. Map reprinted by permission. In MAKING THE CITY OBSERVABLE by Richard Saul Wurman; Walker Art Center and M.I.T. Press, Copyright 1971 by Walker Art Center.



8.11 TOUCH SENSITIVE AUDITORY MAP, BOSTON

By touching any point on the map, the user hears a description of the place he is touching. Sonars (piezo ceramic transducers), situated on two sides of the frame, locate the coordinates where the user's finger is pointing. The corresponding data set is then retrieved from the disk where auditory data is stored digitally. Map reprinted by permission. Architecture Machine Group, M.I.T.



8.12 PARTICIPATORY SIMULATION MAP: MAPPING BY YOURSELF

Part of an ongoing research project, this illustrates a hand-held, 12" x 12" mapping "window" capable of presenting images of an environment from multiple vantage points. In effect, the user can travel through the modeled environment, controlling path, speed, angle of approach, and scale. Touch sensitive layers on the panel allow the user to input request and to manipulate information displayed by using his fingers. Other aspects of the "Mapping By Yourself" project include amplifying maps with sound, representing uncertain information, and transparency or the ability to penetrate ground surfaces. Map reprinted by permission of Architecture Machine Group, M.I.T.

8.13 WALK-THROUGH MODEL: GUATEMALA

The entire country of Guatemala is simulated in this large outdoor topographic model of concrete. Vertical scale is exaggerated. Mountains, rivers, and towns are identified by flags. One may view the model from ground level or from several high viewing towers. Map reprinted by permission. Guatemala City, Guatemala. Photograph by Michael Southworth.

4 COMPUTER CONTRIBUTIONS TO THE MAPPING PROCESS

STEVEN LEVIN
Perceptronics

INTRODUCTION

Computer technology is increasingly being used to decrease the cost and to improve the quality of the mapping process. Today, geographic information may be collected by satellite, transmitted by radio, stored and managed by computers, and formatted for computer-controlled printing and display. This chapter is *not* concerned with these significant improvements to the production of conventional maps; these developments are well documented elsewhere. Rather, the emphasis here will be on the use of computer technology for producing *new kinds* of maps.

The need for new kinds of maps comes from the complexity and difficulty of the problems to which geographic information is being applied. Problems of energy, of population, and of health, to name a few examples, have stimulated the collection of unprecedented amounts of geographic information of many types. Further, as was pointed out in Chapter 2, it is now realized that there are important differences in individual problem solving styles that necessitate idiosyncratic map design and map usage.

In this chapter, we will focus on the use of computer technology to produce realistic and super-realistic geographic displays. Conventional maps present an abstraction of reality from a perspective and position--a great height looking straight down--rarely experienced by map users. Computer technology makes it feasible to present geographic information in a less abstract and more realistic form, and to present that information from more natural perspectives. That is, displays generated by computer can present the mapped area in three dimensions, in color, shaded, and with terrain and cultural features shown in considerable detail.

Realistic display of geographic information is not a new idea. There is a 500-year tradition of realistic, perspective maps in cartography. These maps typically have shown buildings as they are, trees and foliage as they are, rivers and mountains as they are, in perspective, and with shadows and shading. The unique opportunity provided by computer technology is the possibility of producing a variety of realistic displays with very low incremental cost once the initial computer-compatible data base is established. Currently, computer-produced displays provide little economy over manual methods if the goal is to produce one realistic display of a region. However, production of the second, third, and fourth views, from different positions and perspectives, is very inexpensive, while the cost of additional production using manual methods remains high. As a consequence, the computer map user has the unprecedented advantage of being able to experience a place from a variety of positions and perspectives, with simulations of various times of the day, latitude, and even weather, all at modest cost.

The facilitating effects of computer realism on map performance are potentially great. It is well known that a large proportion of people are unable to use conventional maps effectively even after considerable practice. For example, Potash, Farrell, and Jeffrey (1976) have estimated that over 25% of experienced military users still have difficulty reading conventional maps. Much of the research in map design and training procedures is intended to overcome the fundamental problem of visualization, that is, seeing the abstract display and forming a useful mind-picture of the situation. Computer-based display systems can effectively reduce this problem by providing more "natural" representations, that is, representations that are more easily visualized by the map user. Empirical evidence indicates that the benefits of computer-generated pictorial maps are realizable in practice as well as in theory. A recent study at Perceptronics, reviewed below, showed that the use of a computer-generated movie map significantly improved map performance over that achieved with a conventional map. Analysis of the experimental results, and of the potential of more advanced picture-generation systems, suggests greatly expanded utilization of this technology in the immediate future.

PICTURE GENERATING SYSTEMS

Overview

Software systems for generating a variety of realistic, perspective displays of geographic information exist now, and are capable of producing realistic views on an electronic CRT display, on paper, on successive frames of a videotape or videodisk, or on film. The methods employed in calculating different views are similar or identical to those employed in electronic flight simulators for calculating the views that would be seen from aircraft flying over known terrain. The primary difference is that the display calculations in a flight simulator are performed at very high speed (about 30 times per second) by very costly hardware, while the display calculations in a more general-purpose, software-based system for producing realistic perspective displays are performed very slowly (minutes per picture) by relatively inexpensive hardware. Further, the software in flight simulators frequently imposes display and movement constraints to reflect the physical limitations of aircraft flight, while general-purpose perspective systems impose no such restrictions, e.g., it is possible to look at an area from inside a building looking out, or from below a street looking up.

Recently, two research and development projects sponsored by the DARPA Cybernetics Technology Office have resulted in significant progress in the development of general-purpose software for the generation of realistic computer maps using relatively low cost minicomputer systems. This work was conducted by the Evans and Sutherland Corporation, Denver, and by the Mathematical Applications Group, Inc. (MAGI), Elmsford, New York. While both projects have developed computer programs for the automatic production of realistic views from digital representations of geographic information, the end results and the means used to accomplish them differ markedly. It is therefore instructive to review both as a guide to the current state-of-the-art.

Evans and Sutherland System

One way of conceptualizing the Evans and Sutherland (E&S) system is as a set of interactive software tools and associated hardware with which an experimenter can manipulate and control a digital data base. Two forms of visual display and several types of interaction are available. With the E&S system, the user can see the data base displayed: (1) calligraphically (i.e., as a wire-frame world without color and without hidden lines removed), (2) as a line-representation with hidden lines removed; or (3) as colored surfaces, shaded, and with hidden surfaces removed.

The calligraphic displays are generated in real-time on an Evans and Sutherland Picture System II computer. The PS II is a vector graphics terminal with its own display processor. It incorporates special hardware for rotating, translating, scrolling, and transforming three-dimensional graphic scenes.

The full-color "photographic" views are generated in slow time, and in one of two ways. First, single pictures can be requested by the user at any time during his real-time flight through the PS II wire-frame world. Real-time travel is interrupted while the system generates the picture. Depending on the complexity of the scene (function of the number of points and line segments), this process may take from 2 to 30 minutes. Second, a recording can be made of the user's interaction with the data base while using the calligraphic system. The recording, which is in essence the description of object and eyepoint motion while traversing the data base, can be converted in slow-time into a full color movie through scene-by-scene generation.

The single greatest difference between the E&S and the MAGI picture generating systems is in how objects are modeled. E&S uses a uniform point-polygon formalism in which all information in the data base is represented as some combination of n-sided polygons. Real-time and slow-time picture algorithms use this representation for mathematically translating the picture model and analytically solving the hidden line and surface problem. The user is affected in two ways. First, real-time flight, even if limited to a wire-frame world, is possible. Second, in general, objects such as trees are not modeled as discrete, decomposable entities, but as polygonal shapes with tree-like texture and color. As one gets closer to such an object, more detail does not appear, e.g., when approaching a tree, one does not start to see leaves, although the texture may change to produce a similar effect. While technically such detail could be modeled, present computational constraints make it undesirable to do so.

Use of the E&S system requires a PDP-11/34 or larger machine, with 32K memory and a floating point processor. This configuration should have a minimum of two RK05 disk units, a printing device, and console. In addition, the system requires an Evans & Sutherland Picture System II, with 64K memory. For the display of shaded pictures, a frame buffer (5.2 x 5.2 x 8 bits minimum) is desirable. The shaded picture software is written predominantly in FORTRAN and runs on the PDP-11/34 under RSX-11. A user-maintained virtual memory system, integrated with the RSX-11 operating system enables the E&S system to manipulate the required large data arrays.

MAGI System

Like the system developed by Evans and Sutherland, the MAGI Terrestial Visualization System (TVS) is designed to generate realistically toned color photographs of scenes containing natural and man-made features against a natural background. Shadows produced by solar illumination may be included in the scene. The system is designed around a data base which contains terrain data and cultural feature descriptions. A library of man-made objects is also included in the data base; these can be placed at any location in the scene. Because of machine size limitations, it is necessary to generate each image in several scans. These scans are made by any of three geometry processors: for man-made objects, for vegetation, and for terrain. Each scan generates a contribution to the full image, and merges it with previously produced image information. Once the image is complete, a post processor converts it into a form acceptable to the analog output device.

TVS has no real-time capability; instead, users interact with the system in two ways: data base management and picture direction. Creating a picture with TVS first requires that the user select and position those objects from the data base which will appear in the scene. The user interacts with a library program, which can display what previously-defined objects are available. The user then selects those objects he desires (e.g., terrain patches, such as Blue Mountain, man-made objects, such as T54 Tank or forests, such as pines) and orients them in the picture. After the scene is assembled, the user enters a series of commands in a simple director's language. These commands control the movement of a simulated camera through the scene. Parameters for eyepoint position, viewing angle and movement speed can be specified.

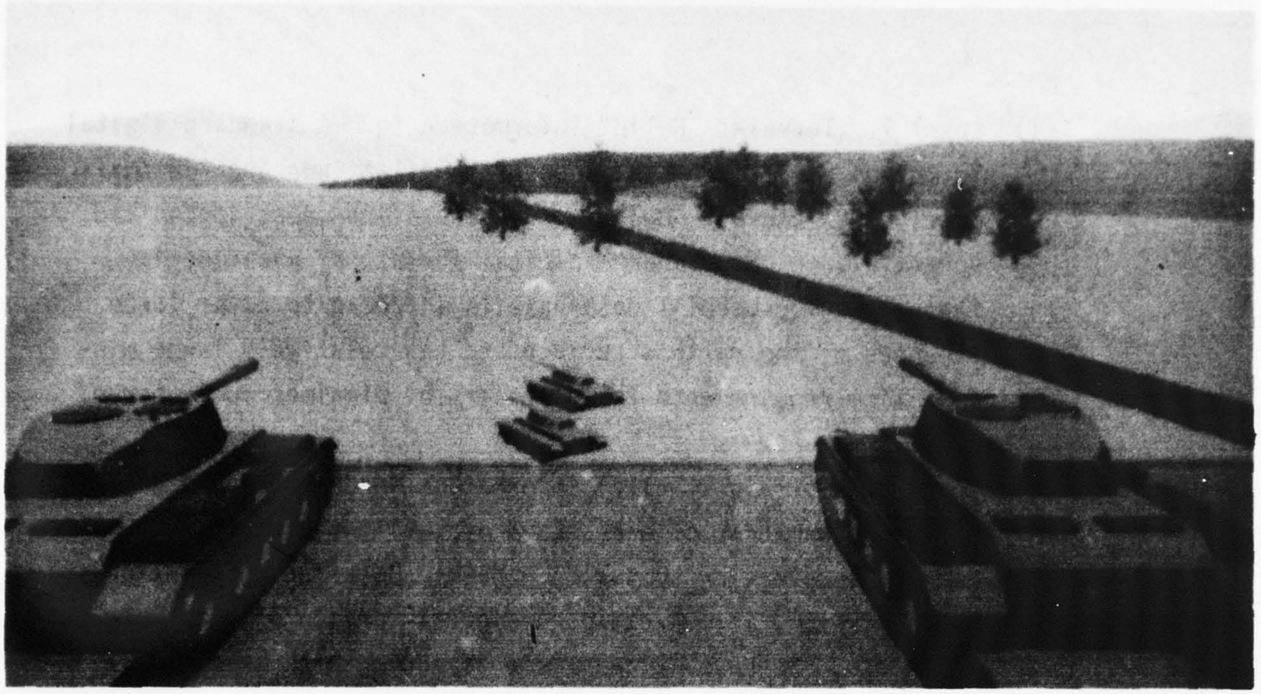
The primary tool for generating images is ray tracing. Specifically, straight lines are traced from the simulated camera position through assigned directions in space. When a ray encounters an object, its identity, distance, and surface normal are recorded. Because of the program size, ray tracing is carried out separately for each of the three geometry processors, using a specific set of data. Further, because of limitations on space for the data, such as for different species of vegetation, a given processor may have to be invoked more than once. During this phase of the operation, the distance to the surface is retained as part of the image information for determining which object is seen from the simulated camera.

TVS objects can be modeled at extremely fine levels of detail. For example, the generation software can actually handle individual leaves of a tree. The result is exceptionally realistic pictures, as evidenced by Figure 4-1, a landscape view incorporating tanks, terrain and vegetation, and by Figure 4-2, a closeup view of a single tree which shows the excellent visual detail that can be achieved with this technology. The cost is the large amount of computer resources required. Computation of a picture that includes extensive detailed vegetation may require in excess of 30 cpu-minutes. Another, less apparent, cost of the TVS realism is in the definition of new objects. Adding new man-made objects, vegetation, or terrain to the TVS libraries requires a combination of trial and error, mathematics, learned skills, and art.

TVS is currently installed on a PDP-11/70. The software is written in ANSI standard FORTRAN IV and will operate under the UNIX operating system. TVS is a very large program, with an expected core requirement of 256K to 512K bytes. Accordingly, the UNIX system under which it will execute has been modified to allow TVS, and other application programs with similar requirements, to access large data arrays.

Automatic Picture Production

Digital Data Bases. Significant trend in current cartography is toward the generation of more encompassing and more detailed digital data bases. For example, The Defense Mapping Agency (DMA) Digital Landmass System (DLMS) is an off-line data base designed to contain cartographic features in digital form with identifying geographical positioning information. Compilation of the DLMS is a world-wide effort involving the DMA and U.S. allies abroad. DLMS is intended to be the standard digital data base used in support of U.S. military systems. DMA has defined two data density levels for terrain and cultural data in the DLMS; these are:



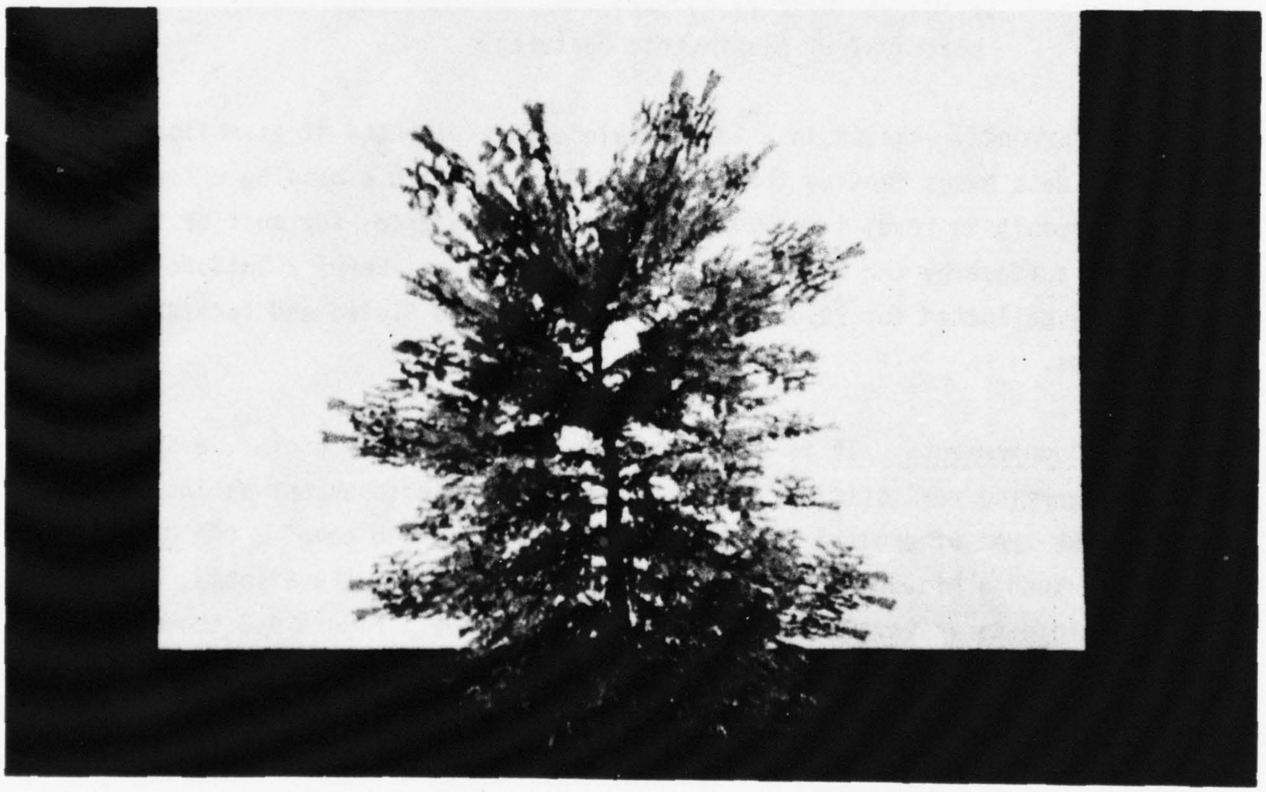


FIGURE 4-1. LANDSCAPE AND TREE GENERATED BY THE MAGI COMPUTER SYSTEM

FIGURE 4-2. DETAILED TVS TREE

(1) Level 1. Terrain: Relief information in DMA standard digital format on a matrix of three seconds of latitude arc (approximately 100 meters). Culture: A generalized description and portrayal, in DMA standard digital format, of planimetric features. The Level 1 data base is intended to cover large expanses of the earth's surface and has relatively large minimum size requirements for portrayal of planimetric features.

(2) Level 2. Terrain: Relief information in DMA standard digital format on a matrix of one second of latitude arc (approximately 30 meters). Culture: A highly detailed description and portrayal, in DMA standard digital format, of planimetric features. The Level 2 data base is intended to cover small areas of interest and has small minimum size requirements for portrayal of planimetric features.

DMA is currently engaged in a large-scale effort directed at establishing digital data bases meeting the DLMS specification. This mapping effort should result in Level 1 terrain and cultural data files for most of the world's surface by the mid 1990's. At the same time, Level 2 cultural data is being collected for selected areas in the United States and foreign countries.

System Requirements. It is clear that, to be practically useful, a system for generating realistic map pictures should be able to accept as its basic input the type of digital data contained in Level 1 and Level 2 DMA data bases. Such a Picture Production System (PPS) is not yet available, but it is possible to anticipate the features it must have. Figure 4-3 shows the organization of a hypothetical PPS which acts on a DLMS type data base to generate a variety of computer map products.

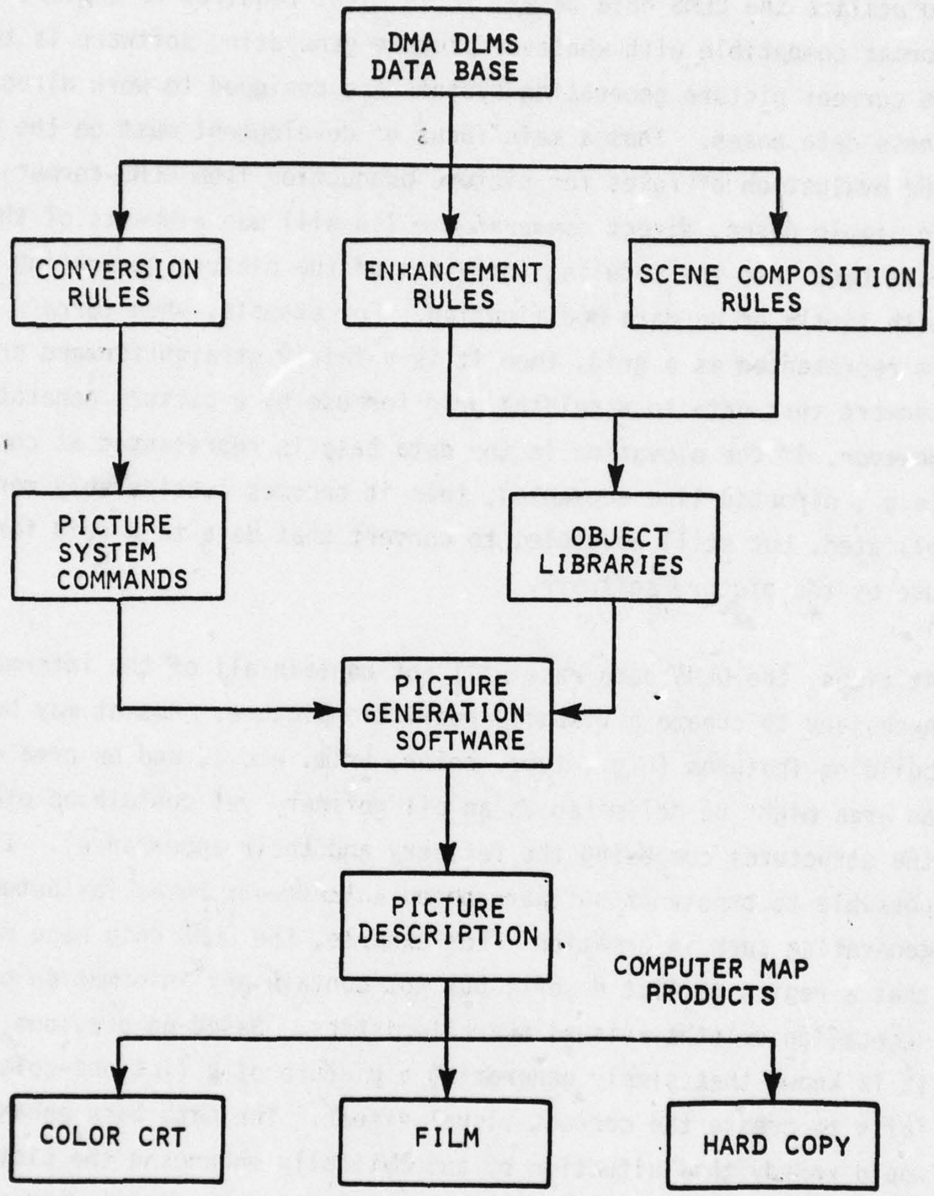


FIGURE 4-3. PICTURE PRODUCTION SYSTEM CONCEPT

To utilize the DLMS data bases, it is first required to convert them to a format compatible with whatever picture generating software is to be used. No current picture generating systems are designed to work directly with these data bases. Thus a main focus of development must be the development and evaluation of rules for picture production from DLMS-format data bases. In simple cases, direct *conversion rules* will map elements of the original data base into the modeling formalism of the picture generating software with little or no data modification. For example, when terrain elevation is represented as a grid, then it is a fairly straightforward process to convert that data to a related grid for use by a picture generating system. However, if the elevation in the data base is represented as contour lines (e.g., directed line segments), then it becomes considerably more complicated, but still possible, to convert that data to a grid format for use by the picture software.

At times, the DLMS data base will not contain all of the information necessary to create a visually realistic picture. Absent may be data on building features (e.g., type, color, trim, etc.), and on area detail (e.g., an area might be delimited as an oil refinery yet contain no other data on the structures composing the refinery and their appearance). It should be possible to construct software-based *enhancement rules* for automatically generating such information. For example, the DLMS data base may indicate that a region is flat desert, but not contain any information on covering vegetation or other visual characteristics. Based on previous experience, it is known that simply generating a picture of a flat one-color surface fails to create the correct visual effect. The data base enhancement rules would remedy this situation by automatically enhancing the picture with color patches, texture, and vegetation to improve visual characteristics. If an area was specified as a refinery, and no other data were available, enhancement rules might synthesize significant refinery detail (e.g., place roads, storage tanks, processing facilities in the object libraries).

One of the limitations of the existing picture generating systems is that they require users explicitly to select and position items from the object libraries to create a picture. This process is both lengthy and tedious for complicated scenes (e.g., a detailed urban area). In addition, it is often difficult to visualize where objects should be placed. *Scene composition rules* would extract items from the object libraries and, based on their location as defined in the Mapping Database, place the objects in the arbitrary coordinate framework used by the picture generating software. While the conversion and enhancement rules discussed above perform local visual optimization, the scene composition rules insure that the composed picture is globally consistent.

The picture generating system's *picture production rules* (PPR) will be used both to convert and to enhance data from the mapping data base for use in the system's object libraries (e.g., terrain, vegetation, cultural features, etc.), and to generate commands governing scene composition for use by the picture generating software. A primary goal in the development and implementation of the PPRs should be to make the various items as independent as possible from the actual picture generating software. Each picture generating system typically uses a highly specialized and complex modeling formalism, and there is virtually no compatibility among them. Without separation or PPR and picture system, there would be little hope for transferring the picture rule software from one picture system to another.

Pictures or, more accurately, picture descriptions, are produced by the Picture Generation Software. The Picture Generation Software operates on a model of the translated digital data base and produces as output a compact frame-by-frame description of each picture. Finally, the picture description is converted to a viewable image on either a color CRT, 16 or 35 mm color film, or hardcopy device, depending on the intended use.

COMPUTER MOVIE MAP STUDY

Computer- generated, three-dimensional, pictures provide a highly natural means of presenting map information. Such picture maps can be used statically, to provide a overview of terrain, cultural, and variable features. They can also be made dynamic by linking a sequence of views to give the illusion of motion. In the dynamic case, computer-generated displays can actually give the user a realistic "guided tour" of the area normally covered by a conventional map. Such a "computer movie map" moves the viewer as if he or she were in an unearthly vehicle that was not restricted by the speed of light or any of the other laws of physics. Much like a travel film, the movie map can provide the user with a sense of immediate presence, almost like experiencing the locale first hand.

A study of map performance with a prototype computer movie map was conducted by Perceptronics under the sponsorship of the DARPA Cybernetics Technology Office. Since the study represents one of the first experimental examinations of realistic computer map products, it is worthwhile to review its methodology as well as its results. A more complete description is available in Ciccone, Landee, and Weltman (1978).

Experimental Approach

Of particular interest in the study was the field maneuver aspect of map utilization: that is, the use of a map to learn enough about an area to move confidently within it. Two basic performance factors have been associated with this type of task; they are: (1) pattern recognition, during landmark identification and (2) directional inference, using landmarks as cues to spatial orientation. These processes are essential to all aspects of field map use, since, for example, route planning and execution cannot begin until position and orientation have been established.

The objective of both computer-based and conventional maps is to provide the user with sufficient information to perform both performance subtasks.

Preliminary analysis suggests that while movie maps provide information relevant to both landmark identification and directional inference, conventional abstract maps place the burden of landmark identification upon the user. Since the identification of geographical landmarks is essential for inferring current location, one advantage of the movie map may be the ease of self-localization it affords the user.

Similarly, movie maps may also facilitate the assimilation of spatial relations by realistically portraying the landmarks used to infer directional heading. Although both conventional and movie maps provide the user with an overview of spatial relations, such information becomes useful only when the map user can also identify landmark cues present in the environment. This suggests that conventional abstract maps may short-circuit the inference process by failing to provide the user with sufficient knowledge of *landmark appearance*.

In accord with the above analysis, the experimental evaluation of the movie map technique included measures of the two critical dimensions of map performance: self-localization and directional inference (spatial-relations). Before describing the experimental technique and assessment strategy, a brief account of the prototype movie map will be presented.

Prototype Movie Map

We wanted to include in the movie map a representative variety of geographic and urban features. Rather than attempt to find a real place with all the desired characteristics, we decided to produce a computer-generated tour of a typical, albeit fictitious, middle eastern city, named by us Dar-El-Mara.

The mid-eastern locale was chosen because (1) it seemed topical and (2) the desert environment eliminated the need for including costly vegetation in the prototype computer model.

To arrive at the layout of Dar-El-Mara, project personnel gave a list of basic specifications (terrain features, built-up areas, number of identifiable landmarks, etc.) to an industrial designer, who returned a preliminary sketch of the locale. Several reiterations of the initial design produced a seaside town, located on a cliff overlooking a bay, and containing a combination of military and civilian buildings. The final design was constructed as an actual physical model, about four feet square, made of foam-core material. The foam-core model was used to check model proportions, to specify color combinations, and to evaluate visual issues associated with candidate tours.

The picture generation technique selected for the experimental study was developed and marketed by MAGI (Mathematical Applications Group, Inc.), Elmsford, New York, under the name Synthavision TM. It is similar to the new MAGI system described in the preceding section. An initial movie was completed which provided an extensive ground-level tour of the area. Preliminary evaluation indicated that while the MAGI technique was able to represent the physical structure of Dar-El-Mara's environment satisfactorily, a ground-level perspective was not sufficient, in itself, to effectively communicate spatial and/or geographical orientation. As a result, a new tour was developed which combined both ground-level and aerial perspectives.

The MAGI film for the revised movie map was photographically augmented to include object legends overlayed on the pictorial views, so as to identify significant landmarks. In addition, a narrative sound track was added to enhance user comprehension. The completed 7-minute film was transferred to videotape to permit experimental viewing under realistic command conditions. A partial "story board" of the movie map, consisting of computer-generated views taken from the tour and the narrative associated with these views, is presented in Figure 4-4.

Methodology

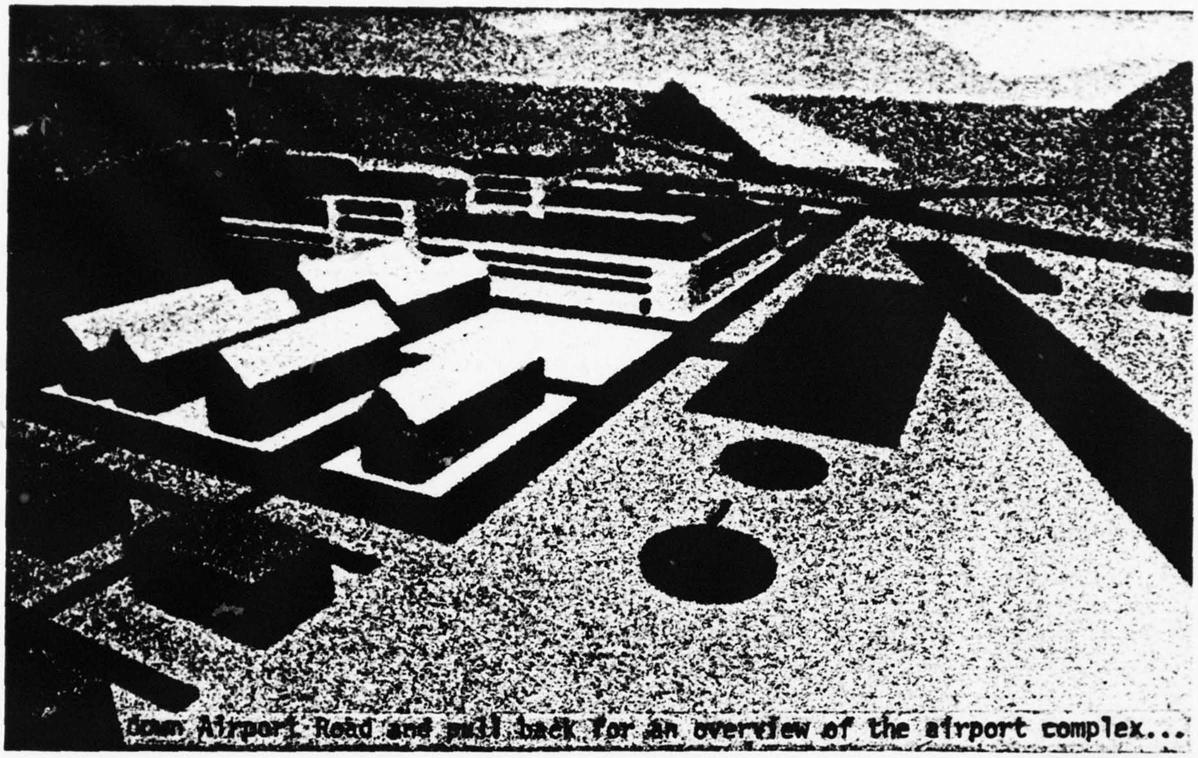
The computer movie map was stored on a 3/4" video cassette and was played on a VCR Model CR 6060U cassette recorder. The movie map display was produced by an Advent, Model 1000A Videobeam color TV projector on a seven-foot diagonal screen. It was viewed from a distance of about 9 feet in a dimmed viewing room. A specially-prepared, four-color paper map of Dar-El-Mara was used to provide appropriate baseline measures of map-user performance. The map, a portion of which is illustrated in Figure 4-5, utilized a "tourist" type format, with the addition of color-coded contour intervals. Map size was about 11 by 14 inches; it was viewed on a work table.

Three independent groups of subjects were used to assess the effectiveness of the computer-generated movie map relative to the conventional map. These groups were:

(1) Map-Only. Fifteen subjects in this group viewed the conventional map of Dar-El-Mara during three 7-minute study sessions.

(2) Map-Movie. Ten subjects in this group viewed the conventional map during an initial session, and the movie map during two subsequent sessions.

(3) Movie-Only. Ten subjects in this group viewed the Dar-El-Mara movie map during three study sessions.



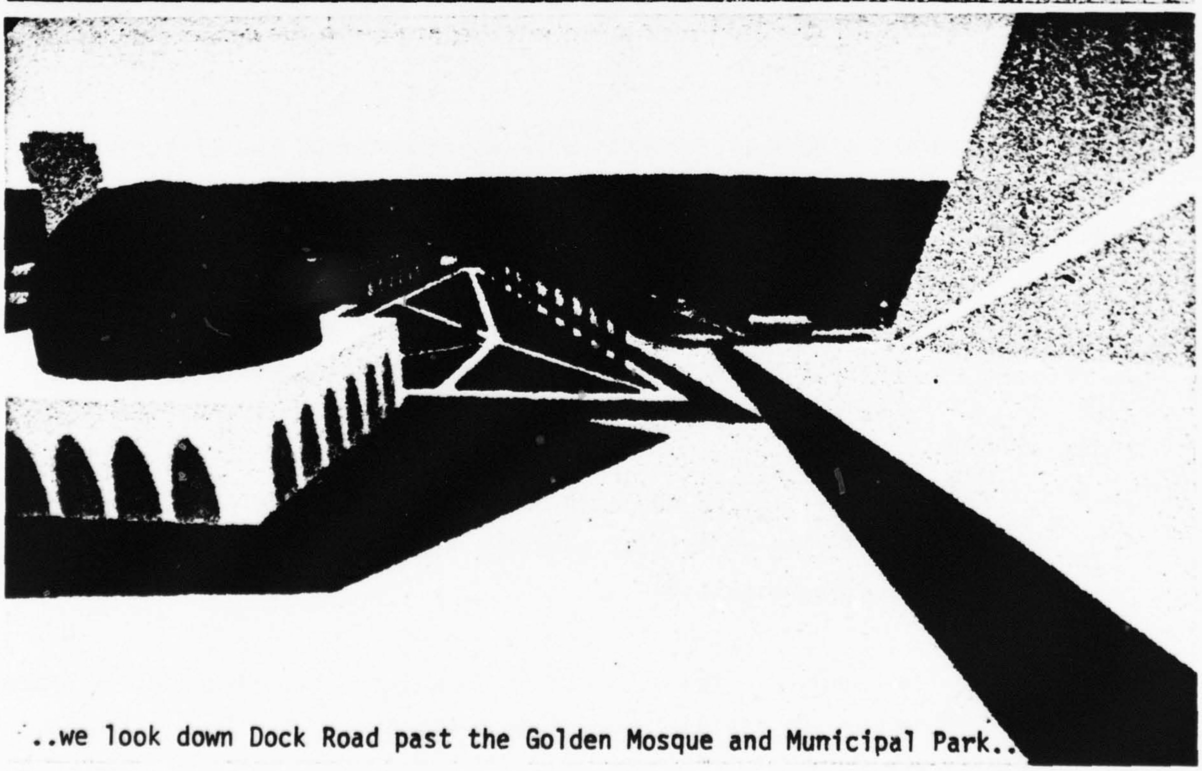


FIGURE 4-4. SCENES FROM THE DAR-EL-MARA MOVIE MAP

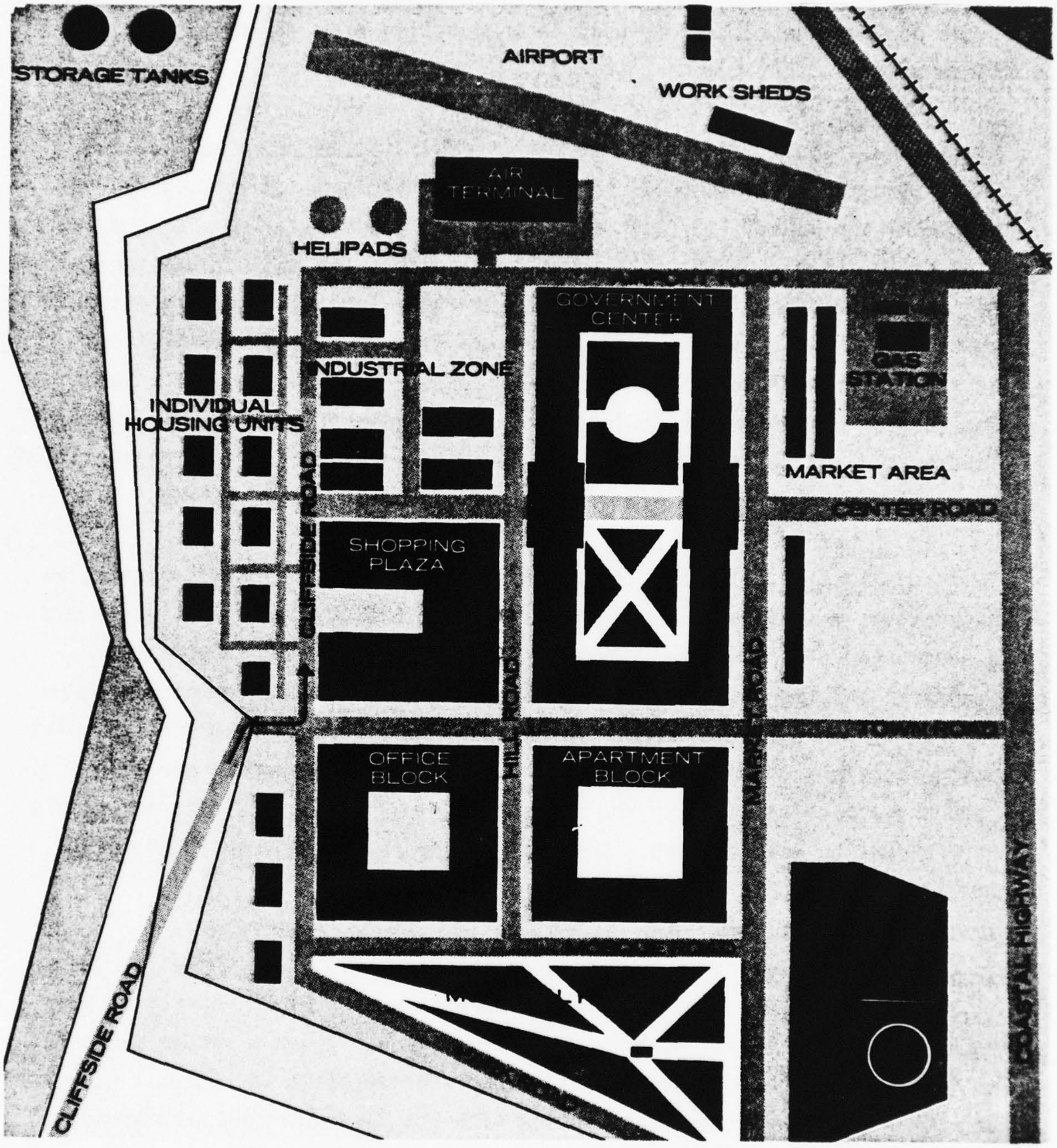


FIGURE 4-5. CONVENTIONAL MAP OF DAR-EL-MARA, SHOWING CENTRAL PORTION OF TOWN

Three performance tests were used in conjunction with the above design; these were:

Spatial Relations. This test, which was administered after each of the three study trials, was based on a non-verbal technique developed by Kozlowski and Bryant (1977). The subject was presented with a ground-level view of Dar-El-Mara selected from the movie map. The subject was instructed to imagine standing in Dar-El-Mara at the exact location and orientation specified by the picture. The subject was then given a blank sheet of 8½ x 11 paper with an "X" in the center to represent the subject's location. The subject's task was to indicate the relative location of seven additional landmarks. The performance measures were the angular error (in degrees) and the distance error (in millimeters) associated with each estimate.

Self-Localization. In this test, administered after the third session, an attempt was made to simulate a field transfer task. The subject was shown a photograph of a computer-generated scene which included a Dar-El-Mara landmark, and was given a conventional map of Dar-El-Mara to which a piece of tracing paper was attached. The instructions were to indicate the point on the map from which each photograph was taken and to use an arrow to indicate the direction in which the photographer was facing. Eight photographs were viewed by each subject. Orientation error was measured in degrees, location error in millimeters.

Topographical Knowledge. This test was also administered only after the third session. The subject was provided with a list of 30 natural or man-made features of Dar-El-Mara. In addition, he was given a randomly-ordered set of 16 written descriptions associated with specific locations. His task was to match each written description with its corresponding geographical feature. The performance measure was the percentage of correct matches.

Results

An overall comparison among the experimental groups indicated that computer movie map performance was clearly superior to that with conventional hard-copy displays. Movie map subjects performed significantly better on virtually every test measure. The difference was particularly striking with regard to spatial relations. Figure 4-6 shows the average orientation error for the three groups, taken over the three test trials. By the second trial, Movie-Only viewers were achieving less than one-half the orientation error of conventional map users. Over all trials, movie maps subjects were able to estimate landmark location with significantly more accuracy than conventional map users.

Performance on the self-localization task was also markedly better for movie maps (Table 4-1). Movie map subjects were significantly more accurate in their location placement, as well as in their orientation estimates. Movie-Only viewers achieved a six-fold reduction in location error over conventional map viewers, and nearly a thirty-fold reduction in orientation error. In fact, the movie map subjects showed virtually no orientation error at all, compared to an average 36.7° error for the conventional map subjects.

Finally, the test of topographical knowledge reflected a significant difference in favor of movie map subjects (Table 4-2). Movie map viewers achieved a mean test score of nearly 89%, an improvement of 30% over the mean test score of conventional map users.

There appeared to be no facilitating effect of using conventional map presentation to precede movie map presentation. On the contrary, the group which received both forms of presentation performed, on the whole, worse than the group which received the movie map only. The effect of repeated

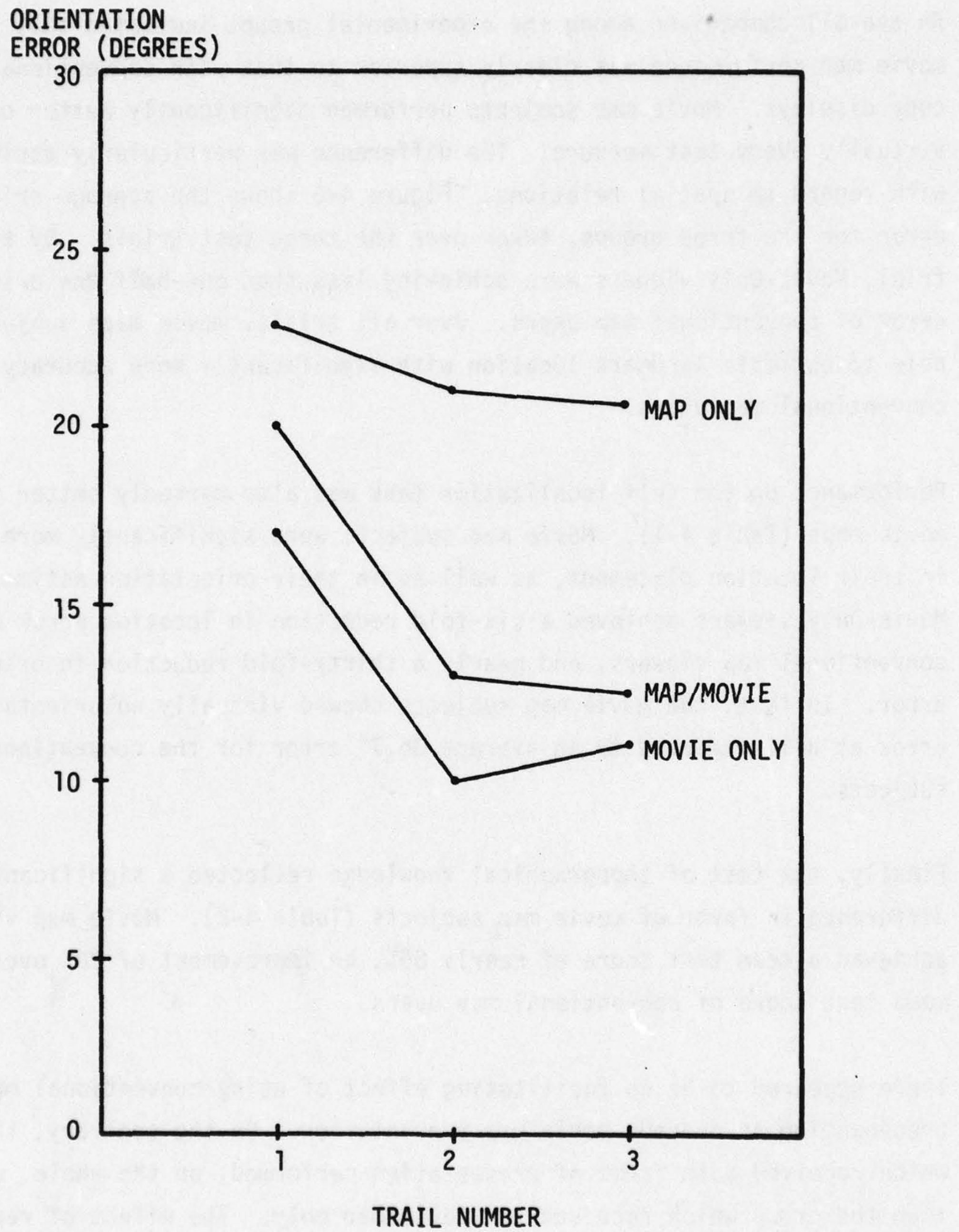


FIGURE 4-6. PERFORMANCE ON ORIENTATION TEST AS A FUNCTION OF MAP EXPOSURE AND TRIAL NUMBER

TABLE 4-1. PERFORMANCE ON SELF LOCALIZATION TEST

GROUP	LOCATION ERROR (MM)	ORIENTATION ERROR (0)
MAP ONLY	31.8	36.7
MAP/MOVIE	8.1	5.3
MOVIE ONLY	5.2	1.3

TABLE 4-2. PERFORMANCE ON TOPOGRAPHICAL KNOWLEDGE TEST

GROUP	% CORRECT
MAP ONLY	68.1
MAP/MOVIE	73.2
MOVIE ONLY	88.8

trials could be observed only for the test of spatial relations. On the distance estimation part of this test, no group appeared to improve with practice. On the orientation estimation part of the test, there was a clear spearation between the conventional map viewers and the computer movie map viewers (Figure 4-6). all groups performed nearly the same on the first trial. Conventional map viewers remained at about their initial performance level for the subsequent trials, while movie map viewers improved markedly. For the movie map viewers, it appeared that there was little or no further improvement after two study sessions.

Conclusions

Reality and Performance Improvement. The result of the experimental study, while certainly not conclusive, do tend to substantiate the hypothesis that realistic computer maps can effectively overcome many of the problems associated with using conventional map products. It appears that the "sense of place" imparted by the movie map is significantly better than that imparted by the conventional map. This was manifested in several ways during the present study. Performance with the movie map was significantly better than with a conventional map for two key performance measures: self-localization and spatial relations. Movie map users seemed to learn more about the locale on repeated exposure, while repeated study of the conventional map did not produce a significant learning effect. In addition, movie map users, by and large, avoided the frequent disorièntations characteristic of conventional map use. These results suggest that the movie map concept will significantly improve map-to-field transfer.

One of the major obstacles faced by the map user is the problem of visualizing an unfamiliar locale. Existing hardcopy maps offer the user no way to "preview" his destination visually. Computer generated scenes, on the other hand, are specifically designed to aid visualization and to provide the user with "first hand" spatial knowledge prior to direct perceptual experience. The quasi-realistic scenes produced by the computer may actually be preferable to a photograph for portraying spatial relations and landmark appearances. Photographic representations are often cluttered with extraneous features that complicate the recognition of geographical patterns. The simplified computer generated image can preserve salient terrain features and simultaneously convey the detail necessary to insure landmark identification. Exactly which features and details must be emphasized in particular scenes will probably have to be determined first on a case-by-case basis, and then in accord with empirically derived rules.

Future Map Systems. A logical next step from the concept of a movie map is the application of flight simulator hardware and technology to the development of systems for allowing the map user to "fly" himself around a geographic region described by a digital data base. This would give the user an opportunity to choose survey routes on the basis of individual needs and interests. Furthermore, the act of selection might in itself reinforce learning. There are two kinds of problems with such a system. The overwhelming difficulty is that flight simulators are very expensive. In the near term, the application of flight simulators to geographic information display will be limited to very important problems or to very wealthy users. The second difficulty is that most people without extensive training are not very good pilots. It takes little aptitude to use a conventional map, or even a computer movie map, but some skill is required to fly comfortably around a region using flight simulator technology. Although there is no danger of collision or crashing, there is unlimited opportunity for getting disoriented and lost.

An acceptable compromise might be to give the user a system which provides more interaction than a preprogrammed movie map, but less control capability than a full-mobility simulator. A technical approach to such a device is offered by the newly developed and economical optical videodisc systems. Such systems are able to store great amounts of pictorial material -- up to 54,000 individual TV frames or up to one hour of continuous TV -- on an inexpensive videodisc the size of a long-playing record. Each individual frame can be instantly and randomly recalled. By storing a large number of computer-generated views and movie-map segments, and giving the user a simple microcomputer controller which allows him to move naturally from one view or segment to another, the main benefits of continuous exploration can be achieved without its costly overhead.

Finally, one might consider another form of dynamic realism in computer maps, namely, the depiction of dynamic changes in the mapped data themselves. In the movie map described above, the user appears to move, but the mapped elements do not. Computer generation certainly provides the capability for such movement, and there are a number of ways it can be accomplished. For example, if the goal is to show the movement of vehicles, a movie map or "fly yourself" system could show moving vehicles completely independently of the changing position and perspective of the user. On a longer time scale, the growth and decay of cities, or the movement of contingents, can be shown as they might actually occur rather than through some abstract representation. Naturally, realistic display of changing geographic information requires the data base to contain a description of the dynamic process, (e.g., successive positions of vehicles, successive size of cities, etc.). Abstract representation of changing data on a conventional map also depends on adequate description in the data base, so that once more the opportunity is for a new way of showing dynamic data, rather than for the generation of new data. The main element of originality is the new perceptions allowed the user by virtue of the advanced presentation techniques.

BEYOND REALITY

Although modern computer technology gives the map-maker the option of providing new kinds of displays that permit realistic representations of static and dynamic data, a totally realistic display is probably a very poor idea. What are some problems with total realism? First, on a totally realistic display no information will be labeled--no names of rivers, roads, cities, countries, and so on. Second, one's perception of information on a totally realistic display will be no better than one's perception of reality. For example, in viewing a realistic display of a large area, all buildings would be invisible because proportionately they would be too small to see. Or, parallel adjacent roads with very small separations might appear like a single highway if viewed from a great height. Or, a church might not be identifiable as such because it did not have a distinct steeple, even if the geographic data base contained information describing the building as a church. Third, in principle, all information would be displayed at all times. What is actually seen would depend on size rather than importance and on appearance rather than on relevance.

The problems with totally realistic map display, made feasible by computer technology, can in turn be solved by automation. Computer-produced maps can be personalized and customized at a cost well below that of idiosyncratic map production based on manual methods. These opportunities are best appreciated by considering several examples.

It is possible to instruct a computer-based mapping system, by typing a series of commands on a keyboard attached to the computer, to produce a fully realistic display, a fully abstract display, or any partially realistic, partially abstract display. For instance, using a "fly yourself" system a map user might ascend to a great height over a realistic display, look down, and instruct the computer to change the realistic display to an abstract display, thus getting what is, in all respects, a conventional map. The change from a realistic representation to an abstract representation, and back again, need not depend on explicit user commands. For instance, when viewed from a great distance, a city might be represented by using a standard map symbol, and as the user approaches the city, the display could change either abruptly or gradually to a realistic representation.

By issuing commands to a computer-based display system, certain kinds of information could be added to it or deleted from the picture. For example, man-made features could be deleted, cities with populations greater than 500,000 could be added, and so on. The decision of what subset of the total geographic data base to display could also be under computer control. For instance, the level of detail could be automatically determined by the scale, the distance of the observer from the information and its size, importance, or characteristics.

Labeling of information can be similarly handled. For instance, by issuing commands to the computer the map user can decide what kinds of information, or what specific features, have labels or do not have labels, thus controlling clutter on the display. In fact, with the advent of touch-sensitive displays, a user may choose to have no labels on his map while retaining the option of touching those features whose name he wishes to know. Under those circumstances, the label need not appear on the map display but could be heard by the user since, with current computer technology, it is relatively easy to synthesize voice.

In all of these examples, there has been a tacit assumption that map users will personally access interactive computer systems to seek geographic information on electronic displays. Many, but not all, of the technically feasible capabilities which have been described are available if less responsive computer systems are used by cartographers in the production of paper-based maps. The trade-off is between personalization of map display versus delay in map production, and higher cost interactive systems versus lower cost "batch" systems.

In summary, computer-based mapping systems provide the means for accessing geographic information using graphic representations which are much more realistic than those currently employed in most manual mapping systems.

Despite the advantages of a totally realistic representation, there are also significant deficiencies. These can, in turn, be overcome by using automation to provide personalization of map displays for individuals, groups and tasks. The technical feasibility of powerful computer-based mapping systems for cartographers or map users is beyond doubt; the practicality of such systems in terms of cost-effectiveness depends on the importance of the application. Predictably, better service costs more.

Since proper integration of geographic information into the decision making process in important areas like energy, population, and health may very well spell the difference between success and failure, more expensive and effective interactive computer-based mapping systems may actually prove to be bargains in disguise.

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LIST OF MAPS

TOPOGRAPHY/NATURAL FEATURES

STREETS/BUILDINGS/PANORAMAS

CULTURE/SOCIETY/PERCEPTION

RELATION/COMPARISON

SIMULATION/PARTICIPATION

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This report is directed toward the designers and users of maps. Its purpose is to facilitate innovation in these functions by: (1) establishing a psychological model of the mapping process, (2) presenting outstanding examples of map designs, and (3) considering implications of computer technology for the production of new and improved maps. Each of these topics forms a separate chapter. The chapter on map examples contains about 160 modern and historical maps, illustrated and briefly described.

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