12-1978

An Analysis of Locational Aspects of the Portland Cement Industry in Kentucky

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1978

AN ANALYSIS OF

LOCATIONAL ASPECTS OF THE

PORTLAND CEMENT INDUSTY

IN KENTUCKY

A Thesis

Presented to

the Department of Geography and Geology

Western Kentucky University

Bowling Green, Kentucky

In Partial Fulfillment

of the Requirements for

the Degree of

Master of Science

by

Wayne F. Perkins

December, 1978

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AN ANALYSIS OF LOCATIONAL ASPECTS OF THE PORTLAND CEMENT INDUSTY IN KENTUCKY

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ACKNOWLEDGEMENTS

I would like to take this opportunity to thank all those who aided me in this study.

Particularly, I would like to thank the chairman of my committee, Dr. James W. Taylor, for his time and encouragement. Also, I would like to thank Dr. Ronald R. Dilamarter and Dr. C. Ronald Seeger for their aid and valuable contributions.

Further, I would like to thank my typist, Freda Mays, for her continued efforts in my behalf.

And most particularly, I would like to thank my mother, Edith Perkins Alpe, who was the real motivating force behind this thesis.

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Factors affecting the spatial distribution of the Portland cement industry are discussed and applied to Kentucky. Cement is found to be both raw material and market oriented and to be highly sensitive to transportation costs. Several areas in Kentucky are found to have the necessary raw materials for cement. However, only one of these sites, Louisville, has sufficient markets to support cement production; this area is served by two factories. There are no unused sites suitable for cement production in Kentucky. The Lexington area has the potential of being able to support cement production by the year 2020.

CHAPTER I

INTRODUCTION

Portland cement occupies a prominent position among construction materials. It is basic to the building industries, being used as the binding agent in concretes and mortars. In the form of mortar, Portland cement is used in most masonry structures. In the form of concrete, it is used in dams, bridges, building blocks, drainage or conduit tiles, paving for highways, and a number of other similar purposes. Because of its varied functions in construction, the cement industry is very important to the industrial economy.

It is the purpose of this thesis to apply the factors which affect the location of cement factories to Kentucky in order to learn which sites in the state are favorable for such factories. By comparing these sites to actual plant locations, it can be determined if there are suitable sites as yet unused. This analysis will then be used to consider the feasibility of locating a cement factory in the Bowling Green-Warren County area.

JUSTIFICATION

No known published report on Kentucky cement industry has previously analyzed it from an integrated market-resource standpoint. If the feasibility of new or expanded cement factories is established, this information could be significant in planning the state's economic development.

PREVIOUS WORK DONE ON THE SUBJEC

A search of the major geographic and cement industry journals and dissertation indices available in the Western Kentucky University Library, and the Western Kentucky University Library stacks, as well as correspondence with the Kentucky and United States Department of Commerce and the major cement organizations revealed few relevant publications. Only two works were found in the Western Kentucky University Library that dealt even in part with the theoretical optimum locations of cement factories. The first is Riley's Industrial Geography (1973). The second is Lukermann's article, "The Geography of Cement?", which was published in the July, 1970 issue of The Professional Geographer. Both emphasize the minimum cost idea in choosing cement factory locations. Transportation and proximity to raw materials and markets were named as the critical factors.

Morrison's (1944) study of cement factory locations describes the cement industry of the Great Lake region. Three papers obtained from the Kentucky Department of Commerce describe the cement raw materials of Kentucky (Eckel, 1913 and 1905; McGrain and Devers, 1968). Correspondence with two cement producing companies elicited their criteria for choosing factory locations.

In spite of the literature and correspondence cited above, no works of any sort were found which dealt with cement factory locations from the approach used in this thesis.

General data on the cement industry were obtained from books and journal articles in the Western Kentucky University Library. Data on the cement industry of Kentucky and its potential were obtained from various editions of Minerals Yearbook, from the Kentucky Department of Commerce, and from telephone calls to cement making and using industries in the state.

PROCEDURE

General data on cement will be presented first. Then, factors that affect the location of cement factories on a national level will be considered. Next, Kentucky cement resources will be presented. Finally, this data will be used to determine favorable cement factory locations. The Bowling Green-Warren County area will be specifically examined to determine its suitability as a cement factory site.

CHAPTER II

THE NATURE OF CEMENT

> "For constructional purposes a cement is a material capable of developing, after appropriate reactions have taken place, those adhesive and cohesive properties that make it possible to bond together mineral fragments to produce a hard compact mass of masonry." (Troxell, Davis, and Kelly, 1968, p. 10).

A variety of materials has been used for cements. The nature of the materials used affects the use to which the cement will be put, as well as the quality of the cement. There are two major base materials used in the cements important in the construction industry. They are the bituminous or asphalt materials and the calcareous materials. These materials are mutually exclusive; they do not both appear in the same cement (Larson, 1968, p. 9-17, 157-160).

Bituminous binders are asphalts which are naturally occurring petroluem products or refined petroleum derivatives. They are used for binding aggregates into asphaltic masses (Larson, 1968, p. 157). Asphalt cement is asphalt, or bituminous binder, refined to paving specifications (Larson, 1968, p. 160).

Calcareous cements are cements which contain lime (CaO) as their basic ingredient (Troxell, Davis, and Kelly, 1968, p. 10). Hydraulic calcareous cements are calcareous cements that set upon the addition of water (Troxell, Davis, and Kelly, 1968, p. 10; Larson, 1968, p. 12; Ladoo and Myers, 1951, p. 129-130). High alumina cements are hydraulic calcareous cements which contain large amounts of alumina (Al_2O_3) (Troxell, Davis, and Kelly, 1968, p. 38; Ladoo and Myers, 1951, p. 91). Heat of hydration is the heat generated by the chemical reactions that take place during the setting of hydraulic calcareous cements; the amounts of heat liberated can be quite large (Larson, 1968, p. 35).

Concrete is made by mixing aggregate materials into cement (Larson, 1968, p. 168). Aggregate materials consist of the relatively inert filler in a concrete (Troxell, Davis, and Kelly, 1968, p. 10, 60; Larson, 1968, p. 9, 157). Unlike cement, concrete is not divided into specific types beyond asphaltic and calcareous types. The types of cement and aggregate materials and their proportions are determined to fit the job. Specialized concretes are based on specific types of cements, and applications of concretes to jobs will be mentioned as necessary under the type of cement involved.

BITUMINOUS BINDERS AND ASPHALT CEMENTS

Asphaltic materials have been known and used since ancient times, having been used as a mortar and water proofer since about 3800 B.C. asphalt cements and concretes are not presently used in heavy construction, because they lack the strength of calcareous cements. However, they have extensive applications for paving, waterproofing, and roofing. For paving and roofing, they are mixed with aggregates to form asphaltic concretes (Larson, 1968, p. 193). The distribution of asphalt production is closely linked to the distribution of the petroleum refining industry.

CALCAREOUS CEMENTS

Primitive Cements. Egyptians, Minoans, and other early civilizations made extensive use of stone masonry construction, sometimes using mortars, which at some time evolved into crude cements and concretes. The Romans made a crude cement from volcanic ash in an area around Pozzuoli in Southern Italy, about 2,000 years ago. Some of the structures made from this material are still standing (Larson, 1968, p. 9-11; Ladoo and Myers, 1951, p. 128).

In 18th century England it was recognized that certain limestones containing clay and sand could be calcined, or heated, and then ground to a fine powder, after which they would set upon the addition of water. These limestones are called hydraulic limes. A similar material was obtained by adding clay and sand to other limestones. This product is called natural cement. Natural cements were first produced in the United States in central New York in 1818 (Larson, 1968, p. 9-11; Ladoo and Myers, 1951, p. 128-129; Troxell, Davis, and Kelly, 1968, p. 10).

Portland Cement. Not much natural cement or hydraulic lime is produced today as they have been superseded by the superior Portland cement. Today Portland cement is the most important of all the cements (Troxell, Davis, and Kelly, 1968, p. 10; Larson, 1968, p. 1; Bureau of Mines, Vol. II, 1972).

Portland cement is made from the same materials as natural cement. The difference is that Portland cement is calcined at much higher temperatures. The Portland cement process was patented in 1824 in Leeds, England, by Joseph Aspdin. The name Portland cement comes from the resemblance of the set material to the then well-known and widely used building limestone called Portland stone. The first Portland cement produced in the United States was produced in the Lehigh Valley in Pennsylvania in 1875 (Troxell, Davis, and Kelly, 1968, p. 10; Larson, 1968, p. 9-11; Ladoo and Myers, 1951, p. 128-129).

Manufacture of Portland Cement. The essential ingredients of both natural and Portland cements are lime (CaO) and silica (SiO_2). After the manufacturing process, these materials react to form hydrated calcium silicates (Troxell, Davis, and Kelly, 1968, p. 10; Larson, 1968, p. 9; Ladoo and Myers, 1951, p. 129).

The first step in making Portland cement is to grind together the raw materials. Raw materials are described in the next section. The grinding may be done by either wet or dry processes. The next step is to place the mixture into a rotary kiln and heat it to a point just short of melting. Finally, the resulting clinker-like material, called clinker, is ground together with gypsum to form the finished product (Troxell, Davis, and Kelly, 1968, p. 18-21; Larson, 1968, p. 9-11; Ladoo and Myers, 1951, p. 129-31; Morrison, 1944, p. 36).

High Alumina Cement. The essential ingredients of high alumina cements are lime (CaO) and alumina (Al_2O_3). The normal composition of high alumina cement is 40% lime, 40% alumina, 10% silica, and 10% iron oxides. This composition is usually made up by a mixture composed of equal amounts of limestone and bauxite. The ratios can be varied for different purposes (Troxell, Davis, and Kelly, 1968, p. 58; Ladoo and Myers, 1951, p. 91-92).

High alumina cement sets quickly, attaining the same strength in 24 hours that normal Portland cement attains in 28 days. It has a pronounced resistance to high temperature and chemical attack.

Off-setting these advantages, it has a very high heat of hydration requiring cooling for proper curing, and it is expensive in comparison to Portland cement. Therefore, fast setting or sulfate-resistant varieties of Portland cement are used in applications where fast setting is needed and the special properties of high alumina cement are not required (Troxell, Davis, and Kelly, 1968, p. 58; Ladoo and Myers, 1951, p. 91-92). The various types of Portland cement will be discussed later.

PORTLAND CEMENT RAW MATERIALS

Most Important Raw Materials. The most important raw materials of Portland cement are limestone, clay or shale, gypsum, and a heat source. For 1,000 barrels of cement, weighing 376 pounds apiece, 225 tons of limestone and 75 tons of clay or shale are heated by 60 tons of coal or an equivalent amount of other fuel, with 5 tons of gypsum added after heating. Using coal, nearly two tons of raw materials are required to make one ton of cement. The ratio calculated from the above data is 1.94 to 1. The ratio of raw materials to finished product varies when other fuels are used, but the relative amounts of limestone, clay or shale, and gypsum do not vary substantially (Troxell, Davis, and Kelly, 1968, p. 10; Larson, 1968, p. 12-15; Ladoo and Myers, 1951, p. 129; Morrison, 1964, p. 36; Riley, 1973, p. 55).

Another cement raw material is blast furnace slag. It can substitute partly or wholly for the limestone and sometimes for some of the clay or shale. When slag is substituted for clay or shale as well as limestone the cement is of low grade and it is known as slag cement. Portland cement in which slag is used instead of limestone only is as good as the limestone variety. The decision whether to use limestone or slag in this case is a matter of cost and availability rather than quality of product (Troxell, Davis, and Kelly, 1968, p. 56; Ladoo and Myers, 1951, p. 129; Morrison, 1944, p. 39).

A variety of Portland cement, called Portland blast furnace slag cement, is produced by grinding blast furnace slag along with the Portland cement clinker and gypsum (Troxell, Davis, and Kelly, 1968, p. 56).

The limestones used for cement manufacturing are high calcic limestones with little magnesia or other impurities. For cement making purposes, limestones composed of 90% or more calcite ($CaCO_3$) are preferred. Magnesia content, usually in the form of dolomite ($Ca,Mg(CO_3)_2$), must be less than 5%. Some high silica limestones may be made suitable for cement making by removing excess silica by a flotation process. Costs of such processing may be offset by savings in fuel and grinding costs (Troxell, Davis, and Kelly, 1968, p. 35; Ladoo and Myers, 1951, p. 129, 131; Morrison, 1944, p. 37).

Other Cement Raw Materials. Some, although not much, Portland cement is made from cement rock, which is limestone containing clay minerals already present in near proper proportions for cement making. This material is little used today because the composition varies too much for proper quality control in the finished product. It is not clear whether or not cement rock is the same as the hydraulic lime previously mentioned. Minerals Yearbook, 1972, Vol. II, mentions the use of cement rock specifically only in Ohio, Pennsylvania, and Texas. Marl, as well as limestone, is used as a lime material in Virginia. Oyster shells are used as a lime source in at least one Louisiana factory.

Aragonite ($CaCO_3$) dredged from the floor of the Caribbean is used as a lime source in Florida (Troxell, Davis, and Kelly, 1968, p. 18; Larson, 1968, p. 12; Bureau of Mines, Vol. II, 1972, p. 185, 328, 609-610, 697-698, 737-738).

TYPES OF PORTLAND CEMENT

There are five basic types of Portland cement, numbered I through V. The differences are in the proportions of the ingredients (see table I). Type I is General Purpose cement. Type II is Modified General Purpose cement. Type III is High Early Strength cement. Type IV is Low Heat cement. Type V is Sulfate Resistant cement (Ladoo and Myers, 1951, p. 131-132; Larson, 1968, p. 14; (Troxell, Davis, and Kelly, 1968, p. 12-13).

Portland cement is composed of four major compounds - tricalcium silicate ($3CaO \cdot SiO_2$, abbreviated C_3S), dicalcium silicate ($2CaO \cdot SiO_2$, abbreviated C_2S), tricalcium aluminate ($3CaO \cdot Al_2O_3$, abbreviated C_3A), and tetracalcium aluminoferrite ($4CaO \cdot Al_2O_3 \cdot Fe_2O_3$, abbreviated C_4AF). Varying the proportions of these compounds results in the different types of Portland cement (see tables I and II; Larson, 1968, p. 17; Troxell, Davis, and Kelly, 1968, p. 13). The calcium is supplied by the limestone or other lime material. The alumina and silica come from the clay materials. Iron may be from impurities in the raw materials or added separately (Larson, 1968, p. 17; Troxell, Davis, and Kelly, 1968, p. 13-16).

Type I cement is the most used cement. It is ordinary Portland cement which is used when no special properties are required. It is the most readily available type of cement (Larson, 1968, p. 14; Troxell, Davis, and Kelly, 1968, p. 13).

TABLE I

COMPOSITION OF CEMENTS

Cement Type		C_3S	C_2S	C_3A	C_4AF
I	General Purpose	49	25	12	8
II	Modified General Purpose	46	29	6	12
III	High Early Strength	56	15	12	8
IV	Low Heat	30	46	5	13
V	Sulfate Resistant	43	36	4	12

After Larson, 1968, p. 27

TABLE II

CHARACTERISTICS OF MAJOR COMPONENTS OF PORTLAND CEMENT

Property	C_3S	C_2S	C_3A	C_4AF
Rate of Reaction	Medium	Slow	Fast	Slow
Heat Liberated per Unit of Compound	Medium	Small	Large	Small
Strength per Unit of Compound				
Early	Good	Poor	Good	Poor
Ultimate	Good	Good	Poor	Poor

After Larson, 1968, p. 28

C_3S - $3CaO \cdot SiO_2$
C_2S - $2CaO \cdot SiO_2$
C_3A - $3CaO \cdot Al_2O_3$
C_4AF - $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$

Type II cement has a lower heat of hydration and a higher resistance to sulfate attacks than Type I. It gains strength more slowly than Type I. It is used where moderate resistance to sulfate attacks or a somewhat lower heat of hydration than that of Type I is desired. It is intermediate in properties between Type I and Types IV and V. It is widely used and readily available in some parts of the country (Larson, 1968, p. 14; Troxell, Davis, and Kelly, 1968, p. 13).

Type III cement is used in situations where quick setting is necessary, as in emergency repairs on rush jobs. It is also used for cold weather work, perhaps due to its high heat of hydration. Partially because of its use in repair work, it is readily available (Larson, 1968, p. 14-15; Troxell, Davis, and Kelly, 1968, p. 13).

Type IV cement is used where heat of hydration must be kept to a minimum. It is a special order material (Larson, 1968, p. 15; Troxell, Davis, and Kelly, 1968, p. 13).

Type V cement is used where high resistance to sulfate attack is necessary. It is much used in irrigation ditches and similar applications in the western part of the United States. It is a special order material (Larson, 1968, p. 15; Troxell, Davis, and Kelly, 1968, p. 13).

Type IV and Type V cements are not quite as strong as Type I cement (Larson, 1968, p. 15; Troxell, Davis, and Kelly, 1968, p. 13).

Derivatives of Types I, II, and III cements are Types IA, IIA, and IIIA cements. These are air entraining cements. Ingredients are added to capture air bubbles in the cement mass. Air entraining cements are used when exposure to severe frost action is expected (Larson, 1968, p. 14-15; Troxell, Davis, and Kelly, 1968, p. 13).

PORTLAND CEMENT DERIVATIVES

Three special derivatives of Portland cement are pozzolan, expansive, and masonry cements. These cements are made by adding the appropriate materials to Portland cements.

Pozzolan Cement. Lime (CaO) is liberated during the setting of normal Portland cements, up to 30% by weight. Under proper conditions, this lime may be leached out, causing the cement mass to disintegrate. Pozzolan cements are used to solve this problem. Pozzolan cements are made by adding pozzolanic materials, such as pumicite or diatomaceous earth, to normal Portland cements. The pozzolanic materials react with the liberated lime to form a relatively strong and stable calcium silicate that will not leach out. Portland pozzolan cements contain from 10% to 50% pozzolanic materials, with 25% the most common proportion (Ladoo and Myers, 1951, p. 128; Larson, 1968, p. 12; Troxell, Davis, and Kelly, 1968, p. 55).

Expansive Cements. Ordinary Portland cements contract while setting and may crack if they are prevented from contracting. Expansive cements do not have this characteristic. They are made by adding sulfoaluminate substances to Portland cement to offset the contraction. This type of cement is useful in making prestressed and cast concretes (Troxell, Davis, and Kelly, 1968, p. 57-58).

Masonry Cement. Masonry cement is the type used for mortars and similar applications. Ordinary Portland cement is not sufficiently plastic for this. Materials can be added to Portland cement to make masonry cement. These materials include chalk, limestone dust, talc, or clay, singly or in combination. Masonry cements can also be made by adding these materials to Portland pozzolan cement, natural cement, and hydraulic lime. The Portland cement based masonry cements are quantitatively the most important. Masonry cement is considered to be of sufficient importance to warrant extended discussion in Minerals Yearbook; Portland cement is the only other kind of cement thus included (Troxell, Davis, and Kelly, 1968, p. 56-57; Bureau of Mines, Vol. II, 1972).

CHAPTER III

LOCATIONAL FACTORS OF THE NATIONAL CEMENT INDUSTRY

THEORIES OF INDUSTRIAL LOCATION

Theories of industrial location fall into five main groups or schools: the least cost school, the transport cost school, the market area school, the marginal location school, and the behavioral school (Riley, 1973, p. 7-8).

The Least Cost School. The least cost school is the first of the five to be developed. Markets and labor are assumed to occur at points where both are assumed to be unlimited. Only three general factors of location are assumed: transport costs, labor costs, and agglomeration tendencies. These factors are used to find the location of least manufacturing cost. Transport cost is used as the basic factor with adjustments made to accommodate the labor cost and then the agglomeration tendency factors (Riley, 1973, p. 7-15).

The Transport Cost School. The least transport cost school is heavily influenced by the least cost school. It postulates a single manufacturer using a single raw material to produce a commodity sold in a single market area with no limit to demand. There are three types of costs: procurement costs, production costs, and distribution costs. Procurement and distribution costs are influenced by transportation costs. The various factors of transportation costs are extensively studied. The weight loss involved in the manufacturing process as well as various types of transportation pricing policies are included in transportation cost analysis. The facotry is located at the point of least transport cost to serve the entire market area (Riley, 1973, p. 15-21).

The Market Area School. The market area school is based on the idea of maximizing profits rather than minimizing costs. Limited demand is assumed. Transportation costs, production costs, size of markets, and demand as a function of price are all used as criteria in determining market areas. Plants are located to serve as many consumers as possible at the least possible cost, thus maximizing profits (Riley, 1973, p. 21-26).

The Marginal Location School. The marginal location school is a small one when compared to the others. Its basic idea is that entrepreneurs establish factories at particular points for a variety of reasons, many of which have nothing to do with traditional industrial location factors. It is considered unusual for a plant to be at a theoretic optimum location. For most entrepreneurs, there are only areas of profit and areas of loss. The marginal location school is concerned with the boundaries, or margins of such areas. The costs that vary with location are examined to identify the areas of profit and determine their boundaries (Riley, 1973, p. 26-30).

The Behavioral School. The behavioral school is similar to the marginal location school in that it takes into account the decisions of individuals. The behavioral school regards subjective decisions of individuals as a vital part of the processes of industrial location. In general, the entrepreneurs with the best information and who make the best decisions will locate plants at the most profitable locations (Riley, 1973, p. 30-32).

APPLICATIONS OF THEORY TO THE CEMENT INDUSTRY

Cement has been almost completely standardized since 1922. There is little or no individuality of product. Sales competitiveness is based almost solely on the price, requiring minimization of manufacturing and distribution costs. This requires transportation costs to be as low as possible, which requires that production sites be as close as possible to markets (Lukermann, 1960, p. 6-7; Riley, 1973, p. 56-62; Louisville Cement Company, 1978, letter; Flintkote Company, 1978, letter).

Other aspects of the cement industry require that cement factories be located as close as possible to sources of raw materials, especially lime. Calcareous cements are low value, bulky commodities; their raw materials even more so. Cements are low value added commodities; the manufacturing process adds relatively little value to the raw materials. Cement loses up to 37% of the weight of its raw materials when processed from dry limestone. The percentage weight loss is even greater when wet limestone or chalk is used. These loss of weight figures do not include fuel. Limestone and other lime materials are heavy, bulky and cheap; therefore, they are relatively expensive to transport. Transportation costs are usually but not always related to distance; cost is the relevant factor in transportation (Lukermann, 1960, p. 1-2; Morrison, 1944, p. 36, 39-40; Riley, 1973, p. 59-62; Flintkote Company, 1977, letter; Louisville Cement Company, 1977, letter).

The distribution of the cement industry follows that of its principal customer, the construction industry, which in turn follows the distribution of population (Isard and Whitney, 1969, p. 161). In the cement industry, as elsewhere, maximum profits require minimum costs. Therefore, optimum cement industry location is best considered from the least cost theory, which takes into account transportation costs and the tendency of cement plants to agglomerate in areas of high population. The markets, usually cities, may be considered as points, which fit in well with least cost theory. Therefore, optimum plant locations will be considered to be those where total costs are minimized. The least cost theory does not deal with market area; market area theory does. As previously mentioned, for market area theory, factories are located so as to serve as many customers as possible. For cement, market areas are determined by least transportation cost, reminiscent of the least cost theory. In general, therefore, the criterion for cement factory location is to minimize costs of production, raw materials, and transportation.

It can be seen from the above discussion that cement is both market and raw material oriented due to the necessity of minimizing transportation costs. This dual orientation is in part made possible by the widespread availability of cement raw materials (Riley, 1973, p. 59-62).

ECONOMIC FACTORS

Market Factors. Cement factories are almost always built in or near population centers, due to the market orientation of cement. Population centers are the major markets for cement. Construction of large dams in sparsely populated areas requires large amounts of cement, but for such jobs, the demand is temporary; therefore, such jobs have no significant effect on cement factory location (Lukermann, 1960, p. 1; Morrison, 1944, p. 45; Riley, 1973, p. 59-62; Isard and Whitney, 1969, p. 161).

An advantage of locating factories in population centers is the reduced transportation cost to markets. Advantages not directly connected to cement production are: transportation facilities are already in place; a labor pool is available; housing and other facilities for workers (or the means to quickly construct them) are present; and the labor force and materials for factory construction are available (Lukermann, 1960, p. 3-4; Morrison, 1944, p. 45).

Cement produced in urban areas can in many cases be loaded onto trucks and delivered directly to the job. Direct delivery replaces the more usual multimode transport with its numerous transfers used over longer distances, thus effecting considerable savings in transportation costs (Lukerman, 1960, p. 3-4; Morrison, 1944, p. 45).

Transportation Factors. Cement factories are usually located on transportation facility junctions. This is necessary to gather raw materials and distribute the finished product. Cement factories located in cities are automatically on transportation junctions (see figures I, II, III, IV, and V). Of necessity cities usually have well developed transportation facilities. Usually these facilities contain junctions of two or more different routes. Cement factories built in cities have easy access to these transportation facilities. The figures referred to above show how both cities and cement plants tend to coincide with junctions of transportation routes.

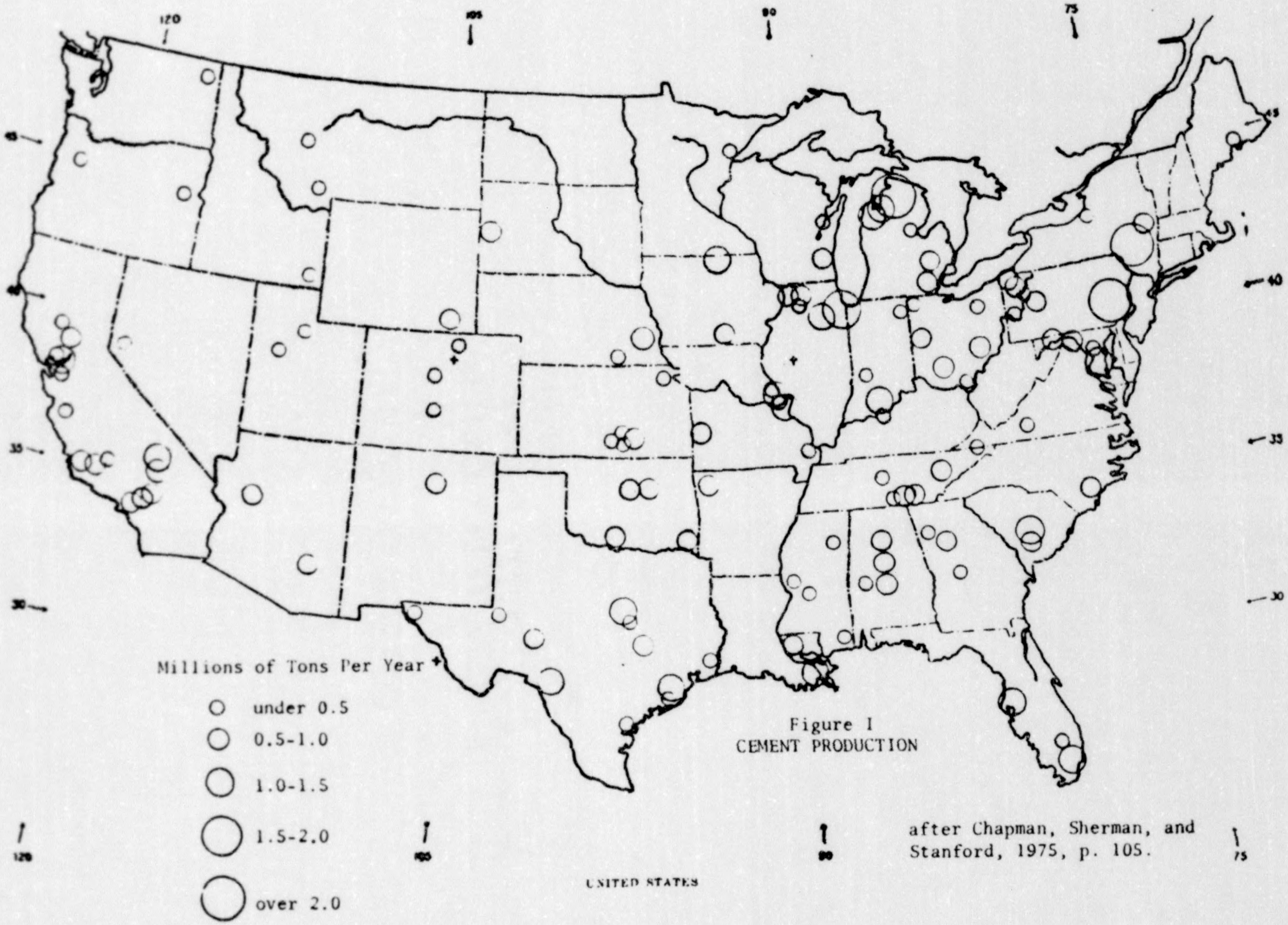

Figure I
CEMENT PRODUCTION

after Chapman, Sherman, and Stanford, 1975, p. 105.

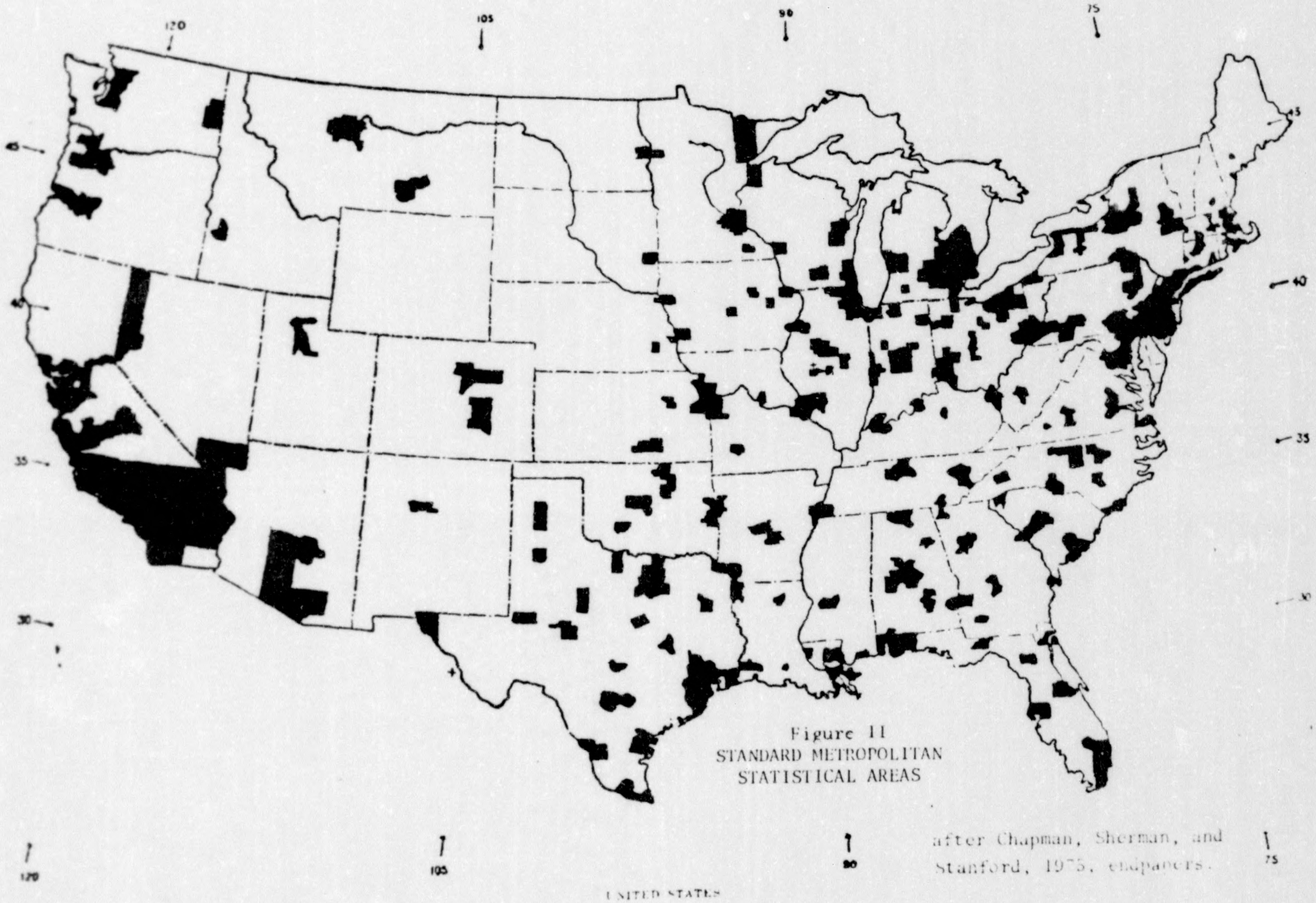

Figure 11
STANDARD METROPOLITAN
STATISTICAL AREAS

after Chapman, Sherman, and
Stanford, 1975, endpapers.

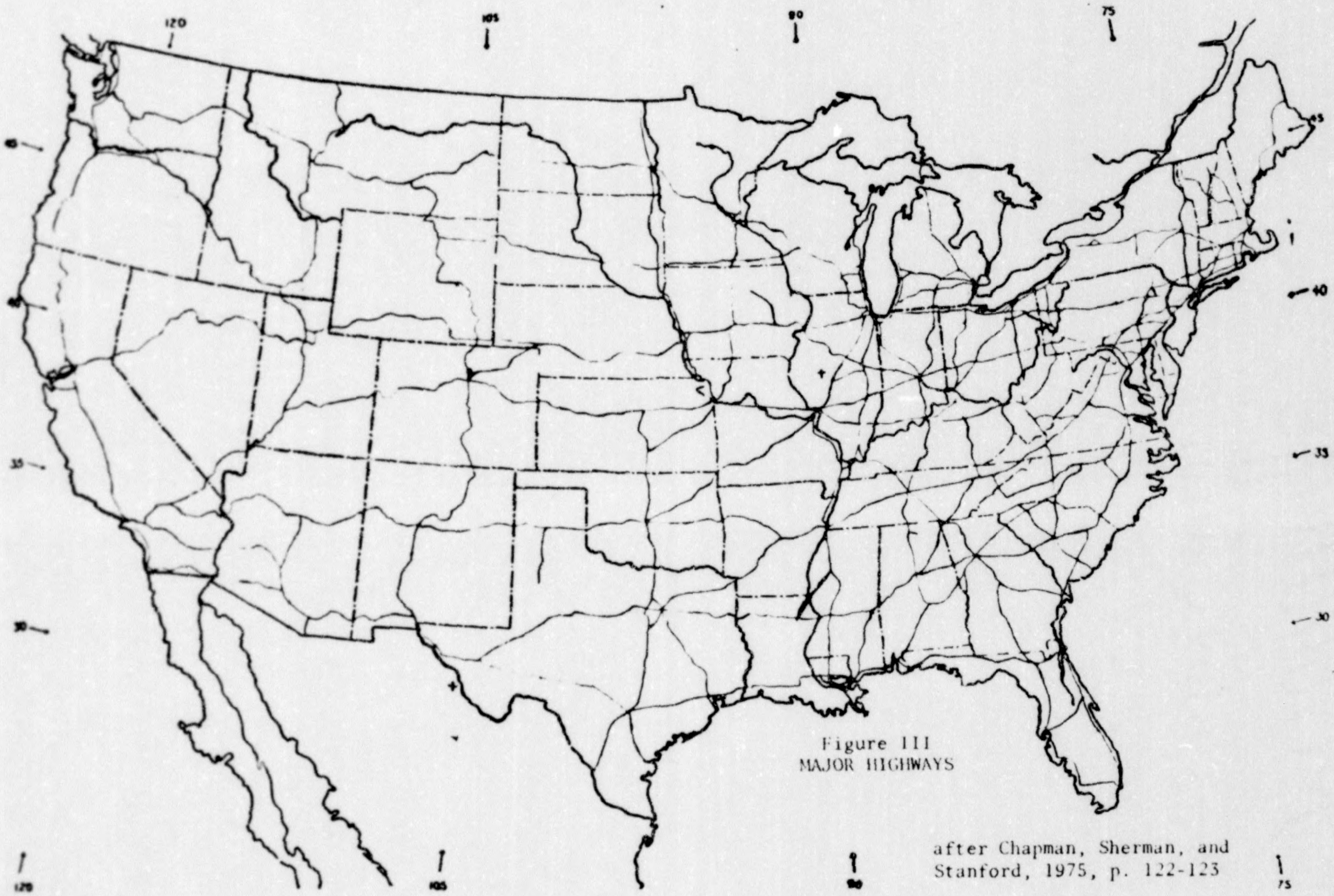

Figure III
MAJOR HIGHWAYS

after Chapman, Sherman, and
Stanford, 1975, p. 122-123

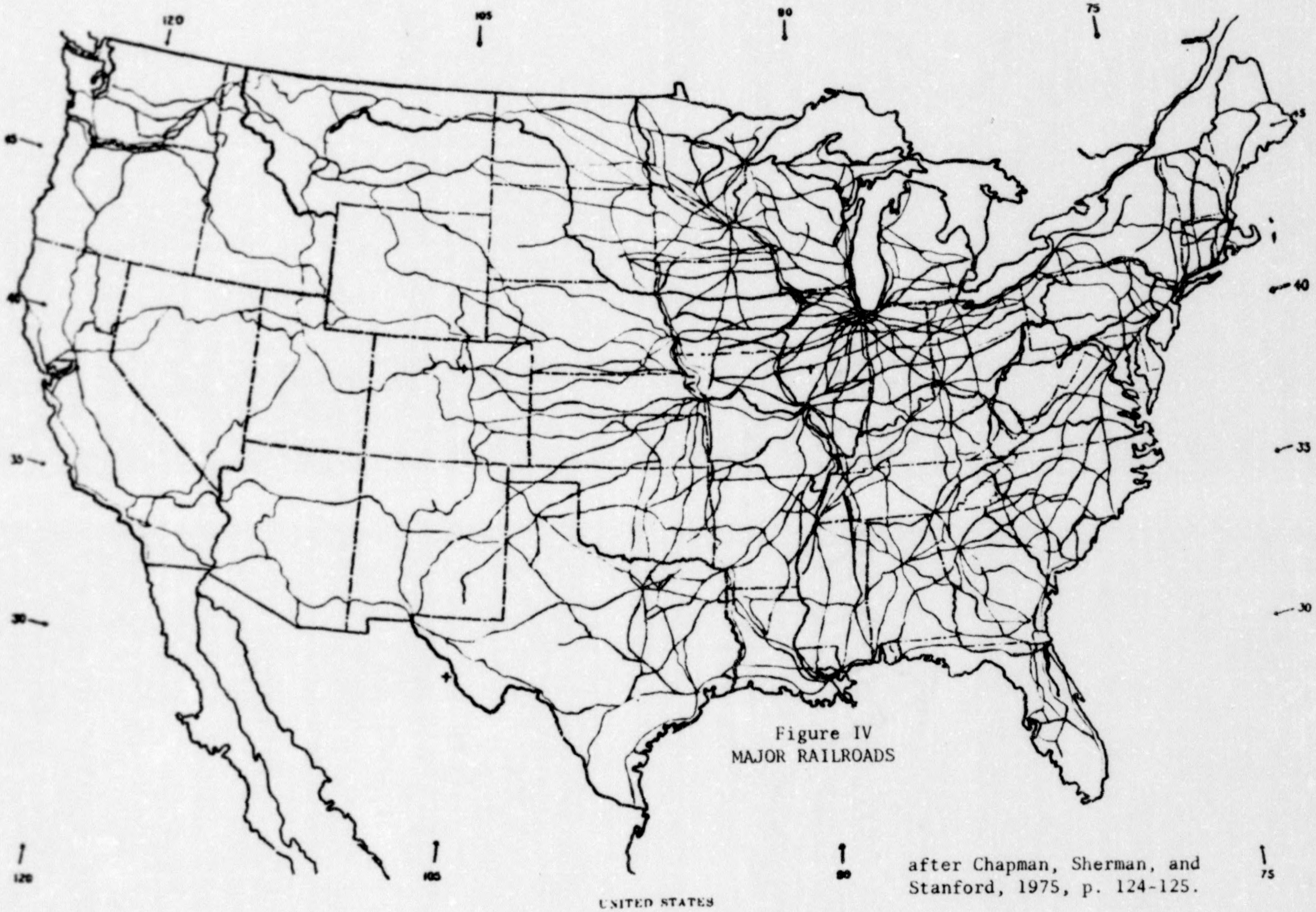

Figure IV
MAJOR RAILROADS

after Chapman, Sherman, and
Stanford, 1975, p. 124-125.

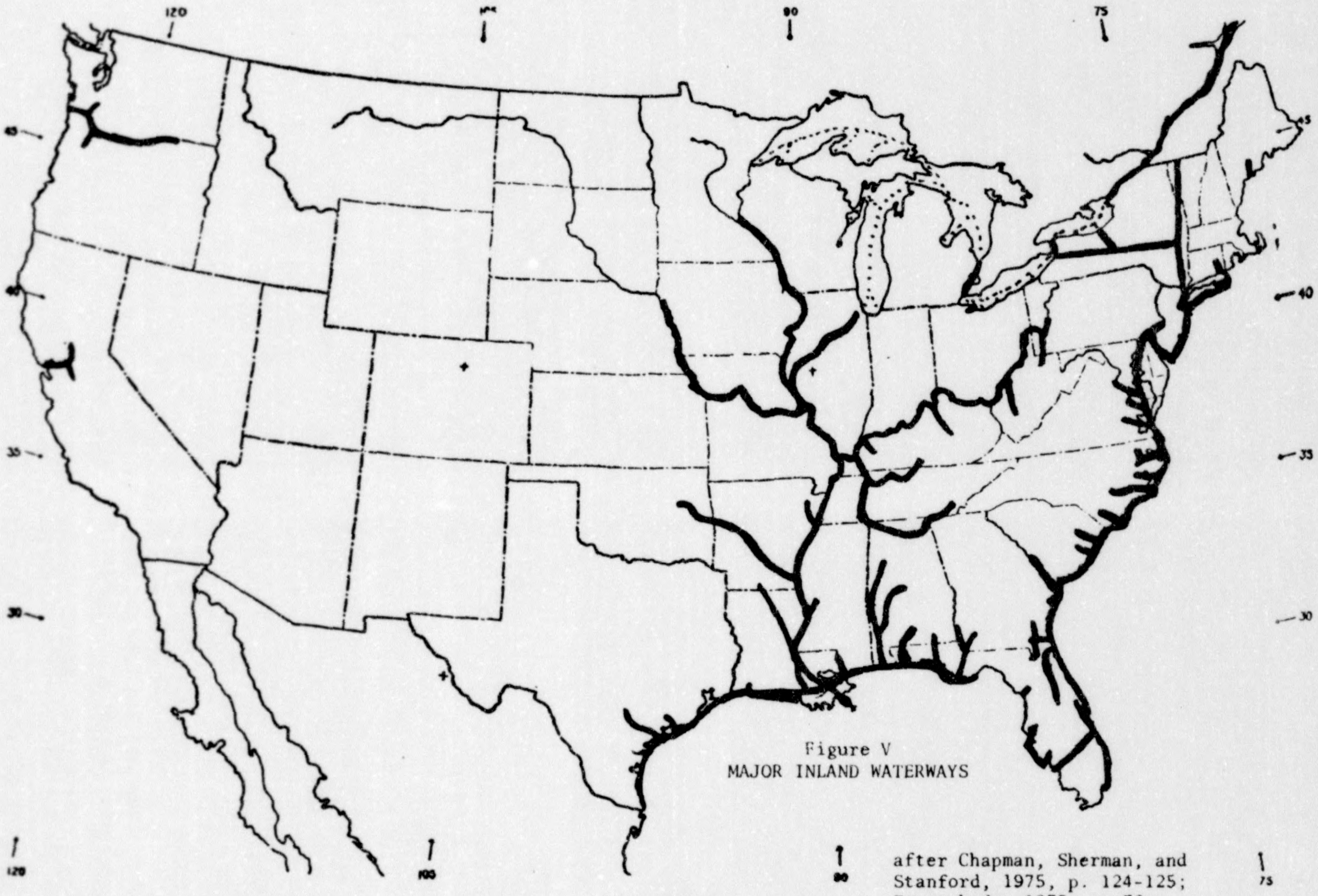

Figure V
MAJOR INLAND WATERWAYS

after Chapman, Sherman, and
Stanford, 1975, p. 124-125;
Espenshade, 1975, p. 72.

The increases in transportation costs of some raw materials caused by plant location in urban areas rather than near sources of raw materials may be offset by reductions in the transportation costs of other raw materials and by relatively low costs of transporting cement to markets. Cement must be protected from the weather as exposure to moisture will cause it to set. Limestone needs no such protection. The cost of protecting the cement may more than offset the difference in transportation costs between cement and limestone. Thus, it may be more economical to transport stone relatively long distances to the factory rather than shipping cement long distances to market (Morrison, 1944, p. 39-40, 45).

The important factor in transportation is not distance but cost. Different modes of transportation have different costs. The cheapest form of transportation is by water; the most expensive is by truck. Rail transportation is intermediate.

An example of the importance of cost over distance is the cement industry of the Great Lakes Region. The Great Lakes cement industry is spatially spread out. Markets, raw materials, and factories are not usually close together. The two major lime sources are limestone from Michigan and blast furnace slag from the steel mills around the Great Lakes. The slag using factories are in the steel making cities, placing them close to both raw materials and markets. The limestone using factories are scattered throughout the Great Lakes region with the greatest concentration being near the western three lakes. Some are located in or near population centers; others are located at the heads of transportation routes to the interior. Still others are located away from major population center and transportation terminals. This great spatial spread is made possible by the cheapness of water transportation. As far as cost is concerned, every point on the Great Lakes is adjacent to every other point. For this reason, it is economical to ship raw materials long distances to factories and to ship cement long distances to markets (Morrison, 1944, p. 40-46).

Rail and water transportation are used for long distance hauling of large quantities of cement. Water transportation is preferred; rail transportation is used when suitable waterways are not available. Truck transportation is generally used for short hauls of small amounts of cement. Truck transportation is used almost exclusively for factory to job or terminal to job hauling. Rail and water transportation methods are used mostly for factory to terminal movements, although some of this is done by truck. Some hauling directly to the consumer is done by water or rail (see table III; Bureau of Mines, Vol. I, 1972, p. 270).

RAW MATERIALS FACTORS

Limestone. Limestone and lime sources in general exert the greatest influence of raw materials on factory location. Lime is the major ingredient of cement and has a high weight loss in the cement manufacturing process. It is a heavy, bulky, cheap material with relatively high transportation costs; the transportation costs are high compared to the actual value of the lime. It is desirable, therefore, to locate cement factories as close as possible to lime sources to minimize transportation costs of lime. To be useful, lime sources must be economically recoverable. Limestone, to be useful,

TABLE III

SHIPMENTS OF PORTLAND CEMENT FROM MILLS
IN THE UNITED STATES, IN BULK AND IN
CONTAINERS, BY TYPES OF CARRIER
(Thousands of Short Tons)

1972

	Shipments from Plants to Terminals		Shipments to Ultimate Consumer				Total Shipments
			From Terminal to Consumer		From Plant to Consumer		
	In Bulk	In Container	In Bulk	In Container	In Bulk	In Container	
Railroad	9,020	295	835	213	11,126	714	12,888
Truck	516	60	17,940	848	43,278	5,253	67,319
Barge and Boat	8,426	5	312	--	843	--	1,155
Unspecified	--	--	--	--	63	7	70
Total	17,962	360	19,087	1,061	55,310	5,974	81,432

after Bureau of Mines, V.I, 1972, p. 276.

should be close to the surface and in an area where quarrying is economically feasible; it is usually not worthwhile to recover limestone from underground mines unless it is a byproduct (Ladoo and Myers, 1951, p. 129; Morrison, 1944, p. 36-38; Riley, 1973, p. 59-62).

Shale and Clay. Shale and/or clay deposits are available in most localities where cement is produced or is likely to be produced. If not, it is more economical to ship clay or shale to lime sources than it is to ship the much larger amounts of limestone, slag, or other lime source necessary to clay or shale. There are exceptions to this, of course; there are some factories along the Gulf Coast where lime materials are brought to clay. These lime materials are dredged from the ocean floor. Thus, it is certainly cheaper to transport lime materials to factories on land than to transport clay materials to the lime sources (Morrison, 1944, p. 39; Riley, 1973, p. 39, 59-62; Bureau of Mines, Vol. II, 1972, p. 609-610, 697-698).

Gypsum. Gypsum, as a raw material, presents no problem. It is used in small amounts and has no weight loss in the cement manufacturing process. Gypsum can be economically transported for long distances. The gypsum industry in Florida processes gypsum from as far away as Nova Scotia. Unprocessed gypsum is used for cement. There are enough major gypsum deposits in the United States so that transportation costs for and availability of gypsum are not likely to be a serious problem (Morrison, 1944, p. 39; Riley, 1973, p. 59-62; Bureau of Mines, Vol. II, 1972, p. 609-610, 697-698).

Fuels. Hoover states that the location of cement production is somewhat affected by geographical differences in fuel costs (Hoover, 1949, p. 129). The effect is not an important one; in the United States, fuel production and distribution facilities are well enough developed that fuel costs are more likely to determine what fuel is used in a particular locality rather than whether a cement factory will be built there at all. The major requirement concerning fuel is location close to a major fuel transportation facility or electric line. The Great Lakes cement factories use coal from as far away as West Virginia (Morrison, 1944, p. 42).

Miscellaneous. Efficiency of production or management has little effect on the location of cement factories. A poorly located factory will not be profitable, no matter how efficient or well managed it is, barring major technological breakthroughs. A well located factory may survive despite inefficiency or poor management.

SYNTHESIS

Cement factory location is based on three important factors: markets, raw materials, and transportation. The ideal site would be that in which all necessary raw materials share location with a market. Where this is not the case, the factory is located so that the cost of production and distribution are minimized. In general, cement factory location appears to follow the least cost school, with modifying elements from the least transportation cost and market area schools.

CHAPTER IV

KENTUCKY CEMENT RESOURCES

> "In Kentucky, Portland cement is manufactured on a large scale at Kosmosdale, about 20 miles north of Louisville on the Ohio River. Here the chief raw materials are of Mississippian limestone from Meade County and alluvial clay from the river bottom. However, limestone and clay or shale, the essential material in cement manufacture, are available at many localities in the state." (Street, 1958, p. 311).

LIME

There are two blast furnaces in Kentucky, in the Ashland area, belonging to Armco Steel Company (Bureau of Mines, Vol. II, 1972, p. 312). All the slag output is contracted out and none is available for cement production or any other purpose (Armco Steel Company, 1978, phone call). No other references to non-limestone sources of lime were found for Kentucky. Therefore, this section will deal only with limestone.

LIMESTONE

Limestones with surface or near surface outcrops occur in several areas of the state. (see Figure VI; Figure VII for location of counties). However, not all of these limestones are suitable for cement.

Big Lakes Region. In Trigg County the area around Lake Barkley contains an outcrop of limestone suitable for cement manufacturing (see Figure VII for location of counties). This limestone is the

CEMENT LIMESTONES, KENTUCKY

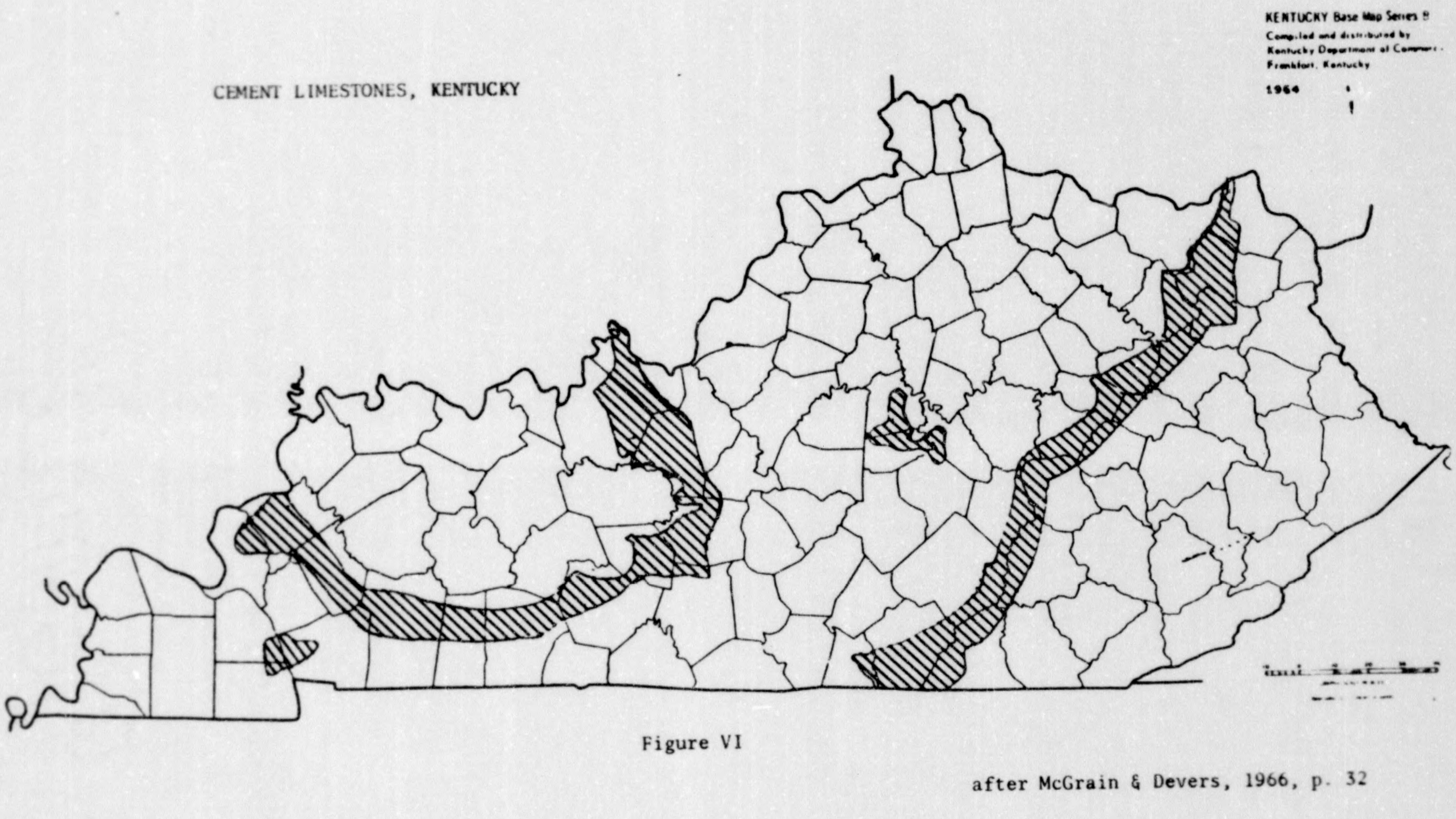

Figure VI

after McGrain & Devers, 1966, p. 32

COUNTY NAMES, KENTUCKY

KENTUCKY Base Map Series 8
Compiled and distributed by
Kentucky Department of Comm-
Frankfort, Kentucky
1964

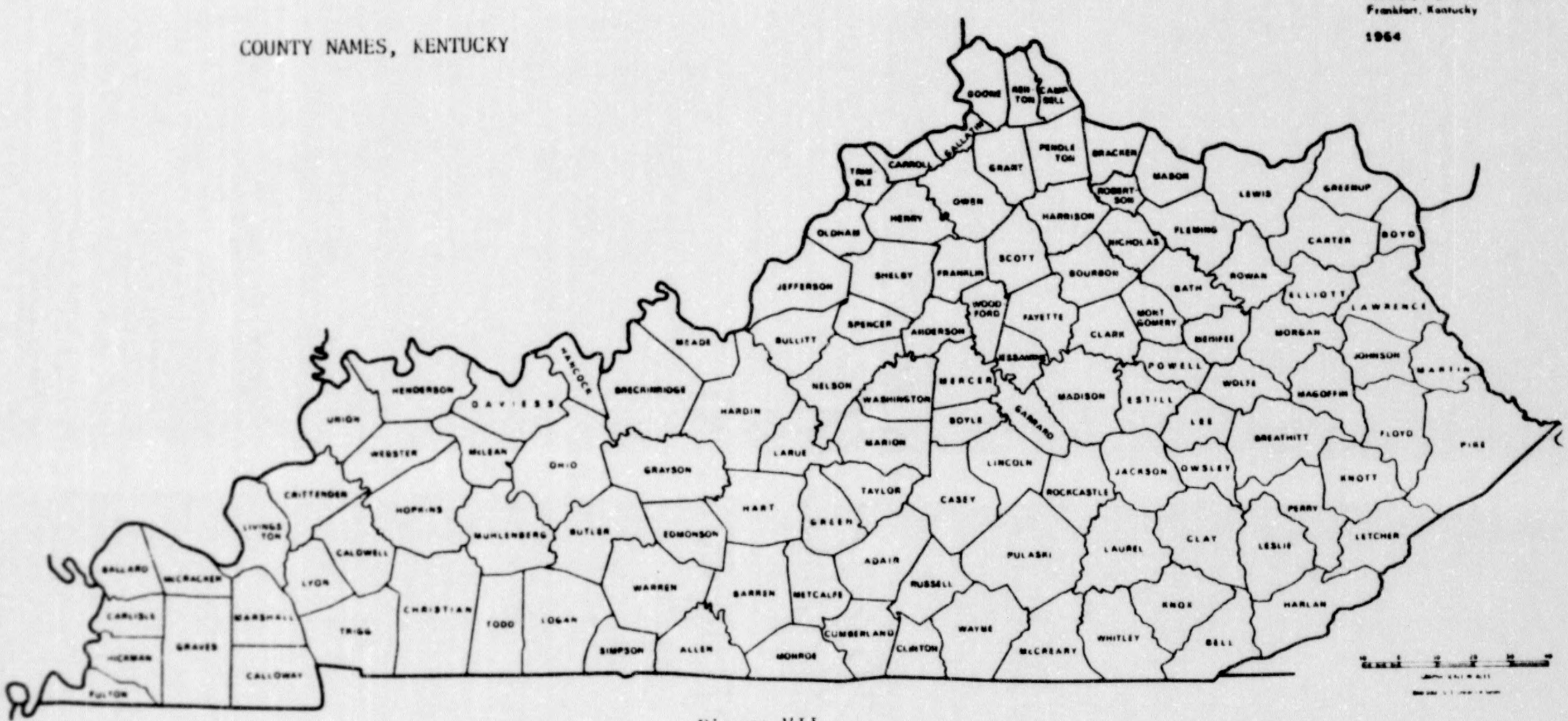

Figure VII

Mississippian age Warsaw Limestone Formation. Part of this limestone outcrop is untouchable as it is in the Land Between the Lakes Recreation Area, being developed by the Tennessee Valley Authority. However, part of the outcrop is located outside the Recreational Area on the east shore of Lake Barkley.

Western Coal Field Region. One of the two major areas in Kentucky containing limestone suitable for cement is in a belt surrounding the Western Kentucky Coal Field Region. These limestones are Mississippian in age. The Ste. Genevieve Limestone Formation is geologically the best known unit in this belt; more than 30% of the state's active rock quarries are located in it. There are several low magnesium zones in the Ste. Genevieve Limestone used in the Flintkote Company's factory at Kosmosdale (McGrain and Devers, 1966, p. 33-37; Eckel, 1913, p. 189-190; Eckel, 1905, p. 173-174).

In the same outcrop belt are other high calcic, low magnesia limestones. These include Paoli, Beaver Bend, Reelsville, and Beechcreek Limestone Formations, which are all members of the Lower Chester Group (McGrain and Devers, 1966, p. 33-37; Eckel, 1913, p. 189-190; Eckel, 1905, p. 173-174).

The second major limestone formation suitable for cement in this region, after the Ste. Genevieve Limestone, is the St. Louis Limestone Formation. This thick, widespread formation contains several thick beds of oolitic limestone suitable for use as a cement raw material (McGrain and Devers, 1966, p. 33-37; Eckel, 1913, p. 189-190; Eckel, 1905, p. 173-174).

Boyle and Mercer Counties. In Boyle and Mercer counties in central Kentucky, the Perryville Member of the Lexington Limestone Formation is suitable for cement making. The shale-limestone in the nearby Maysville area of Mason County may be suitable for cement manufacturing without further additions of clay or lime. Whether or not this is so, the Salvisa and Faulcover Beds of the Perryville Member are suitable lime sources for cement (McGrain and Devers, 1966, p. 37; Eckel, 1913, p. 189; Crossman, 1973, Danville Quadrangle).

The Boyle and Mercer counties area has the advantage of being well located with respect to the growing market area of central Kentucky (McGrain and Devers, 1966, p. 37).

Eastern Coal Field. A belt of high calcic limestone parallels the Eastern Coal Field Region along the western side of the Appalachians. The outcrop is apparently an eastward extension of the Mississippian age limestone previously mentioned as surrounding the Western Coal Field (see Figure VI; McGrain and Devers, 1966, p. 33; Eckel, 1905, p. 191; Eckel, 1913, p. 174).

CLAY AND SHALE

Eckel's two works deal only with limestone as a cement raw material. The paper by McGrain and Devers deals both with limestones and clay materials, with limestones much emphasized. This implies that clay materials are relatively unimportant as cement raw materials, or that clay materials are sufficiently ubiquitous to require little consideration. The latter supposition seems to be closest to the truth (see Figure VIII for distribution of clay and shale; McGrain and Devers, 1966; Eckel, 1905; Eckel, 1913).

CEMENT CLAYS AND SHALES,
KENTUCKY

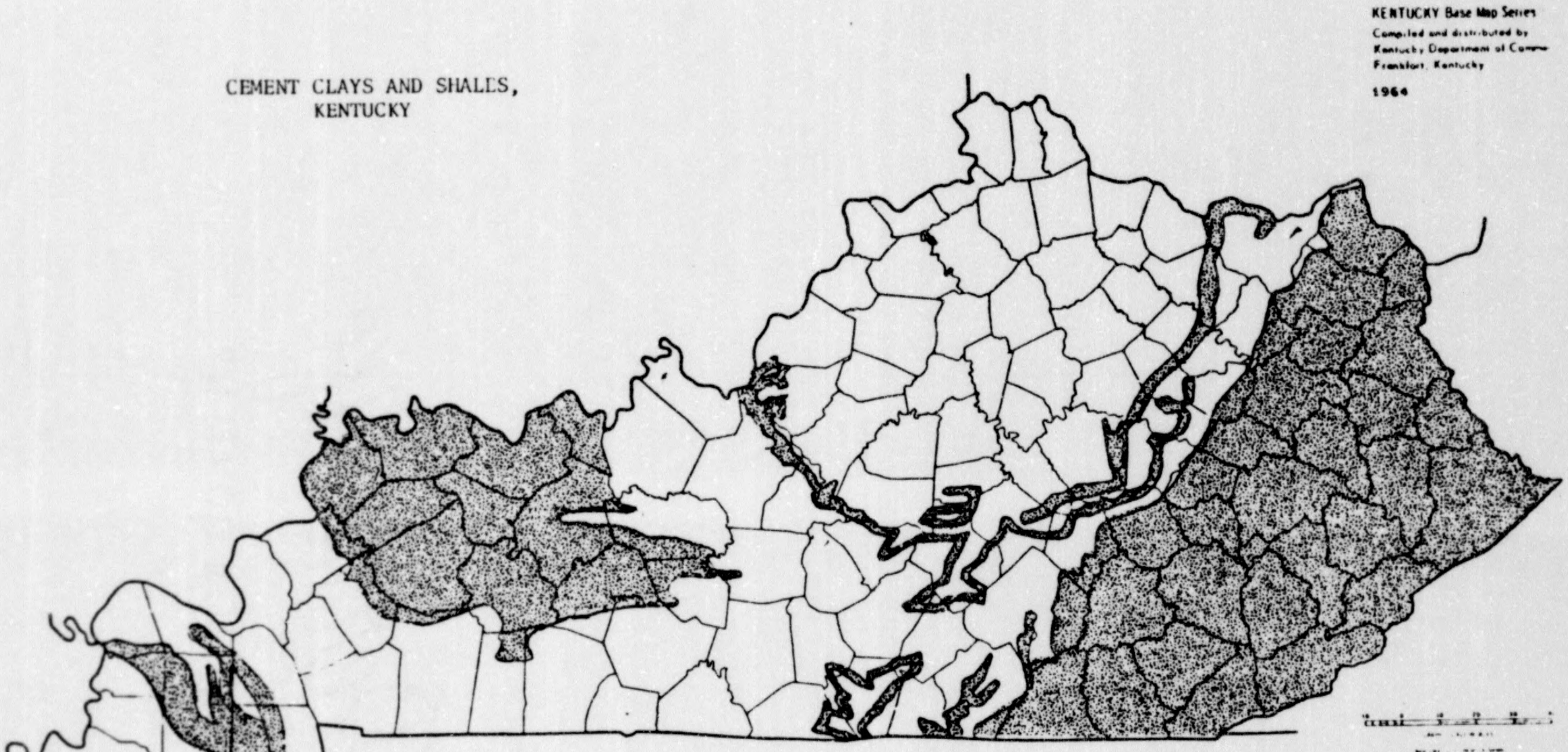

Figure VIII

after McGrain & Devers, 1966, p. 38.

Western Kentucky. The Tertiary age clays of the Mississippi Embayment in the Jackson Purchase have many uses in the ceramic industry. Clays not suitable for chinaware may still be useful for cement. The iron oxide content of these clays, less than 3%, is such that they could be used for white or light colored cements. Their proximity to river transportation may add to their attractiveness as cement raw materials (McGrain and Devers, 1966, p. 40; Kentucky Department of Commerce, 1975b, p. 23-25).

The Porters Creek Clay Formation, also of Tertiary age, is made up of absorbent clays, known as fuller's earth. These clays occupy a northwest trending belt which extends through Kentucky's Embayment region. The formation in places is greater than 150 feet thick. The magnesia content is less than 2%. Pozzuolan properties are inferred from similar properties of the formation in Illinois (McGrain and Devers, 1966, p. 40; Kentucky Department of Commerce, 1975b, p. 23-25).

In Marshall County, there are exposures of Cretaceous age clays suitable for use in cement (McGrain and Devers, 1966, p. 40).

Western Coal Field. Clays and shales of Pennsylvanian age are associated with the major coal deposits in the Western Coal Field. The best exposures of these materials are in excavations associated with coal mines. They generally have less than 3% magnesia content but, in places, may be pyritic. Many of these materials are underclays (shales or clays underlying coal seams) that are too thin to be economically recovered by themselves, but some of them may be recovered as a byproduct in conjunction with surface coal mining (McGrain and Devers, 1966, p. 40).

Shales suitable for use in cement are located outside the Western Coal Field in close spatial and stratigraphic proximity to the high calcic low magnesia limestones of the Lower Chesterian, Ste. Genevieve, and St. Louis formations previously described. This proximity makes them of greater than normal interest as cement raw materials due to the low transportation costs involved in bringing lime and clay materials together (see Figure IX for superimposed limestone, clay and shale, and coal locations, and Figure X for stratigraphic sections). The iron oxide content is greater than that of the clays of the Mississippi Embayment and most underclays, but it is not too great to preclude usefulness. The magnesia content is usually less than 3% (McGrain and Devers, 1966, p. 41).

Central Kentucky. The New Providence Formation, of Lower Mississippian age, is a shale formation well exposed on both flanks of the Cincinnati Arch. Thickness is as great as 150 feet at Louisville, but is less toward the southeast. Magnesia content is generally less than 3%, but is known to be greater than 4% in Bullitt and Jefferson counties. There are phosphate nodules a few inches above the base which should be avoided if phosphate levels are critical in the finished product (McGrain and Devers, 1966, p. 41).

The Devonian age New Albany-Ohio-Chattanooga Shale outcrops in a horeshoe shaped belt around the outer part of the Bluegrass Region. Minimum thickness of the formation outcrops is 40 feet (McGrain and Devers, 1966, p. 41).

The Silurian age Estill Shale Formation occupies a narrow belt from Lincoln County northeast to Lewis County on the Ohio River.

CEMENT LIMESTONES, CEMENT CLAYS AND SHALES, AND
COAL, KENTUCKY

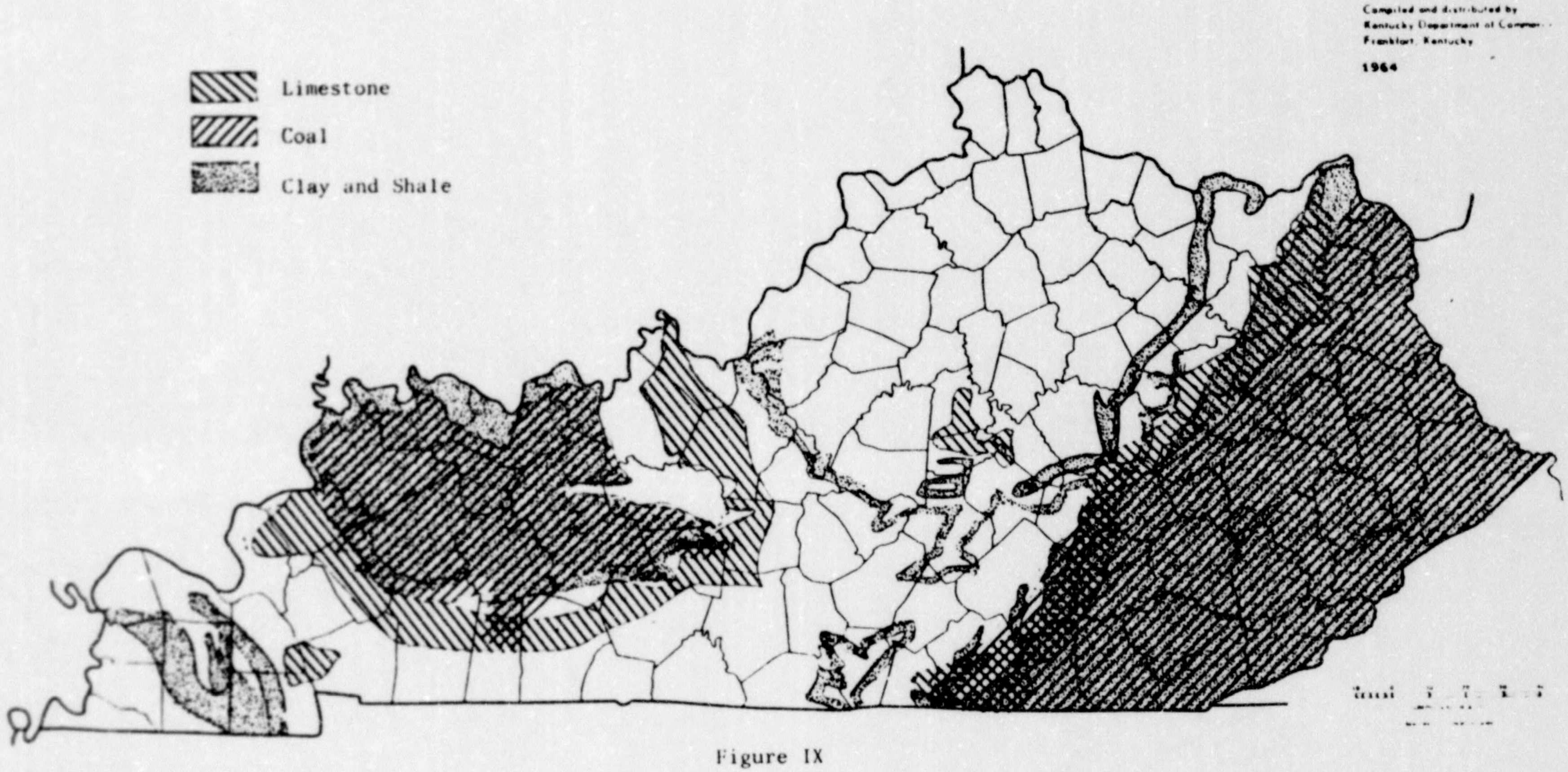

Figure IX

after McGrain & Devers, 1966, p. 32,38;
and Kentucky Department of Commerce,
1955, p. 5.

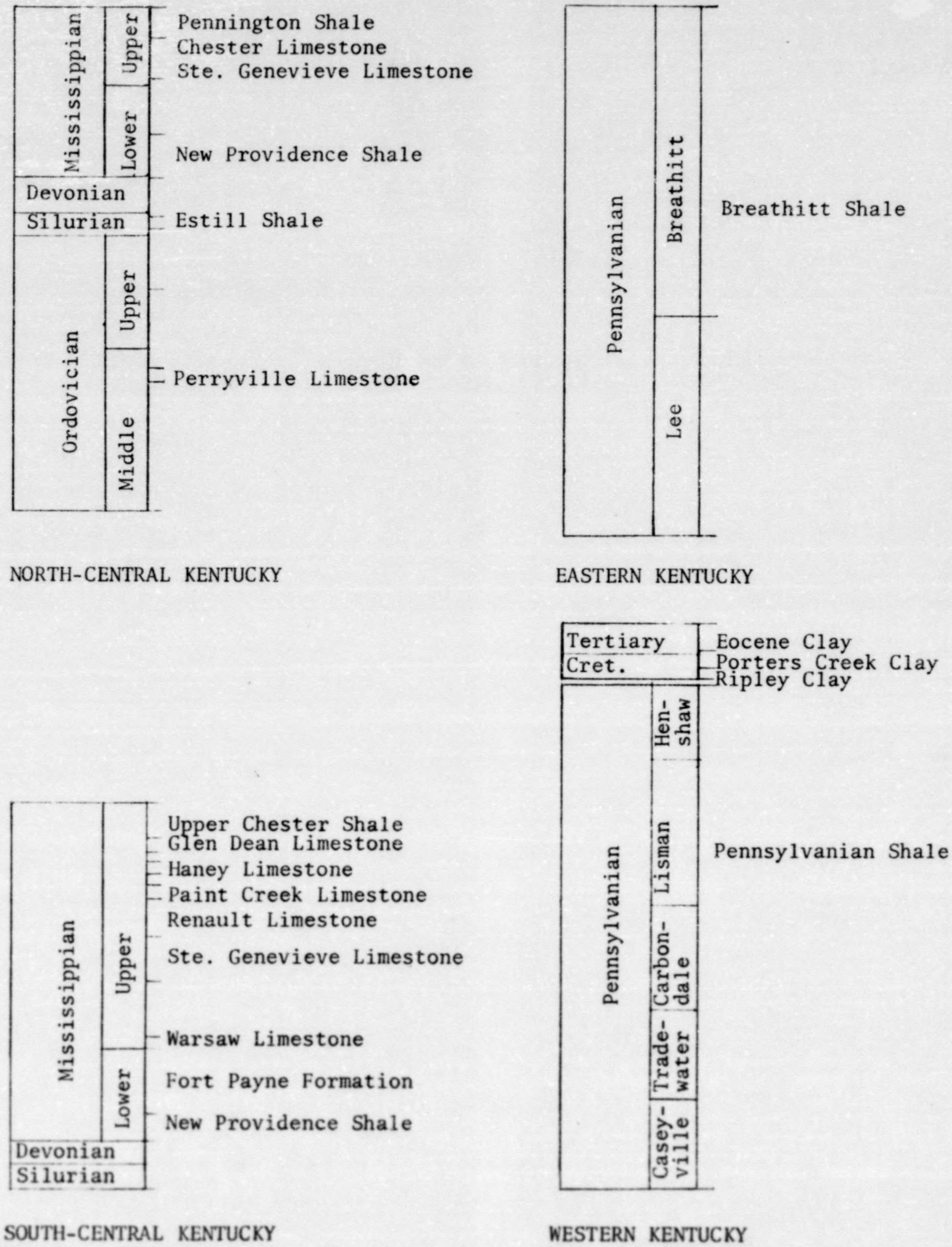

Figure X
STRATIGRAPHIC SECTIONS

after McGrain & Devers, 1966, p. 34.

Its thickness in outcrop varies between 40 and 125 feet; the thickness generally increases into the more northern counties. The magnesia content is less than 3% (McGrain and Devers, 1966, p. 41).

The Lubegrud Shale and Plum Creek Shale members of the Noland Formation are found a short distance below the Estill Shale Formation. These shales are considered too thin for commercial consideration because the thicker Estill Shale is more easily available in the same area; it is otherwise suitable for use in cement manufacturing (McGrain and Devers, 1966, p. 41).

Eastern Coal Field. Shales are associated with both the coal field itself and the parallel limestone belt, similar to the situation previously described for the Western Coal Field (McGrain and Devers, 1966, p. 40-41).

Miscellaneous Materials. A Kentucky Department of Commerce map shows several clay workings of unspecified type and age scattered around the state. If these deposits are extensive enough, they are probably suitable for cement (Kentucky Department of Commerce, 1975b, p. 23).

The floodplains of rivers and their tributaries contain alluvial sands and clays. These deposits are spread throughout the state. It is unclear from the references whether these alluvial clays are of sufficient quantity and quality for use in cement except for those in the Ohio and Mississippi River valleys (McGrain and Devers, 1966, p. 39-40; Street, 1958, p. 29-35; Jillson, 1929).

GYPSUM

There are appreciable amounts of bedded gypsum and anhydrite in Kentucky at mineable depths, between 100 and 500 feet in depth--depending on topography and structure. The equivalent units are mined in Indiana. The units and their locations are not specified (Kentucky Department of Commerce, 1975b, p. 32).

FUEL

Until recently, the cement industry was very dependent on oil and natural gas. The petroleum shortage of recent years, however, has forced the industry to return to coal as a fuel to assure uninterrputed production (Bureau of Mines, Vol. I, 1973, p. 251).

The possibility of using electricity to heat the kilns of a cement factory is not as likely as using coal. In the last few winters, there have been several electricity cutbacks. It seems unlikely, therefore, that electricity is a sufficiently reliable power source for the foreseeable future to assure continuous production.

Kentucky has major coal resources and considerable oil and natural gas resources. Oil and natural gas production is declining, however, and Kentucky is a net importer of oil and natural gas. On the other hand, Kentucky is the nation's leading coal producer, with production increasing to fill the need caused by the general decline of oil and natural gas availability (Kentucky Department of Commerce, 1975b, p. 5-19). Because of the decline in the availability of oil, natural gas, and electricity, and the abundance of coal in Kentucky, any new cement plants in Kentucky would almost certainly use coal for heating kilns. (See Figure XI for distribution of coal.)

COAL, KENTUCKY

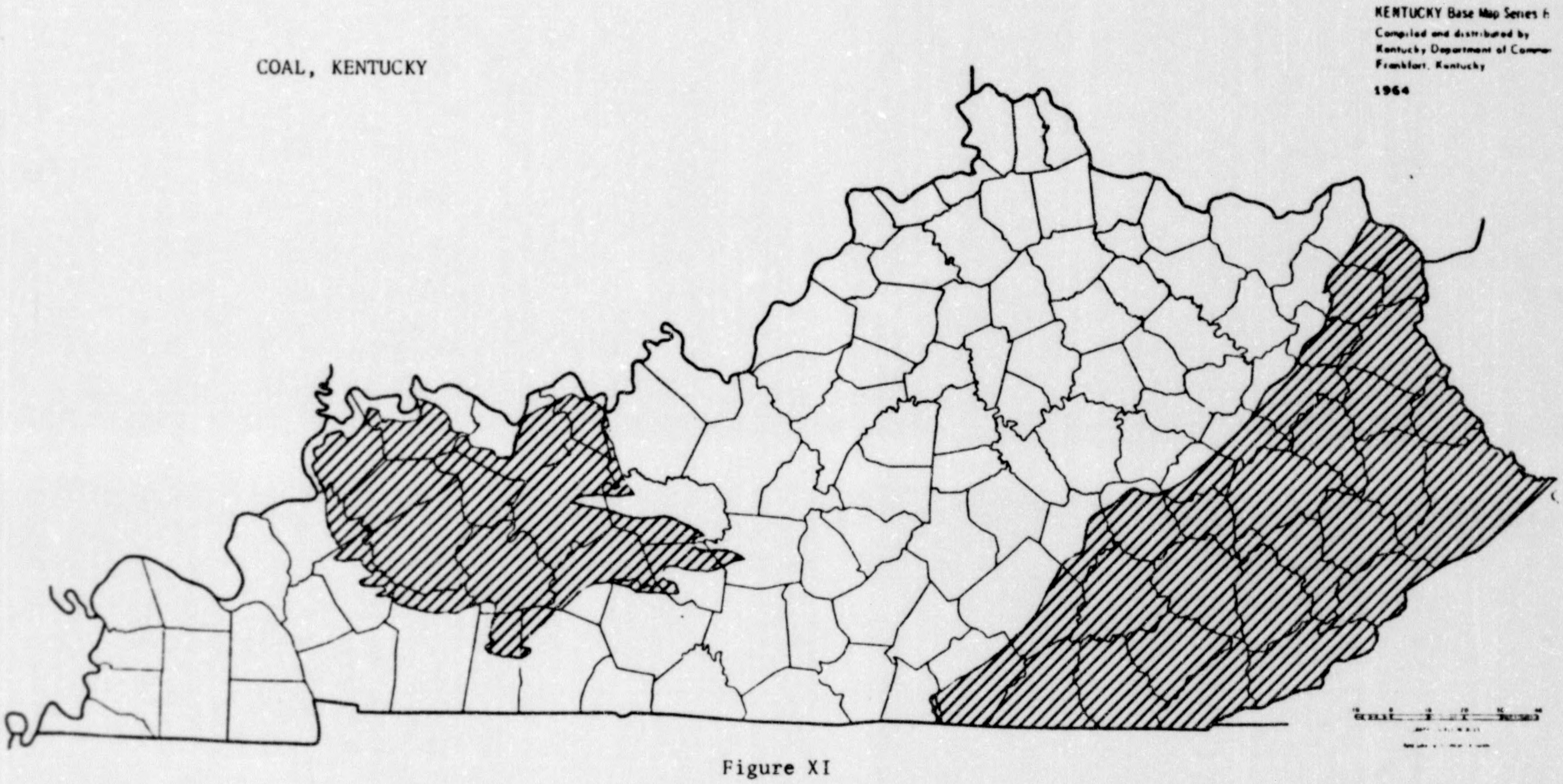

Figure XI

after Kentucky Department of Commerce, 1956, p. 5.

Kentucky's coal deposits are located in two coal fields. The coal fields are so distinctive that they give the names to two of Kentucky's regions: the Eastern Coal Field and the Western Coal Field. Both coal fields yield high quality bituminous coals and contain enormous reserves. The Eastern Coal Field lies in the Cumberland Plateau section of the Appalachians. The Western Coal Field lies in a structural basin and is surrounded by the great limestone arch in western Kentucky centered on Daviess County (Kentucky Department of Commerce, 1975b, p. 9-19).

SYNTHESIS

It is apparent from the above information that Kentucky has an abundance of the natural resources needed to support a large scale Portland cement industry.

CHAPTER V

CEMENT FACTORY LOCATIONS IN KENTUCKY

ACTUAL AND POSSIBLE CEMENT FACTORY LOCATIONS

The locations of the operating cement plants in and around Kentucky and the railroad network are shown in Figure XII. The dashed lines show the hinterlands of these factories as determined by measuring points equidistant from the factories along the rail lines. The railroad network is used alone as, for the most part, the road network parallels the railroad network. Water transportation is ignored, as the state's navigable waterways do not connect producing areas with market areas as shown in Figures V, VII, VIII, and XIV. An exception is the Ohio-Mississippi complex which serves the areas near the state's borders. This waterway system has little penetration into the state's interior. The two plants in Louisville area are treated as one due to their proximity.

The smallest cement factory built or planned from 1970 through 1974 has a capacity of 376,000 tons per year (Bureau of Mines, Vol. I, 1972, p. 254). Ladoo and Myers state that the smallest economically viable cement factory that could be built in 1952 would have a capacity of at least 188,000 tons per year (Ladoo and Myers, 1952, p. 130). This, along with the lack of plans for smaller factories, would seem to indicate that a factory of 376,000 tons per year capacity is the smallest one that can be economically built and operated today probably due to inflation.

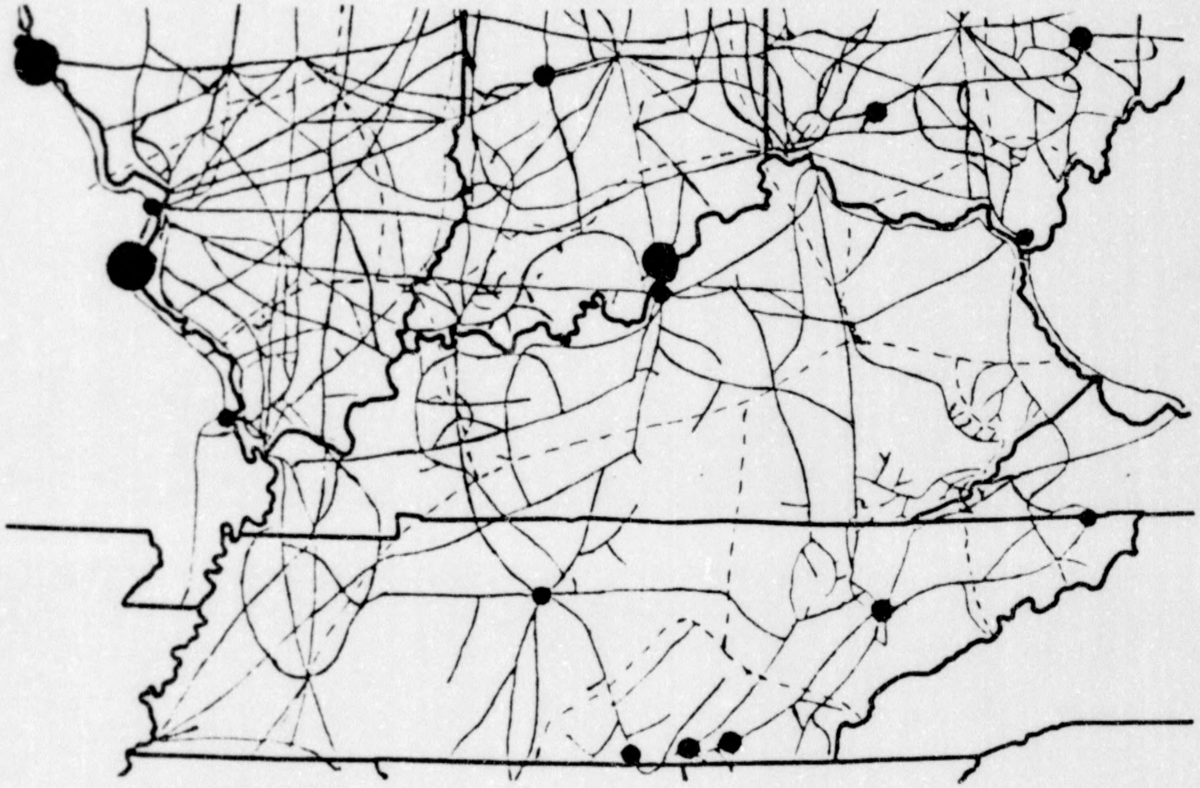

Figure XII
CEMENT FACTORIES, RAILROADS, AND HINTERLANDS

after Rand McNally, 1972, p. 17, 18, 21, 28, 44, and 46, and Chapman, 1975, p. 105.

Figure XII, with Figures III, VI, VIII, IX, and XI, show four areas in which resources coincide with transportation facilities. These areas contain actual or possible cement factory locations. They are 1) Trigg County, 2) the eastern half of the limestone arc surrounding the Western Coal Field, 3) Boyle and Mercer counties, and 4) the belt of limestone that parallels the Eastern Coal Field.

The Trigg County and Eastern Coal Field areas can be eliminated as sites for cement factories on both environmental and market grounds. Assuming that cement grade limestone has approximately the same density of calcite, about 2.7 gm/cm^3, and working with Morrison's data on proportions of raw materials to finished products, it is calculated that a plant of 376,000 tons per year capacity would require 198,000 cubic yards of limestone per year. As surface mining is usually the most economical method of recovering limestone for cement, this amount of limestone requires a large quarry which will continually get bigger as time progresses and more limestone is removed (Berry and Mason, 1968, p. 232; Morrison, 1944, p. 36). Even if it were legally feasible, environmental groups are not likely to allow such mining of Trigg County limestone because of its proximity to Barkley Lake and the Land Between the Lakes Recreational Area. The Eastern Coal Field limestone lies beneath the Daniel Boone National Forest; therefore, a limestone quarry is not likely to be allowed there.

In addition to environmental considerations these two areas are also eliminated by market considerations. Figures XIII and XIV show the cement using industries of Kentucky (Cement products plants that also produce Ready-Mix Concrete are classified as Concrete

CONCRETE PRODUCTS PLANTS

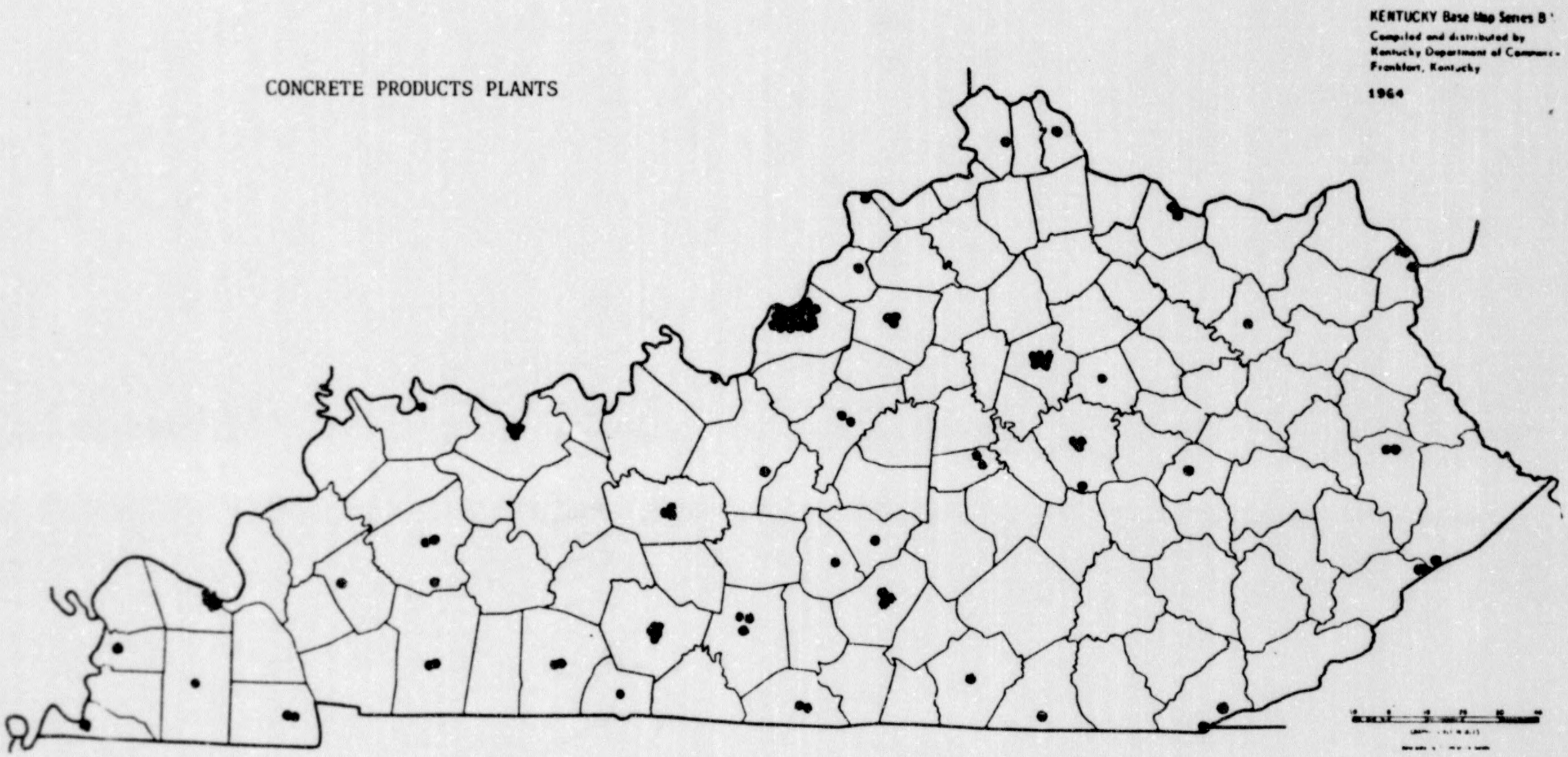

Figure XIII

after Kentucky Department of Commerce, 1976, p. 249-252.

READY MIX CONCRETE

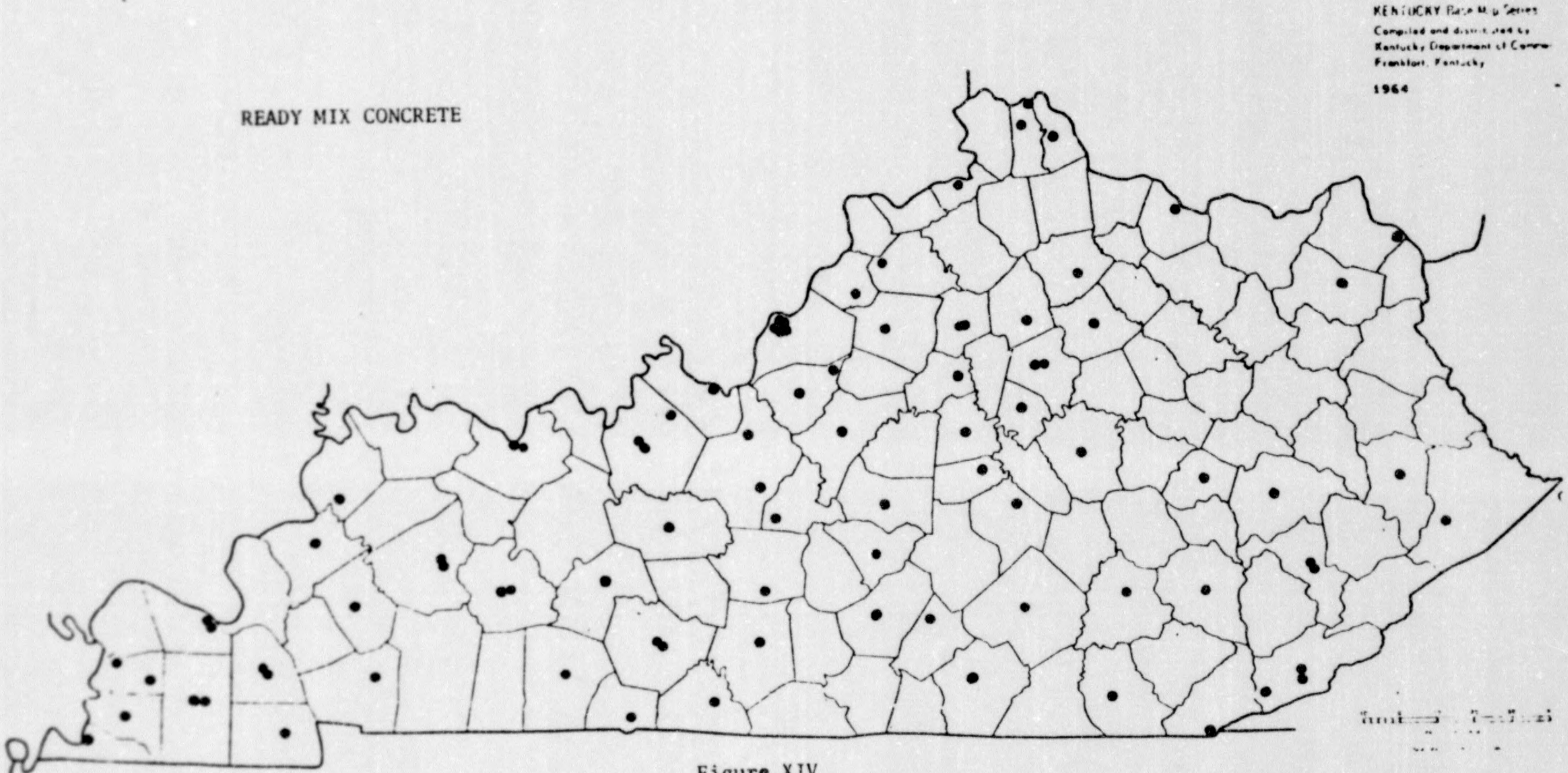

Figure XIV

after Kentucky Department of Commerce,
1976, p. 252-254.

Products plants. Those plants that produce only ready-mix concrete are included in Figure XIV.). Few such industries are near enough to these areas to use cement from them; transportation costs would favor other suppliers. Thus, there is little chance that cement factories will be developed in these areas in the near future.

This leaves the Western Coal field limestone arc and the Boyle and Mercer counties area. In these areas, markets are large and environmental factors are less critical.

The only major concentration of cement using industries in Kentucky is in Louisville. A secondary concentration is in Lexington. A minor concentration, which is not large, is in Bowling Green (see Figures XIII and XIV; Kentucky Department of Commerce, 1976, p. 249-254).

Louisville already has two cement factories: Flintkote Company's plant at Kosmosdale, Kentucky, and Louisville Cement Company's plant just across the Ohio River in Speed, Indiana. These factories by themselves are capable of supplying all of Kentucky's cement needs; but other plants also supply the state due to low transportation costs to some of Kentucky's markets (Bureau of Mines, Vol. I, 1973, p. 254-255).

The Flintkote Company's factory at Kosmosdale is the only one in Kentucky. It is in the northeasternmost part of the limestone arc surrounding the Western Coal Field. It is close to Louisville, which has the state's largest concentration of cement using industries. It has recently been expanded to accommodate a growing market (Bureau of Mines, Vol. I, 1973, p. 254-255). Flintkote Company estimates that between 250,000 and 300,000 tons of cement are consumed a year in Louisville (Flintkote Company, 1977). The Louisville plants have a large market area, supplying a large part of the state of Kentucky, thus making up the difference between production and the Louisville market. Bowling Green is served from Louisville (Steen Concrete, 1978; BG Concrete, 1978).

Flintkote Company's criteria of location include: 1) the availability of proper raw materials, 2) the availability of cheap fuel, 3) the availability of rail, truck, and water transportation facilities, and 4) the proximity to a major market (Flintkote Company, 1977). The Kosmosdale plant is well located with respect to these criteria.

Louisville Cement Company has similar criteria; they emphasize the importance of transportation costs (Louisville Cement Company, 1978, letter). Their plant in Speed, Indiana, is well located with respect to these criteria.

The location criteria used by the Flintkote Company and the Louisville Cement Company fit quite well in a least cost - least transportation cost model. This reinforces inferences drawn from general data presented earlier. Once an area has been shown to have sufficient demand for cement, the plant location can best be derived from a least cost model, which will include least transport cost ideas due to the importance of transport costs for cement and its raw materials.

The smallest cement plant built since 1970 is of 376,000 tons per year capacity and is assumed to be the smallest economically viable plant. It is logical to assume, therefore, that to support a cement factory, an area must have a minimum demand of about 376,000 tons per year which cannot be more cheaply met by other factories.

There is a cement terminal in Lexington: Southwestern Portland Cement. It is located at the Chesapeake and Ohio railroad yard (General Telephone Company, Directory, p. 79, Yellow Pages, 1977), indicating the importance of rail transportation. The terminal is served by rail from the Southwestern Portland Cement factory at Fairborne, Ohio, which is near Dayton, Ohio (John Wild, June 29, 1977). The reason that Southwestern Cement Company can economically serve Lexington from Fairborne, Ohio, when Louisville is much closer is that the same company owns both factory and terminal. By eliminating the wholesaler's profit, the company may save enough money to offset the high transportation costs.

Lexington is large enough to support a cement terminal. The question is whether Lexington can support a cement factory. Southwestern Portland Cement estimates that the Lexington market, including the concrete products industries and the ready mix concrete industries, is capable of consuming 400,000 tons per year of cement. It was left ambiguous, perhaps for trade secret reasons, whether the Lexington market area actually does consume 400,000 tons per year of cement (John Wild, 1977). There is a problem here, for Flintkote Company estimates that Louisville, with many more cement using industries than Lexington, consumes only 250,000 to 300,000 tons per year of cement (Flintkote Company, 1977; Kentucky Department of Commerce, 1976, p. 249-254). The chances are that one or both estimates are incorrect. The Lexington area is growing; the area is expected to nearly double in population by 2020 (McGrain and Devers, 1968, p. 37; Kentucky Program Development Office, 1972, p. 383-385). Therefore, the Lexington area is likely to grow to a point that it can support a cement factory by 2020 even if it is not now capable of doing so.

The third concentration of cement using industries in Kentucky is in Bowling Green. The concentration is not a large one; just large enough to be called a concentration. Bowling Green is much smaller than Lexington or Louisville, having about one third the population of Lexington and one tenth the population of Louisville. The cement using industries of Bowling Green are smaller as well as fewer than those of Lexington (Kentucky Department of Commerce, 1975a, p. 8, 12; Kentucky Department of Commerce, 1976, p. 249-252).

The various cement using industries of Bowling Green have widely varying estimates of the amount of cement consumed annually in the Bowling Green Area. Estimates range from 8,000 tons per year to 26,000 tons per year. Some cement is obtained from Nashville, but most comes from the two Louisville area plants; the Bowling Green area managers like the salesmen and service of the Louisville companies. This preference offsets any added inconveniences or expense that may be due to the greater distance to Louisville. Industries with rail sidings take delivery by rail; the others take delivery by truck. (Steen Concrete, 1977 and 1978; BG Concrete, 1977 and 1978; Cloud Concrete Products, 1977; Ennis Concrete, 1977; Western Concrete, 1977).

The cement consumed by Bowling Green is not nearly enough to support a cement factory. Population projections show that by 2020 Bowling Green will have three quarters of the present population of Lexington (Kentucky Program Development Office, 1972, p. 119-121, 383). It is, therefore, highly unlikely that the Bowling Green area will be able to support a cement factory until some time after 2020.

SYNTHESIS

The biggest cement market in Kentucky is the Louisville area, which has two cement factories close by. The second largest cement market in Kentucky is in the Lexington area, which is served by a terminal.

The Lexington area is the only market area except for the Louisville market area that has the potential of supporting a cement factory before 2020. The Lexington area does not contain cement raw materials, but the nearby Boyle and Mercer counties area does. Danville is approximately in the center of this area and is linked directly to Lexington by road and rail (see Figures VI, VII, VIII, IX, and XII). A cement plant could be located in either Danville or Lexington. A Danville plant would have the advantage of shipping cement, which is less bulky and more valuable than the raw materials, and would have low transportation costs for raw materials. On the other hand, a Lexington plant would have the advantage of being right in the market area. A factory location at the point of least transportation cost between the two areas would have the advantage of minimum transportation costs but would be away from population centers with all the disadvantages of such a location. The exact location of such a factory would be influenced by many factors, including the personal factors mentioned in the behavioral school and marginal location school economic models discussed previously. The important point is that this relatively small area does have the potential to eventually support a cement factory.

SUMMARY AND CONCLUSIONS

Cement is a low value added commodity which is highly sensitive to transport costs. The market for cement follows population. The factors most affecting cement factory location are proximity to raw materials, particularly limestone, and proximity to markets. Therefore, the model describing the spatial distribution of the cement industry is based on least cost and least transport cost theory, with elements of market area theory.

Utilizing these ideas, it is found that the Louisville cement factories are well located with respect to market and raw materials, and the Lexington terminal is well located with respect to market.

There are several areas in the state other than the Louisville area that have the proper raw materials for cement manufacture. With one exception, population projections show that these areas will not develop sufficient market potential to support cement factories until well after 2020. The exception is the Lexington area. This is the only area of the state in which a cement factory is likely to be located in the foreseeable future.

Therefore, there are no presently unused sites suitable for cement factories in the state. The single suitable site at Louisville is well utilized. The only potential unused site is the Lexington area. The Bowling Green area will not be able to support a cement factory until well after 2020, unless large scale unexpected growth occurs. In general, the cement manufacturing industy in Kentucky is well located with respect to all criteria discussed in this work.

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