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Mapping movement : a study of existing and potential methods

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MAPPING MOVEMENT:

A Study of Existing and Potential Methods

By

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The purpose of this thesis is to create new methods for mapping movement. As a first step, existing methods are surveyed; spatial interaction maps are identified in the literature, collected, cataloged, and classified according to criteria based on map symbolism. The classification scheme proves to be a useful tool for both familiarization with existing mapping methods and to facilitate the design of new methods.

After surveying existing methods, four new methods are developed using interstate migration data for the period 1975-80 published by the U.S. Bureau of Census. They include the following: Map 1, the classless choropleth dot map, an alternative method for producing classless choropleth maps without sophisticated computer techniques; Map 2, the nodal region flow map, designed to fill a vacant category created by the classification scheme; Map 3, the connectivity network map, designed to represent a familiar topic (interstate migration) in a different perspective using an existing mapping method; Map 4, the surface relief flow map, an attempt to symbolize movement explicitly without using flow lines.

A social survey is then conducted in which a small sample of respondents evaluate the four maps in terms of their form, content, and utility. In the survey respondents gain familiarity with each map by answering questions concerning map content. Respondents then record their opinions about each map's form, content, and utility. Map 1 is very accurately read and also well received by respondents. This method is potentially the most utilitarian of the four designed in the thesis. Map 2 is the most popular with map users due to its use of familiar symbols (flow lines). Map 3 is easily read but the concept of connectivity, applied to interstate migration, proves to be a handicap in it acceptance by respondents. Map 4 proves to be readable but it has a dichotomy of appeal to users. The apparent three-dimensional surface of the map, produced by a computer plotter, attracts the interest of some map users but repels others.

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Chapter 1

INTRODUCTION

Movement is a condition common to all things on the earth. Known to geographers as spatial interaction, movement of things is studied in order to learn the reasons causing it, to forecast its occurrence, and to plan for problems it may cause in the future. Maps are tools geographers use to study and analyze spatial problems. In addition to depicting geographic distributions, maps of spatial interaction are also faced with the problem of depicting changes in the distribution of things within time intervals and the changes between time intervals. The branch of cartography which produces such maps is relatively new and is an attractive area for research.

Thematic Cartography Defined

Cartography is generally subdivided into two branches: topographic and thematic. Topographic cartography produces maps which depict surface features such as rivers, lakes, mountains, and coastlines. General cultural features such as administrative boundaries, cities, and roads are often included in topographic maps as points of reference.

Thematic cartography[1], on the other hand, produces maps which depict one or more special subjects in a geographic context. Depicting data in map form allows users to view and analyze geographic relationships which may not be apparent otherwise. The special subjects for thematic maps may be drawn from both physical and cultural geography and may be qualitative or quantitative in nature.[2] Average annual precipitation, soil types, vegetative cover, population density, average sales price per house, and traffic patterns are a few examples of the unlimited range of subjects dealt with by thematic maps.

Reasons for Thematic Maps

It is an understatement to say a map is a picture worth ten thousand words. When dealing with a large amount of geographic data, one of the most stimulating and efficient representations is a map. Maps are interesting to look at; they format geographic data into a spatial context. An incredible amount of information can be compiled onto a map, saving the person faced with the task of analyzing columns and rows of data the trouble of visualizing spatial distributions and relationships.[3]

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[1]Thematic cartography is also referred to as statistical cartography (Raisz), special, and applied cartography (Imhof). Erwin Raisz, Principles of Cartography (New York: McGraw-Hill Book Company, 1962), p. 195.; Eduard Imhof, "Tasks and Methods of Theoretical Cartography," in International Yearbook of Cartography, ed. by Eduard Imhof (Gutersloh: C. Bertelsmann Verlag, 1963), p. 15.

[2]Qualitative description identifies things by class, kind, and other non-numerical characteristics. Quantitative description identifies things by numerical characteristics such as number and size.

[3]Tufte states that "highly detailed maps portray 100,000 to 150,000 bits (of information) per square inch.". He further cites that "the average U. S. Geological Survey topographic quadrangle... is estimated to contain over 100 million bits of information, or about 250,000 per square inch.". Further examples of bits of information contained in maps are found in Edward R. Tufte, The Visual Display of Quantitative Information (Cheshire, Connecticut: Graphics Press, 1983), pp. 26, 29, 30, 168.

Despite all of the information maps are able to condense into a single graphic depiction, they still are not always able to show all the details. Imagine the impossibility and absurdity of mapping the sales price per house for each house in a medium- or large-sized city. Generalization is a process which abstracts a subject of study by dropping out details in favor of presenting a broader picture. Since the physical and technical limitations of thematic maps often necessitate the generalization of data, they serve as excellent tools for portraying abstractions. Because thematic maps display abstractions of data in a geographical context, they often present viewers with a new perspective of a subject.

Development of Thematic Maps

Compared to topographic mapping, which dates back to antiquity, thematic mapping is a relatively recent cartographic development. As one might expect, the origin and development of thematic mapping closely parallels that of the systematic sciences, the sources of special subjects for thematic maps.[4] Topics in the newly developing systematic sciences were first mapped by scientists such as Edmund Halley, Alexander von Humboldt, and John Snow in the 17th, 18th, and 19th centuries respectively.[5] Rapid scientific and technological advances in

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[4]The "beginning of the scientific revolution" and the appearance of specialized fields of study, the systematic sciences, occured in the 17th and 18th centuries respectively. The development of scientific thought in general and of geography in particular are discussed in the chapter "What Was New?" in Preston E. James and Geoffery J. Martin, All Possible Worlds (New York: John Wiley & Sons, 1981), pp. 135-61.

[5]John Noble Wilford, The Mapmakers (New York: Vintage Books, 1982), pp. 313-14.

computer science during the past two decades have been adopted by cartographers, helping advance the frontiers of thematic cartography. Considering the variety of subjects that thematic cartography serves, the relative newness of the discipline, and the recent developments in mapping technology, the potential for research and experimentation is unlimited.

Thematic Cartography and Spatial Interaction

Thematic maps are used as tools for understanding many geographical concepts. One of these concepts, spatial interaction, is pertinent to all geographic phenomena. Spatial interaction is plainly defined as flow or "physical movement of something, between two places."[6] The 'something' that moves can be physical objects such as people, manufactured goods, and glaciers, or abstract things such as information and ideas. Some examples of spatial interaction are migration, commuting, tourism, commercial trade, flow of glacial ice, mail, telephone calls, and gossip. Various models in geography and other disciplines attempt to define and predict the movement of things between places.

Since dynamism is a condition of spatial interaction, cartographers are faced with the problem of depicting movement with static cartographic symbols. Cartographers use letters, numbers, points, lines, and areas in depicting spatial interaction. Used properly, these symbols are compatible with the depiction of movement.

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[6]Peter Haggett, Geography: A Modern Synthesis (3rd ed.; New York: Harper & Row, Publishers, 1983), p. 442.

Statement of Problem

The goal of this thesis is to design and evaluate several new methods for mapping spatial interaction. Effectiveness of the methods is evaluated by interviewing a small population familiar with graphics or spatial interaction.

Interstate migration of people in the United States over the period 1975-80 is used as a case study in the thesis. The particular case study is chosen somewhat arbitrarily. Any number of topics in spatial interaction could serve as the basis for the design of new mapping methods. A desirable characteristic of methods produced in this thesis is their utility in mapping a number of topics rather than being limited to a single topic. It is assumed that methods produced for depicting interstate migration will also be applicable to other topics in spatial interaction. Interstate migration is chosen in large part because of the availability and accessibility of the data.

Methodology

The approach used to design new methods for depicting spatial interaction may be divided into four parts: survey of existing spatial interaction maps, analysis of migration data, design of mapping methods, and evaluation of those methods.

A survey of existing maps is undertaken to determine not only what types of maps exist, but also to determine what potential map types exist. To find out what types of maps already exist prevents duplication of research. Defining the potential types of maps that may exist directs the path of research. Methods for producing maps defined by these potential types are designed and evaluated in the chapters which follow.

Analysis of migration data and design of new mapping methods should be studied concurrently due to the mutual influence each exerts upon the other. To proceed with one process exclusive of consideration for the other is to be ignorant of the interdependence of the two. Data analysis proceeds with an eye toward evaluating each cartographic technique. Migration data are stored into a computer input file which is used by various programs for analysis. As data are processed into forms compatible with each cartographic technique, the mapping methods are designed. Cartographic techniques range from traditional pen and ink drafting to more contemporary computer printing and plotting.

Following map design, a social survey is conducted to compile opinions concerning the effectiveness of maps produced in the thesis. A small sample of those with expertise in graphics and those who may use maps of spatial interaction, such as demographers and planners, are questioned about the content and form of each map. Visual appearance as well as utility is evaluated.

Chapter 2

A SURVEY OF SPATIAL INTERACTION MAPS

This chapter surveys maps that depict spatial interaction. The endeavor begins as a search for sources of such maps; examples of them are then collected, cataloged, and classified according to criteria based on the various kinds of map symbols employed. Several of these different kinds of maps are shown in the thesis, and their symbolization systems are displayed as examples to illustrate the various classification criteria. A number of cartographic methods which have been used to depict spatial interaction are identified from the population of maps collected by the survey.

The purpose of identifying existing methods of depicting spatial interaction is to facilitate the development of new mapping methods. In the process of building the classification scheme which follows later in this chapter, spatial interaction maps are subdivided into numerous types. The logic of the classification provides a category for every spatial interaction map. Some classes, or categories, have numerous examples of maps which fit into them; others have very few; some have none. Where categories exist but no maps are found which fit, then the possibility of creating new mapping methods exists. This is only one way the new mapping techniques discussed in the next chapter are developed. Other ways the classification scheme is used to develop mapping techniques are discussed at the end of this chapter.

Sources For Maps of Spatial Interaction

The problem of mapping spatial interaction is only one part of the total universe of mapping geographic phenomena. Being such a specific cartographic problem, mapping spatial interaction receives little direct attention in the literature of cartography. References to spatial interaction maps in cartography textbooks usually are found under the name, "flow maps"[7] or "linear data."[8] Such textbooks consider the problem of mapping spatial interaction from the viewpoint of representing linear flows between places. This is an effective method for mapping the given problem, yet other methods exist and potential methods need to be explored.

Rather than use the literature of cartography as the major source of maps, a more productive approach is to direct the survey toward the literature dealing with spatial interaction. Since movement is universal, many disciplines are concerned with spatial interaction. Map examples involving the movement of people, animals, goods, and services may be drawn from the literature of human geography, zoology, entymology, sociology, history, and economics to mention only a few. The variety of map sources lends diversity to the map examples in the survey and produces a more complete list of spatial interaction maps.

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[7]Willard C. Brinton, Graphic Presentation (New York City: Brinton Associates, 1939), pp. 216-30; Erwin Raisz, Principles of Cartography (New York: McGraw-Hill Book Company, 1962), pp. 218-19; Phillip C. Muehrcke, Map Use: Reading, Analysis, and Interpretation (Madison, Wisconsin: JP Publications, 1978), p. 78

[8]Arthur Robinson, Randall Sale, and Joel Morrison, Elements of Cartography (4th ed.; New York: John Wiley & Sons, 1978), p. 78; David J. Cuff and Mark T. Mattson, Thematic Maps: Their Design and Production (New York: Methuen & Co., 1982), p. 43

Library of Congress subject headings are used to locate sources containing maps of spatial interaction.[9] Additional sources for maps are atlases, journals, and textbooks of both spatial interaction and cartography. Bibliographic entries under the various subject headings are examined for a description of the contents and the presence of maps. From these entries, and the other sources mentioned, a hand-picked group of maps is collected. Since the maps are collected for the purpose of building a classification scheme, they are selected on the basis of whether or not each newly discovered map represents a unique class of maps. Conceivably, collecting examples of spatial interaction maps could continue indefinitely. In order to know when to stop, the requisite question to be asked may be: "Is the population of maps collected so far representative of the entire universe of spatial interaction maps?". In this survey, map collection and classification are concurrent processes. Maps are collected and criteria for classification are simultaneously developed. An intuitive feeling for the diversity of spatial interaction maps is acquired while collecting the group. Map collection ends and a working classification scheme can be developed when new map types are found only rarely in the literature. It should be noted that because collection and classification are concurrent processes in this study, the task of classification can never be complete. Since the universe of spatial interaction maps can never be completely known, revisions may be needed as exceptions to the scheme are found. As an ongoing process, revisions to the classification scheme will provide

[9]A list of subject headings used in the survey can be found in Appendix A.

the means for further exploration of mapping methods.

Classification Rationale

Once a number of spatial interaction maps are collected, can each map be considered unique? If each map is considered unique, with characteristics unrelated to all other maps in the group, no comparisons can be made among them. This is not the case, however, because similarities do exist among the maps. Classification is integral to the survey because it brings order to the population of maps that is collected. Classification, according to characteristics developed later in the thesis, establishes similarities and differences among the maps and makes it possible to consider the population as coherent groups of maps rather than as a collection of individual maps. Grigg succinctly states the purpose of classification:

1. To give names to things.
2. To transmit information.
3. To make inductive generalizations.[10]

Before classification of maps is possible, a basic understanding of graphic communication, especially the process of map making, is necessary. Graphic communication, or graphicacy, is one of the four modes of human intelligence and

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[10]David Grigg, "The Logic of Regional Systems," Annals of the Association of American Geographers, Vol. 55 (September, 1965), 469.

communication noted by Balchin.[11] Graphicacy is fluency in communication of spatial information using graphic methods such as cartography, computer-graphics, photography, diagrams, and charts.

What is the process that produces maps? Cartographic communication, a form of graphic communication, includes the ability to make maps as well as the ability to read maps. Making maps involves several steps and requires knowledge of concepts and skills such as: objectives of the map, intended audience of the map, data collection and analysis, data symbolization, map design, and production methods. Map making is composed of cartographic input elements, interpretation and processing by the cartographer, and output elements. Four steps, or levels of processing, in the map making process are shown in Figure 2-1. Each level of processing represents increasing involvement by the cartographer in the map making process and also increasing abstraction of the phenomenon under study. Understanding the process of map making helps define the characteristics of maps and develop the criteria for use in classifiying maps.

Classification may proceed by either logical subdivision of a group toward individuality, or by agglomeration of individuals into groups. Agglomerative techniques of classification are usually based on measurable quantitative

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[11]The other three modes of human intelligence and communication are numeracy (fluency in numerical communication), literacy (fluency in written communication), and articulacy (fluency in verbal communication). See W. G. V. Balchin, "Graphicacy," The American Cartographer, Vol.3, No.1 (1976), 33.

	INPUT (elements)	INTERPRETATION/PROCESSING (processes)	OUTPUT (abstractions)
STEP 1	Phenomena >>>>>>>	Knowledge of: objectives, audience, data collection and analysis, symbolization, design, and production.	>>> Raw Data
STEP 2	Raw Data >>>>>>>>		>>> Analyzed Data
STEP 3	Analyzed Data >>>		>>> Symbolized Data
STEP 4	Symbolized Data >		>>> Map

Figure 2-1: The process of map making, a part of cartographic communication

characteristics of the individuals to be grouped.[12] Since individuals are assembled into subgroups, and subgroups are further assembled into groups of higher order, the agglomerative technique obviously works best if the entire population is known at the onset of classification. New and different individuals are likely to upset the logic of a classification scheme created by an agglomerative technique to the extent that devising a new scheme may be necessary to accommodate them. Conversely, classification by logical subdivision is based on the qualitative characteristics of a population which may not be known in its entirety. As subgroups with new characteristics are identified, new classes are created to accommodate them. In this way new individuals may fit into an existing subgroup or a new subgroup may be created for that purpose. Logical subdivision may, however, create classes that have no members. Maps in these classes exist only

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[12] R. J. Johnson, Classification in Geography, Concepts and Techniques in Modern Geography, No.6. (Norwich: Geo Abstracts, 1975), p. 5.; Robert H. Stoddard, Field Techniques and Research Methods in Geography (Dubuque, Iowa: Kendall/Hunt Publishing Company, 1982), p. 283.

in the logic of the classification system. These "empty" classes, discussed later in this chapter, provide one means for exploring new mapping methods.

Creating a classification scheme evokes the inevitable question, "When should the process stop?". When does logical subdivision of the population of maps end? Subdivision could proceed until a separate class exists for each existing spatial interaction map. Classification is a subjective process used as a tool for specialized purposes. Consequently, the point where classification ceases is subjective depending upon its purpose. One objective of this chapter is to look for theoretical classes of spatial interaction maps where no or only a few maps are found. Classification by subdivision stops when two conditions are met: when specialized criteria for classification describing maps of spatial interaction have been used in the scheme, and when vacant classes of maps are created.

Criteria for Classification

The criteria established for classifying maps describe characteristics of map symbolism rather than characteristics of spatial interaction. The thesis does not focus on analysis of spatial interaction but uses analysis as a tool in the design of mapping methods. The question asked in classification is "How does the map depict spatial interaction?" rather than, "What are the characteristics of interaction shown by the map?." Classification progresses from criteria describing map characteristics in general to criteria which are specific to maps of spatial interaction.

Three criteria are used to develop the classification scheme for maps of spatial interaction.

1. Form of symbolism
2. Scale of symbolism
3. Movement symbolism

Each of these is discussed in the sections which follow.

Form of symbolism

Symbols used by cartographers to represent data include letters, numerals, points, lines, and areas. Letters are usually used by cartographers to symbolize qualitative data of either a positional, linear, or areal nature. Numerals are used to symbolize quantitative data also of either a positional, linear, or areal nature (Figure 2-2 and 2-5). Point symbols are graphic devices usually used to represent positional data such as buildings, oil wells, mountain peaks, or cities (Figure 2-12). Occasionally, point symbols are used to represent data common to areas, such as states (Figure 2-3 and 2-4). Line symbols are graphic devices used to represent geographic data of various dimensions in nature. Contour lines are line symbols which represent the elevations at a number of data points. Obviously, line symbols may represent linear data such as rivers and roads. Line symbols may also represent data which show movement between areas (Figure 2-11). Area symbols are graphic devices used to symbolize data common to areas or geographic regions (Figure 2-6, 2-7, and 2-10).

Points, lines, and areas which appear on a map may be described as pictoral symbols, in contrast to letters (literal symbols) and numerals (numerical symbols). In much the same way that the images in a painting are visually integrated by a

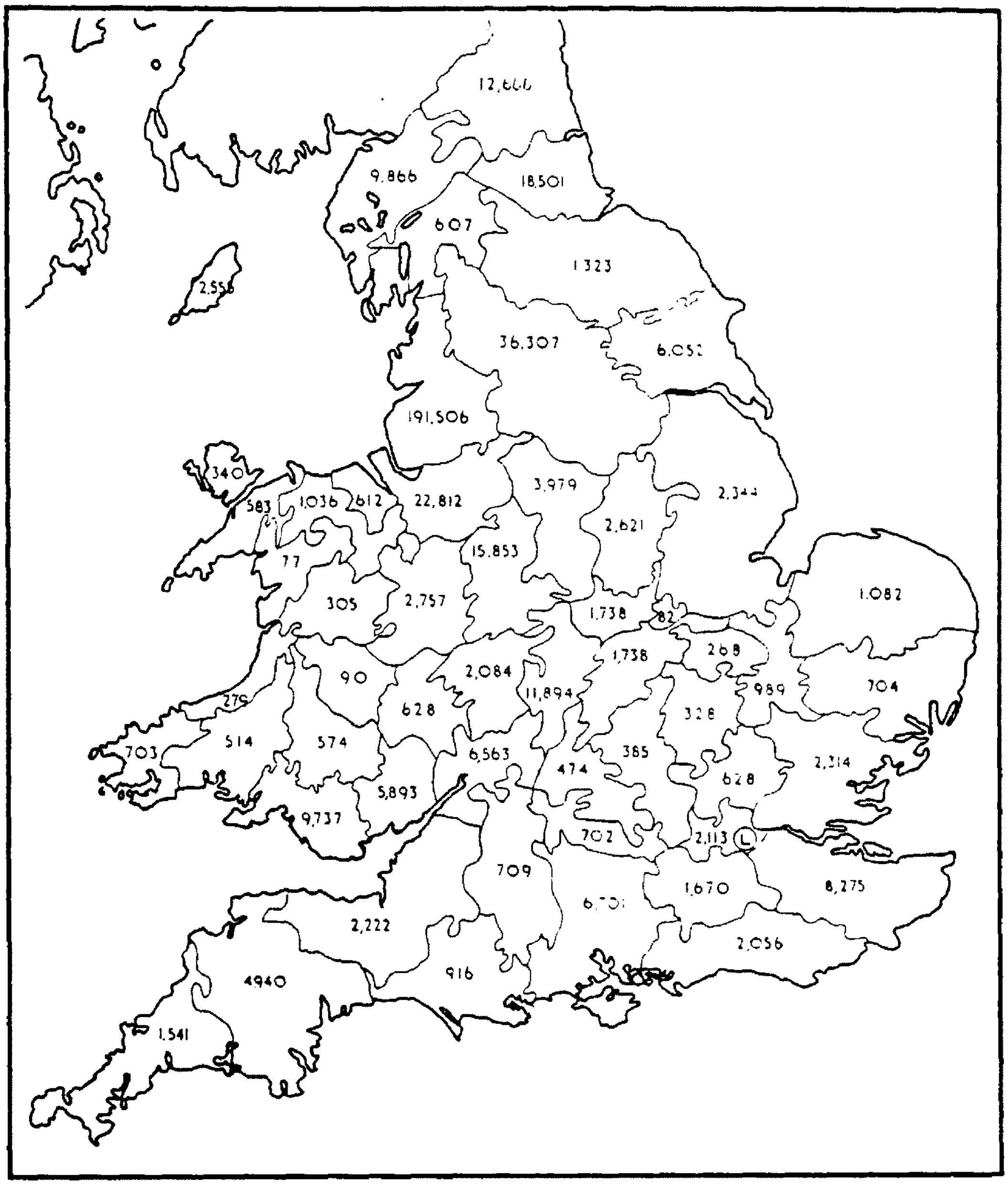

Figure 2-2: Irish migrants in Great Britian[13]

viewer, and in contrast to images in a written text which are read sequentially, a

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[13]Arthur Redford, Labour Migration in England, 1800-1850 (2nd. ed.; Manchester: Manchester University Press, 1964), p. 194.

map representing data with pictoral symbols can be read as a whole. The graphic elements listed by Robinson[14] (hue, value, size, shape, spacing or pattern, orientation, and location) can be varied for point, line, and area symbols, to change both their appearance and their meaning. Increased size of the point symbols (spheres) used in Figure 2-3 represents a larger number of student migrants. The meaning of letter and numeral symbols is not changed by variations in these graphic elements. By altering the graphic elements, point, line, and area symbols may produce maps that show distribution and movement of things more readily than maps using only letters or numerals. The maps in Figures 2-2 and 2-3 convey similiar information, yet Figure 2-3 creates a greater visual impact by allowing the viewer to picture the distribution of migrating students in the fifty states at a glance.

All graphic symbols, especially line symbols, are used in maps of spatial interaction. All geographic phenomena are perceived to possess a distinct spatial form, either positional, linear, areal, or volumetric. In thematic mapping, the way spatial data are depicted depends upon the interpretation of the cartographer. Symbolization is the process of changing data into graphic form (Figure 2-1). The process is subjective; cartographers may chose to represent data and phenomena with various graphic forms. This is illustrated by the maps appearing in Figures 2-4 and 2-5. Point symbolism is used to portray migration to and from the state of Utah over a period of time in Figure 2-4. The point symbols (small human

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[14]Arthur H. Robinson, et al. Elements of Cartography (5th ed.; New York: John Wiley & Sons, 1984), pp. 141-43.

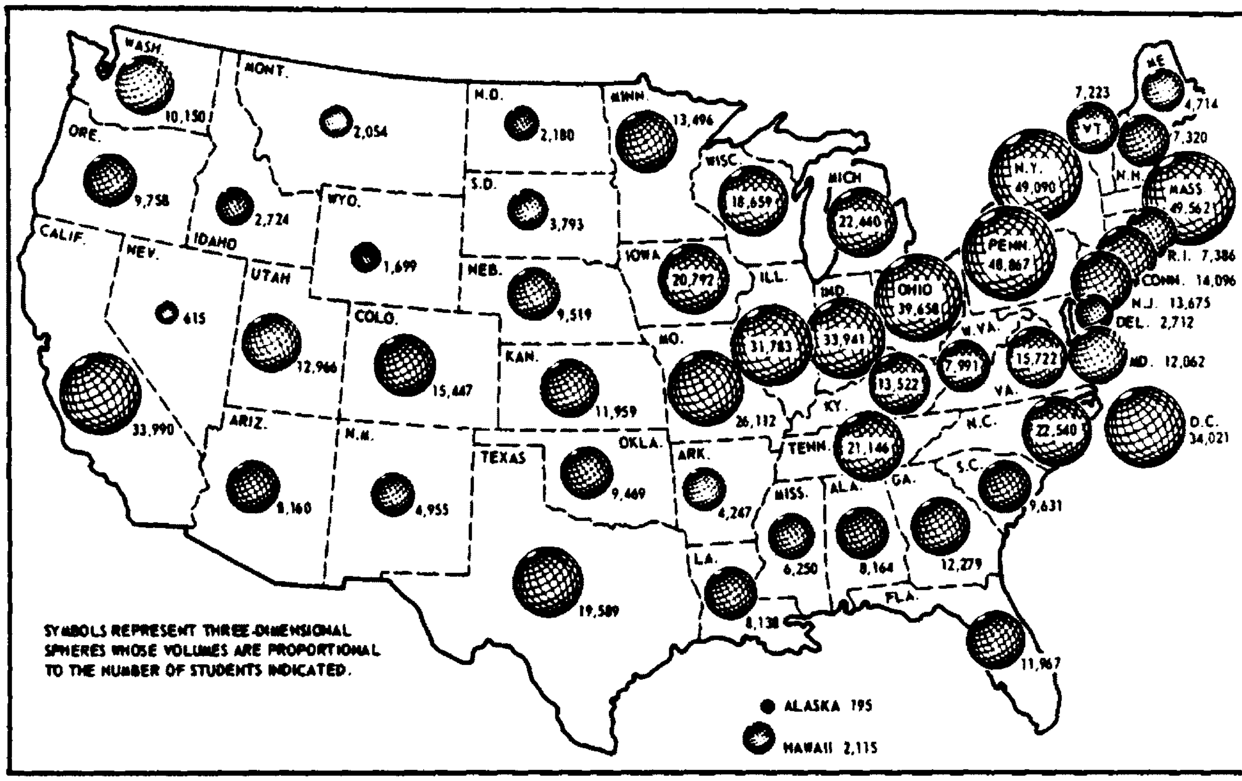

Figure 2-3: Student in-migration, U.S., 1963[15]

figures) display the origins, destinations, and quantity of migrants either leaving or entering Utah from every other state in the contiguous United States. Essentially the same type information found in Figure 2-4 is depicted for North Dakota in Figure 2-5; but in this instance, line symbols are used rather than point symbols. Origins, destinations, and quantity of migrants are all symbolized by lines.

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[15]Charles S. Gossman, Migration of College and University Students in the United States (Seattle: University of Washington Press, 1968), p. 17.

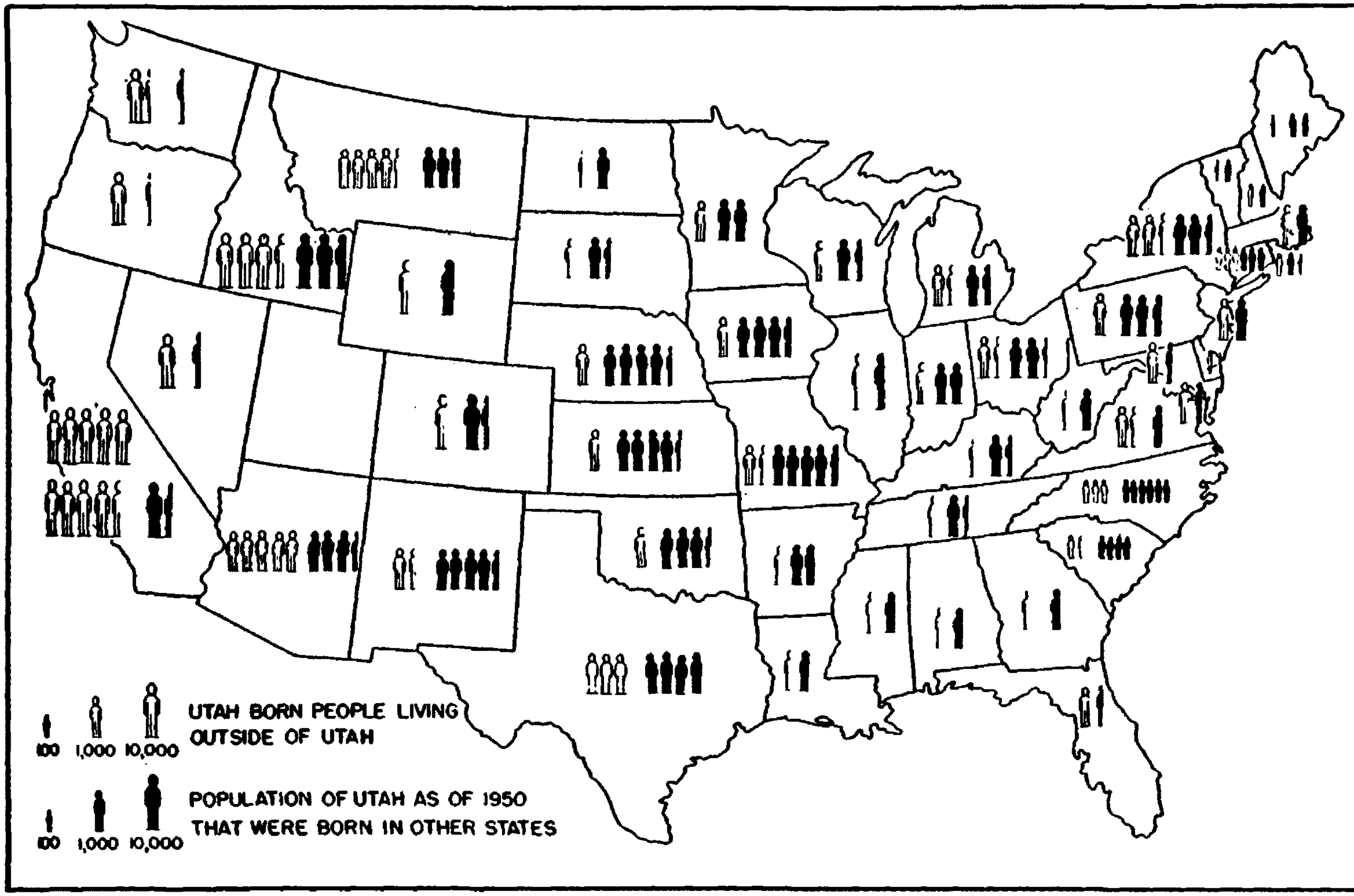

Figure 2-4: In- and out-migrants, Utah, to 1950[16]

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[16]Elroy Nelson Utah's Economic Patterns, Salt Lake City: University of Utah Press, 1956, p. 5

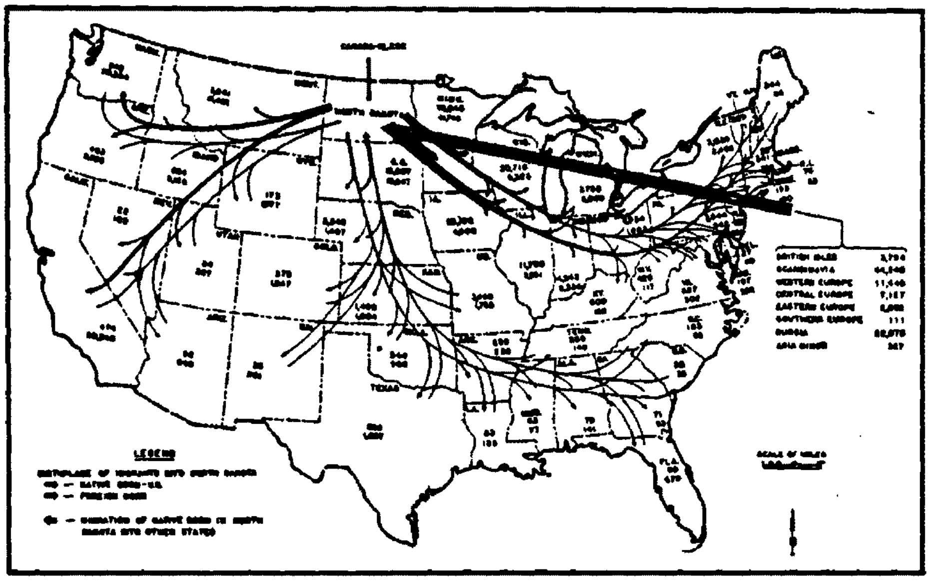

Figure 2-5: Migration to and from North Dakota: 1920-1930[17]

All maps employ symbolism of one or more forms. Each form of symbolism possesses certain characteristics which the cartographer must choose between in order to produce maps which are both effective and accurate.

[17]Willard C. Brinton, Graphic Presentation (New York City: Brinton Associates, 1939), p. 220.

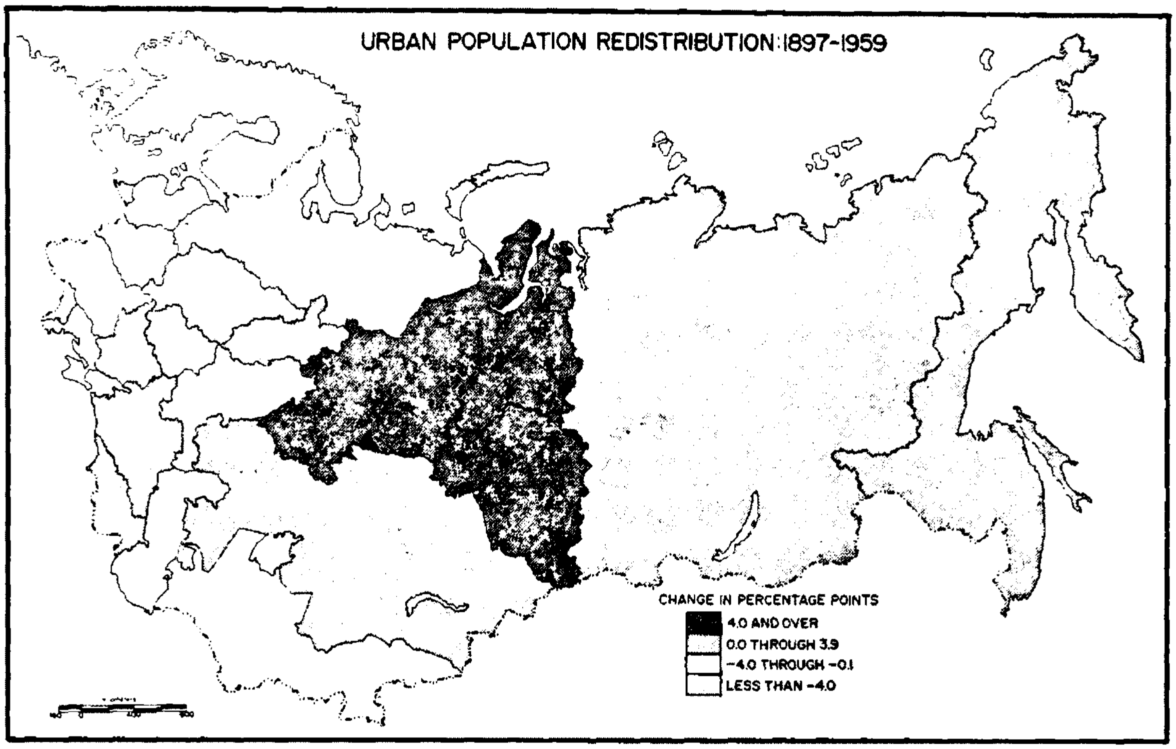

Figure 2-6: Population redistribution, USSR, 1897-1959[18]

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[18]Robert A. Lewis and Richard H. Rowland, "Urbanization in Russia and the USSR: 1897-1966," Annals of the Association of American Geographers, Vol. 59, No. 4 (December, 1969), 786.

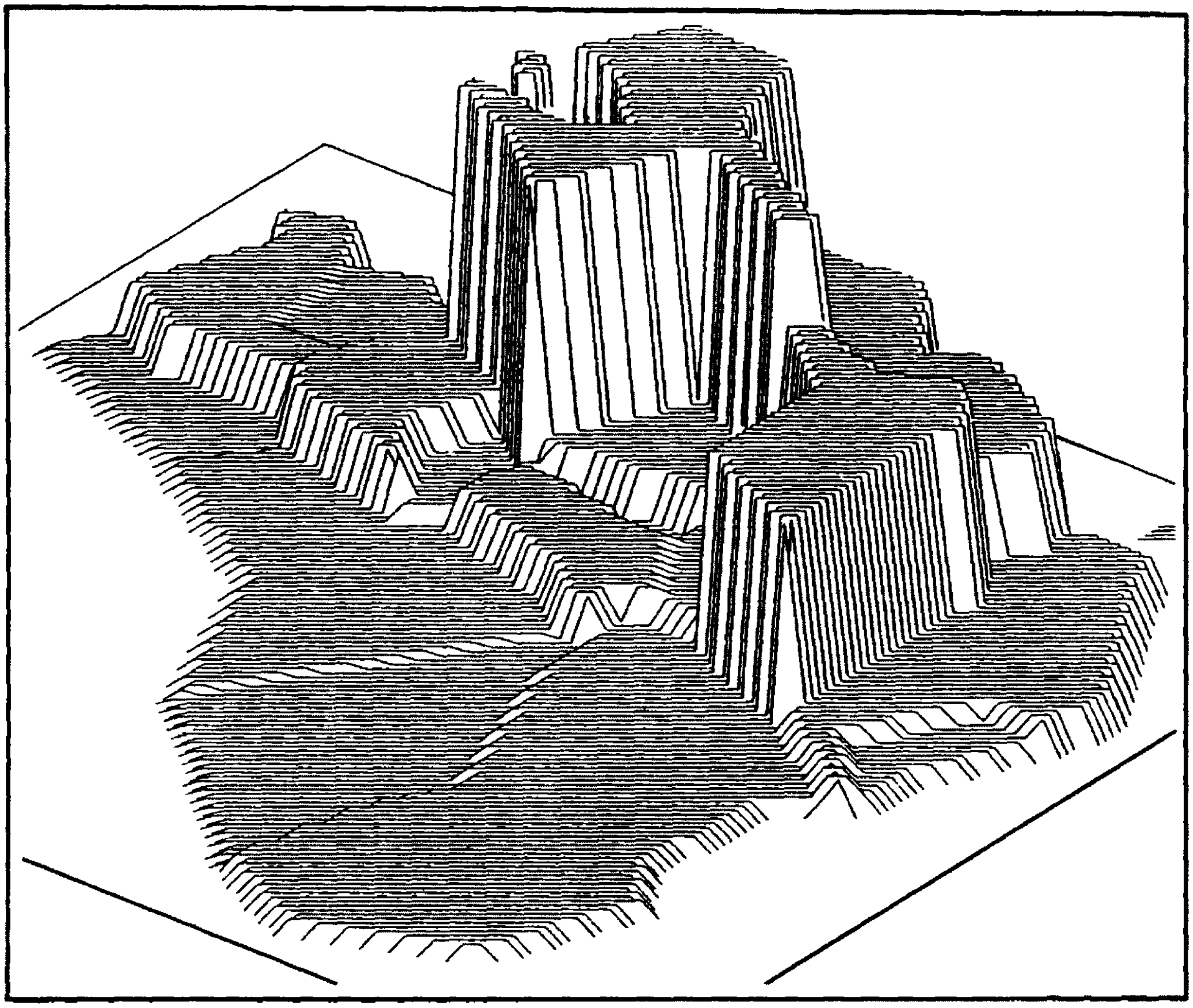

Figure 2-7: Rate of growth by region, Ecuador, 1945-75[19]

[19]Daniel R. Vining, "The Growth of Core Regions in the Third World," Scientific American, Vol. 252, No. 4, April, 1985, p. 45.

Scale of symbolism

Symbolism represents geographic phenomena on three scales of increasing precision: nominal, ordinal, and interval/ratio. Nominal scale symbolism differentiates mapped phenomena by qualitative characteristics. Roads, rivers, gas pipelines, oil pipelines, and power transmission lines may all be shown with different types of lines on the same map. The process is known as nominal scaling. The geographic phenomena are divided into categories on the basis of kind only, no quantities are involved. Figure 2-8 provides an example of the use of nominal scale symbolization.

Ordinal scale symbolism depicts the rank order of classes into which the data are grouped. Grouping data into classes and the ranking of classes is done according to either qualitative or quantitative characteristics of the data.

Qualitative rank ordering involves establishing a qualitative hierarchy according to inherent characteristics of the data and creating a class for each level in the hierarchy. Data are then grouped into the classes most fitting to their qualitative characteristics. As administrative units, settlements can be grouped into classes defined by state capitals, county seats, and towns. The hierarchy, or rank of settlements, is determined by the level of government located in a settlement.

In Figure 2-9, quantitative rank ordering creates classes with numerical intervals into which the data are grouped according to their quantitative value. In the process of grouping, and during the subsequent symbolizing of groups, the exact quantitative identities of the data values are replaced by the more general

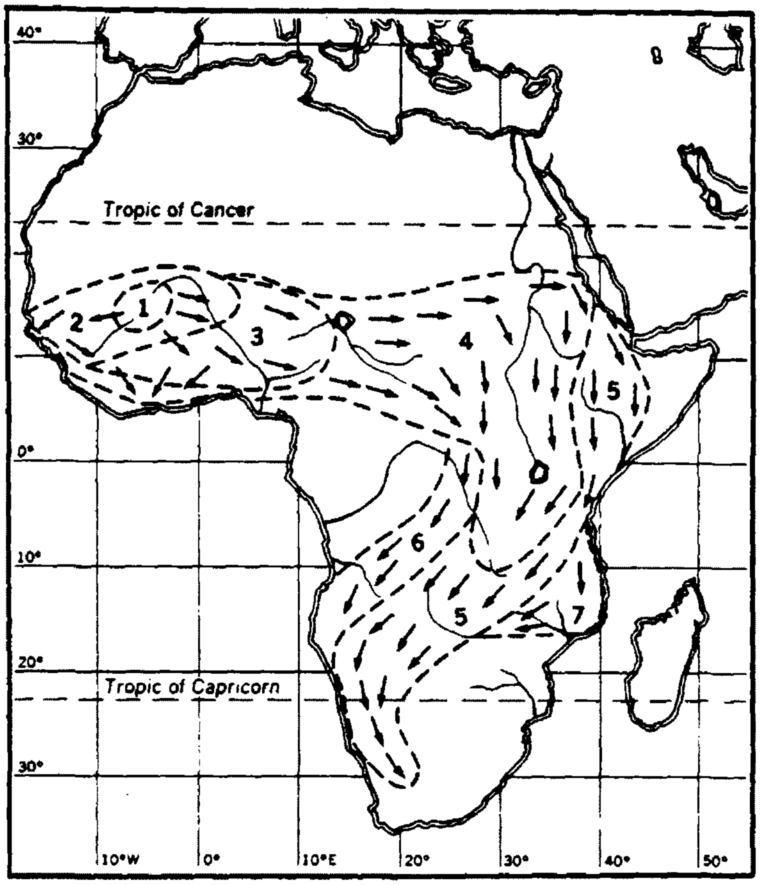

Figure 2-8: Increase and spread of locust in Africa, 1928-34[20]

interval identities of the classes into which they are grouped. Settlements are grouped according to the quantitative characteristic of population size in Figure 2-9. After grouping and symbolizing, the rank order of settlement size can be determined for settlements of different classes, but not for settlements within a single class.

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[20] Robert T. Orr, Animals in Migration (London: Collier-Macmillan Ltd., 1970), p. 9

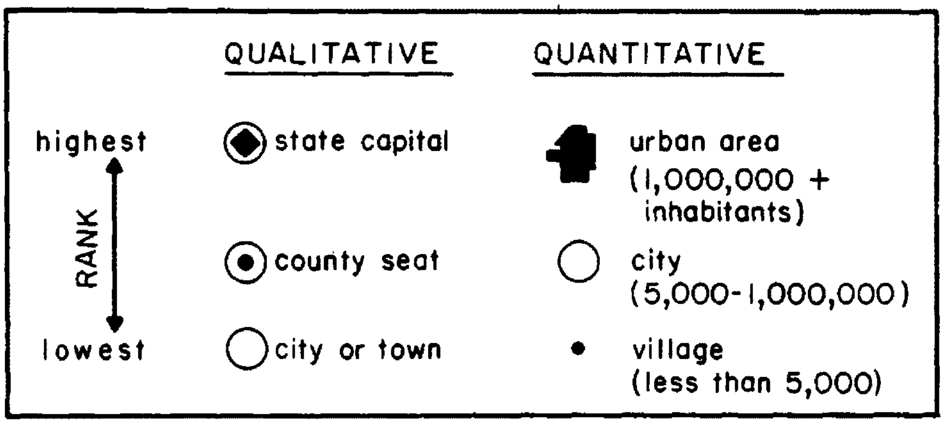

Figure 2-9: Ordinal symbolism, qualitative and quantitative rank

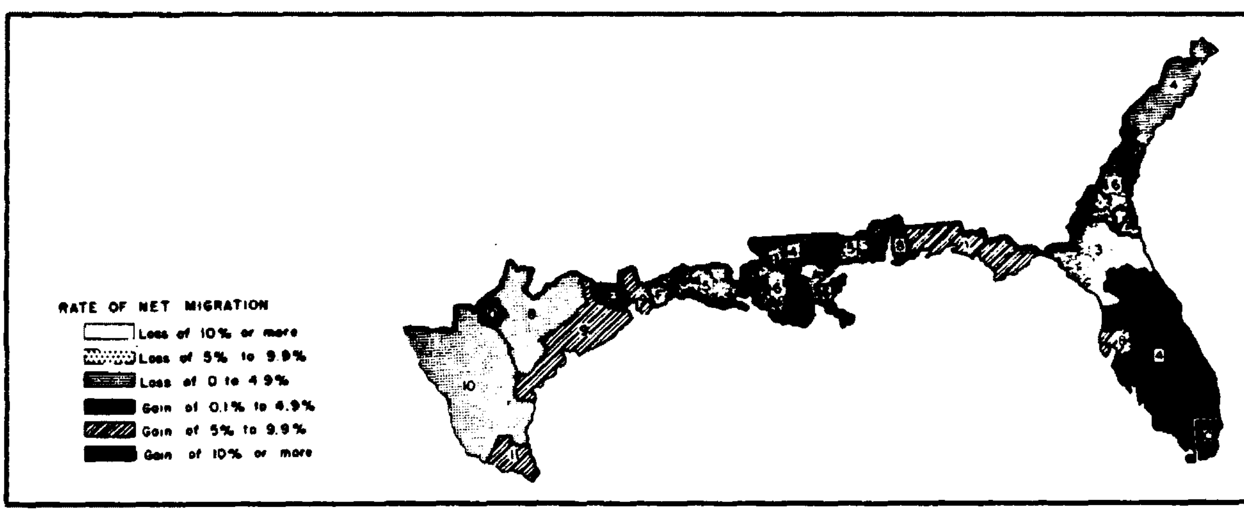

Figure 2-10: Net migration by regions, Gulf Coast states, 1935-1940[21]

Interval/ratio scaling and symbolization differentiate things by units of

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[21]Donald J. Bogue, Henry S. Shyrock Jr., and Siegfried A. Hoermann, Subregional Migration in the United States, 1935-40, Vol. 1: Streams of Migration Between Subregions (Oxford, Ohio: Scripps Foundation, Miami University, 1957), p. 86.

quantitative measurement. Interval/ratio symbolism is scaled to fit the individual data values, in contrast to ordinal symbolization which is scaled to the values of classes intervals. Theoretically, exact data values can be retrieved from a map using interval/ratio scale symbolization. Quantitative characteristics are represented on an interval/ratio scale by altering the shape, size, value, or other graphic element of the symbols employed. In Figure 2-11, line symbols are scaled in size (width) to the number of migrants.

The scale of symbolization of the data on a map is an important consideration in the process of mapmaking. It is determined by the data compiled, the map audience, and the intended uses of the map. As such, the scale of symbolization is used as a criterion in classifying maps of spatial interaction.

Movement symbolism

One property of maps is their ability to represent phenomena in a spatial context; that is, they show where things are located. A specialized property of spatial interaction maps is their ability to represent movement from places, to places, and between places. When making such maps, cartographers compile data and select an appropriate form of symbolism and scale of symbolization in order to represent movement.

Movement may be symbolized in spatial interaction maps either implicitly or explicitly. Maps that implicitly depict movement symbolize the location of a place or places involved in spatial interaction without actually showing the path of movement with lines, arrows, or other symbols. For example, in Figure 2-12, only the place of origin of migrants is shown. Neither verbal nor graphic descriptions

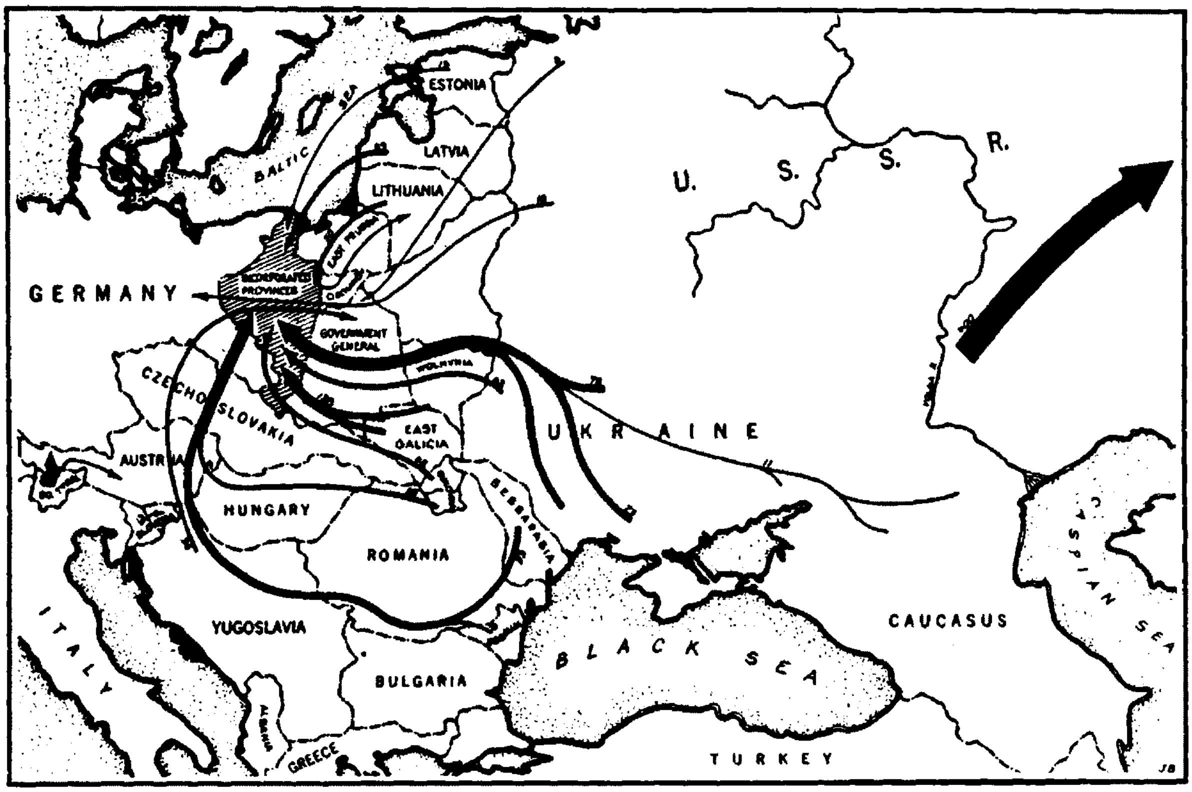

Figure 2-11: Transfer of German minorities, 1939-1945[22]

are made concerning the destinations of the migrants.

Implicit depiction of movement by a map may include both the place of origin and the place of destination. An example of this is the map in Figure 2-4 that shows both the destinations of out-migrants and the sources of in-migrants for the state of Utah. This map implicitly depicts movement since no graphic

[22]Joseph B. Schechtman, European Population Transfers (New York: Oxford University Press, 1946), p. 254.

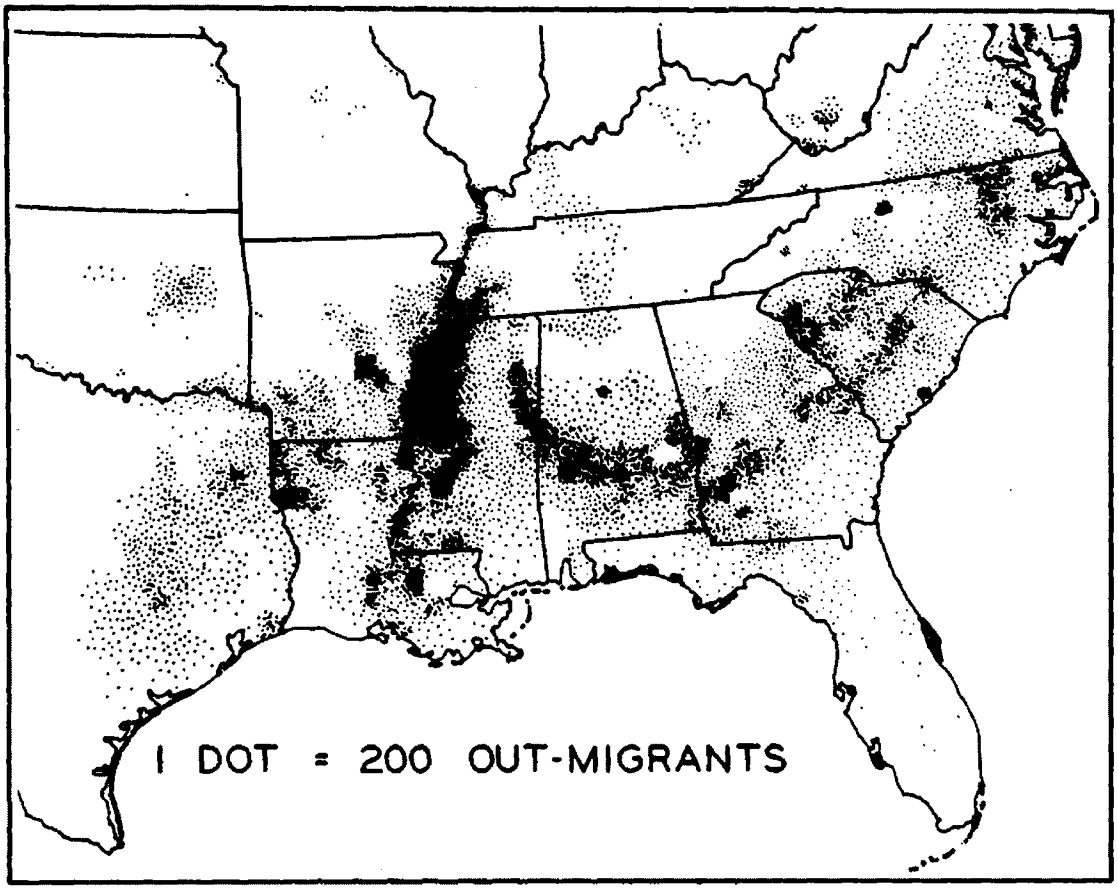

Figure 2-12: Nonwhite out-migrants, southern U.S., 1940-1950[23]

connections are made between origins and destinations. The implicit depiction of interaction works because map readers have the ability to infer movement even though it is not explicitly depicted by symbols.

Two factors help the viewer to infer this movement. First, the map title

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[23]George J. Demko, Harold M. Rose, and George A. Schnell, Population Geography: A Reader (New York: McGraw-Hill Book Company, 1970), p. 403.

ordinarily states that the subject of the map has to do with some aspect of spatial interaction. Second, the geographic context of point, line, and area symbols provides clues which lead to the conclusion that movement has occurred. Even though no graphic connections are made between places of origin and places of destination, the viewer has the ability to read the map and make mental geographic connections between the symbols. The map viewer may be able to infer specific movements between places depicted by this type of map. Even though very specific, detailed, geographic movements of commodities are implied by some maps, the reader still has the ability to infer the movements involved.[24]

Maps that explicitly depict movement symbolize the geographic connection between interacting places by placing line symbols (flow lines) between them. Appropriately, cartographers refer to this type of map as a flow map.[25] The map viewer need not mentally establish geographic connections between the two places since the symbols do the job explicitly. Flow lines depict movement of phenomena between places on a map. The viewer visually follows the flow lines connecting the places and conceptualizes the interaction between them. If a line connecting two places is not directed (not an arrow), then the viewer cannot

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[24]For examples of maps depicting detailed, specific movements implicitly see: U. S. Department of the Interior, "Shipments of Commodities by Manufacturers: 1963," The National Atlas (Washington D. C.: Government Printing Office, 1970), p. 240.; D. P. Bickmore and M. A. Shaw, "U. K. Overseas Trade: Exports to and Imports from Commonwealth and Foreign Countries," The Atlas of Britian and Northern Ireland (Oxford: Clarendon Press, 1963), p. 171.

[25]Willard C. Brinton, Graphic Presentation (New York City: Brinton Associates, 1939), p. 216.; G. C. Dickinson, Statistical Mapping and the Presentation of Statistics (2nd ed.; London: Edward Arnold Publishers Ltd., 1973), p. 66-7.; Arthur Robinson, Randall Sale, and Joel Morrison, Elements of Cartography (4th ed.; New York: John Wiley & Sons, 1978), p. 242-43.

differentiate which place is the origin and which is the destination of movement. An example of this type of explicit symbolization is shown in Figure 2-13.

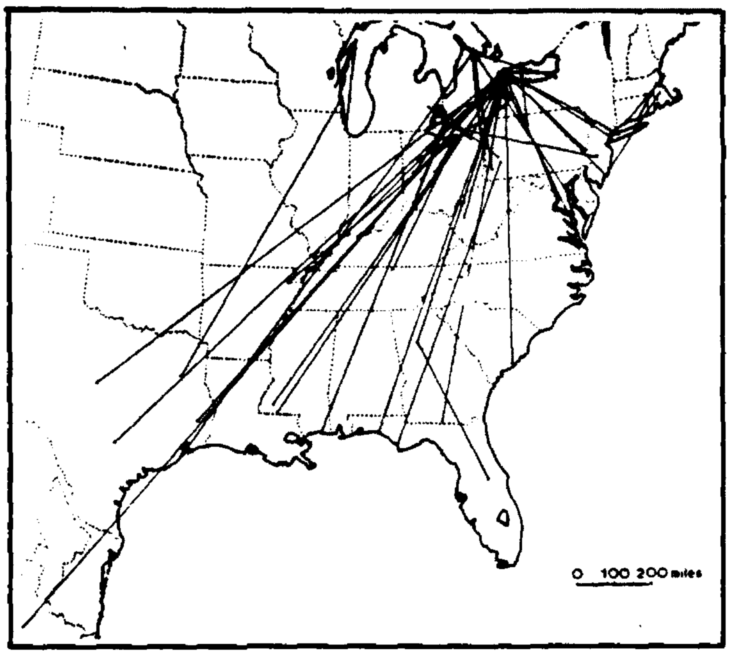

Figure 2-13: Release and capture points of Monarch butterflies[26]

More detailed movement may be shown by simply making lines into arrows. Arrows direct the viewer's eye from place of origin to destination. Interaction depicted in this way is no longer general movement between places but is directed movement (Figures 2-5, 2-8, and 2-11).

Flow lines may depict absolute paths of interaction, as in traffic flow maps,

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[26] C. G. Johnson, Migration and Dispersal of Insects by Flight (London: Methuen & Co. Ltd., 1969), p. 571.

or they may depict conceptual paths of interaction (Figure 2-11). In the case of conceptual paths of interaction, placement of flow lines may be entirely a consideration of graphic design. Lines then serve only to connect places; their paths are irrelevant.

A Classification Scheme

As described earlier in this chapter, the process of developing a classification scheme, or similiarity tree, and the collection of those maps occurs simultaneously. The procedure begins by consulting the sources to find maps of spatial interaction. As maps are encountered in the literature, they are examined to see if they depict a topic in spatial interaction. If not, they are placed in the category "all other maps" (Figure 2-14). If they do depict spatial interaction, they are placed in a group which is then further subdivided by the classification criteria described in previous passages: the form of symbolism, the scale of symbolism, and whether movement is symbolized implicitly or explicitly.

The first step is to examine spatial interaction maps to determine which form of symbolism is used to depict movement: letter or numeral symbols, point symbols, line symbols, or area symbols. Some maps use more than one form of symbolism. Examples are commonly found which combine numeral and point symbols (Figure 2-3), numeral and line symbols (Figure 2-11), and line and area symbols (Figure 2-15) to name a few. Maps using multiple forms of symbolism are classified by that form which most readily displays the interaction taking

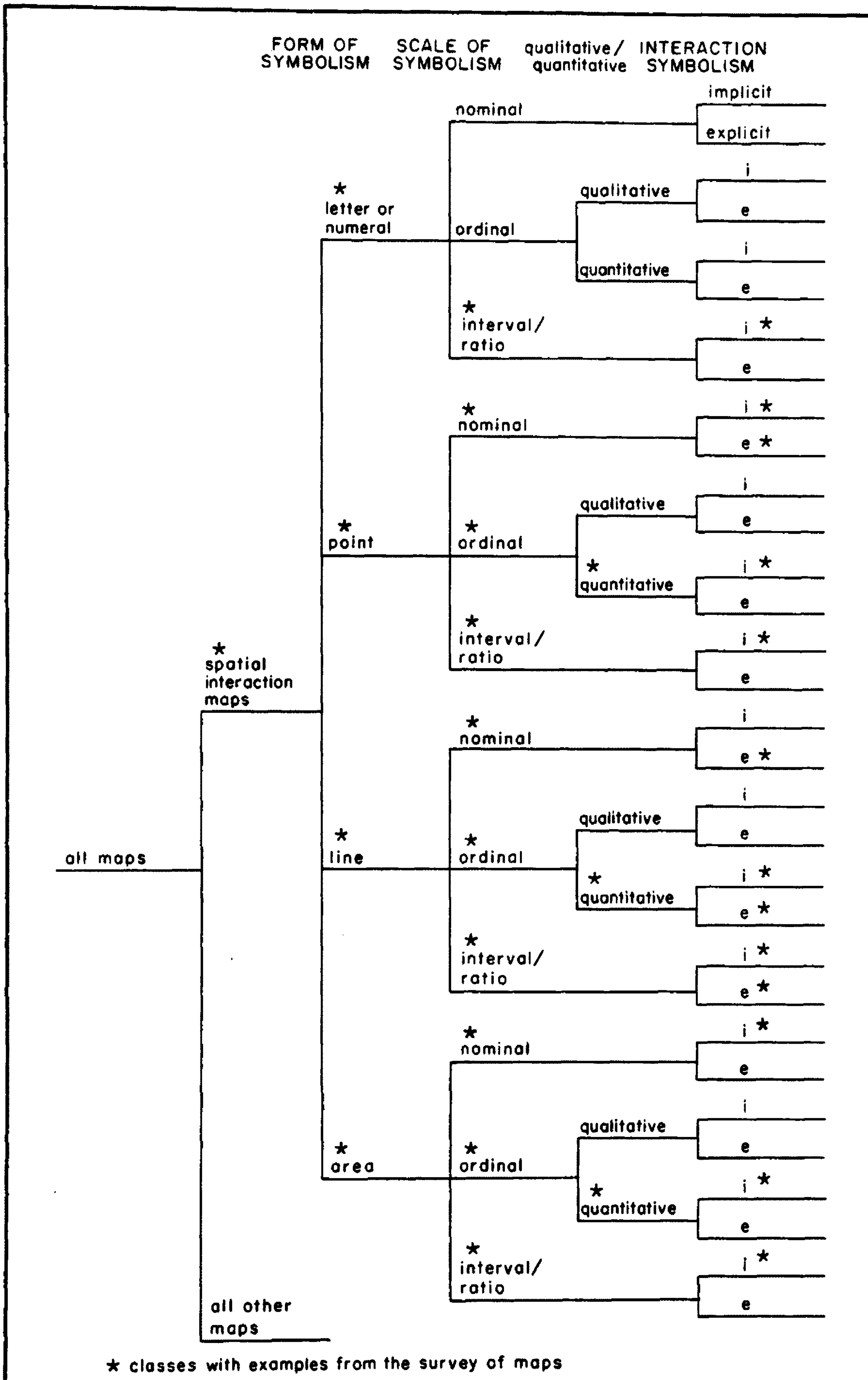

Figure 2-14: Classification tree for spatial interaction maps

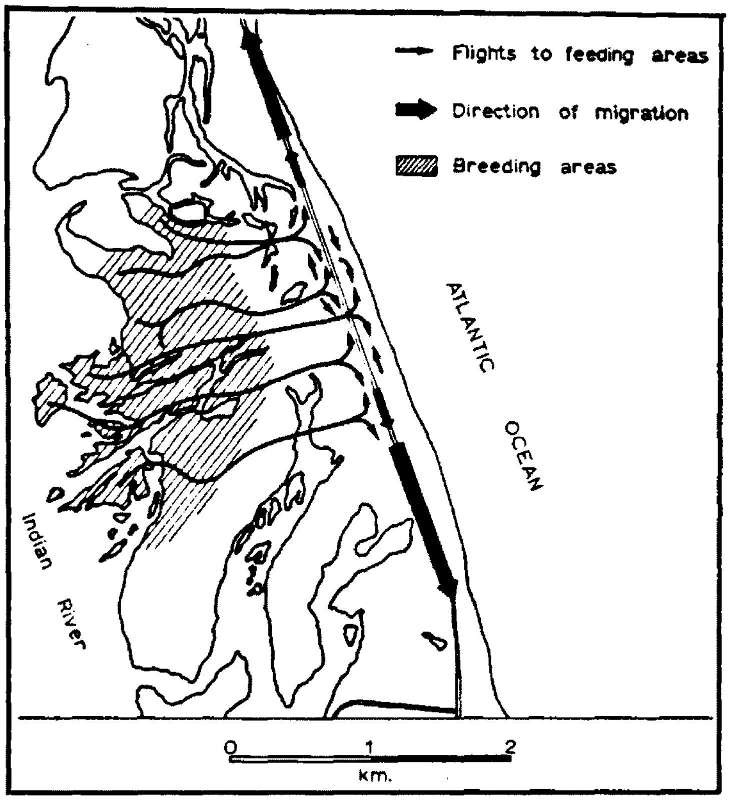

Figure 2-15: Direction of flights for butterflies, Florida[27]

place.[28]

After the principal form of symbolism is determined, then maps are examined to determine whether the scale of symbolization is nominal, ordinal-qualitative,

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[27]C. G. Johnson, Migration and Dispersal of Insects by Flight (London: Methuen & Co. Ltd., 1969), p. 443.

[28]Including the various combinations of multiple forms of symbolism would make a single classification tree too unwieldly. The third level of subdivision in such a tree would have at least fifteen classes, rather than the four classes present at the same level of subdivision in Figure 2-14.

ordinal-quantitative, or interval/ratio. Following this, it is seen if the interaction symbolism depicts movement implicitly or explicitly. Classes in the tree are filled as classification of maps proceeds. No running total of maps in classes at the lowest level of subdivision is kept. One assumption in the classification process is that some classes at the lowest level of subdivision would remain unfilled by maps. This is found to be the case as only thirteen of the thirty-two possible classes are filled by examples of maps found in the literature.

The unfilled, or empty, categories in the classification tree provide the most straightforward means for exploring the possiblity of new mapping methods. In the following chapter, one of the maps (Map 2, a nodal region flow map) is designed to fill such a category.[29] Map 2 uses line symbolism, qualitative ordinal scale symbolization, and an explicit depiction of interaction. This category in the classification tree is unfilled by the group of maps collected by the survey.

All maps examined in the process of classification which depict movement explicitly are found to use only line symbolism for that purpose. Can other forms of symbolism besides lines effectively represent movement explicitly? Map 4, a surface relief flow map, explores this problem in the following chapter. In this map, the size (height) of area symbolism is altered, creating an apparent gradient between contiguous states, to represent the direction of net migration.

Categories which are filled in the tree may also call attention to potentially different methods for mapping spatial interaction. Figure 2-7 fills the category

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[29]Map 1, Map 2, Map 3, and Map 4 are introduced on page 39 of the following chapter. They appear on pages 46, 56, 64, and 69 respectively.

defined by area symbolism, ratio scale symbolization, and implicit depiction of interaction. Ratio scale symbolization of in-migration in Figure 2-7 is achieved by altering the size (height) of area symbolism. A new mapping method, one which makes a map that fits into the same category as Figure 2-7, may use variations of a graphic element other than size. In Chapter 3, Map 1, a classless choropleth dot map, is designed which also uses area symbolism. Ratio scale symbolization is achieved by Map 1, however, by altering the graphic element *spacing* (pattern) for dots inside area symbols.

Figure 2-16 shows a standard airline route map using line symbolism, nominal scale symbolization, and explicit interaction symbolization. In Chapter 3, U.S. interstate migration is represented by Map 3, a connectivity network map. Map 3 is essentially the same type of map as Figure 2-16, but mapping migration in this way requires devising a special method for abstracting the data.

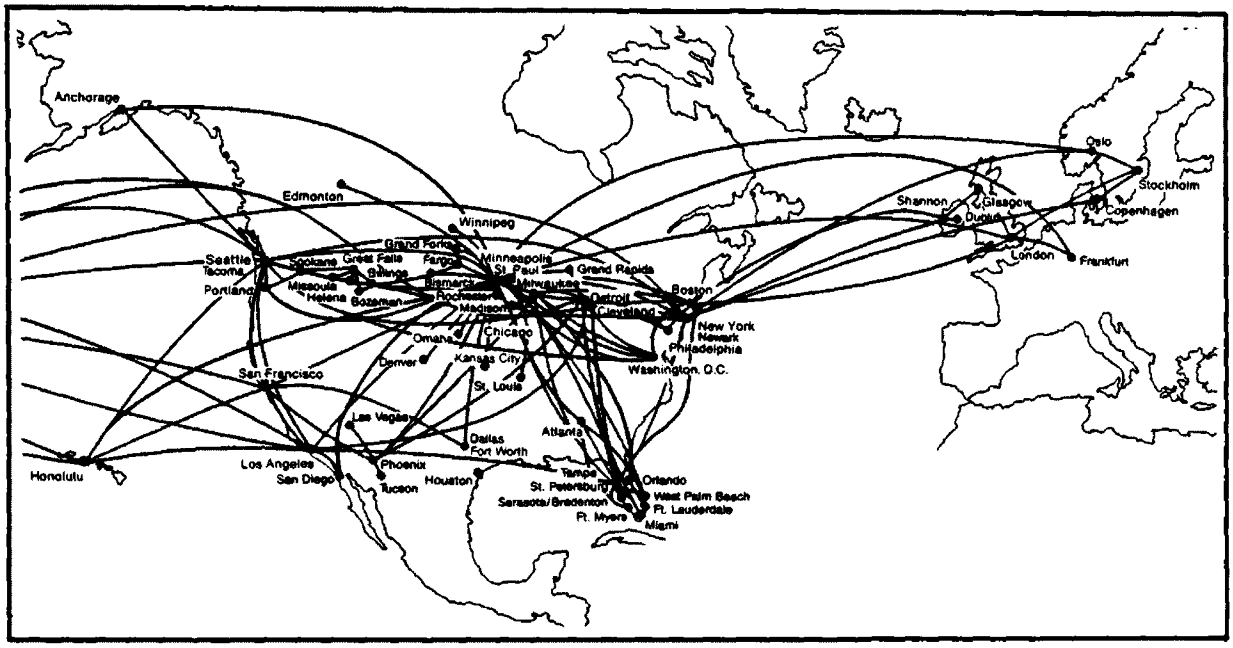

Figure 2-16: Standard airline route map[30]

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[30] Northwest Orient, System Timetable Effective March 2, 1986, p. 2.

Chapter 3

ANALYSIS AND DESIGN

Analysis of migration data and design of mapping methods to display these data are the objectives of this chapter. The two are organized so that they proceed concurrently. Four mapping methods are designed which fit into several of the various classes of maps defined by the classification scheme in Chapter 2. Each of these mapping methods will be discussed in the passages which follow. They include Map 1, the classless choropleth dot map; Map 2, the nodal region flow map; Map 3, the connectivity network map; and Map 4, the surface relief flow map. Data analysis involves manipulating and abstracting the data into forms compatible with the types of maps produced.

Migration Data

Sources

In 1983 the Census Bureau published a special report titled, State of Residence in 1975 by State of Residence in 1980.[31] This document is the principle source of information for the maps produced later in this thesis. It contains the volume of interstate migration between all of the states, plus the District of

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[31]U.S. Department of Commerce, Bureau of the Census, State of Residence in 1975 by State of Residence in 1980, Supplementary Report, 1980 Census of Population, (Washington D.C.: Government Printing Office, 1983)

Columbia, for the five-year period between 1975 and 1980. These interstate movements are represented by 2550 data values. A matrix of the original census data is shown in Table B-1, Appendix B. Migration data for the time intervals 1935-40, 1949-50, 1955-60, and 1965-70 are represented in one of the maps. The data for these periods are not listed in the appendix, but sources for them are provided in the bibliography.[32]

U.S. migration data are chosen as the basis for the design of the new mapping methods for two reasons. First, most people are familiar with the map of the United States. Familiarity with the study area should facilitate viewing and interpreting the resulting maps. Secondly, both the general topic of spatial interaction and the more specific topic of interstate migration are important in a society as mobile as that of the United States. New methods of cartographically representing migration may be of interest to those in the social sciences, history, planning, commerce, and travel and tourism.

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[32]U.S. Bureau of the Census, Sixteenth Census of the United States: 1940 Population, Internal Migration 1935 to 1940, Color and Sex of Migrants. (Washington D.C.: U.S. Government Printing Office, 1943), pp. 27-118.; U.S. Bureau of the Census, U.S. Census of the Population: 1950 Vol. IV, Special Reports, Part 4, Chapter B, Population Mobility - States and State Economic Areas. (Washington D.C.: U.S. Government Printing Office, 1956), p. 33.; U.S. Bureau of the Census, U.S. Census of Population: 1960. Subject Reports. Mobility for States and State Economic Areas Final Report PC(2)-2B. (Washington D.C.: U.S. Government Printing Office, 1963), pp. 72-77.; U.S. Bureau of the Census, U.S. Census of Population: 1970. Supplementary Report. Interstate Migration by State: 1970 PC(S1)-48. (Washington D.C.: U.S. Government Printing Office, 1973), pp. 316-20.

Data analysis

Analysis of the data is one step in the process of making new maps for depicting spatial interaction. Manipulating large quantities of census data is facilitated by the use of automated data processing techniques available at the University of Montana. All migration data values are stored in a file using the DECSYSTEM-20 mainframe computer. Data are formatted into a matrix for ease in handling and analysis. Once stored, the data are easily accessed for input into personally written computer programs. A short, one-page computer program written in BASIC+2, which is used for analysis of data, is listed in Appendix C and discussed in the appropriate section later in this chapter. A personal computer is adequate for data handling and analysis of this type.

Map 1, The Classless Choropleth Dot Map

Traditional choropleth maps

Choropleth maps (Greek: choro~place, plethos~quantity) depict either quantity or quality of a phenomenon within the boundaries of established areas. These areas are usually administrative units such as counties, states, or countries for which data have been gathered. The traditional choropleth map "always uses a sequence of shades or tones (values) applied to the areas" in the process of symbolization.[33] For quantitative choropleth maps, this sequence of values, or

[33]David J. Cuff and Mark T. Mattson, Thematic Maps: Their Design and Production (New York: Methuen & Co., 1982), p. 36

variation in some other graphic element, is usually proportional to the quantitative value of the phenomena within given areas. Darker values are normally associated with greater intensities of the phenomenon in the areas depicted. Qualitative choropleth maps may employ some other rationale for organizing graphic elements of the symbolism employed.

In the process of analysis and mapping, areas are grouped into several classes, usually numbering between three and eight. The process of classification strives for maximum homogeneity within classes and maximum heterogeneity between classes. In practicality, the number of classes depicted in choropleth maps is more often than not determined by the number of values discernible by the human eye. In the field of map perception, a considerable amount of research has been conducted and various opinions exist concerning this subject. A comprehensve discussion of selecting class intervals[34] and the efficacy of class intervals[35] is beyond the scope of this thesis.

Migration ratio by state is the subject for the design of the first mapping method. The migration ratio, r, is simply the per capita migration, including both in- and out-migration, for a state over a period of time. The value of r increases in direct proportion to the migration per capita for a state. This ratio, r, is defined

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[34]George F. Jenks and Michael R. C. Coulson, "Class Intervals for Statistical Maps," International Yearbook of Cartography, Vol. 3, 1963, (Gutersloh, Germany: C. Bertelsmann Verlag, 1963), pp. 119-33.

[35]Michael W. Dobson, "Choropleth Maps Without Class Intervals?: A Comment," Geographical Analysis, Vol. 4, No. 4 (October, 1973), pp. 358-360; Jean-Claude Muller, "Perception of Continuously Shaded Maps," Annals of the Association of American Geographers, Vol. 69, No. 2, (June, 1979), pp. 240-49.

by the equation

$$r = (m_o + m_i) / p_t$$

where r is the migration ratio for a state, m_o is all out-migration from the state, m_i is all in-migration to the state, and p_t is the total population of the state. Table 3-1 contains migration data for all states in the U.S. used in calculating r, the migration ratio.

For comparison to the first mapping method, a traditional choropleth map employing a sequence of gray is presented in Figure 3-1.[36] For this map, data are grouped into four classes in the following manner: first, the data are normalized by taking the log of each state's r value; second, normalized r values are then grouped into classes with equal steps.

Classless choropleth maps

The idea of classless choropleth maps is not new.[37] Tobler purports that classless choropleth maps are "now technologically feasible to produce. . . by using automatic map drawing equipment".[38] Line symbolism is drawn by a computer plotter in densities proportional to the ratios of the phenomenon for areas of the map (Figure 3-2).

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[36]For a full discussion of the first mapping method, see the section titled "Mapping method" which appears on page 48.

[37]Classless choropleth maps are also known as unclassed choropleth maps; B. D. Dent, Principles of Thematic Map Design (Reading, Massachusetts: Addison-Wesley, 1985), p. 208.

[38]W. R. Tobler, "Choropleth Maps Without Class Intervals?," Geographical Analysis, Vol. V, No.3 (July, 1973), 262.

Table 3-1: Migration ratio by state, 1975-80.

s STATE	m_i IN-MIGRATION	m_o OUT-MIGRATION	p_t POPULATION	r RATIO
ME	112670	106420	1124660	.19
NH	158633	113868	920610	.30
VT	68055	60596	511456	.25
MA	375613	542597	5737037	.16
RI	77907	92955	947154	.18
CT	270848	345300	3107576	.20
NY	624078	1721275	17558072	.13
NJ	539089	764394	7364823	.18
PA	573592	837775	11863895	.12
OH	570115	931195	10797630	.14
IN	384207	467014	5490224	.16
IL	642389	1095726	11426518	.15
MI	440213	687167	9262078	.12
WI	290020	327998	4705767	.13
MN	274941	318299	4075970	.15
IA	213026	272704	2913808	.17
MO	429001	452378	4916686	.18
ND	75988	86699	652717	.25
SD	70504	90019	690768	.23
NE	152520	180993	1569825	.21
KS	275485	288142	2363679	.24
DE	73839	83060	594338	.26
MD	411716	486469	4216975	.21
DC	98137	170630	638333	.42
VA	694880	630442	5346818	.25
WV	155865	150576	1949644	.16
NC	538400	451156	5881766	.16
SC	331687	265013	3121820	.19
GA	581553	450430	5463105	.19
FL	1801362	978135	9746324	.29
KY	302827	279889	3660777	.16
TN	450858	347872	4591120	.17
AL	319954	272714	3893888	.15
MS	213197	215407	2520638	.17

table continued on following page

Table 3-1, continued

s STATE	m_o IN-MIGRATION	m_o OUT-MIGRATION	P_t POPULATION	r RATIO
AR	262214	206074	2286435	.20
LA	324666	278116	4205900	.14
OK	382721	265903	3025290	.21
TX	1436237	862230	14229191	.16
MT	108314	106796	786690	.27
ID	170218	125840	943935	.31
WY	120161	72803	469557	.41
CO	551339	422654	2889964	.34
NM	206948	176868	1302894	.29
AZ	598368	352680	2718215	.35
UT	203062	136664	1461037	.23
NV	234606	121917	800493	.45
WA	621101	340684	4132156	.23
OR	412552	245696	2633105	.25
CA	1877289	1782831	23667902	.15
AK	105570	121650	401851	.57
HI	149919	173741	964691	.34

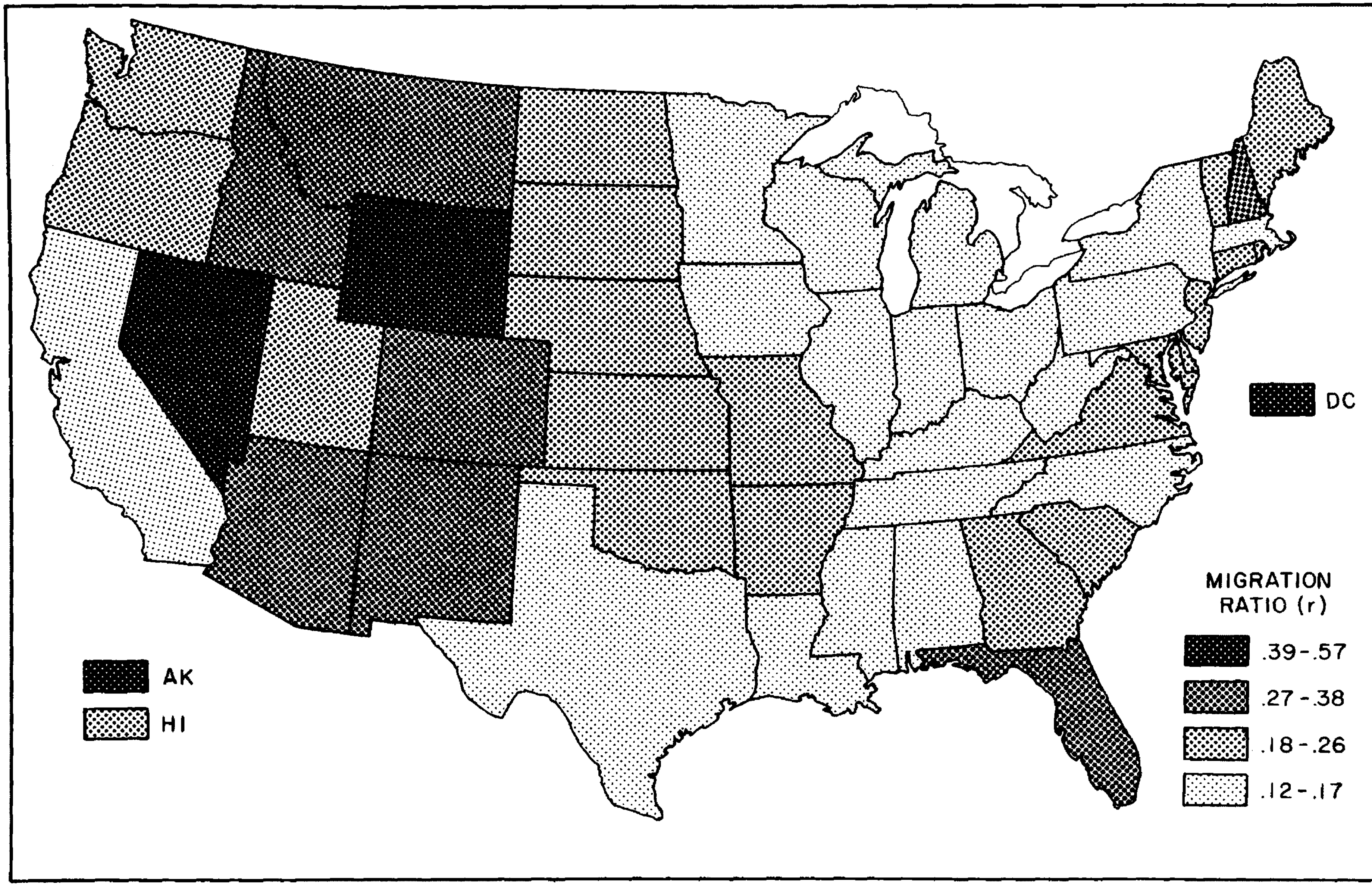

Figure 3-1: Traditional choropleth map using values

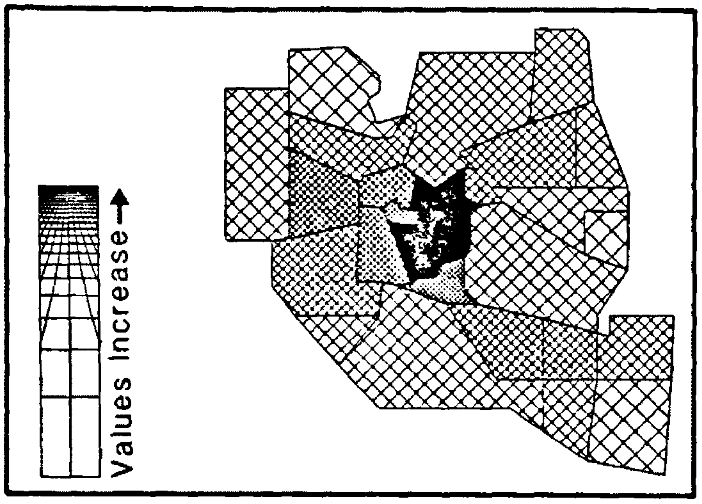

Figure 3-2: Classless choropleth map drawn by a computer plotter[39]

More recent work with this cartographic problem produces gray tones by facsimile in proportion to quantitative values.[40] Classless choropleth maps do not group data into class intervals; rather, symbolism is scaled in proportion to the exact quantitative value for each choropleth area. For example, potentially, there are fifty-one discrete data values for migration within the U.S. because there are census data for fifty states and the District of Columbia. A classless choropleth map will display varying shades for as many of those states as actually have

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[39]David J. Cuff and Mark T. Mattson, Thematic Maps: Their Design and Production (New York: Methuen & Co., 1982), p. 37

[40]The facsimile method produces continuous tones, either electronically or photographically, in proportion to areal data values. Jean-Claude Muller and John L. Honsaker, "Choropleth Map Production by Facsimile," The Cartographic Journal, Vol. 15, No. 1 (June, 1978), 14-19.

different values of migration.

The mapping method

Map 1, the classless choropleth dot map, uses variations in the density of dots in place of the traditional values to depict migration characteristics for each state. Dots have long been used by cartographers as a form of point symbolism on maps. The distribution dot map in Figure 2-12, and the "pointillism" described by Jenks[41] are examples of dots used as point symbols. Actually, the shades used to represent different classes in many traditional choropleth maps are printed as geometric patterns of minute black or colored dots which the viewer mentally blends into grays or shades of a color. As the proportion of inked area on the map surface increases, darker grays or shades of a color are perceived by the viewer.

Three characteristics of dots are considered in making a dot map. These characteristics, which apply to both the standard distribution dot map and Map 1, are:

1. Number of dots.
2. Size of dots.
3. Pattern of dots on the map.

For a distribution dot map, the number of dots is directly proportional to the number of things represented. In Figure 2-12, there is one dot located at the place of origin for every 500 out-migrants. In Map 1, the density of dots is

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[41]George F. Jenks, "'Pointillism' as a Cartographic Technique," The Professional Geographer, Vol. 5, No. 5 (September, 1953), 4-6.

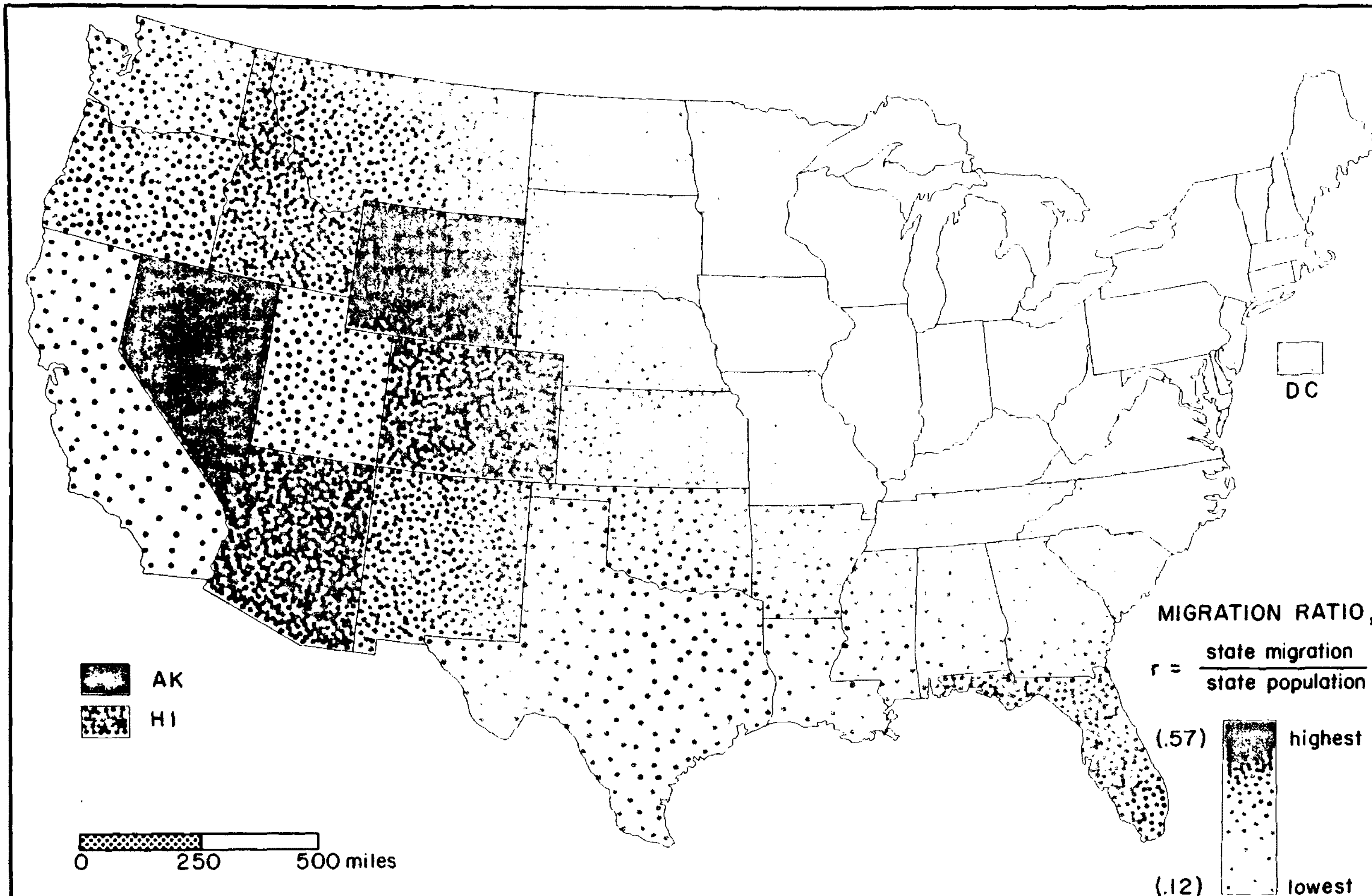

Figure 3-3: MAP 1: Classless choropleth dot map

proportional to the migration ratio, r, for each state (Figure 3-3). The number of dots in each state is directly proportional to *both* the migration ratio, r, and state size, a. Figure 3-4 illustrates how variations in either the migration ratio or area size affects the number of dots used to represent the ratio for an area.

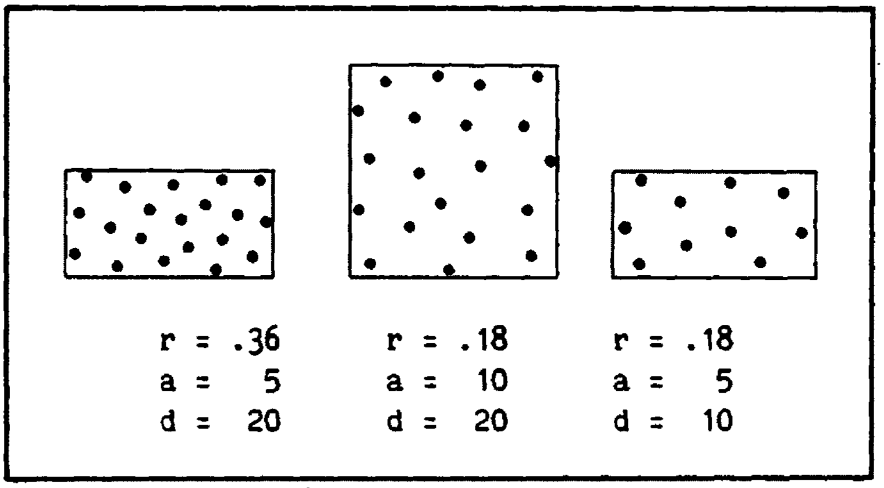

Figure 3-4: Variations in ratio, r, area, a, and dot number, d

The combination of size and number of dots determines what portion of mapped area is covered with dots. Calculating both size and number of dots is an empirical process, determined by both the range of migration ratio values and the range of state sizes. Values of r, shown in Table 3-2, range from .12 to .56 with most of them clustered between .12 and .20. In order that the dot density be visibly distinctive, a relatively bold dot size, .80mm, is used. Three considerations affect the formula used for calculating the number of dots, d,: small states with small r values must have at least one dot; states with high r values must not have excessive overlapping of dots; and differentiation should be possible for dot densities representing very small variations in r. For this map of the U.S., the formula for calculating dot number per state is

$$d = (a(r^{2.5})) \; / \; 1500$$

where d is the calculated number of dots to be placed in the map area, a is state size in thousands of square miles, and r is the state migration ratio. The exponent 2.5 is determined experimentally to increase the difference in dot densities representing states with small differences in migration ratio (e.g. r = .15 and r = .16). The denominatior 1500 which is also determined experimentally, establishes the maximum and minimum number of dots per state on the map.

A distribution dot map and a choropleth dot map are distinguishable because the patterns of dots are different in each instance. A distribution dot map depicts the location of phenomena in an area with accurately positioned dots on the map. The cartographer determines the location of phenomena in the compilation stage of map making and positions the dots accordingly on the map. Ideally, the distribution of dots on the map mimics the location of phenomena in the field. In a classless choropleth dot map, the distribution of dots in no way reflects the location of phenomena in the field. Rather, the dots are positioned in either a random or uniform pattern inside of each region or state (Figure 3-5).

Data sources used for compiling state size should be chosen with care. Values listed for the size of a state may differ significantly from one source to another. For example, Goode's World Atlas lists values for state size using state

Table 3-2: Number of dots per state

s State	a Area (in 1000's square miles)	r Ratio	d Dots per state
ME	33.2	.19	35
VT	9.6	.25	20
MA	8.3	.16	6
RI	1.2	.18	1
CT	5.0	.20	6
NY	49.6	.13	20
NJ	7.8	.18	7
PA	45.3	.12	15
OH	41.2	.14	20
IN	36.3	.16	25
IL	56.4	.15	33
MI	58.2	.12	19
WI	56.2	.13	23
MN	84.0	.15	49
IA	56.3	.17	44
MO	69.7	.18	64
ND	70.6	.25	147
SD	77.0	.23	130
NE	77.2	.21	104
KS	82.3	.24	155
DE	2.1	.26	5
MD	10.6	.21	14
DC	0.1	.42	1
VA	40.8	.25	85
WV	24.1	.16	17
NC	53.6	.16	37
SC	31.1	.19	33
GA	58.9	.19	62
FL	58.6	.29	177
KY	40.4	.16	28
TN	42.2	.17	34
AL	51.6	.15	30
MS	47.7	.17	38

table continued on following page

Table 3-2, continued

s State	a Area (in 1000's square miles)	r Ratio	d Dots per state
AR	53.1	.20	63
LA	48.5	.14	24
OK	69.9	.21	94
TX	267.3	.16	183
MT	147.1	.27	372
ID	83.6	.31	298
WY	97.9	.41	703
CO	104.2	.34	468
NM	121.7	.29	367
AZ	113.9	.35	550
UT	84.9	.23	144
NV	110.5	.45	1001
WA	68.1	.23	115
OR	97.0	.25	202
CA	158.7	.15	92
AK	586.4	.57	9589
HI	6.5	.34	29

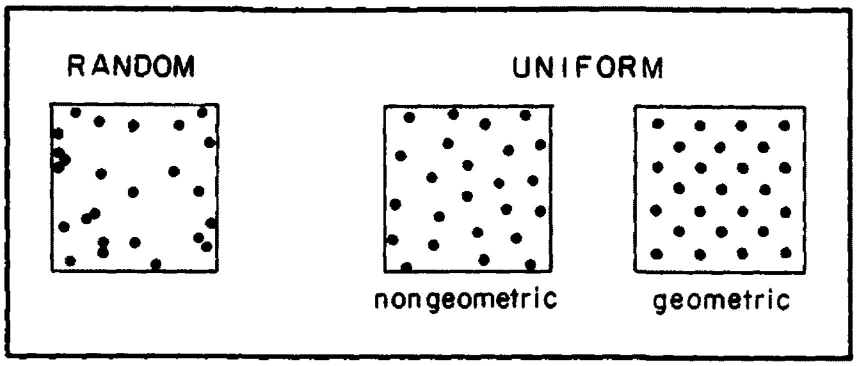

Figure 3-5: Patterns of dot distribution

boundaries that extend into adjacent large bodies of water, such as the political boundaries of the Great Lake states.[42] State size determined in this way can be quite different from state size determined by using the physical boundaries, shorelines, of these states.

Map 2, The Nodal Region Flow Map

Nodal regions of migration with inherent flow of migrants between nodes are explicitly depicted by the second mapping method (Map 2, the nodal region flow map). This method, employing rudimentary analytical and mapping techniques, efficiently synthesizes and displays migration data. Graph methods used in combination with linear symbolism are part of this method.

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[42] Edward B. Espenshade, Jr., ed., Goode's World Atlas (17th ed.; Chicago: Rand McNally & Company, 1986), pp. 241-45.

Nodal regions

Nodal or functional regions contain networks in which movement of things, such as goods, people, or information, focuses upon central locations or nodes.

> The functional region, also called the nodal region, is a coherent structure of areal units organized into a functioning system by lines of movement or influence that converge on a central node or trunk.[43]

A node is any place, or relatively confined areal unit, that has a unique geographic identity separate from other places. Depending upon the geographic scale of study, a node could be a neighborhood, city, county, state, or nation. The hierarchy of nodes in a region is ordinarily comprised of central and peripheral nodes. The central node is the dominant place in a region in terms of the functional association, or movement of phenomenon, that defines the region. Several levels of peripheral nodes may exist within the hierarchy of the region. Linkages, or routes, of movement in the region are structured in such a way that each peripheral node directs its dominant flow of migrants toward a larger node next higher up in the hierarchy of the region. In this example, the nodal region is defined by the interstate migration of people, and nodes are characterized by the states of the United States.

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[43] Jesse H. Wheeler, Jr., J. Trenton Kostbade, and Richard S. Thoman, Regional Geography of the World (3rd ed.; New York: Holt, Rinehart and Winston, Inc., 1969), p. 4.

Graphs and matrices

Matrix and graph methods are used to analyze spatial characteristics of the network in a nodal region. A directed graph, or digraph, depicting interstate migration in the United States is shown in Figure 3-6. Digraphs depict not only linkages between nodes but also direction of flow along linkages. The graph of a network can be used to build a numerical matrix representing the network. Similarily, a graph can be constructed from a numerical matrix. The matrix of interstate migration values displayed in Table B-1, Appendix B is used to construct the digraph in Figure 3-6.

Linkages are determined by the largest movement, or flow, of migrants from each node. Each state is linked, in the forward direction, to only one other state. This single forward linkage from each state is to the state to which it sends its largest flow of out-migrants. For example, the matrix in Table B-1 shows Texas to be linked in the forward direction to California.

Hierarchy is determined by the relative functional size of the nodes. Functional size is found by ranking states according to the size of their in-migrating population. The central state of a regional network sends its largest flow of out-migrants to a state functionally smaller in size. Forward linkage is not depicted for central states as they are the largest nodes in the regions and occupy the top of the nodal heirarchy. Peripheral states are linked in the forward direction to states larger in functional size. Third order peripheral states are linked in the forward direction to second order peripheral states. Second order peripheral states are linked in the forward direction to first order peripheral states. Illinois,

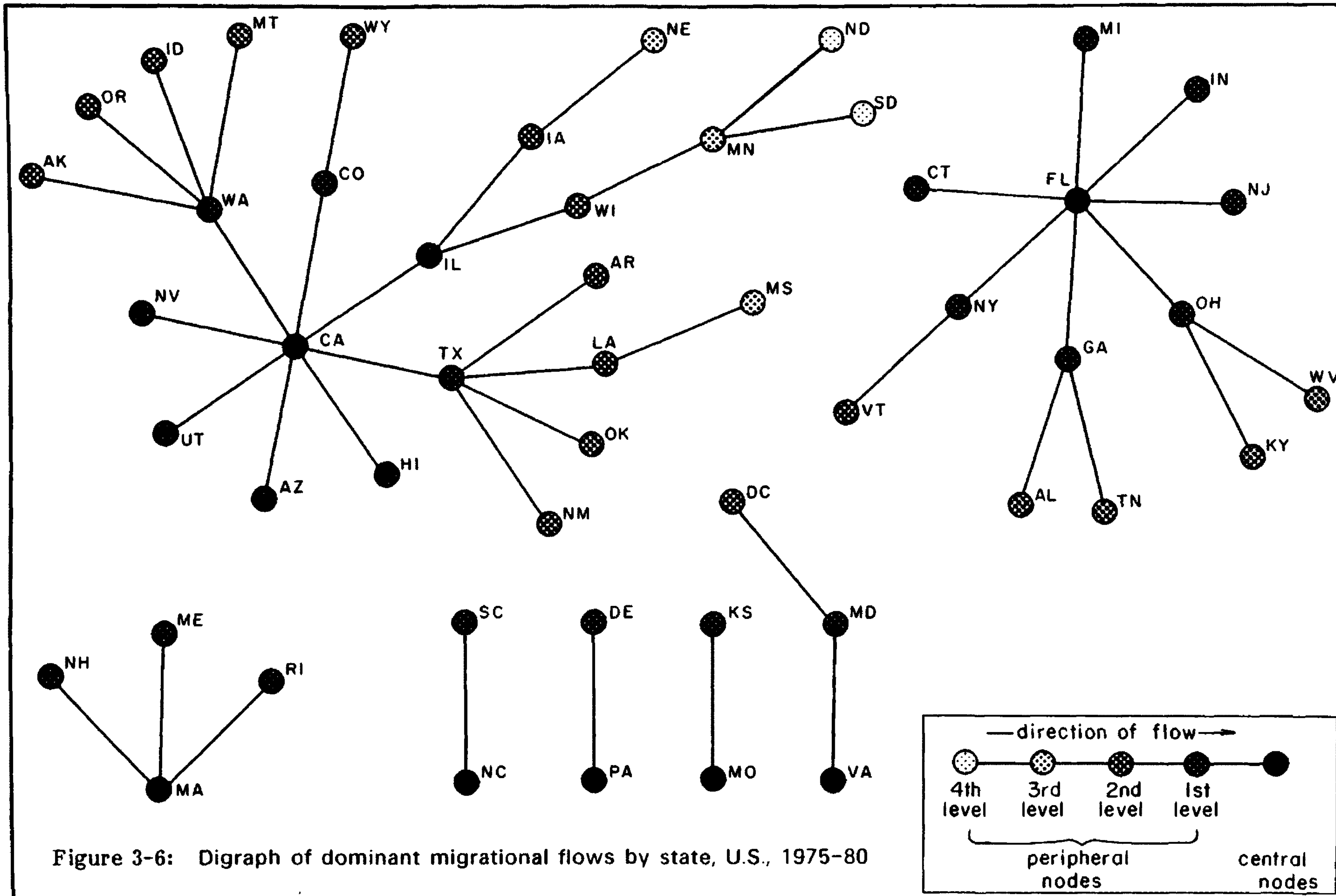

Figure 3-6: Digraph of dominant migrational flows by state, U.S., 1975-80

Wisconsin, Minnesota, and North Dakota are first, second, third, and fourth order peripheral states, respectively. California is the central state of that regional migrational network.

The mapping method

The geometry of graphed networks is topological (Figure 3-6). Unlike other geometries used by geographers, topology is not concerned with geographical properties such as distance, orientation, and shape.[44] Topology presents a highly abstracted geometrical view of spatial structures "concerned with the preservation of certain non-metrical relationships such as proximity, separation, order, enclosure, continuity, and contiguity or connectedness."[45] Transforming the graphed network in Figure 3-6 onto a base map adds geographic characteristics to the graphed data. The geographic nature of maps is the distinguishing characteristic between cartography and graphics in general. Cartographic depiction is both topological and topographical, within limitations. The graphed nodal regions are shown in map form in Map 2 (Figure 3-7).

The method of mapping used to produce Map 2 lends itself to use in a graphic which depicts a time series by employing multiple maps within a single display. A time series is the display of "data gathered over a period of time,

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[44]A brief discussion of the geometries used by geographers is found in John P. Cole and Cuchlaine A. M. King, Quantitative Geography (London: John Wiley & Sons Ltd., 1968), pp. 69-71.

[45]William J. Coffey, Geography, Towards a General Spatial Systems Approach (London: Methuen & Co. Ltd., 1981), p. 120.

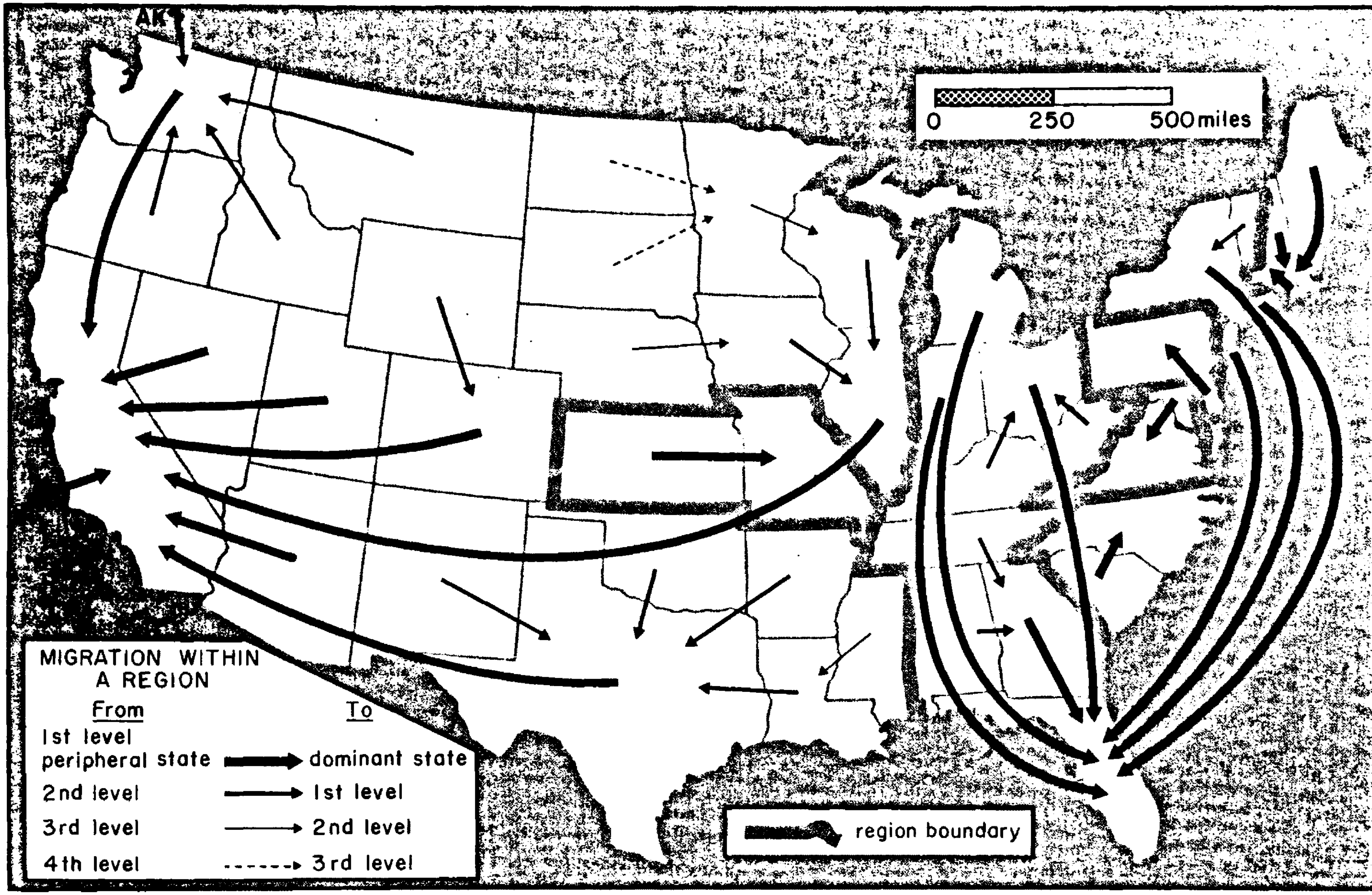

Figure 3-7: MAP 2: Nodal region flow map

usually at regular intervals."[46] Time is an integral component of spatial interaction. The nodal region map in Figure 3-7 depicts flow in a network of migration *within* an interval of time. The time series display in Figure 3-8 depicts both the flow in migrational networks *within* an interval of time and the geographic changes in nodal regions *between* periods of time. Simplicity in data analysis and map compilation allows the synthesis of a large quantity of migration data into a single graphic display. Figure 3-8 incorporates over 10,000 migration data values (2,550 values for each time interval) within a single graphic display.

Map 3,The Connectivity Network Map

The third mapping method, which is illustrated by Map 3, the connectivity network map (Figure 3-10), uses line symbolism to explicitly depict the interstate migration of people in the United States. A method for abstracting the migration data using automated techniques is presented.

The mathematics of connectivity

Connectivity is a mathematical concept in topology used to describe linkages, or routes of two-way movement between nodes in a network.[47] A connectivity network has a maximum number of linkages, l, between nodes, defined by:

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[46]Haggett, Peter. Geography: A Modern Synthesis (New York: Harper & Row, Publishers, 1983), p. 590.

[47]Ronald Abler, John S. Adams and Peter Gould, Spatial Organization (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1971), pp. 255-68.

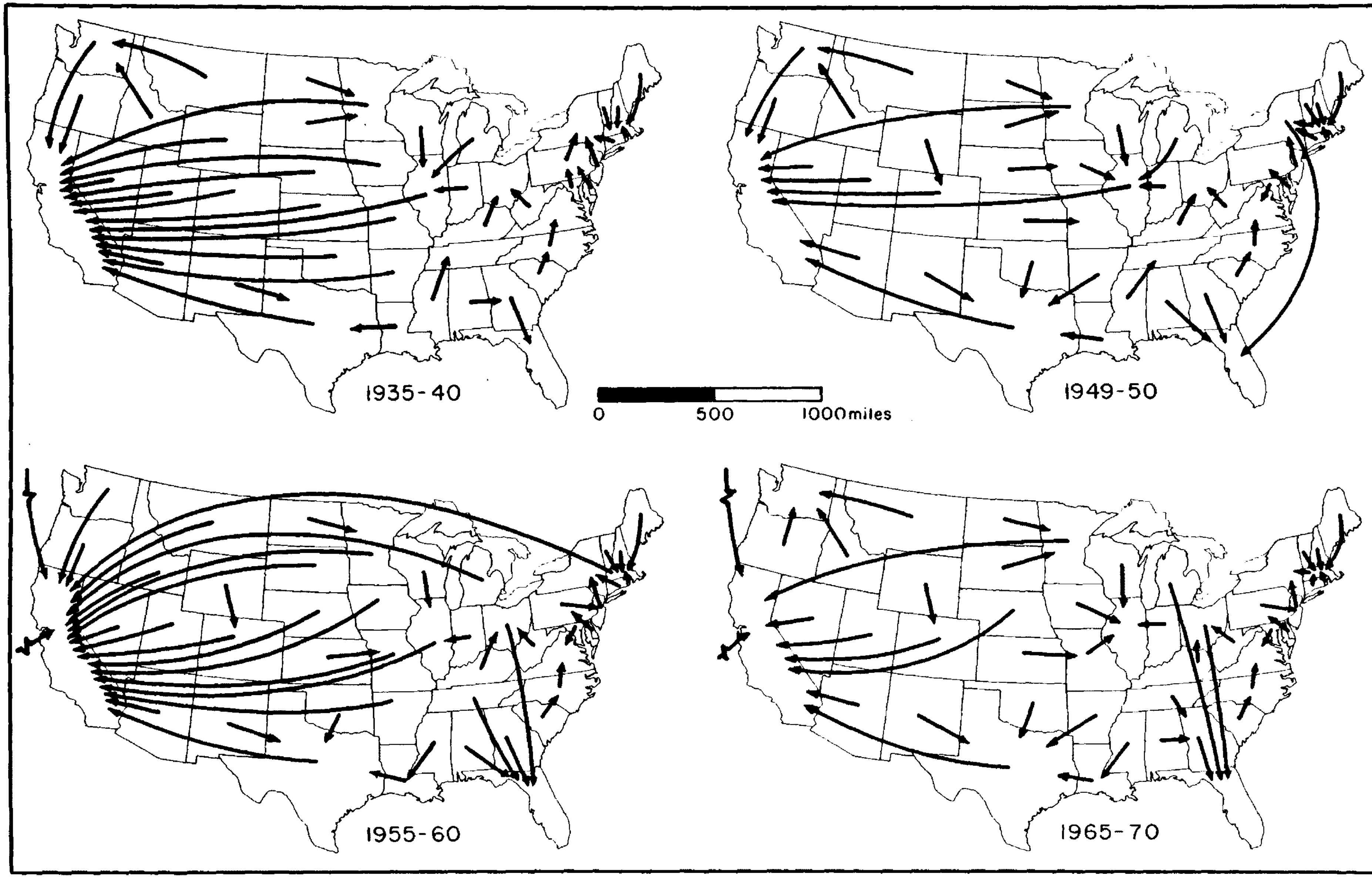

Figure 3-8: Time-series of nodal regions of migration

$$l = (n^2 - n) / 2$$

where n is the number of nodes in the network. The connectivity of a network ranges from total nonconnectivity, no linkages between nodes, to complete connectivity, the maximum number of linkages possible.

Symbolizing migration linkages between states with line symbols poses substantial graphic problems. Topologically, the network of migration in the U.S. is completely connected. The matrix of migration values in Table B-1, Appendix B shows linkages of migration to exist between each state and every other state in the United States. In this case, representing complete migration connectivity in map form is folly because of the impracticality of placing that much line symbolism on one map. The maximum number of migration linkages between states and the number of lines necessary to symbolize them for Map 3 is 1275.

$$l = (51^2 - 51) / 2$$

$$l = 1275.$$

Coffey expresses the need for abstraction in the scientific process:

> In geography, as well as in science generally, it is often desirable to consider a problem at a higher level of abstraction so as to gain further insight into the more general relationships that exist among phenomena.[48]

Abstraction of the migration data is necessary in analyzing this problem of connectivity in order to display main migrations of people between states.

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[48]William J. Coffey, Geography, Toward a General Spatial Systems Approach (London: Methuen & Co. Ltd., 1981), p. 118.

The mapping method

Developing a measure of the strength of migration linkages between states and establishing a threshold value for linkages is necessary in order to cartographically depict a connectivity network of migration in the United States. The strength of the linkages between states is determined as a ratio in order to avoid a bias in linkages toward states with large migrating populations. The value representing strength of linkage between two states, k, is defined by the equation

$$k = m_{a\ to\ b} + m_{b\ to\ a} / m_{ao} + m_{bo}$$

where $m_{a\ to\ b}$ is the migration from state a to state b, $m_{b\ to\ a}$ is the migration from state b to state a, m_{ao} is the total out-migration from state a, and m_{bo} is the total out-migration from state b. Linkage strength between two states, k, increases as the number of migrants between them increases. Two states with a strong migration linkage are Washington and Oregon.

$$k_{WA,OR} = (m_{WA\ to\ OR} + m_{OR\ to\ WA}) / m_{WA\ o} + m_{OR\ o}$$

$$= 58887 + 71786 / 340684 + 245696$$

$$= .22$$

These two states send a high percentage of the sum of their out-migrating populations to each other. In contrast, North Dakota and Oklahoma have a much weaker migration linkage.

$$k_{ND,OK} = (m_{ND\ to\ OK} + m_{OK\ to\ ND}) \,/\, m_{ND\ o} + m_{OK\ o}$$

$$= (1543 + 435) \,/\, (86699 + 265903)$$

$$= .01$$

These two states send a relatively small percentage of the sum of their out-migrating populations to each other.

A computer program titled kvalues.b20, shown in Appendix C, calculates linkage values for pairs of states. A file containing the total migration for pairs of states and a file containing the total out-migration for each state are input into the program and stored in matrix form. Linkage values, k, are calculated for all pairs of states using simple loop structures in BASIC+2 programming language (FOR/NEXT statements). Calculated linkage values are then output into another computer file, percent.in. This file is input into a program which formats the linkage values into a matrix and prints them out as hard copy.

A threshold value for linkage strength, for which connectivity is depicted by the network map, is determined in large part by cartographic limitations. The mutual dependence of data and technique sometimes limits cartographic processes.[49] Just as the number of classes chosen for a choropleth map is limited by the number of values discernible by the human eye, so is the number of linkages limited by the number of flow lines that can be displayed without confusion on the base map. Table 3-3 displays linkage strength values, k, the

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[49]Arthur H. Robinson, The Look of Maps (Madison, Wisconsin: The University of Wisconsin Press, 1952), p. 21.

cumulative percent of migration, c, that each k value represents, and the cumulative number of linkages, or flow lines needed on the map, for each k value.

Table 3-3: Linkage strength linkages for U.S. migration, 1975-80.

k LINKAGE STRENGTH	c CUMULATIVE PERCENT OF MIGRATION	t NUMBER OF LINKAGES
.22	00.6	1
.15	03.2	3
.14	04.4	5
.13	08.0	10
.12	10.6	12
.11	15.1	20
.10	16.0	23
.09	19.9	31
.08	23.0	40
.07	28.4	55
.06	36.9	75
threshold value of k for graphically representing migration linkages		
.05	45.8	109
.04	54.9	151
.03	65.0	216
.02	79.9	355
.01	96.3	821

Migration linkages with strength of .06 and greater are represented in Figures 3-9 and 3-10, but those with a strength below .06 are not depicted. A threshold value for k of .06 is chosen for these maps because it is felt that 75 is the maximum number of flow lines these particular maps can clearly display. Displaying 151 or even 109 flow lines may be counterproductive to representing interstate migration patterns. Additional empirical research into the topic of line symbolism and map readability may yield valuable information.

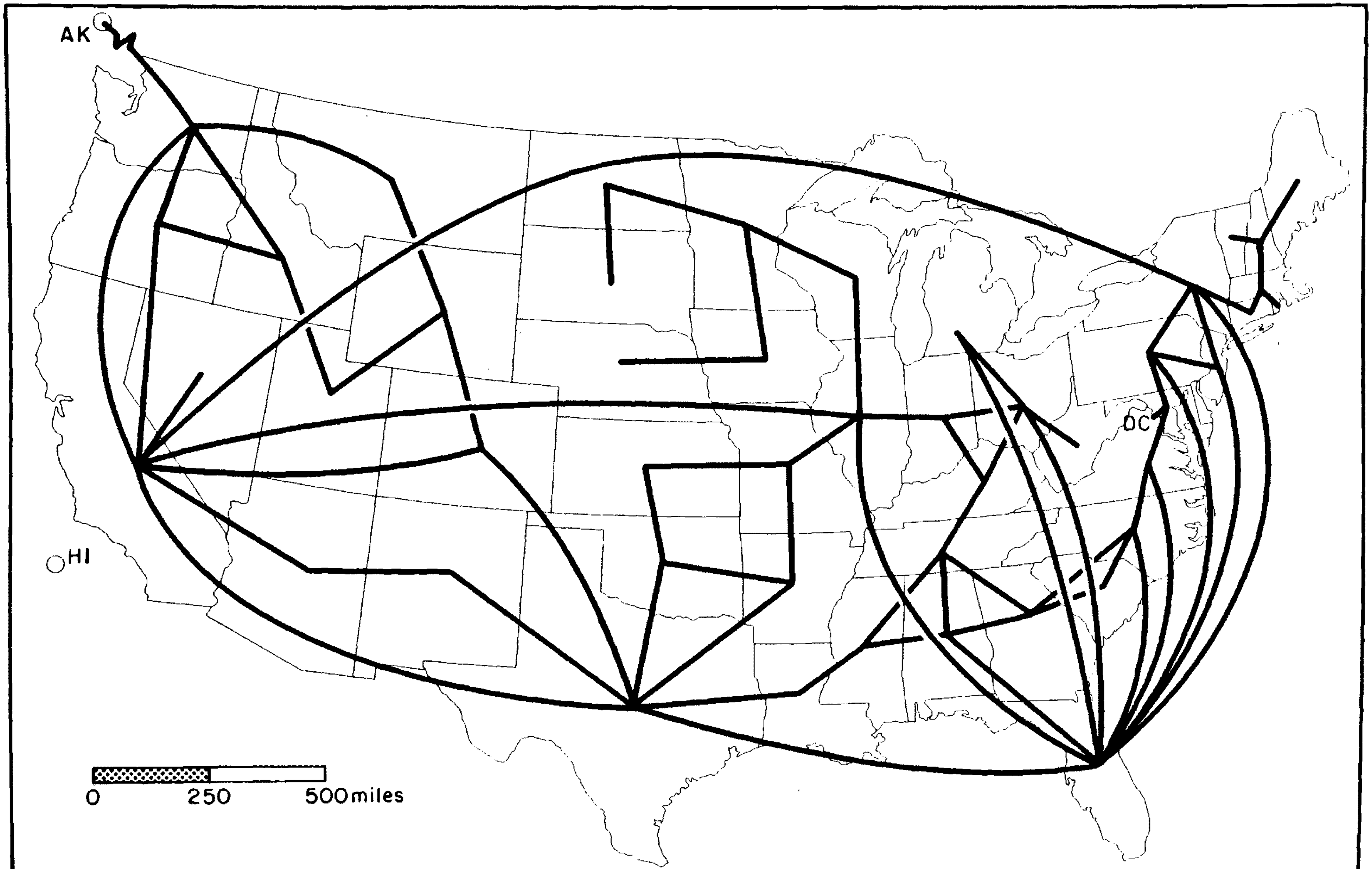

Figure 3-9: Connectivity network map, nominal symbolism

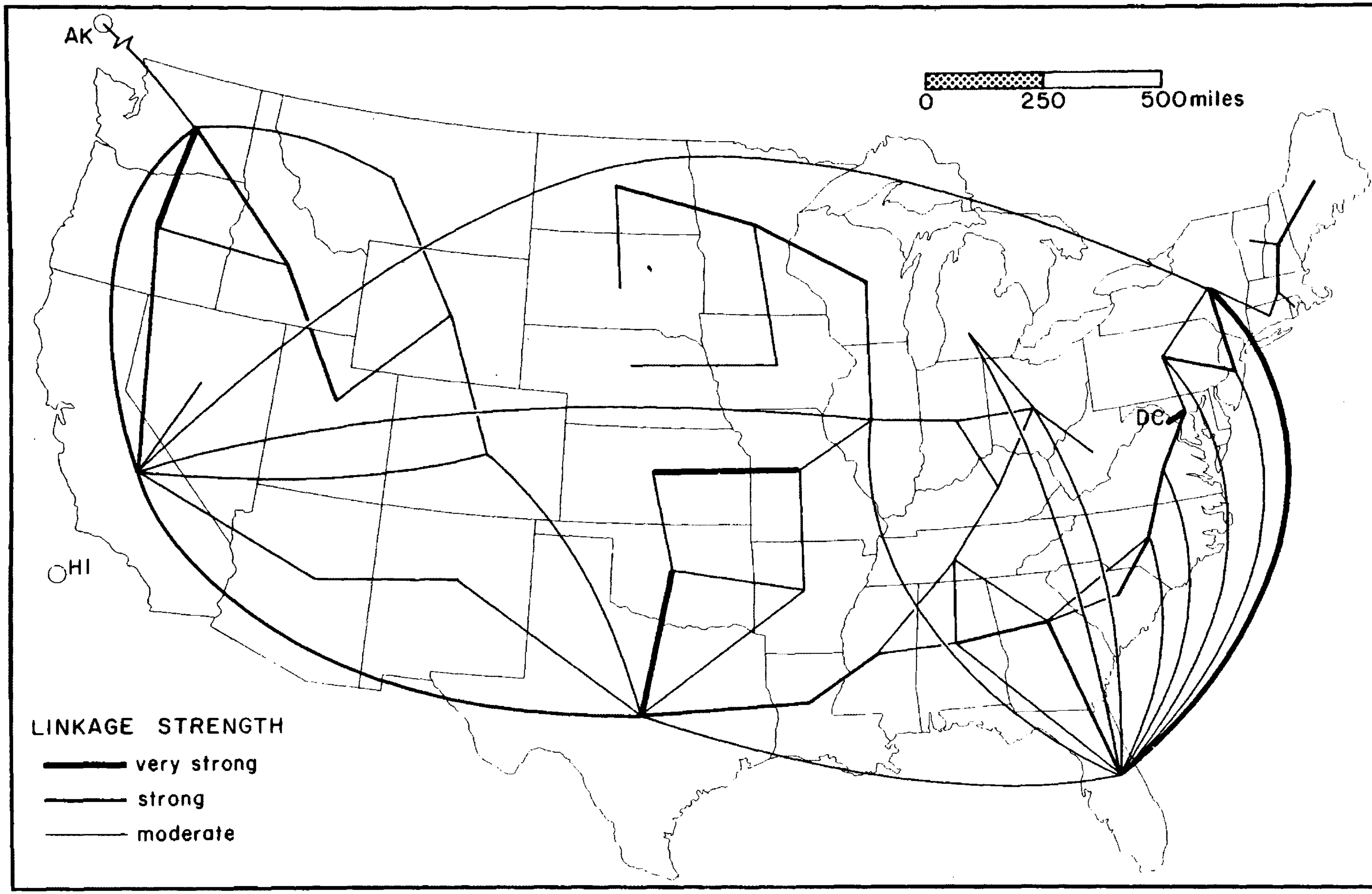

Figure 3-10: MAP 3: Connectivity network map, ordinal symbolism

These connectivity network maps abstract migration between states in much the same way that transportation connectivity between towns and cities is depicted by road maps. A map of the U.S. Interstate System depicts a relatively sparse transportation network linking few U.S. towns and cities. Considering all U.S. towns and cities, a map of interstate highways depicts a network closer to total nonconnectivity than to complete connectivity. Including U.S. highways in the above map increases the number of linkages and the number of towns and cities linked with the transportation network. Further inclusion of state highways and county roads increases connectivity of the transportation network of U.S. towns and cities even more.

Interpretation

A linear link between states on a connectivity map represents migration between those states. Figures 3-9 and 3-10 reveal distinct patterns of interstate migration. Some states are frequently linked within the network (California and Florida) while other states are totally unlinked within the network (Hawaii and Delaware). Questions arise such as "Why are noncontiguous states sometimes linked?"; "Why are contiguous states sometimes unlinked?"; "Why are some states without any linkages?"; "Why are some states frequently linked within the network?". Viewing and interpreting the connectivity network map may best be done with Ullman's model of spatial interaction.[50] Linkages between Florida and northern states may be due to the large number of retirement age people migrating south during the years 1975-80 seeking a more comfortable environment. Intervening opportunities for people in Nebraska and Kansas may affect the interstate migration between those two states. Obviously, transferability is a major factor in the relatively unconnected conditions for Alaska and Hawaii.

Map 4, The Surface Relief Flow Map

Net migration and barriers to migration between contiguous states are depicted by the last mapping method. Explicit depiction of net migration between contiguous states is accomplished without using line symbolism by altering the graphic element *size* (height) of the area symbolism on the map. The concept of connectivity described in the previous section is used to develop this mapping method. Automated mapping techniques produce two different maps in the process of creating Map 1, the surface relief flow map. A third map, produced using traditional techniques using flow lines, is included for comparison.

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[50]The determinants of spatial interaction postulated by Ullman are complementarity, intervening opportunity, and transferability. Complementarity describes the condition where a surplus of things occurs in one place and a deficit of the same occurs in another place, acting as a stimulus to interaction between those places. If, however, intervening opportunities for supply or demand exist, the course of interaction may be affected. The third factor, transferability, describes resistance to interaction between places. Time and cost are two transferability factors. Edward Ullman, American Commodity Flow (Seattle: University of Washington Press, 1957), pp. 20-27.

Explicit depiction of flow

The survey of maps of spatial interaction conducted in Chapter 2 finds movement between two places to be depicted either implicitly or explicitly. All maps of spatial interaction examined and classified as explicit are found to symbolize movement with flow lines. (See Figures 2-11, 2-5, and 2-13). Figure 3-11 depicts net migration between contiguous states, in a traditional manner, with flow lines.

Symbolizing net migration between contiguous states without flow lines is accomplished by two means. First, contiguity of states is broken where migration between those states is below a certain threshold value. The concept of linkage strength, k, developed in mapping method number three is used to determing contiguity of states in Map 4. The threshold value used for Map 3, is also used for Map 4. Second, the net flow of migration is symbolized by a gradient created by the apparent differnces in the relief surfaces of states. Figure 3-12 depicts net flow of migrants following the gradient created by the apparent differences in the heights of the relief surfaces of contiguous states. SYMAP and ASPEX, two computer software packages, are used in conjunction with each other to create three-dimensional perspective maps.[51] In addition to width (x-dimension) and length (y-dimension), height (z-dimension) is used to describe each state area in

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[51]The Synagraphic Mapping System (SYMAP) and Automated Surface Perspectives (ASPEX) are used to produce Figures 3-15 and 3-12, respectively. Mark Hanson, ASPEX User's Reference Manual (Cambridge, Massachusetts: Laboratory for Computer Graphics and Spatial Analysis, Graduate School of Design, Harvard University, 1978); Allan H. Schmidt and Eric D. Teicholz, SYMAP User's Reference Manual (5th ed.; Cambridge, Massachusetts: Laboratory for Computer Graphics and Spatial Analysis, Graduate School of Design, Harvard University, 1978).

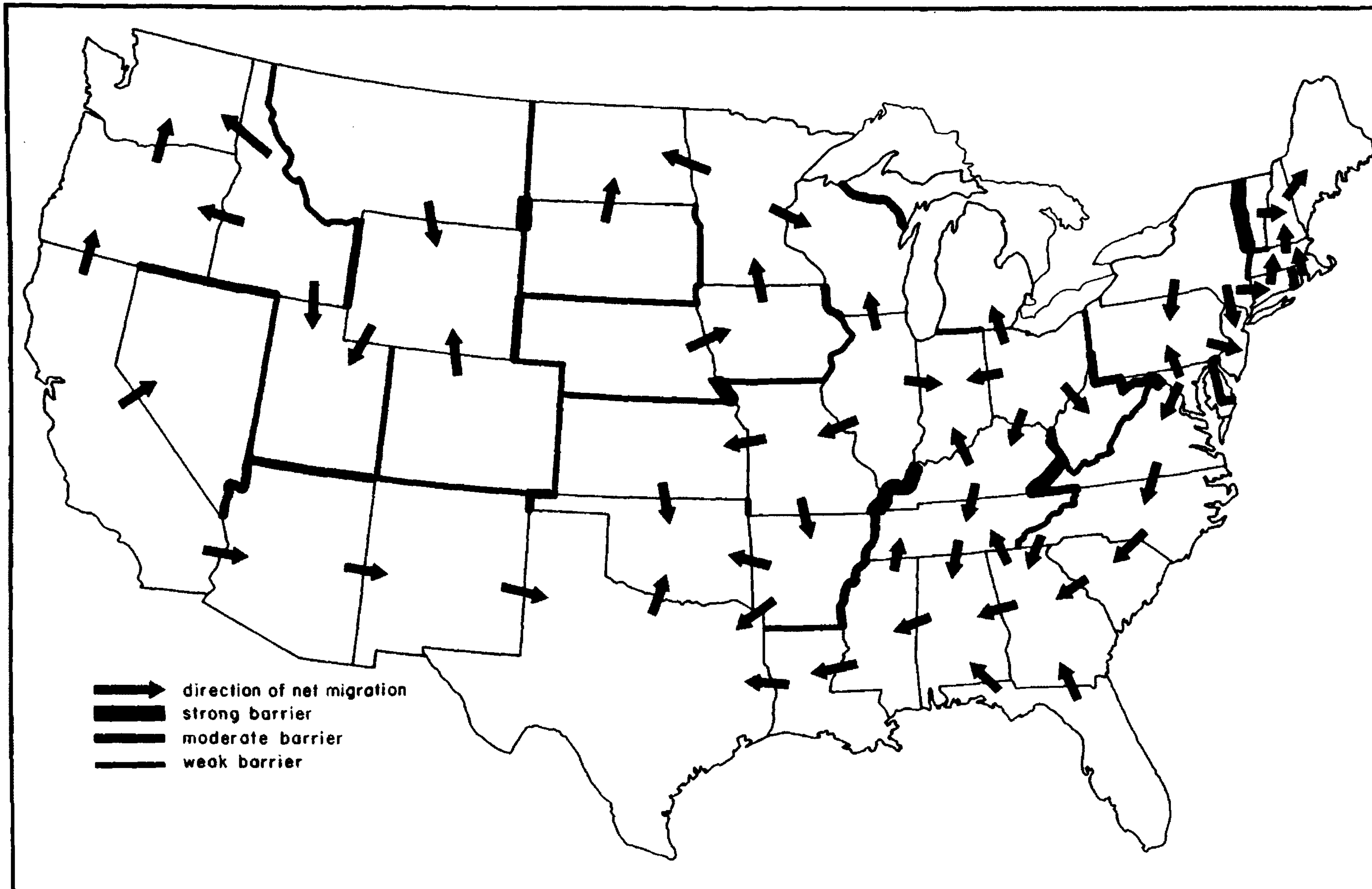

Figure 3-11: Net migration, contiguous states, using flow lines

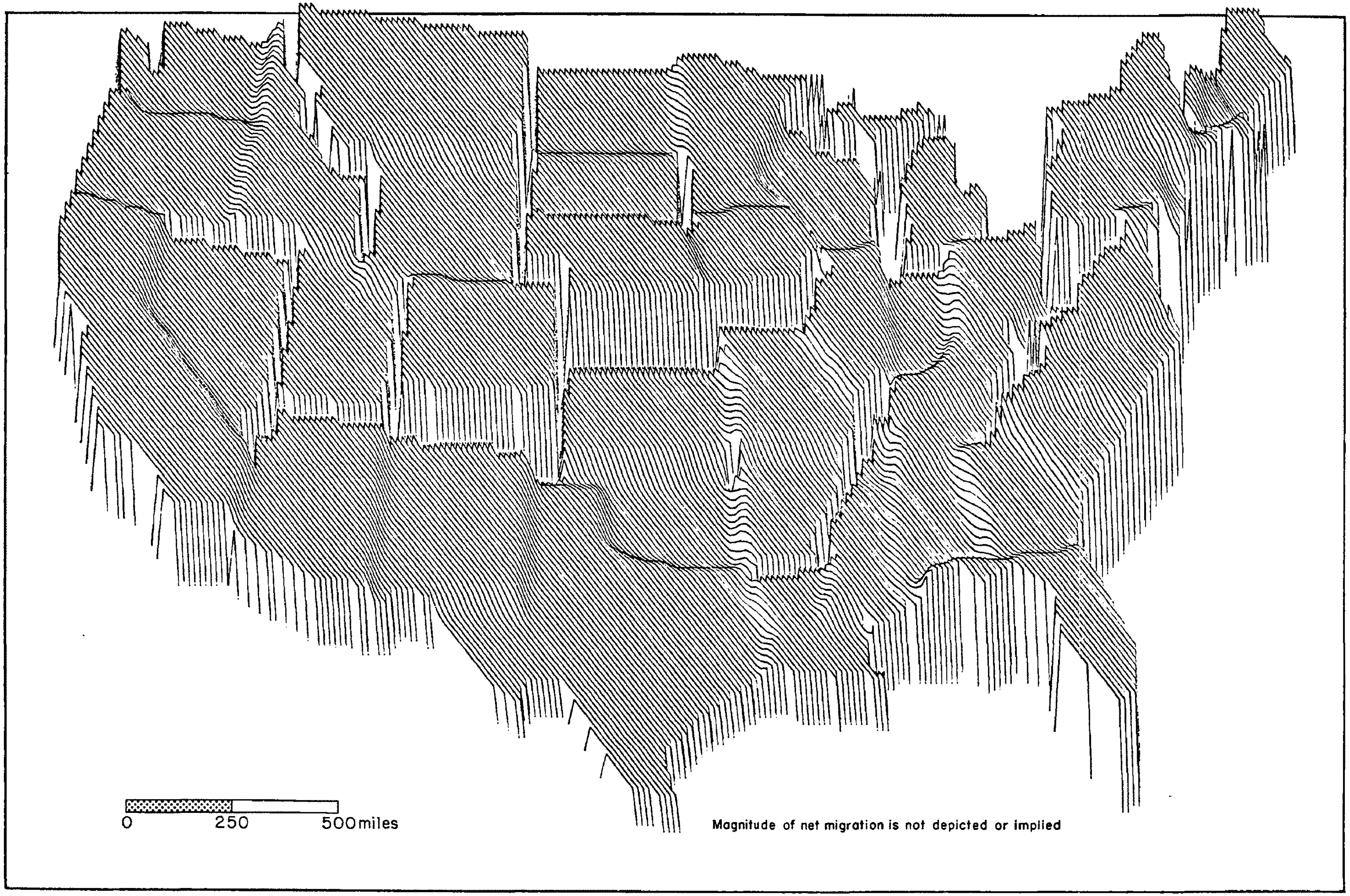

Figure 3-12: MAP 4: Surface relief flow map

the ASPEX computer program. A computer plotter draws state areas with heights corresponding to the z-dimension values assigned to them in the program. The direction of net flow between contiguous states is from the state symbolized by the higher relief surface to the state symbolized by the lower relief surface. A scheme showing direction of net flow is presented in Figure 3-13.

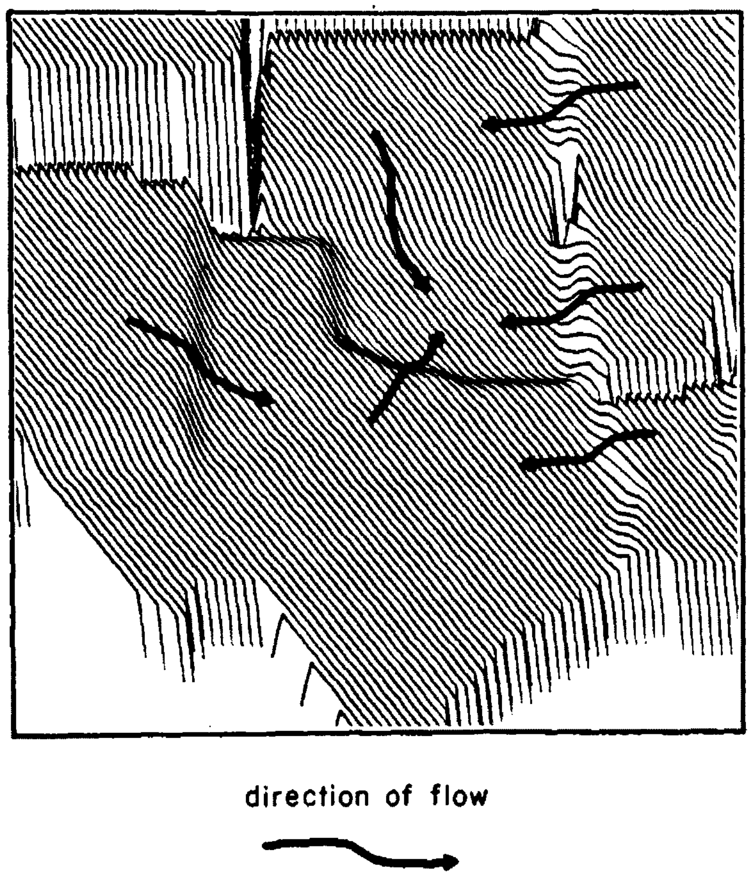

Figure 3-13: Symbolization of direction of net flow

Mapping method

Data analysis involves determining both the strength of migration linkages and the direction of net migration between contiguous states. Where the strength of migration linkages falls below .06, barriers to migration are interpreted to exist and contiguity between states is broken. Values of k below .06 are grouped into three classes; .01-.02, .03-.04, and .05-.06, representing strong, moderate, and weak barriers to migration, respectively. Barriers to migration are depicted on the map as breaks in the continuity of the area symbolism (Figure 3-15) or as breaks in the relief surface (Figure 3-12) which are proportional in width to the intensity of the migration barrier. Linkage strength, barrier intensity, and corresponding map barrier width are listed in Table 3-4.

Table 3-4: Linkage strength and corresponding barrier characteristics

k linkage strength	i barrier intensity	mapped barrier width
.01 - .02	strong	8 mm
.03 - .04	moderate	6 mm
.05 - .06	weak	4 mm

Barriers are plotted on a working base map by redrawing state boundaries. Gaps are drawn in proportion to barrier intensity. Figure 3-14 illustrates redrawn state boundaries to reflect barriers of migration between South Dakota and neighboring states. Data points along redrawn state boundaries are digitized on an inverted Cartesian coordinate system for entry into the mapping program. The

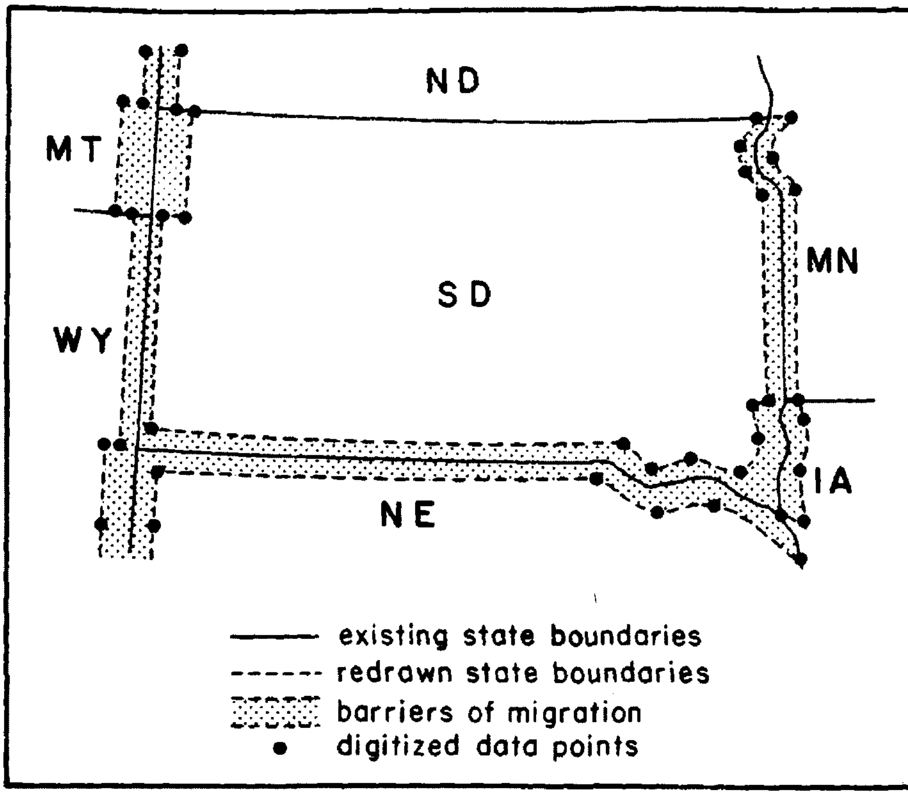

Figure 3-14: Working base map with redrawn state boundaries

SYMAP mapping program serves as an intermediate step in the final production of the surface relief flow map. The SYMAP version, shown in Figure 3-15, uses area symbolism (overprinted characters) formed by a line printer. The ASPEX program transforms the two-dimensional area symbolism in Figure 3-15 into the three-dimensional relief surfaces in Figure 3-12 using a computer plotter.

Interpretation

Barrier intensities are more discernible in Figure 3-15 than in Figure 3-12. In Map 4 interstate barriers are differentiated from interstate flows of migrants by

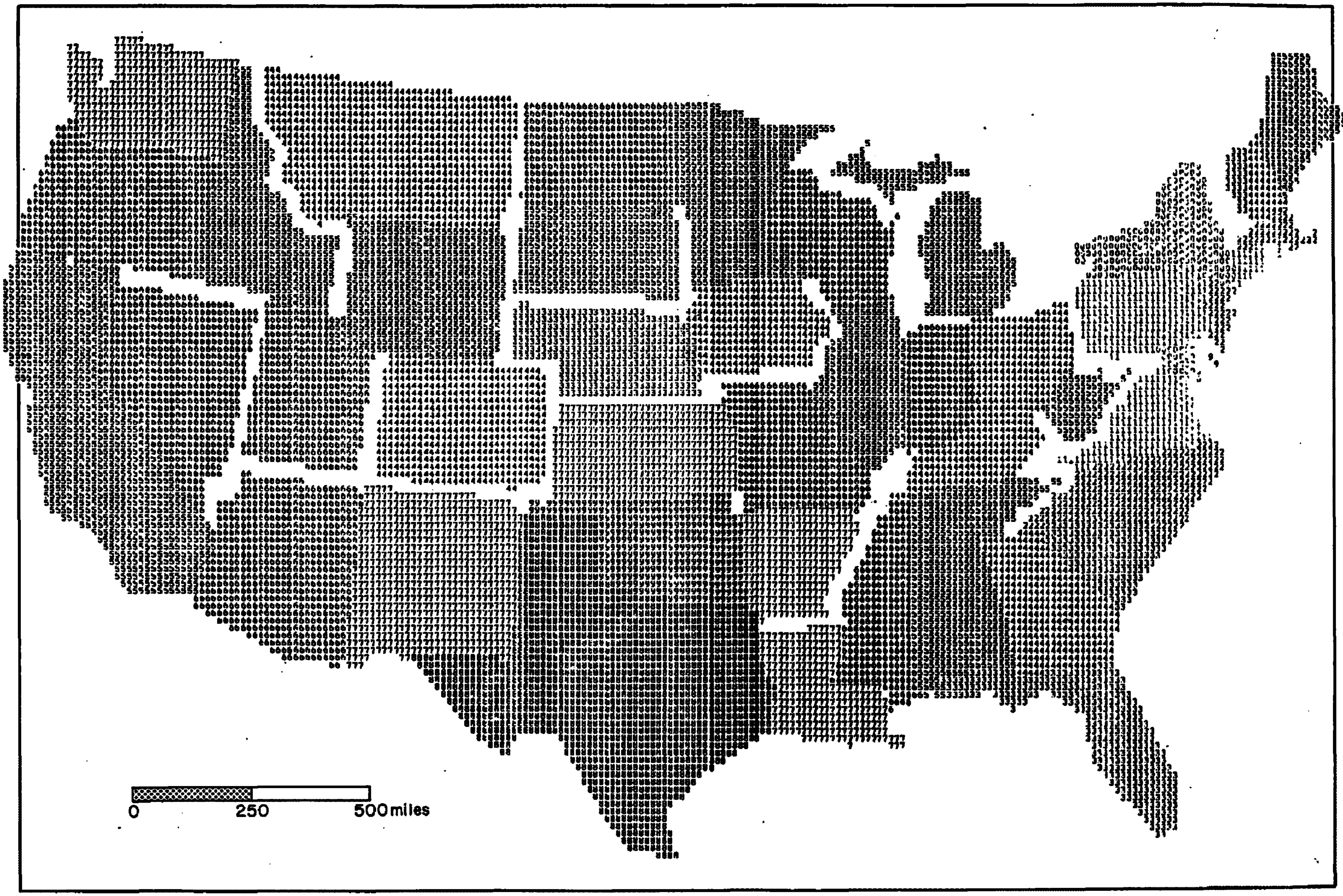

Figure 3-15: Explicit flow using area symbolism; SYMAP version

being more angular at their edges. A smoothing function[52] in the ASPEX program is used to achieve this effect. Examples of barriers between contiguous states are shown in Figure 3-16.

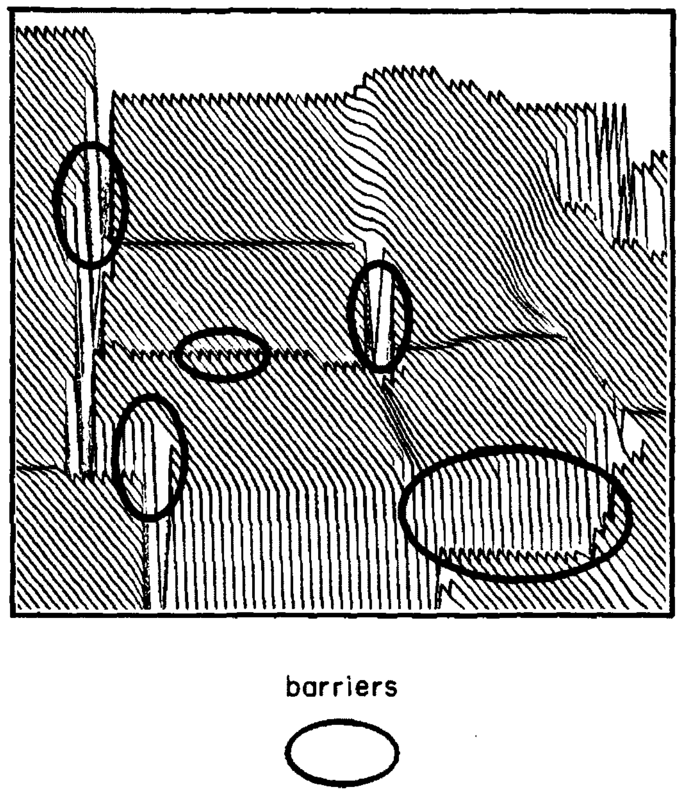

Figure 3-16: Symbolization of barriers between contiguous states

In the surface relief flow map (Figure 3-12), direction of net migration is seen to occur from California to Arizona, Texas to Oklahoma, and from New York to Pennsylvania. Neither magnitude of flow between contiguous states nor net

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[52]Computer mapping smoothing techniques eliminate abrupt transitions in the surface representing the z-dimension values of the data. Each z-value is compared to adjacent z-values and is modified to more closely resemble them in value. As a result, the three-dimensional relief surface representing data z-values is smoothed in appearance. See Arthur Robinson, Randall Sale, and Joel Morrison, Elements of Cartography (4th ed.; New York: John Wiley & Sons, 1978), pp. 163-68.; Mark Hanson, ASPEX User's Reference Manual (Cambridge, Massachusetts: Laboratory for Computer Graphics and Spatial Analysis, 1978), pp. 80-81.

flow between noncontiguous states is implied by the surface relief flow map. It is noted that in representing migration, some states are close to the level of their neighbors (Oregon and Washington), but some are at a higher level (Idaho and Washington). This apparent contradiction is unavoidable when representing the data with this method. It is assumed that the disclaimer on the map stating "Magnitude of net migration is not depicted or implied" will serve to avoid erroneous conclusions by map viewers.

One problem with both maps is the loss of detail in smaller states, such as those found in New England. This problem exists with other mapping methods but is magnified in the case of Map 4 by the relatively low resolution inherent in the computer mapping program. A larger-scale inset of problem map areas, where possible, is one solution to this problem. Another problem arises where a state is contiguous to a number of other states, such as is the case with Tennessee. Tennessee is contiguous to eight states and poses a problem in mapping without flow lines. The solution here divides Tennessee into two segments; a western one-third and an eastern two-thirds.

The surface relief flow map depicts several characteristics of migration. Barrier patterns are identified, such as the northern Rocky Mountains, the lower Mississippi River, and the Appalachian Mountains. Regions of net migration between contiguous states are identified along the Atlantic-Gulf coast states, Pacific coast states, and North Central states. Also, certain states such as Utah, Nebraska, and West Virginia appear relatively isolated in terms of contiguous migration.

Chapter 4

EVALUATION

The Social Survey

Objectives

> The processes and functions which probably will occur between the eye and the mind of a (map) reader must be predicted and analyzed if the technique is to be properly evaluated. To do so is difficult to say the least.[53]

An evaluation of the maps produced in this thesis is necessary to discover their effectiveness and utility. A social survey is designed and administered to a small group of map users after which their responses are compiled, analyzed, and displayed. The results are used to understand the successful and unsuccessful characteristics of the four mapping methods described in the previous chapter. The social survey collects facts and opinions from the selected group of respondents concerning Maps 1, 2, 3, and 4. This information is then analyzed to help determine the effectiveness and utility of the maps and to help understand why they do or do not work.

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[53]Arthur Robinson, The Look of Maps: An Examination of Cartographic Design (Madison, Wisconsin: University of Wisconsin Press, 1952), p. 20.

Form and organization of the survey

A booklet of questions, Maps 1, 2, 3, and 4, and a reference map for locating the states of the United States comprise the social survey. A copy of the survey is displayed in Appendix D. Both questionnaire and personal interview techniques are used in the survey. The survey is organized in the following manner. Initially, an explanation of the purpose of the survey, of the rationale for selecting respondents, and of the structure of the survey is given to respondents in the Introduction. Part 1, comprised of structured questions regarding the content of each map, comes next (pages 2, 5, 8, and 11 of the survey). Questions about map content are asked first so the respondents can become familiar with each map by using it. Part 2, comprised of both structured questions (pages 3, 6, 9, and 12) and personal interview questions (pages 4, 7, 10, and 13), seeks the respondents' opinions about each map. Structured questions concerning the form of the maps use the semantic differential technique for recording opinions.[54] Respondents record their opinions about characteristics of each map along a scale between polar opposite word pairs such as unique-conventional, valuable-worthless, and clear-confusing. The six questions in this part of the survey are identical for all four maps. Part 2 has a second section which consists of open-ended questions asked of the respondents in a personal interview. Respondents are able to voice,

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[54]With the semantic differential technique, responses are recorded along a scale defined at either end by polar opposite word pairs describing a characteristic of the map. The respondent is able to record opinions on the scale in one of seven positions in a continuum between the polar opposite word pairs. See Charles H. Backstrom and Gerald D. Hursh, Survey Research (Northwestern University Press, 1963), p. 77.

in their own words, both favorable and unfavorable impressions of either the form or the content of each map. Part 3 of the survey (page 14) asks respondents to rank the four maps highest to lowest according to two criteria: ease of interpretation and visual appearance. Part 4 (page 15) asks background information about the respondents: area of expertise, frequency of map use, education, and current occupation.

Respondents

Based on two assumptions, a 'purposeful' sample of respondents is chosen to evaluate the maps.[55] The audience of these maps is assumed to be limited to individuals with specialized knowledge of spatial interaction, such as demographers, historians, planners, and geographers. It is also assumed that the most significant evaluation of these maps can be done by either those persons familiar with graphic and cartographic design or those persons who use maps regularly.

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[55]Respondents chosen to evaluate the four maps are Dan Obermeyer, community planner; Harold Bockemuehl, professor, geography; Bette Williamson, cartographic technician, U.S. Forest Service; Major Frederick Moench, assistant professor, military science; Dick Lane, instructor/statistician; H. Duane Hampton, professor, history; John McQuiston, professor, sociology; David James, assistant professor, art; and Karen Rausch, travel agent. All are from the community or the University of Montana, Missoula, Montana.

Survey method

The social survey is designed to be conducted personally, by appointment. Respondents are given a copy of the questionnaire booklet, the four maps, and a reference map for locating states. They begin by answering the structured questions in Parts 1 and 2, which are designed to be self-administered. After these questions are completed, the open-ended interview questions of Part 2 are asked of the respondent by the interviewer. Responses to questions are recorded by the interviewer in the form of hand-written notes. This procedure of questioning is then repeated in sequence for Maps 2, 3, and 4. Next, Parts 3 and 4 are then completed by the respondent following the same procedures used for Part 1 and the first section of Part 2. The interviewer is present throughout the survey to answer any questions which may arise.

Results and Analysis

Part 1, Structured content questions

The purpose of Part 1 is to test whether the maps convey the information to map users that is intended. Toward this end the survey respondents are asked questions about the dot density (Map 1), the heirarchy of movement within regions (Map 2), state connectivity (Map 3), and the direction of net migration (Map 4).

Map 1

For Map 1, the classless choropleth dot map, respondents are asked in page 2 of the survey to differentiate migration ratios for several pairs of states (question 1) and for one group of four states (question 2). Pairs of states such as North Dakota-South Dakota and Kentucky-Tennessee are chosen on the basis of variations between them concerning a number of characteristics: contiguity, difference in the migration ratio, difference in the size (area), and the difference in the density of dots used to symbolize the migration ratio. The results to these questions are displayed in Figure 4-1. The percentage of questions answered correctly for Part 1, Map 1, listed by respondent, ranges from 100% correct to 25% correct, with a mean score of 69%. There are two possible explanations as to why the mean score for responses to Map 1 is comparatively low. Respondent #4 scored low by writing in the answer "same" for six of the eight state pairs listed in question 1. These answers are considered incorrect. A second explanation is that the questions in Part 1, Map 1 are harder to answer than the questions asked in Part 1 for the other maps.

Tables 4-1 and 4-2 present the responses to question 1, Part 1, Map 1, in more detail. The state pairs listed in question 1, the variations in characteristics between states in the pairs, and the percentage of respondents choosing the correct state (the state with the higher r value) are listed in Table 4-1. As an example, the pair of states, Washington-Georgia, are not contiguous, they have migration ratios of .23 and .19, respectively; they have state areas of 68,000 square miles and 59,000 square miles, respectively; they have a difference in area of 9,000

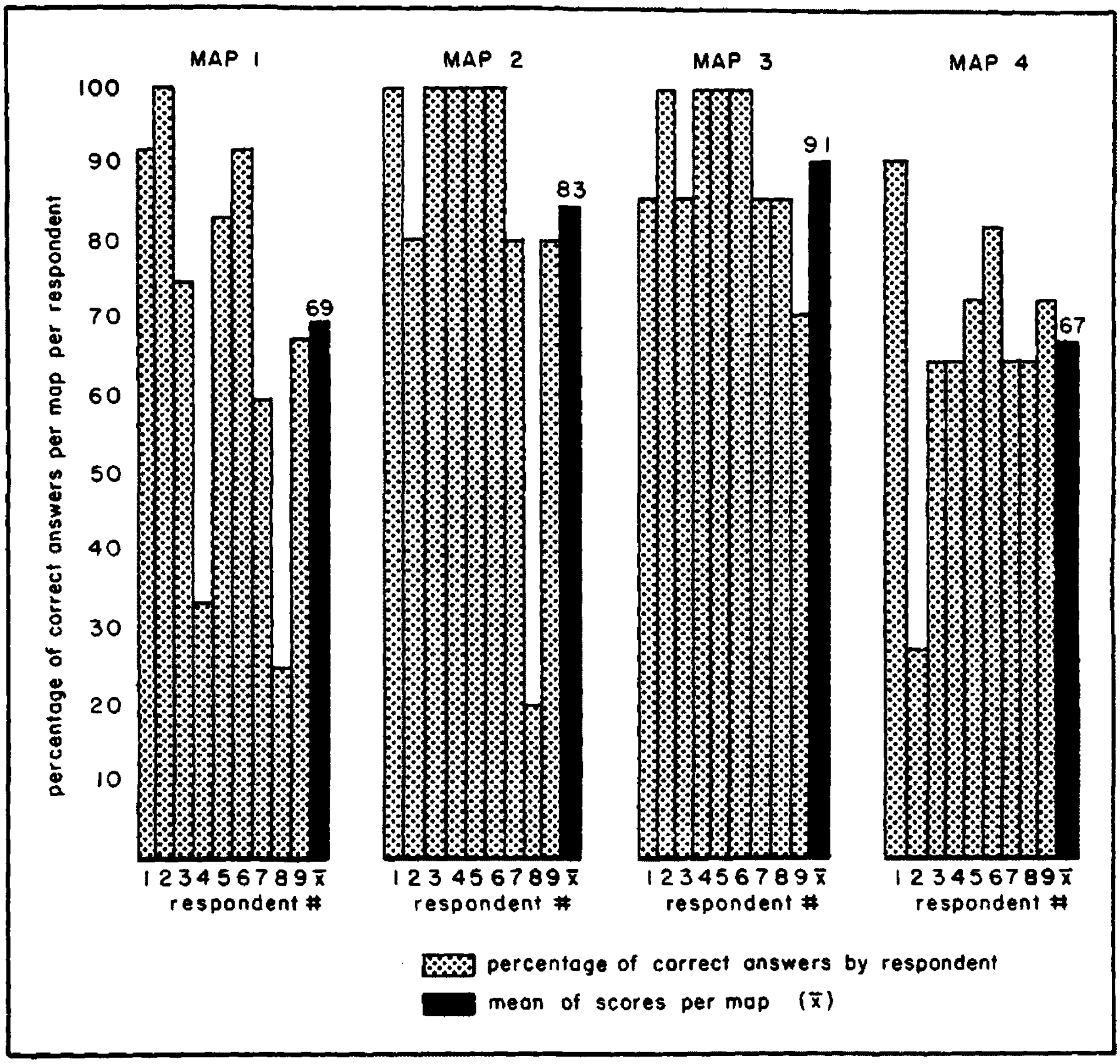

Figure 4-1: Percentage of answers correct, by map and respondent, Part 1

square miles; and their migration ratios are symbolized with 115 dots and 62 dots, respectively. For this state pair, all respondents (100%) correctly chose Washington as having the higher migration ratio. Correlation coefficients, r_c, between values in Column 7 (Table 4-1) and values derived from data in Columns

3, 4, 5, and 6 (Table 4-1) are shown in Table 4-2.[56] The correlation coefficients in Table 4-2 suggest that accuracy in reading a classless choropleth dot map decreases (Column 7, Table 4-1) as the size of the states decreases (Column 4, Table 4-1) and as the number of dots per state decreases (Column 6, Table 4-1). Map reading accuracy may be increased for a classless choropleth dot map by experimenting with the size and number of dots per state and by experimenting with different types of base maps which alter the relative sizes of the states (Figure 5-2).

Map 2

In Part 1, Map 2, the nodal region flow map, respondents are questioned on whether or not they recognize the existence of discrete regions of migration that are portrayed on the map (questions 1, 4, and 5) and whether or not they understand the hierarchy of movement within each region (questions 2 and 3). Figure 4-1 shows the respondents' mean score for Part 1, Map 2, to be the second highest mean score for the four maps (mean = 83).

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[56]Coefficients are calculated using the Pearson Product Moment Coefficient of Correlation method; John W. Alexander and Lay James Gibson, Economic Geography (2nd ed.; Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1979), p. 433.

Table 4-1: State pairs; scores; characteristics, question 1, Part 1, Map 1

1 STATE PAIRS	2 CONTIG-UOUS	3 MIGRATION RATIOS	4 STATE AREAS (in 1000's sq. mi.)	5 DIFFERENCE IN AREA (in 1000's sq. mi.)	6 # OF DOTS IN STATES	7 PERCENT CHOOSING CORRECT STATE
WA/GA	no	.23/.19	68/59	09	115/62	100
ND/SD	yes	.25/.23	71/77	06	147/130	78
ID/FL	no	.31/.29	84/59	25	298/177	78
CA/CT	no	.15/.20	159/05	154	92/06	78
KY/TN	yes	.16/.17	40/42	02	28/34	67
DE/MD	yes	.26/.21	02/11	09	05/14	56
MA/RI	yes	.16/.18	08/01	07	06/01	56
NH/NM	no	.30/.29	09/122	113	31/367	44

Table 4-2: Correlation coefficients (r_c)

	DIFFERENCE IN STATE RATIOS	DIFFERENCE IN STATE AREAS	SIZE OF SMALLER STATE	FEWER NUMBER OF DOTS IN STATE PAIR
PERCENT CORRECT FOR STATE PAIR	.36	.18	.70*	.44

* Correlation significant at the .05 level of significance.

Map 3

In Part 1, Map 3, the connectivity network map, respondents are asked questions about the connectivity of states (questions 1, 2, 3, and 5) and about the strength of linkages between states (question 4). Scores for Map 3 range from 100% to 71%, with a mean score of 91%, the highest mean score for Part 1 for all the maps (Figure 4-1). A possible explanation for the high scores of respondents for both Map 2 and Map 3 lies in the ordinal scale of symbolization used. Maps 2 and 3 symbolize data values grouped into only four and three classes, respectively. In contrast, Map 1 represents 24 discrete data values with ratio scale symbolization. Differentiating between three or four different line symbols is much easier than differentiating between the variations in dot densities representing the twenty-four discrete data values. Had Maps 2 and 3 used ratio scale symbolization of the data, the mean scores for those maps in Part 1 would most likely have been similiar, or lower than, the mean score for Map 1.

Map 4

Respondents are asked to determine the direction of net migration between contiguous states in Map 4 by differentiating between the apparent heights of the relief surfaces of states (question 1). Question 2 is used to determine the respondents' understanding of the scale of symbolization. The percentage of correct answers for Map 4 ranges from 92% to 27%, with a mean score of 67% (Figure 4-1). This is the lowest mean score for Part 1 of all four maps. Possible reasons for this low score are discussed in the results of the personal interview responses. It is interesting to note that four of the nine respondents answered question 2 incorrectly, assuming that the map represented quantities of migrants, despite a disclaimer in the margin stating otherwise. These respondents obviously interpreted differences in the levels of the states to represent differences in quantities of migrants. This mistake could be expected as apparent three-dimensional symbolism is normally scaled on the interval/ratio level.

Part 2, structured opinion questions

In the first section of Part 2, respondents are asked the same six structured opinion questions about each of the four maps (pages 3, 6, 9, and 12 of the survey). Opinions are recorded by respondents on a scale in one of seven discrete positions between polar opposite words describing some aspect of the maps. These questions deal with the symbolism used in the maps (questions 1, 2, 3, and 4), the readability of the maps (question 5), and the interpretation of map contents (question 6). Figure 4-2 displays four linear profiles, each representing the mean response for each question for each map. It is noted that opinions in Part 2 of the survey are recorded on an ordinal scale of measurement, in one of seven classes represented by integer values. Differentiation between opinions recorded in the same class (i.e. the same integer value) is not possible. Therefore, when representing the data in Part 2 it is necessary to use the same classes that were used to collect it. Failure to use significant figures in representing the mean value would be to misrepresent data recorded on the ordinal scale as data recorded on the ratio scale of measurement.[57]

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[57]Robert H. Stoddard, Field Techniques and Research Methods in Geography (Dubuque, Iowa: Kendall/ Hunt Publishing Company, 1982), p. 48.

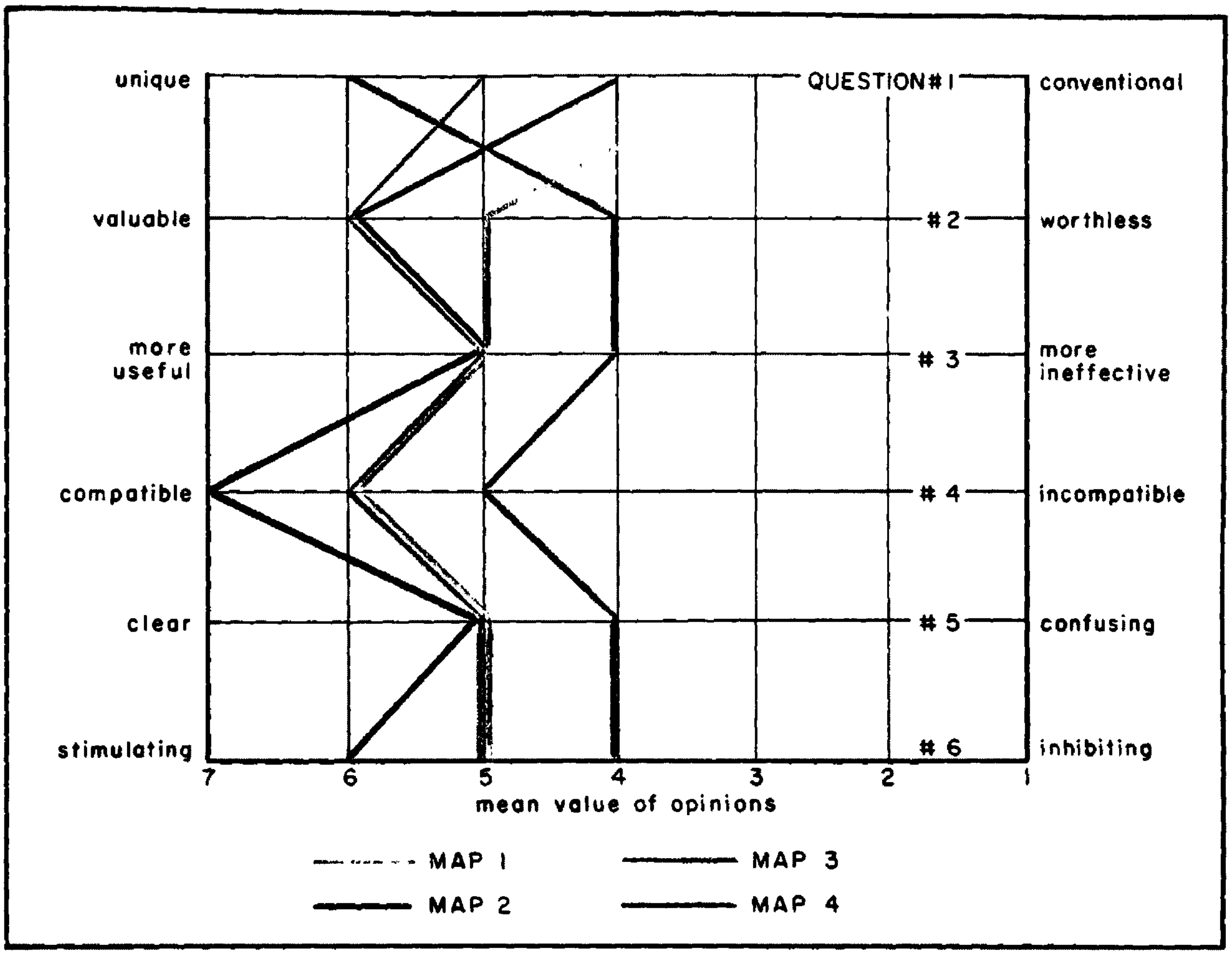

Figure 4-2: Profile of mean of opinions for Part 2 questions, by map

Surprisingly, but maybe not so surprisingly, the dots in Map 1 are perceived to be the most conventional use of symbolism of all four maps (question 1). Some respondents may have confused the appearance of a classless choropleth dot map with the appearance of distribution dot maps. Only the geographer/cartographer in the sample of respondents rated the use of symbolism as unique (7) in Map 2. As expected, Map 4 is rated as the most unique use of symbolism (mean = 6).

In question 2, Maps 2 and 3, both employing ordinal scale symbolization, are ranked highest for purposes of analyzing migration. It is seen in the results of Part 1 that respondents were most successful in answering the question for Maps 2 and 3. Those maps which are more easily read by viewers apparently are more useful to them.

In answering question 3, respondents feel quantitative values could make Maps 1, 2, and 3 more useful (mean = 5). The demographer in the group of respondents definitely feels that including quantitative values would make Maps 1, 2, and 3 more useful. It was seen in the results of question 2, Part 1, Map 4 that almost half of the respondents assumed Map 4 to be quantitative in nature.

The flow lines (arrows) on Map 2 are perceived by respondents as unquestionably the most compatible form of symbolism for representing migration (mean = 7). Only in Map 2 is the direction of movement between places symbolized in the traditional manner using arrows. Ironically the attempt to depict direction of movement without arrows appearing in Map 4 is seen as the least compatible symbolization of migration. Since Map 4 is the most experimental in its symbolization of movement, this reaction by respondents is not a surprise.

In terms of readability (question 5), Maps 1, 2, and 3 rank equal (mean = 5) with Map 4 ranking lower (mean = 4). Respondents find Maps 1, 2, and 3 equally easy to read even though their mean scores in Part 1 are 69%, 83%, and 91%, respectively. This suggests that map readers may understand how to read a given map without being able to perceive small differences in its symbolization (i.e. Map

1).

When evaluating the responses to question 6, Map 2 emerges as the the most stimulating for interpreting migration. Maps 1 and 3 are less stimulating; Map 4 is the least stimulating. As suggested in the results to question 4, respondents may feel most comfortable when reading spatial interaction maps when the movement is symbolized in the traditional manner using arrows. Map 4 forces readers to interpret the pattern of movement from an unfamiliar method of symbolization.

Part 2, personal interview opinion questions

Part 1 and the first section of Part 2 occur at the beginning of the questioning sequence to provide respondents ample opportunity to develop opinions regarding the maps. The personal interview section of Part 2 follows allowing respondents to voice their opinions in a format which would allow the maps to be compared and discussed in the following passages.

Map 1

The strong point of Map 1 voiced by respondents is the use of symbolism. Dot density is an efficient way to depict the comparative migration ratios of states. One goal of this mapping method is to allow viewers to visually construct regions of migration based upon areas of similiar dot density. Two comments, one favorable and the other unfavorable, support this goal of the mapping method. "Regional impression of ratio is possible with this map."[58] Regions such as the

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[58]Comment by Dick Lane.

states of the Midwest, the Great Plains, the Rocky Mountains are somewhat visually homogeneous because of the relatively similiar dot densities found throughout each. Another comment, "The Midwest visually blends together in dot density,"[59] also reinforces the characteristic of this method which allows viewers to distinguish regions of relatively homogeneous migration ratio. Distinctions can be made between dot densities within these "regions," something which is not possible with traditional choropleth maps (Figure 3-1).

Manipulating the number of dots per state and the size of dots to increase readability may be limited by a minimum effective dot size. One respondent stated, "The bold dots are striking,"[60] suggesting that reducing dot size beyond some undefined minimum size may have deleterious effects when comparing dot densities.

Dot patterns, either random, uniform geometric, or uniform nongeometric, identify another factor in the effectiveness of the mapping method. "The haphazard (uniform nongeometric) dot pattern may not be the best dot pattern."[61] More rigorous experimentation with dot patterns is necessary to determine the extent of their effect on readability.

Content is of concern to respondents in viewing Map 1. The desire to distinguish migration ratio, r, as either in-migration, out-migration, or total

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[59]Comment by John McQuiston.

[60]Comment by Bette Williamson.

[61]Comment by Dick Lane.

migration is expressed repeatedly.

Map 2

The respondents are more likely to have greater familiarity with the form and use of the symbolization for Map 2 than any of the others. Directed flow lines (arrows) are frequently used symbols on spatial interaction maps. Recurring interview comments about Map 1 are "clean, simple, uncluttered," "not noisy," "straightforward," and "reads clean." The map, however, uses many flow lines, more than forty lines in all.

One obstacle to reading Map 2 is its content, an opinion voiced several times in the interviews. Respondents are concerned about the terms "dominant" and "peripheral" and about how the hierarchy of migration within the nodal regions is defined. Two respondents expressed the desirability of including absolute numbers of migrants in the symbolization.

Map 3

As with Map 1, the conceptual framework of Map 3, connectivity, is seen as being esoteric to respondents and is voiced as a major concern among the interview comments. "I'm not sure I know what it (the map) means."[62] "The content is unclear." "What is the message of the map?" "The map is readable,

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[62]Comment by H. Duane Hampton.

however."[63] "This map exists for itself; it is Dada."[64] The concept of connectivity applied to migration may be esoteric, but its form is familiar in the thematic maps of other topics in spatial interaction. The type of map displayed in Figure 2-16 illustrates the connectivity of international cities by an airline.[65] Other problems with the content of Map 3 were a desire to discern both the direction of migration and absolute numbers of migrants.

The general form is seen as "clean looking" and "uncluttered" despite the map having seventy-five flow lines superimposed on a linear base map. Minor improvements in form, such as more contrast in line weights and heavier state outlines, are suggested.

Map 4

A variety of contradictory interview comments describe Map 4, most of them concerning its form. "Some parts are very easy to read." "Very difficult to interpret." "Roughly easy to follow the pattern of flow." "I like the looks of it." "It makes you kind of blurry-eyed." "Visually disturbing." "Intriguing." More comments were made about this map than about any of the other maps.

The parallel diagonal lines that form the relief surfaces are a major obstacle

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[63]Comment by Dick Lane.

[64]Comment by John McQuiston. Dada refers to a movement in art in the early twentieth century "based on deliberate irrationality, anarchy, cynicism, and negation of the laws of beauty and social organization."; Webster's Third New International Dictionary of the English Language Unabridged, 1967.

[65]Karen Rausch, a travel agent, immediately noticed the similiarity between Map 3 and airline route maps, saying "This looks like an airline map!"

in viewing the map. The lines are variously described as "eye-tiring," "hard to look at up close," "creating an optical illusion effect," and " the map starts to move," when the pattern of migration is interpreted from the map.

One of the comments, comparing the viewing of Map 4 to the viewing of stereo aerial photographs, may best summarize the problem most respondents had in interpreting this map. The viewer usually does not immediately discern variations in surface relief, but must instead train himself to see them. After viewing Map 4 for a period of time, variations in the relief surfaces become discernible and the concept of flow from high to low surfaces becomes apparent.[66]

Part 3, Rank Ordering of the Maps

Part 3 of the questionnaire asks respondents to rank, highest to lowest, all four maps according to the two criteria - ease of interpretation and visual appearance. Histograms in Figures 4-3 and 4-4 display the results of respondents' rankings.

For ease of interpretation, Map 2 is ranked first and second most frequently while Map 4 is ranked third and fourth most frequently. No respondents rank Map 4 either first or second in ease of interpretation. A similiar pattern occurs when the maps are ranked in terms of visual appearance. Map 2 is ranked first and second most frequently while Map 4 is ranked fourth most frequently, suggesting that ease of interpretation is closely associated with visual appearance. Curiously, Map 4 is ranked first in visual appearance by three of the respondents. Apparently

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[66]From H. Duane Hampton.

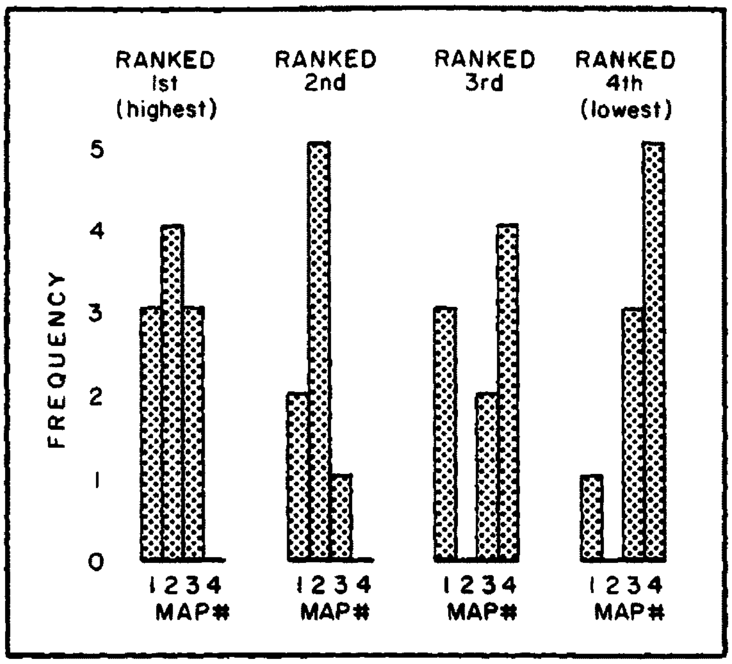

Figure 4-3: Frequency of ranking for 'ease of interpretation'

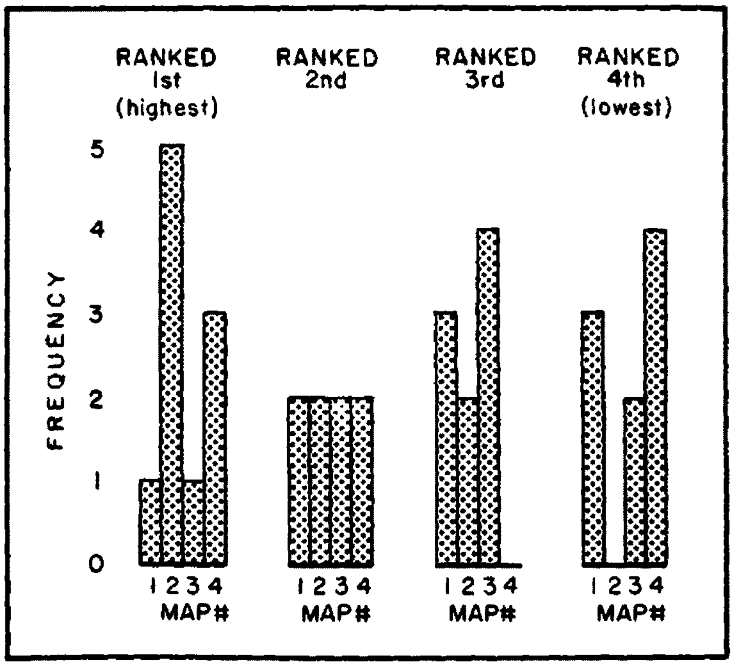

Figure 4-4: Frequency of ranking for 'visual appearance'

it has a dichotomy of appeal to respondents; it is either strongly received or strongly rejected. This dichotomy of appeal is supported by impressions recorded in the interview section of the survey.

Part 4, Background Information

The questions in Part 4 are included in order to obtain background information about the group of survey respondents: area of expertise, frequency of map use, level of education, and current occupation. Area of expertise for the respondents is evenly divided between those with knowledge in graphics or cartographics and those with knowledge in the geographic movement of people. Responses indicate that they are frequent map users with eight of the nine respondents using maps weekly or daily.

Chapter 5

CONCLUSIONS

Considering the number of ways it is used in this thesis, and considering the numerous potential ways it may be used, the classification scheme developed in Chapter 2 provides unlimited means for exploring new methods to map spatial interaction. In the process of classifying the group of maps collected in the survey, it is seen that spatial interaction maps depict movement either implicitly or explicitly. All maps which explicitly depict movement between places are seen to do so with line symbolism (flow lines). Since no other form of symbolism is used for this purpose, the classification scheme developed in this thesis presents the problem of explicitly representing interaction without line symbolism. Map 4, the surface relief flow map, is only one solution to this problem. Many more potential solutions exist when all of the forms of symbolism found in thematic cartography are considered.

The classification scheme proves to be useful in a second way by showing that graphic elements such as size, value, and spacing (pattern) may be altered for a form of symbolism, thus providing new methods for mapping. Area symbols in Figure 2-7 are altered in size (height) to give ratio scale symbolization of the data. The symbolism in Figure 3-2 is altered by varying the spacing (pattern) of lines within areas. Map 1, the classless choropleth dot map, alters the spacing of dots within areas. The method used to produce Map 1 is an attractive alternative to anyone wishing to make a classless choropleth map, but is without access to sophisticated computer mapping equipment.[67]

The process of classification familiarizes the mapmaker with a variety of map types. These maps types may be used to represent familiar topics, such as interstate migration, with new and different perspectives. Figure 2-16 serves as the model for the connectivity network map of interstate migration in this thesis. After a method for manipulating migration data is developed, the maps in Figures 3-9 and 3-10 are produced.

Finally, vacant classes in the scheme invite the design of mapping methods that will produce maps to fill them. Map 2, the nodal region flow map, fills such a void in the classification scheme. Only one of the thirteen vacant classes in the scheme (Figure 2-14) is filled by mapping methods explored in this thesis, leaving a number of mapping opportunities open to future research in thematic cartography.

Research to produce new mapping methods may focus on one specific category in the classification tree, developing it in more detail. The classification tree in Figure 5-1 is expanded in detail for those maps which use area symbolism scaled at the interval/ratio level. After developing the tree in more detail, map collection may be appropriate in order for the mapmaker to become familiar with what examples exist in the literature. Then, systematically, the mapmaker may experiment with each graphic element listed in the tree to develop different

[67]See Chapter 3, Classless choropleth maps.

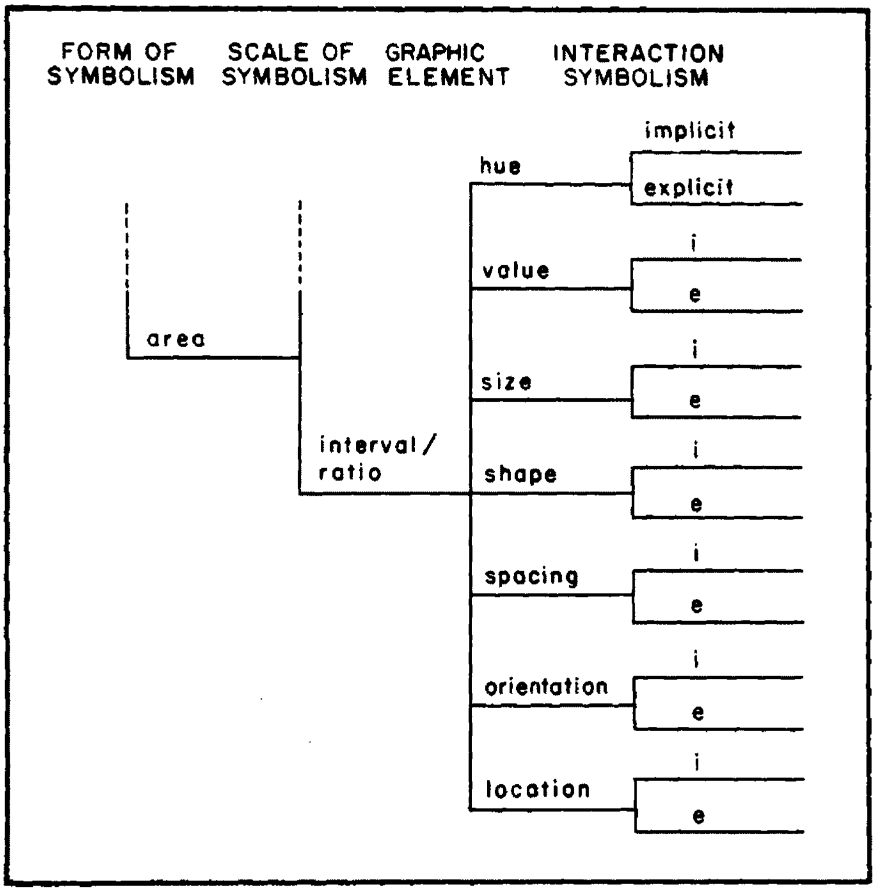

Figure 5-1: Expanded map classification tree

mapping techniques. Another area for future research is to expand the classification tree to include multiple forms of symbolism.

In many ways, Map 1, the classless choropleth dot map, is a successful map.

It is likely to be the most utilitarian of the four maps. As a choropleth mapping method, its uses include the representation of a variety of geographic topics in addition to spatial interaction. A classless choropleth dot map is easy to produce, requiring little more equipment than drafting pens and a hand-held calculator.

The method is very successful in representing small differences in the values of areal data. Users of Map 1 are able to discern extremely small variations between the pattern of dots in the states. For the pair of states, Kentucky-Tennessee, in question 1, Part 1, Map 1, six of the respondents correctly chose Tennessee as having the higher migration ratio of the two states. The other three respondents did not choose Kentucky, but rather chose to indicate the two states as having equal migration ratios. The difference in migration ratio between these two states is only one percent (1%). For comparisons made between states small in size, however, map reading accuracy is seen to decrease. A cartogram which increases the relative sizes of small states, such as Rhode Island and Connecticut, may make the dot densities of small areas more readable. Experimentation with cartograms such as the one displayed in Figure 5-2 may improve the readability of both classless and classed choropleth maps.

Well received by respondents in their form, Maps 2 and 3, the nodal region flow map and the connectivity network map, respectively, are successful in several ways. Respondents like the way these maps look. Line symbolism is unambiguous in representing movement. In Maps 2 and 3, movement is made even less ambiguous by the careful organization and layout of the line symbolism. Whenever possible, lines are not allowed to cross each other. When lines must

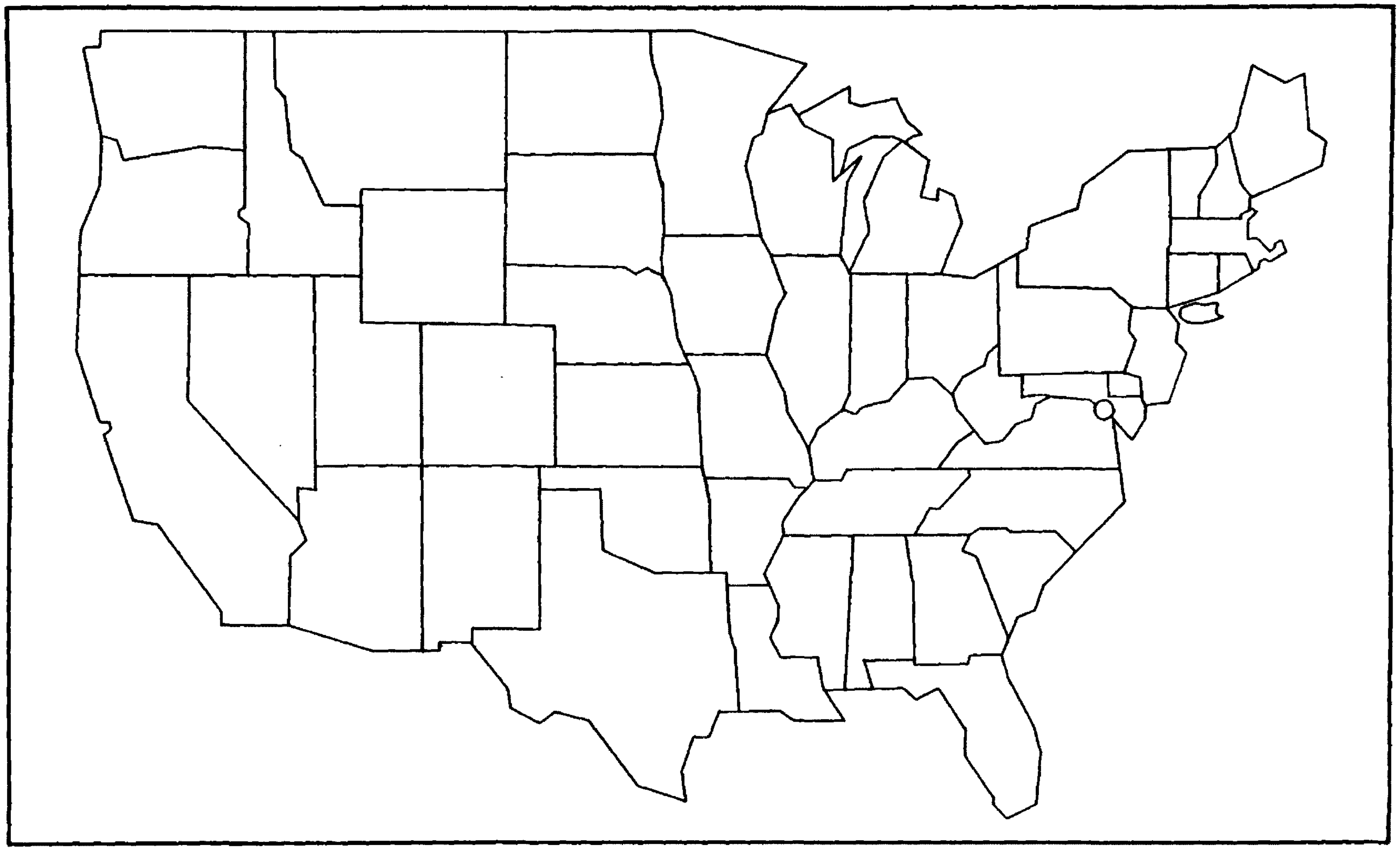

Figure 5-2: Base map with altered states sizes[68]

[68] Girl Scout Pocket Planner 1986.

cross, the shortest line is broken to help the users perceive long distance movements. Straight lines are used to connect contiguous states; curved lines are used to connect noncontiguous states. It is for these reasons that most respondents see Maps 2 and 3 as "clean and uncluttered." Further experimentation with this type of line symbolism, such as using terminal points at the vertices in the connectivity network map, may help to improve readability.

The nodal region flow map may be useful in representing a number of different types of regions defined by the flow of such things as people, products, money, or communications. This type of map is not likely to be displayed alone, however, outside of a supporting text as most map readers other than professional geographers are probably not familiar with the concept of nodal regions. For similiar reasons, it is unlikely that Map 3 would be displayed outside of a supporting text. The abstract concept of connectivity, applied to the topic of migration, is foreign to most users. Respondents are able to read Map 3 easily, but do not understand the meaning of what they read. As a result, this map may have little use except as a tool for specialized purposed in spatial analysis.

Map 4, the surface relief flow map, is most successful in eliciting reactions from users. It is a fascinating map for some, objectionable to others. None of the users are ambivalent towards it. The form of the apparent third dimension, once perceived by users, is the main factor in the dichotomy of attitudes towards Map 4. The apparent third dimension is created by a series of diagonal, parallel lines drawn by a computer plotter. Most map users regard these lines as an optical nuisance. This attitude is reflected in the interview responses presented in

Chapter 4. Other methods may be used to produce an apparent third dimension, such as relief shading or computer programs that plot two sets of parallel lines at various angles to one another forming a network of parallelograms and rectangles which convey the impression of a three-dimensional image. Experimentation with these methods for mapping an apparent third dimension may make the surface relief flow map easier to look at, easier to read, and more acceptable to users.

Users are reasonably successful in reading the direction of flow between large states on Map 4. Problems arise, however, in representing flow between small states. Much of the detail of state shape and state relief in these areas is lost due to the low resolution of the computer mapping program. A solution to this problem is to map regions with small states separately, at a larger scale. The method used to produce Map 4 is complicated, time-consuming, and requires access to specialized computer hardware and software. For these reasons, uses of this mapping method are likely to be limited.

Appendix A

SOURCES FOR MAPS

Library of Congress Subject Headings

Air travel
Airways
Animal migration
Animal orientation
Bats - Migration
Birds - Migration
Cities and Towns - Growth
City traffic
College student mobility
Commerce
Commercial products
Communication
Communications and traffic
Communications, Military
Emigration and immigration
Fishes - Dispersal
Fishes - Migration
Geography, Commercial
Geography, Economic
Geopolitics
Graduate student mobility
Insects - Migration
Labor mobility
Land settlement
Man - Migrations
Migrant labor
Migration, Internal
Migrations of nations
Migratory locust
Military geography
Movement of animals
Network analysis
Population density
Population geography
Postal service
Railroads
Residential mobility
Roads
Rural-Urban migration
Shipment of goods
Shipping
Student mobility
Telecommunications
Tourism
Trade routes
Traffic engineering
Transportation

Appendix B

MIGRATION DATA

Interstate Migration, United States, 1975–1980

Migration data for the interstate movement of people for the five-year period, 1975–1980, are listed in the following four pages. States of origin are listed in the columns along the top of the matrix. States of destination are listed in the rows along the left-hand edge of the matrix. The number of migrants from the state of origin to the state of destination is listed in the matrix.

Table B-1: Matrix of interstate migration, U.S., 1975-80

STATE OF ORIGIN

STATE OF DESTINATION	ME	NH	VT	MA	RI	CT	NY	NJ	PA	OH	IN	IL	MI	
ME	0	11489	2233	25600	2143	11234	9699	4731	3978	2624	761	1736	1634	ME
NH	10630	0	7369	65310	2904	9225	13701	7221	4389	2042	684	2111	1606	NH
VT	1980	6231	0	11675	1221	7141	13791	4725	2603	1368	293	773	921	VT
MA	13446	22573	7322	0	21374	39076	74774	25943	18756	9699	3277	10754	7944	MA
RI	1928	1852	622	20841	0	9059	10783	4742	3031	1285	465	1642	1011	RI
CT	5490	4584	2935	30456	6627	0	77213	20135	13119	7400	3155	8239	5353	CT
NY	5475	6106	7815	48772	6681	39027	0	94666	60404	24808	7368	21114	18250	NY
NJ	1956	2254	1578	16790	2350	13117	197322	0	107753	12430	4496	13728	8177	NJ
PA	3057	2339	1978	16406	2678	14370	94215	100676	0	42772	8051	15615	12905	PA
OH	2218	1368	1136	10225	1390	7209	39431	16820	53595	0	34739	28532	45524	OH
IN	840	773	252	3663	384	3592	13484	6125	12125	48062	0	65820	30769	IN
IL	1844	1581	481	11291	1813	7417	33100	18065	20381	35960	48023	0	36589	IL
MI	1938	864	464	6752	969	4979	22763	9243	16220	56454	31259	44206	0	MI
WI	569	558	453	3316	500	2146	8026	3401	5304	9112	9592	78628	21145	WI
MN	496	928	326	3811	345	1643	7263	3094	4730	8228	5693	24884	11008	MN
IA	471	359	192	1326	102	1215	4319	1866	2876	5166	4355	37079	5538	IA
MO	903	981	427	4225	638	2223	10801	5757	8022	12653	11948	61501	12195	MO
ND	342	149	46	402	66	206	1625	517	1164	1251	896	1886	1453	ND
SD	205	151	12	500	58	163	1397	543	825	1096	684	2420	1267	SD
NE	529	422	92	1120	99	529	3663	1317	1769	3116	2342	6050	3408	NE
KS	461	593	219	1775	346	1399	6786	2863	4633	6852	4700	12623	5421	KS
DE	310	561	183	1471	43	825	5460	9087	18582	1999	651	1713	929	DE
MD	1999	1564	850	10285	1726	7082	36254	18962	38733	11143	3708	7911	6137	MD
DC	308	205	158	4598	555	2112	10564	4305	6049	2422	675	2524	1585	DC
VA	4214	2667	1820	16705	3927	11791	62351	30554	44068	26458	9544	17505	14990	VA
WV	277	272	284	831	97	1038	5682	4742	17121	30896	2707	4285	4396	WV
NC	2296	1854	1061	10190	1449	7932	57124	24371	23704	22483	7404	14211	13090	NC
SC	1226	1363	469	4434	1306	5226	31746	11719	14257	13686	4791	7364	8271	SC
GA	1284	1714	639	9658	901	5846	38498	17612	16776	25600	10285	21593	15743	GA
FL	12327	12977	6387	63383	10087	49029	364450	134150	104710	135219	53546	102192	95246	FL
KY	680	616	378	2118	464	1294	10105	4245	7073	55896	33185	18926	17820	KY
TN	1276	936	359	4559	515	2782	13967	6180	10231	27143	16411	28274	21056	TN
AL	768	461	122	2920	638	2283	13190	4697	6109	13238	7128	13399	11354	AL
MS	379	383	91	1586	298	1063	4581	2051	2409	5441	4201	15835	5089	MS
AR	464	316	102	884	217	890	4277	1499	2145	5041	6129	23476	8521	AR
LA	1081	641	188	4029	547	2468	11824	4485	5808	7543	3961	12467	6312	LA
OK	826	867	191	2362	299	1492	9951	3746	5008	10368	5305	13073	8005	OK
TX	3754	3281	2016	19817	3246	11848	80139	32134	38643	61275	32970	77207	47054	TX
MT	272	246	249	670	91	548	2175	1161	1628	2119	921	2694	1919	MT
ID	345	375	91	567	142	997	2285	1094	1813	2147	1186	2954	2399	ID
WY	133	323	214	858	101	287	2383	737	1949	2506	1474	3554	2529	WY
CO	1865	1408	1393	8545	1105	5403	27007	11626	13877	19163	9868	34574	18735	CO
NM	688	689	199	2268	318	1309	10732	3300	4330	5341	2625	8225	4066	NM
AZ	2017	2354	1281	10686	1047	7004	43083	15284	19724	34852	15317	48847	31498	AZ
UT	797	461	369	1599	366	862	5210	2178	2421	3207	1492	4964	2961	UT
NV	271	821	320	2817	345	1062	11809	3157	4401	6857	2309	8210	5099	NV
WA	2122	1181	766	7160	683	4079	15227	6612	8628	11427	4745	16619	11284	WA
OR	901	914	630	3563	255	1748	8083	3174	3285	5597	3022	8269	6087	OR
CA	7394	7048	3355	55027	8710	30076	179601	64860	63367	84317	35489	128967	76795	CA
AK	772	559	281	1522	257	660	3366	1134	1489	2268	1043	2012	2735	AK
HI	596	656	198	3229	532	1294	5995	3088	3760	3165	2141	4541	3344	HI
TOTAL	ME	NH	VT	MA	RI	CT	NY	NJ	PA	OH	IN	IL	MI	
OUT-MIGRATION	106420	113868	60596	542597	92955	345300	1721275	764394	837775	931195	467014	1095726	687167	

Table B-1, continued

STATE OF ORIGIN

STATE OF DESTINATION	WI	MN	IA	MO	ND	SD	NE	KS	DE	MD	DC	VA	WV	
ME	405	643	298	487	90	136	580	534	287	2774	316	3149	278	ME
NH	741	768	238	463	140	299	251	347	412	2413	317	2895	216	NH
VT	366	320	61	398	21	26	137	130	215	1314	324	2336	115	VT
MA	3731	3024	1390	3154	382	272	818	1250	1363	9817	2631	10762	842	MA
RI	294	334	171	324	22	95	195	293	246	1664	306	3453	177	RI
CT	2133	2149	869	2098	222	84	655	878	997	5530	1243	8343	790	CT
NY	6482	4927	2596	5635	929	647	2088	3096	2566	17438	6887	21963	2500	NY
NJ	2642	2214	1908	3032	556	159	627	2279	4941	14343	2488	14415	1955	NJ
PA	3802	3158	2563	4749	912	322	1492	3609	15629	44237	4309	29045	10411	PA
OH	7891	4757	4907	9695	1239	994	2622	4166	1899	12087	2099	19365	30072	OH
IN	8131	4707	4512	9215	912	744	2017	3841	701	4478	753	9060	2942	IN
IL	40007	15280	26922	47494	1766	1754	6861	8552	1798	8497	1966	15265	3075	IL
MI	17138	6551	4786	8870	1080	784	2424	3652	1285	7249	1413	11054	3548	MI
WI	0	37135	11528	6628	1427	1597	2576	2330	634	2863	638	4651	712	WI
MN	37098	0	22309	6083	19134	10868	5283	3526	404	2724	632	4633	344	MN
IA	10239	18774	0	15453	1529	7042	19820	6014	403	1515	287	2585	391	IA
MO	6922	6499	20808	0	1658	1459	8260	49991	366	4077	727	7533	1430	MO
ND	2404	22555	1239	1031	0	5938	1097	842	180	638	128	893	115	ND
SD	1907	10471	7916	1230	4573	0	5200	1602	129	540	116	745	151	SD
NE	2117	5487	21291	7377	2545	7455	0	10521	96	2155	203	2441	324	NE
KS	3002	3889	7297	53082	1395	2309	11444	0	403	2202	371	4375	694	KS
DE	211	54	109	439	53	68	130	310	0	11604	505	3325	667	DE
MD	2308	1472	1239	3723	331	374	1149	2269	10891	0	79087	47819	6356	MD
DC	764	410	252	825	55	0	269	309	412	22599	0	10929	645	DC
VA	5249	3678	3301	8235	1029	762	3449	5393	5244	73785	25298	0	18441	VA
WV	634	245	246	1105	157	94	163	567	1329	17364	857	20668	0	WV
NC	4076	3262	2469	6021	1204	808	1431	3427	2678	22122	5064	61771	6084	NC
SC	1780	1524	1443	2964	965	307	1107	1973	1580	9226	2570	17982	3650	SC
GA	5188	4219	2260	7031	901	578	1914	3889	1690	11687	2392	22448	3597	GA
FL	24275	15182	9366	21905	2390	1627	4879	7064	6490	52902	4617	57794	16289	FL
KY	3133	1255	2459	6394	383	504	927	2406	790	3881	782	9109	6447	KY
TN	3262	2054	2500	10090	417	481	1491	3196	1117	7328	806	24150	3647	TN
AL	2092	1477	1903	4332	637	386	816	2958	859	4287	818	9377	1764	AL
MS	2201	892	719	4571	615	258	753	1436	501	3176	386	5494	537	MS
AR	2719	2308	5912	21489	591	601	2969	7764	342	2313	262	3952	644	AR
LA	2412	1525	1819	6606	767	353	1723	4182	940	4076	818	8650	1343	LA
OK	3169	4428	4569	20341	1543	1536	5176	28099	1009	3646	554	6039	1116	OK
TX	17966	17270	16631	46145	4001	3972	13781	33551	3933	20632	3921	35975	5599	TX
MT	2442	5977	1600	1360	5105	2846	1554	1196	86	958	53	1305	98	MT
ID	1852	2398	1354	1506	1057	848	1695	1190	113	959	136	1756	295	ID
WY	1968	3573	1948	2561	1745	5550	5512	2749	110	688	89	1120	340	WY
CO	10599	15153	15012	13451	4041	6233	17974	20580	1119	7880	1254	9718	1337	CO
NM	2869	1939	2096	2813	443	658	1795	3159	265	2165	311	3932	542	NM
AZ	15201	14974	12093	10788	2876	3610	6574	7559	564	6268	579	7964	1553	AZ
UT	1852	2221	1465	2511	686	1097	1512	1754	294	1879	378	3105	362	UT
NV	3329	2611	1604	2957	599	654	1598	1601	144	1611	169	2642	352	NV
WA	8271	11733	6803	6581	4191	3061	4461	5318	1084	6567	922	10934	1112	WA
OR	4235	6536	3679	4281	1649	1809	2914	2840	460	2170	475	3947	487	OR
CA	32773	32429	22662	41142	6923	6833	16646	21235	3545	31685	8705	50333	5529	CA
AK	1736	2238	632	1501	435	604	1104	1062	256	1160	423	2028	183	AK
HI	1980	1620	950	2212	378	523	1080	1653	261	3291	245	7215	478	HI
TOTAL	WI	MN	IA	MO	ND	SD	NE	KS	DE	MD	DC	VA	WV	
OUT-MIGRATION	327998	318299	272704	452378	86699	90019	180993	288142	83060	486469	170630	630442	150576	

Table B-1, continued

STATE OF ORIGIN

	NC	SC	GA	FL	KY	TN	AL	MS	AR	LA	OK	TX	MT	
ME	1259	852	498	5022	704	464	297	371	591	508	580	2296	74	ME
NH	1328	930	612	4745	346	447	229	261	138	448	419	1848	100	NH
VT	671	287	247	1930	122	182	167	179	12	93	98	514	125	VT
MA	5457	2586	4114	16619	1492	2050	1402	719	696	1590	954	6920	413	MA
RI	1192	646	541	2415	297	466	72	246	72	271	267	735	36	RI
CT	4423	3745	2945	11494	1042	1395	1743	769	576	1166	782	5657	351	CT
NY	14785	9437	11722	49452	4051	4496	4726	2750	1226	3544	2786	15046	827	NY
NJ	9498	5129	7010	25342	2107	2740	2501	1168	835	1953	2046	8869	413	NJ
PA	12267	5559	6896	29125	3816	4557	3379	2404	1054	2085	1839	12045	893	PA
OH	13919	5795	10690	40431	35935	12011	8354	4211	2450	3117	3535	19347	881	OH
IN	5276	3111	5590	21748	33852	8740	3636	3012	3380	2494	2333	12659	380	IN
IL	8916	5170	9602	30741	11546	13699	7473	12546	9604	5645	5503	25848	1658	IL
MI	8816	3413	7698	30665	9504	9305	7656	5546	4818	3076	3067	15640	994	MI
WI	3610	1568	2332	8539	2246	2565	1349	3576	1822	1936	1607	6600	1153	WI
MN	2553	1617	2644	7535	2114	2148	1333	827	896	1372	2171	7973	3296	MN
IA	1954	943	1704	4772	1356	1387	1050	1071	2371	915	2133	6253	1175	IA
MO	5358	2394	6525	13596	5894	7811	3776	4266	15939	3786	13198	23532	1049	MO
ND	660	373	828	1555	371	416	287	537	164	568	435	2977	4350	ND
SD	461	236	529	1264	424	306	414	274	498	366	668	1839	2002	SD
NE	1253	853	1060	2873	723	888	1030	968	1462	1316	2126	6186	1678	NE
KS	3606	2034	4372	6777	2309	3313	2516	1676	6155	2761	19404	20124	1062	KS
DE	1728	588	1118	2638	352	598	357	182	126	327	212	2112	17	DE
MD	12052	5105	6764	17230	2984	4013	3490	1570	1268	2042	1441	9736	254	MD
DC	4225	1510	1632	2415	382	649	673	378	206	830	163	1993	203	DC
VA	49972	19345	18675	42971	9466	15659	8259	5146	2460	6545	4887	22774	1374	VA
WV	4934	1608	1838	7820	5521	2205	986	507	663	888	572	3106	145	WV
NC	0	41831	29905	51749	7425	18382	8714	3479	2498	4357	3142	15348	663	NC
SC	50759	0	30549	29799	4471	8977	6233	2691	1749	3727	2301	10575	377	SC
GA	34695	32887	0	103782	10762	31516	35641	7683	3740	8777	4401	24103	683	GA
FL	45599	23758	75596	0	25274	30127	34047	13128	7557	14474	6486	39690	1669	FL
KY	8304	4038	8846	19622	0	19703	5627	2910	2276	2778	2423	10033	333	KY
TN	20590	9838	32711	40908	26014	0	22172	24165	11675	6434	3841	18186	535	TN
AL	10202	6689	43433	46682	6719	22294	0	16985	3391	8730	2993	16460	512	AL
MS	4247	3624	8613	16444	2621	24086	17496	0	6854	25731	2831	14993	249	MS
AR	3288	2377	4214	8912	2464	13123	3152	7129	0	11043	16565	33669	399	AR
LA	6032	5439	9634	23977	3515	7508	12514	27281	12926	0	7414	65363	297	LA
OK	5383	3226	5688	10713	3140	4711	3818	3163	19870	7211	0	76825	994	OK
TX	27069	15299	32842	81402	17343	26313	24285	26093	38823	86150	75820	0	4131	TX
MT	545	313	581	1758	388	404	244	332	483	567	1088	3118	0	MT
ID	754	762	717	2613	401	551	491	626	646	712	1469	5370	6970	ID
WY	736	532	889	2036	442	562	231	438	773	924	2604	6074	7462	WY
CO	5100	2842	6189	19135	3609	4303	3627	2442	3777	5132	10696	37820	5958	CO
NM	1478	927	1821	5466	1010	1390	1384	791	2011	1853	4090	35488	1145	NM
AZ	4509	1556	3993	13004	3386	3435	2731	1949	3393	2510	5334	25111	4281	AZ
UT	1864	875	1398	3970	859	1106	1092	592	776	1280	1540	7835	4020	UT
NV	1738	863	1886	7566	791	998	868	1080	1023	2019	1964	7317	2068	NV
WA	4817	3909	4757	13333	2310	3431	3079	2005	3032	4314	5102	22519	18103	WA
OR	2083	1037	1704	5383	1266	1446	623	858	1746	1412	2918	9385	6813	OR
CA	25888	14090	22415	69922	13698	18440	14779	12555	15985	25508	24405	120381	11457	CA
AK	1886	954	1609	3852	1184	947	1249	1099	718	1446	1709	6249	2134	AK
HI	3417	2513	2254	6393	1841	1609	1462	773	870	1385	1541	7689	640	HI
TOTAL	NC	SC	GA	FL	KY	TN	AL	MS	AR	LA	OK	TX	MT	
OUT-MIGRATION	451156	265013	450430	978135	279889	347872	272714	215407	206074	278116	265903	862230	106796	

Table B-1, continued

STATE OF ORIGIN

STATE OF DESTINATION

	ID	WY	CO	NM	AZ	UT	NV	WA	OR	CA	AK	HI	TOTAL	IN-MIGRATION
ME	68	113	1447	487	591	240	260	849	434	5497	574	755	ME	112670
NH	166	255	1172	233	894	416	238	807	341	4775	443	345	NH	158633
VT	30	117	691	199	328	109	22	282	166	2535	293	171	VT	68055
MA	391	184	3898	969	2391	877	727	2044	1403	20782	959	1602	MA	375613
RI	59	27	384	78	349	81	102	512	166	3583	47	428	RI	77907
CT	434	175	2197	722	1466	503	130	1530	954	14044	312	1596	CT	270848
NY	1343	620	8052	2346	6686	1566	1348	5474	2567	46140	1792	3056	NY	624078
NJ	161	287	3340	867	2802	675	1615	2050	711	20981	614	1865	NJ	539089
PA	770	397	4734	1786	4424	1148	1091	2607	1006	26065	1401	2944	PA	573592
OH	815	797	7478	2260	7649	1455	1383	3580	1608	34297	1536	2601	OH	570115
IN	587	350	4146	1441	5557	1096	714	2607	1197	19113	1049	2237	IN	384207
IL	881	925	12148	3438	10007	2465	2008	5601	3041	52733	1366	4043	IL	642389
MI	789	848	7637	1732	6284	1767	1172	4283	2175	32906	2296	2181	MI	440213
WI	745	507	5214	903	3317	791	507	2524	1756	16696	1162	1526	WI	290020
MN	943	827	8064	1105	4735	1185	972	5018	3475	22928	2341	1382	MN	274941
IA	568	720	7782	713	3490	643	686	2377	1321	16939	691	1096	IA	213026
MO	1414	1205	11517	2425	7681	1500	1442	4567	2664	41827	1637	1994	MO	429001
ND	520	815	2435	365	1072	837	117	1867	942	5400	589	445	ND	75988
SD	630	2153	3707	637	1227	425	284	1432	767	5291	512	257	SD	70504
NE	878	3515	12878	994	3148	1052	661	2428	1390	14902	769	1021	NE	152520
KS	1061	986	16497	2999	4906	1187	1456	3842	1781	22518	1564	1445	KS	275485
DE	15	80	630	63	527	148	23	336	179	1627	413	154	DE	73839
MD	404	284	3845	1409	2201	1245	592	3529	889	21707	1356	2934	MD	411716
DC	10	13	945	290	478	86	110	1591	334	5087	147	258	DC	98137
VA	1230	644	6932	2956	5385	2126	1424	6808	2461	44417	2983	9523	VA	694880
WV	167	272	1044	157	787	175	358	675	254	4323	271	532	WV	155865
NC	649	323	3917	1376	2712	888	809	3371	1346	23196	1766	2968	NC	538400
SC	643	276	2430	1555	1552	531	604	2162	667	12315	1167	2648	SC	331687
GA	524	711	4943	1215	3689	1243	984	4042	1475	24007	2440	3667	GA	581553
FL	1326	1125	11720	4818	9274	2052	3110	7732	3405	60531	3571	6810	FL	1801362
KY	632	250	2942	918	1791	565	396	1907	950	11819	919	1575	KY	302827
TN	509	226	3272	1139	2755	753	929	2244	1644	22572	1181	2337	TN	450858
AL	400	323	2959	909	2116	365	569	1736	698	13656	1330	1790	AL	319954
MS	167	432	1846	1071	1324	437	555	1283	778	10943	645	981	MS	213197
AR	653	597	4464	2181	5519	509	1372	2402	2261	27919	1292	883	AR	262214
LA	507	639	5039	2603	3619	936	1581	2402	1089	24136	1445	2202	LA	324666
OK	913	1826	12280	7504	8179	1939	1556	4756	3119	48439	2626	2124	OK	382721
TX	3768	4840	39952	44363	32217	7064	6546	17153	7145	160387	9050	11421	TX	1436237
MT	5491	4998	7264	870	2075	2708	1586	9783	4799	16414	2350	882	MT	108314
ID	0	2748	6302	1491	5314	13208	5770	20735	13455	43174	3100	1285	ID	170218
WY	2961	0	17994	2304	3588	6098	1196	2659	2102	11114	911	530	WY	120161
CO	4239	11313	0	14614	16855	10076	3884	9742	5810	76472	3954	4830	CO	551339
NM	1275	1977	16390	0	16371	4532	2023	3227	1734	29895	2080	1513	NM	206948
AZ	3969	2820	23695	15351	0	8795	6001	11423	9020	112005	3233	3267	AZ	598368
UT	16429	6232	12404	4434	12089	0	8491	7720	5576	52136	1675	2666	UT	203062
NV	3128	928	5955	2679	10825	5554	0	4960	4413	94620	1906	2108	NV	234606
WA	28366	3595	16377	4117	17056	9627	7500	0	71786	177466	21122	11807	WA	621101
OR	15504	2195	11640	2033	11044	6114	6797	58887	0	165157	10105	5392	OR	412552
CA	15801	6309	62957	25135	88708	26575	38384	72412	59339	0	14551	52149	CA	1877289
AK	1891	785	4017	1498	2721	1246	773	12070	5858	16700	0	1515	AK	105570
HI	1016	219	3081	1116	2905	1051	1059	6656	3245	40645	2114	0	HI	149919
TOTAL	ID	WY	CO	NM	AZ	UT	NV	WA	OR	CA	AK	HI		
OUT-MIGRATION	125840	72803	422654	176868	352680	136664	121917	340684	245696	1782831	121650	173741		

Appendix C

BASIC+2 COMPUTER PROGRAM FOR DATA ANALYSIS

kvalues.b20

```
00100 rem   kvalues.b20; Craig Bacino; U of Montana
00200 rem   November, 1985
00300 rem
00400 rem   THIS PROGRAM CALCULATES CONNECTIVITY VALUES,
00500 rem   k, FOR ALL PAIRS OF STATES.
00600 rem   TOTAL NUMBER OF MIGRANTS BETWEEN IS INDEXED
00700 rem   TO k VALUES FOR ALL PAIRS OF STATES.
00800 rem
00900      dim tm(51,51)
01000      dim e(51)
01100 rem   tm = total migration between two states
01200 rem   e = the total out-migration from a state
01300 rem   k = the connectivity value between two states
01400 rem   tmig80.in: input file listing total migration
01500 rem    between pairs of states
01600 rem   ststats.in: input file with state names and
01700 rem    migration data
01800 rem   percent.in: input file holding k values and
01900 rem    indexed number of migrants
02000 rem
02100      open "tmig80.in" for input as file #1
02200      open "ststats.in" for input as file #2
02300      for i = 1 to 51
02400         input #2,a$,b,c,d,e
02500         let e(i) = e
02600         for j = 1 to 51
02700            input #1,tm
02800            let tm(i,j) = tm
02900         next j
03000      next i
```

```
03100       close #2
03200       close #1
03300 rem
03400       open "percent.in" for output as file #3
03500       for i = 1 to 51
03600          for j = 1 to 51
03700             let k = tm(i,j) / (e(i) + e(j))
03800             print #3, using ".###########",k;
03900             print #3, ",";
04000             print #3,tm(i,j)
04100          next j
04200       next i
04300       close #3
04400 rem
04500       end
```

Appendix D

SOCIAL SURVEY

The social survey used in Chapter 4 is reproduced on the following pages of Appendix D.

INTRODUCTION

No.___

The purpose of this survey is to evaluate the effectiveness of maps depicting migration. The maps are part of an MA thesis (Department of Geography, University of Montana) that devises methods for depicting the interstate migration of people in the United States. Respondents have been chosen on the basis of their knowledge and expertise in either graphics/cartographics or the geographic movement of people. Survey results will be incorporated into the thesis. Respondents may be quoted within the thesis in a chapter on map evaluation.

Four maps are to be evaluated in this survey. Questions concerning the maps are divided into four parts:

* Part 1 asks questions about the content of each map. Map title and legend should provide sufficient information for reading each map and answering the questions. Respondents should not be overly concerned about answering all questions correctly. Some questions are purposely made difficult to answer. The purpose of the survey is to evaluate the maps, not the respondent.

* Part 2 asks questions about the form of each map after the respondent has had the opportunity to use the map in Part 1.

* Part 3 asks the respondent to rank the four maps, highest to lowest, in both 'EASE OF INTERPRETATION' and 'VISUAL APPEARANCE'.

* Part 4 collects background information about the respondent.

** PLEASE TURN THE PAGE **

2

MAP 1, Classless Choropleth Dot Map.

PART 1

1) For each of the pairs of states listed below circle the state with the higher migration ratio.

EXAMPLE***

FLORIDA - TEXAS

****

NORTH DAKOTA - SOUTH DAKOTA

KENTUCKY - TENNESSEE

DELAWARE - MARYLAND

MASSACHUSETTS - RHODE ISLAND

WASHINGTON - GEORGIA

IDAHO - FLORIDA

CALIFORNIA - CONNECTICUT

NEW HAMPSHIRE - NEW MEXICO

2) Rank the following four states from highest to lowest migration ratio:

WISCONSIN ______________ highest

CALIFORNIA ______________

NEW JERSEY ______________

LOUISIANA ______________ lowest

** PLEASE TURN THE PAGE **

MAP 1, continued

PART 2

Place an 'X' on the scale in the position which most closely matches your response.

EXAMPLE **

This map is: interesting___ ___ ___ ___ ___ ___ ___dull
7 6 5 4 3 2 1

****

1) Use of symbolism in this map is:

unique___ ___ ___ ___ ___ ___ ___conventional

2) Considering that quantitative measurements of migration cannot be derived from this map, for purposes of analysis the map is:

valuable___ ___ ___ ___ ___ ___ ___worthless

3) Including quantitative values in the presentation would make the map more:

useful___ ___ ___ ___ ___ ___ ___ineffective

4) Symbolism on this map and the topic of migration are:

compatible___ ___ ___ ___ ___ ___ ___incompatible

CONTINUED ON FOLLOWING PAGE

5) Using only map title and legend, reading this map is:

clear___ ___ ___ ___ ___ ___ ___confusing

6) For interpreting the pattern of migration, this map is:

stimulating___ ___ ___ ___ ___ ___ ___inhibiting

** STOP **

4

GENERAL IMPRESSIONS OF MAP 1

PART 2, continued

Having used the map, what are your FAVORABLE impressions of this map?

What are your UNFAVORABLE impressions of this map?

5

MAP 2, Nodal Region Flow Map

PART 1

1) What is the dominant state of the largest (in area) region of migration?

____

2) Which of the following states is a first level peripheral state?

___ IOWA

___ ILLINOIS

___ VIRGINIA

___ MINNESOTA

3) Migrants from which 2nd level peripheral state flow into the above 1st level peripheral state?

___ NEBRASKA

___ WISCONSIN

___ MARYLAND

___ NORTH DAKOTA

4) Each region of migration is contiguous.

___ TRUE ___ FALSE

CONTINUED OF THE FOLLOWING PAGE

5) If the answer for #4 is FALSE, then name the dominant state of a noncontiguous region of migration.

____

** PLEASE TURN THE PAGE **

6

MAP 2, continued

PART 2

Place an 'X' on the scale in the position which most closely matches your response.
EXAMPLE **
This map is: interesting___ ___ ___ ___ ___ ___ ___dull
7 6 5 4 3 2 1
****

1) Use of symbolism in this map is:

unique___ ___ ___ ___ ___ ___ ___conventional

2) Considering that quantitative measurements of migration cannot be derived from this map, for purposes of analysis the map is:

valuable___ ___ ___ ___ ___ ___ ___worthless

3) Including quantitative values in this map would make the map more:

useful___ ___ ___ ___ ___ ___ ___ineffective

4) Symbolism on this map and the topic of migration are:

compatible___ ___ ___ ___ ___ ___ ___incompatible

CONTINUED ON THE FOLLOWING PAGE

5) Using only map title and legend, reading the map is:

clear___ ___ ___ ___ ___ ___ ___confusing

6) For interpreting the pattern of migration, this map is:

stimulating___ ___ ___ ___ ___ ___ ___inhibiting

** STOP **

7

GENERAL IMPRESSIONS OF MAP 2

PART 2, continued No.____

Having used the map, what are your FAVORABLE impressions of this map?

What are your UNFAVORABLE impressions of this map?

8

MAP 3, Connectiviey Network Map

PART 1

1) Which of the following states is most isolated (un-connected) in the migration network?

___ ALASKA

___ DELAWARE

--- MICHIGAN

___ MAINE

2) Individual states with the most migration linkages tend to be in which half of the U.S.?

___ NORTHERN ___ SOUTHERN

3) There are more migration linkages between contiguous states for which section of the U.S.? (sections are delineated in yellow)

___ NORTHEAST ___ SOUTHEAST

4) Very strong migration linkages occur more frequently between contiguous states than between non-contiguous states.

___ TRUE ___ FALSE

CONTINUED ON THE FOLLOWING PAGE

5) Rank the three states with the greatest number of migration linkages.

______________ greatest number of linkages

______________ second greatest number of linkages

______________ third greatest number of linkages

** PLEASE TURN THE PAGE **

MAP 3, continued

PART 2

Place an 'X' on the scale in the position which most closely matches your response.
EXAMPLE **
This map is: interesting___ ___ ___ ___ ___ ___ ___dull
7 6 5 4 3 2 1
****

1) Use of symbolism in this map is:

unique___ ___ ___ ___ ___ ___ ___conventional

2) Considering that quantitative measurements of migration cannot be derived from this map, for purposes of analysis the map is:

valuable___ ___ ___ ___ ___ ___ ___worthless

3) Including quantitative values in the presentation would make the map more:

useful___ ___ ___ ___ ___ ___ ___ineffective

4) Symbolism on this map and the topic of migration are:

compatible___ ___ ___ ___ ___ ___ ___incompatible

CONTINUED ON THE FOLLOWING PAGE

5) Using only map title and legend, reading this map is:

clear___ ___ ___ ___ ___ ___ ___confusing

6) For interpreting the pattern of migration, this map is:

stimulating___ ___ ___ ___ ___ ___ ___inhibiting

** STOP **

10

GENERAL IMPRESSIONS OF MAP 3

PART 2, continued

Having used the map, what are your FAVORABLE impressions of this map?

What are your UNFAVORABLE impressions of this map?

11

MAP 4, Surface Relief Flow Map

PART 1

1) Indicate either the direction of net migration or the existence of a barrier to migration between the following pairs of contiguous states by using the symbols provided in the example below.
EXAMPLE ***
IDAHO WASHINGTON (flow from ID to WA)

IDAHO MONTANA (barrier)
****

NEW MEXICO	TEXAS
OHIO	PENNSYLVANIA
GEORGIA	FLORIDA
SOUTH DAKOTA	WYOMING
KENTUCKY	ILLINOIS
NEW HAMPSHIRE	VERMONT
NEBRASKA	SOUTH DAKOTA
NEW YORK	PENNSYLVANIA
NEBRASKA	IOWA
VIRGINIA	NORTH CAROLINA

CONTINUED ON THE FOLLOWING PAGE

2) Which is greater?

___ net migration from IDAHO to WASHINGTON

___ net migration from IDAHO to OREGON

___ cannot tell from this map

** PLEASE TURN THE PAGE **

MAP 4, continued

PART 2

Place an 'X' on the scale in the position which most closely matches your response.

EXAMPLE ***

This map is: interesting___ ___ ___ ___ ___ ___ ___dull
7 6 5 4 3 2 1

****

1) Use of symbolism in this map is:

unique___ ___ ___ ___ ___ ___ ___conventional

2) Considering that quantitative measurements of migration cannot be derived from this map, for purposes of analysis the map is:

valuable___ ___ ___ ___ ___ ___ ___worthless

3) Including quantitative values in this map would make the map more:

useful___ ___ ___ ___ ___ ___ ___ineffective

4) Symbolism on this map and the topic of migration are:

compatible___ ___ ___ ___ ___ ___ ___incompatible

CONTINUED ON THE FOLLOWING PAGE

5) Using only map title and legend, reading this map is:

clear___ ___ ___ ___ ___ ___ ___confusing

6) For interpreting the pattern of migration, this map is:

stimulating___ ___ ___ ___ ___ ___ ___inhibiting

** STOP **

13

GENERAL IMPRESSIONS OF MAP 4

PART 2, continued

Having used the map, what are your FAVORABLE impressions of this map?

What are your UNFAVORABLE impressions of this map?

14

RANK ORDERING OF MAPS

PART 3

Rank the maps, by identifying number (Map 2, etc.) according to:

	EASE OF INTERPRETATION	VISUAL APPEARANCE
highest	__________	__________
	__________	__________
	__________	__________
lowest	__________	__________

** PLEASE TURN THE PAGE **

BACKGROUND INFORMATION

PART 4

1) For which one of the following is your knowledge/ expertise more extensive?

___ graphics/cartographics

___ geographic movement of people

2) Do you use maps?

___ daily ___ yearly

___ weekly ___ never

___ monthly

3) Level of education:

___ HS ___ BA ___ MA ___PHD

4) Current occupation:

____

** THE END **

Thank you for your participation in this survey.

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* * * L P T S P L   R u n   L o g * * *

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19:29:15 LPDAT    Job THESIS sequence #738 on Printer 2 at  5-Jun-86 19:29:15
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21:42:16 LPMSG    Finished File PS2:<SCRATCH>THESIS.X27.3
21:42:16 LPEND    Summary:  436 Pages of Output
21:42:16 LPEND              146 Disk Pages Read
21:42:16 LPEND           77.980 Seconds CPU Time Used
21:42:16 LPEND        $   30.52 [Approximate] Printer Charges
21:42:16 LPEND        $    2.26 [Approximate] Printer Balance
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