The location of the Victor Chemical Works elemental phosphorus plant at Silver Bow Montana

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THE LOCATION OF THE VICTOR CHEMICAL WORKS
ELEMENTAL PHOSPHORUS PLANT AT
SILVER BOW, MONTANA

by

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I. INTRODUCTION

In November 1951 the first railroad tank car of elemental phosphorus was shipped from Montana. High state officials, including the Governor, were on hand for the event. The first production from a new manufacturing plant might go almost unnoticed in some areas, but Montanans are acutely conscious of any new industrial activity within the borders of their state. Sparsely populated and remotely located, Montana has long been by-passed by manufacturers. Agriculture, mining, and lumbering, together with local trade and service activities, have always been the chief sources of income and employment in the state.

Since World War II, however, several significant developments have taken place in the resource pattern of the state. In addition to new oil and copper mining activities and expansion in the lumber industry, two industries entirely new to the state have located in Montana. An aluminum ingot plant is currently under construction at Kalispell and the $10 million Victor Chemical Works elemental phosphorus plant at Silver Bow was put into production in the fall of 1951.

This study is concerned with the location of the Victor plant. Locational theory as it has been developed by economists since the early nineteenth century is first considered, and then an attempt to fit the pattern of the elemental phosphorus industry, its movement west after World War II, and the specific location of Victor Chemical Works at Silver Bow, Montana, into the framework of modern theory is made.
In 1952, the writer prepared a report for Bonneville Power
Administration on the Victor Chemical Works plant at Silver Bow
entitled "Phosphorus Production in Montana", and published by the
Bureau of Business and Economic Research, Montana State University in
June, 1953. While the report for Bonneville was in preparation,
numerous trips to Silver Bow for conferences with plant officials were
necessary. A great deal of the material contained in chapters IV and
V of this report was obtained during these conferences.
II. THE DEVELOPMENT OF LOCATION THEORY

For many years, economists failed to provide an adequate explanation of the factors determining the location of economic activity. Several described existing locational patterns in their writings, and economic geographers attempted to explain location by physical factors, but no theory of location as such was developed.

Early economists noted that prior to the Industrial Revolution, industrial population tended to concentrate in regions of surplus food. Adam Smith observed in 1776, "An inland country, naturally fertile and easily cultivated, produces a great surplus beyond what is necessary for maintaining the cultivators, and on account of the expense of land carriage, and inconvenience of river navigation, it may frequently be difficult to send this surplus abroad. Abundance, therefore, renders provisions cheap, and encourages a great number of workmen to settle in the neighborhood, who find that their industry can procure them more of the necessaries and conveniences of life than in other places."

Thus up until the eighteenth century, the industrial population of Europe was concentrated in northern France and Flanders, eastern and southeastern England, the fertile valleys of the Po and the Rhine, and in Holland and sections of Italy where food was readily available. The significance of this population distribution lies in the fact that during this period of history, food, as the major item in the subsistence

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of labor, was more absolute in its locational attraction than industrial raw materials, fuel, or power in the present day.  

The Industrial Revolution meant primarily four things as far as location was concerned: lower costs of transportation, the removal of barriers to trade, the use of mechanical power, and the use of coal as a fuel. All these things tended to develop and increase geographic specialization. As the technology of industry progressed from hand labor to the use of various fuels and power and as transportation improved, the attraction of food as a locational factor diminished. With cheaper and faster transportation, regional trade increased rapidly, and industrial and commercial centers developed along established transportation routes and junctions, at points accessible to both population and resources.

Despite the rapid changes which occurred in the location of economic activity, little effort was made to construct a general theory of location before the twentieth century. The reaction of German economists of the nineteenth century to the classical school, which precipitated the rise of the German historical school, played an important role in the beginnings of location theory. In the study of the stages of economic development, the spatial structure of economic activity was necessarily of primary concern.

Johann Heinrich von Thunen, writing far in advance of his time, did progress toward a general locational analysis in the early 1800's, and is generally regarded as one of the founders of modern location theory. In Der Isolierte Staat (1826), he constructed and attempted

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to explain a pattern of agricultural activity. For this purpose, he described an isolated state with these characteristics: a very large town was situated in the middle of a fertile plain which had neither canals nor navigable rivers. At a considerable distance the plain ended in an uncultivated wilderness. The town drew its produce from the plain, to which it supplied manufactured products. Wage rates were equal throughout the area, and a uniform price existed for each agricultural product. Thunen then worked out a plan of location for the agricultural activity of the plain. Products of a perishable nature, or those difficult to transport, would be produced nearest the town. Other forms of cultivation would be arranged in concentric circles around the town in accordance with the relationship between the price of the products in the town and the distance from the town. That is, a particular crop would be produced in a certain location only if it could be sold in the town at a price which would cover the cost of production and transportation costs to the market, and provided that the land could not be used more profitably for any other product. Thus Thunen isolated transportation costs as the basic element in the location of agricultural activity.

Whereas Thunen's theory of location was a by-product of his effort to determine which kind of agricultural production would best be carried on at a given place, Alfred Weber, in his *Über den Standort der Industrien* (1909)\(^3\), undertook the analysis of industrial location for its own sake. In his study of German economic development, particularly the growth of large industrial and population centers and shifts in industrial location,

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\(^3\) Translated and edited by C. J. Friedrich as *Theory of Location of Industries*, University of Chicago Press, Chicago, 1929.
Weber came to believe that economists must provide an explanation of these phenomena. He concluded that it was possible to develop a general theory of location which would apply to all industries, in any economic system.

In developing his theory, Weber assumed an area consisting of an even plain, with equal transportation rates throughout. Unlike Thunen, he assumed many consuming centers scattered about the plain. Equal costs of fuel and raw materials (at unevenly distributed deposits) and immobility of labor were also assumed.

Weber defined locational factors as advantages in cost, and found two types of variable factors affecting industrial location: those which are primary causes of the regional distribution of industry (regional factors) and those which influence location within the regional distribution (agglomerating and deglomerating factors).

The regional factors are defined by Weber as transportation costs and labor costs. Transportation costs (expressed in ton-mile rates) are considered as the most fundamental element determining location. With labor costs constant and transportation costs variable, the location of manufacturing industries is determined by the ratio between the weight of the raw materials used in production and the weight of the finished product. That is, under these simplified conditions, the question of location may be resolved into a balancing of the transport advantages of nearness to materials and nearness to markets.

4 Weber recognized, however, that the industrial location of contemporary Germany was not entirely explained by his "pure" rules of location, due largely to what he termed the "central aspects" of modern capitalism.

5 All other costs are eliminated as basic locational factors.
Raw materials are classified by Weber as either "ubiquities" (materials which occur practically everywhere in certain areas) or "localized materials" (relatively scarce materials not to be had everywhere). In the case of localized materials used in production, the weight of the materials will pull toward the material source, particularly if the production process involves a loss of weight, and the weight of the product toward a location near the market. The use of ubiquities strengthens the pull of market location, particularly if it adds weight to the product, because ubiquities are available everywhere. In general, Weber described the locational pull of transportation costs as toward the place of consumption except (1) when one "pure" (non-weight-losing) material is used, the location may be anywhere between the source and the market; (2) when only one weight-losing material is used, the location will be at the material source; and (3) when ubiquities are used in addition to weight-losing materials, the location may be either at the source of materials or at the market, depending upon the relationship between the loss in weight and the weight of the ubiquities.

Relaxing his assumptions to allow for varying labor costs among different locations, Weber states that a pull toward low-cost labor areas will be exerted on those industries whose labor costs constitute a high proportion of total costs. A location will be moved from the point of minimum transportation costs to a more favorable labor location, however, only if the savings in the cost of labor are larger than the additional transportation costs involved.

According to Weber, transportation and labor costs are the only two factors affecting the regional location of industry. All others

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6. Refers to level of personal efficiency as well as wage levels.
work only as part of the agglomerative or degglomerative forces determining the distribution of industry within a region.

An agglomerative factor is an advantage of lower cost of production or marketing resulting from the fact that production is carried on to a considerable extent at one place. Agglomeration of industry may be divided into two categories: the enlargement of plants due to economies of large-scale production and local concentration of several plants (social agglomeration). Among the factors influencing social agglomeration are the development of technical equipment and better facilities for replacing and repairing equipment of an industry concentrated in one locality; greater availability of labor; better sources of supply for materials as a result of large-scale demand; and improved marketing facilities.

Weber defines degglomerative factors as counter-tendencies to agglomeration, all following from the rise of land values or labor costs which accompany agglomeration.

These principal statements of Weberian location theory are still widely used as the basis for the development of a modern theory.
III. A MODERN THEORY OF INDUSTRIAL LOCATION

During the past two decades, location theory has been considerably enlarged and refined. Whereas in earlier years German economists had dominated the field, at least three major modern works have been contributed by American economists: Edgar M. Hoover's Location Theory and the Shoe and Leather Industries (Harvard Economic Studies, Volume LV, Harvard University Press, Cambridge, Massachusetts, 1937) and The Location of Economic Activity (McGraw-Hill Book Company, Inc., New York, 1948) and William H. Dean, Jr.'s The Theory of the Geographic Location of Economic Activities, cited on page 4.

As economic activity has become more complicated and interrelated, location theory has necessarily taken on many new aspects. Since locational problems arise chiefly in connection with manufacturing industries, it is this area to which the most study has been devoted. The location of extractive and service industries can usually be quite simply explained by the necessity of their being located in relation to resources (in the case of extractive industries) and consumers1 (service industries). There are few manufacturing industries today, however, for which one locational factor far outweighs all others. Geographic, economic, social, and political considerations all play a role in establishing patterns of specialization and concentration of manufacturing activities. Further difficulties are encountered because the actual pattern of location is always different from the norm or long-run

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1Individual, commercial, and industrial.
adjustment. New sources of raw materials, technological developments, and changes in consumer tastes all influence the pattern of locational development today as they did in the past. Locational economists have found it possible, however, to formulate a theory which isolates a number of distinct factors that influence the location of a manufacturing industry at a given time.

The most comprehensive approach to an understanding of industrial location is an examination of the typical locational problems of the business firm with a payroll. The activities of an individual producer can be divided into three stages: procurement (purchasing and bringing the necessary materials, fuels, and supplies to the site of processing); processing (transforming the materials into more valuable forms); and distribution (selling and delivering the products).\(^2\) The primary aim of the producer in locating a plant is to choose a site where these functions may be performed at minimum cost.

It should be noted at the outset that many plant locations do not meet these specifications. In the case of some, location has been little more than a historical accident. Others have been located in a haphazard manner due to lack of information or ignorance of the factors involved. Once a plant has been established, the cost of moving to another location may be prohibitive, and the business may continue to operate at the original site as long as it exists. Despite haphazard location of some plants, however, the location of entire industries tends to form some semblance of a reasonable pattern. Insofar as competition prevails, well-located enterprises are rewarded and poorly-located ones penalized or eliminated.

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When a private business enterprise sets about to determine the optimum location of a manufacturing plant, the first step should be to set forth its production requirements in quantitative terms. Possibilities of substitution of materials and the use of alternative production processes should be considered. Once the materials and services required have been determined, the next step is to determine their cost at each location under consideration. From the standpoint of procurement, the prospective producer must establish the cost of the necessary materials delivered at his site; thus transportation costs are included. To determine processing costs, basic information on the cost and availability of labor, capital, and land must be secured.

The size and scope of the proposed plant must be carefully determined. Production costs per unit may vary with the size and the degree of integration.

In considering distribution, the producer needs to know the demand for his product at particular locations as well as the distribution costs involved.

Other, less tangible considerations may also play a role in the choice of a location; for example, monopolistic tendencies and price policies and governmental influence.

The selection of a location may involve several stages of progressive elimination: first, a choice between regions on the basis of inter-regional differences in locational advantage; second, a decision as to size or class of community; and third, a choice between several cities or towns offering approximately equal advantages. In the latter case, factors such as personal preferences or convenience may play a decisive role.
**Major Locational Factors**

**Transfer Costs**

Transfer operations, involving transfer costs, play a major role in both the procurement and distribution functions. Unless the suppliers and the customers of a manufacturing concern absorb transportation costs completely (which rarely happens), they play an important role in locational preference. On the one hand, the cost of transporting raw materials or fuels exerts a pull toward the material or fuel source, while costs of transporting the finished products pull toward the market.

Costs of transfer vary with distance, direction of haul, type of commodity, volume of shipments, and the relative transportability of the goods. Rates are generally less than proportionately greater for long hauls than short ones, lower in the direction of lighter traffic flow, lower for large shipments and large shippers, and lower for compact and easily handled goods and goods of low value in proportion to weight. Transfer costs, however, involve more than the rates which the transfer agency charges. Such things as interest, insurance, deterioration (either physically or with respect to style changes), reliability of delivery, and increased costs of sales promotion and customer servicing at longer distances are all a part of transfer costs.

Advantageous locations from the standpoint of transfer costs are found sometimes at material sources, sometimes at markets, and sometimes at specially situated intermediate points. In a case where only one material is used and one commodity is produced for sale at a single market point, the location of a plant will occur near the source of the material, if it costs less to transport the product than the material,
and near the market if it costs less to transport the material. The greater the loss of weight in processing, the greater the attraction of the material source. Thus copper smelters and beet-sugar refineries are usually located near their sources of material. Since the initial processing of materials frequently involves a considerable weight loss, the early stages of production are more often than not material-oriented. The same generalization may be applied to processes with large fuel requirements, since fuel does not enter into the weight of the product.

Market-oriented industries are usually those producing finished products. Distribution costs are apt to be higher per ton of product than procurement costs per ton of raw material, because the product may be more fragile, more valuable in relation to its weight, or may be shipped in smaller lots. The baking industry provides an example of this type of market orientation. Other industries may require the use of "ubiquitous" materials which add weight to the finished product, thus providing an incentive to locate near the market. Breweries and soft drink bottling establishments, for example, use large quantities of water and are generally located near their major markets.

In some cases an intermediate location between the material source and the market provides the lowest transfer costs. This is frequently true where two different types of transport meet; for example, rail and water. In such cases the cost of transferring either the material or the product from rail to water (or vice versa) is saved, since the processing takes place at the junction. "Fabrication-in-transit" privileges, frequently utilized by the flour milling industry, also make intermediate locations feasible.
Most manufacturing industries, of course, utilize more than one important material and produce several products. In such cases the configuration of transfer routes and the geographical sequence of sources, junctions, and markets along these routes play an important role in location. Manufacturing industries may be material- or market-oriented, if any one material or product is sufficiently predominant. If not, the location offering minimum transfer costs may be at any of the material sources, markets, or junctions along the way. The ideal procurement or distribution center for such industries is frequently at a junction point. Flexibility in the combination of materials or fuels used or goods produced increases the area of locational choice.

**Processing Costs**

While transfer costs generally exert an important influence upon the location of a manufacturing industry, in some lines of business they vary so little with location that processing advantages assume a leading role.

Processing costs include labor costs, interest, costs of administration, rents and royalties, maintenance and depreciation, and taxes. Because the factors of production (land, labor, capital, and management) are not completely mobile, geographic differentials in their prices exist, and the producer seeking processing economies will seek a location where the cost of the particular combination of services he requires is at a minimum.

**Labor.** It is difficult to assess the over-all influence of labor upon location; what appears to be a labor-oriented industry may in fact be market-oriented, for the labor force is distributed roughly in proportion to the population. On the whole, it appears that labor
considerations are a contributing factor in the location of many industries, but decisive in only a few.\footnote{Ibid., p. 235.}

The labor force contains persons differing greatly in education, skill, and efficiency. These differences lead to differences in rates of remuneration, but there are also geographic differences in the wage rates of individuals performing the same tasks. These differences are the result of immobility on the part of the labor force. There are many reasons why labor is not completely mobile: persons become attached to their surroundings; they prefer certain types of cultural and natural environments; the expense of moving is high; making new contacts may be difficult; knowledge of job opportunities in other areas may be lacking; in the case of movement between countries, linguistic or political difficulties may be present.

Geographic variances in reproduction rates also affect the labor supply—and therefore wages—in different areas. Labor costs may be low in certain areas because of population pressure; that is, where employment opportunities have failed to keep pace with population growth.

Low-wage areas may attract industries whose labor costs constitute an important part of total costs. The movement of the textile industry to the South has become the classic example of the locational influence of low labor costs,\footnote{National Resources Planning Board, Industrial Location and National Resources, pp. 92-93.} although other factors such as nearness to raw materials and low power costs also played a role in the shift of the industry.

Locations with high money wage rates do not necessarily repel industry. Producers are interested in low processing costs, which depend...
in part upon labor productivity, and in some cases high wages are an indication of high productivity. Also, it is frequently possible to vary the amount of labor used in production by increased mechanization where wages are high.

Some locations are able to attract industries by virtue of the type of labor available rather than through any advantage in wage rates. Certain skills may be available only in particular areas. For example, New York City, as a leading clothing manufacturing center, offers labor skilled in that field. Seasonal industries may locate advantageously in areas where surplus labor is generally available during their peak seasons.

Capital. The availability of capital sometimes influences the location of industries, particularly new ones. To the extent that the mobility of capital is still imperfect, its readier availability in some places than in others may constitute a locational factor. The personal preferences of persons who own or control the necessary capital for an industrial plant may sometimes determine a location. Among the familiar examples of industrial location affected by local residents with capital to invest, or with the ability to obtain capital, are Ford Motor Company in Detroit, Eastman Kodak Company in Rochester, and Willys-Overland in Toledo.5

New ventures or those ineligible for listing on a major stock exchange may be dependent for capital upon a limited group of investors who may be interested only if the plant is located in their own vicinity. In general, however, capital is extremely mobile, and the question of its availability is rarely a separate locational consideration.

5Ibid., p. 235.
After a plant is constructed, a large amount of capital reserves is more or less frozen at the location selected and the expense of moving may be so heavy as to be out of the question. In this way, capital considerations may act as a deterrent to the relocation of industry.

Management. Management personnel has become increasingly important in business organizations, as size of enterprises has grown larger and specialization has become widespread. There appears to be some variation between regions as to the availability of management, with concentration in a few large industrial areas.

Business leaders have tended to become more mobile as their remuneration has increased. Unwillingness to break established professional, personal, and business ties frequently occurs, however, and, as in the case of labor requirements, it may be advantageous for a new plant to be located in an established center for its particular industry in order to take advantage of the management talent located in the area. Where an established plant needs additional capacity, the reluctance of administrators to move to other areas, or to travel back and forth, may result in expansion at the established site.

Size of Plant or Firm. In selecting a plant location, the producer is concerned with choosing a site where a satisfactory combination of the factors of production can be procured at the lowest cost. Another feature of production costs is the relationship between the cost per unit of production and the size of the plant or the firm.

The size of manufacturing plants and firms has been steadily increasing. Large-scale operations frequently have lower production costs because they can utilize labor and machinery more fully; because a large unit can operate with a smaller proportion of its resources
tied up in reserves; and because of the advantages of large-scale purchasing of materials. Eventually, of course, the advantages of size diminish and actual diseconomies may result. The tendency toward one large plant rather than several small ones, however, has been a major factor in the concentration of industry.

In some cases, economies in production depend not so much upon the size of the plant itself as upon the degree of local industrial concentration. New York City, in addition to offering labor skilled in clothing manufacture because of the concentration of the industry there, has the advantages of specialized auxiliary and service industries, and of being established as an important wholesale clothing buying center. These economies are available to all clothing plants in the New York City area, regardless of plant size.

Frequently, economies of production are effected by the integration of two or more processes in one plant, firm, or location. Usually the primary advantage from the producers' standpoint is in the control of markets and prices, or the convenience of having the various units of a firm close together.

Other Factors

While transfer and processing costs are necessarily of primary importance in the location of a plant, other more or less intangible factors are frequently influential in location determination. Here questions of the degree of competition or monopoly in a particular industry, price policies, and governmental influences such as expenditures, taxation, subsidies, trade policy, etc., arise.

Monopolistic Influences. The principal effect of monopolistic influences appears to be in a reduction of the number of producing units,
especially where the monopolistic control gives effective output control, or where monopoly is substituted for inefficient competition. Monopoly control may also mean that irrational forces, or the desire to protect existing investment, may for long periods determine the locational pattern by preventing or delaying the process of locational change.

The window glass industry provides an illustration of how monopolistic control may influence location. Before 1935, there were three large concerns and twelve small ones in the industry. With financial assistance from the three leaders, an executive of one of the smaller companies was able to buy out the other eleven small producers. Of the eleven plants purchased, eight were closed down permanently, drastically changing the locational pattern of the industry. Today there are still only four companies producing window glass in the United States.6

Price Policies. One of the least tangible of the factors which influence location is the existence of price policies.7 The mere existence of a price policy implies that the seller can influence the price at which his product is sold. Price policies are not a dominant

6Ibid., p. 281.

7Price policies may be classified as follows:
1. Delivered prices vary according to transport costs
   a. F.o.b. pricing
   b. Basing-point pricing (quasi-f.o.b.)
      (1) Single basing-point system
      (2) Multiple basing-point system
2. Delivered prices uniform within area
   a. Nationally uniform delivered prices
   b. Uniform within geographic zones
3. Delivered prices vary unsystematically
4. Various combinations of the above patterns.

loational factor. They are rarely established for the primary purpose of influencing location. Nevertheless, any price policy which eliminates or prevents the entry of potential competitors affects the locational pattern by reducing the number of producing locations and concentrating production at fewer points. The location of fabricating industries which are material-oriented to a product for which a price policy has been established is also affected.

Governmental Influences. Nearly all the governmental influence upon industrial location comes from the Federal level. State and local governments sometimes exert influence through promotional activities, special tax concessions, regulation of public utilities, development of transport facilities, or the erection of interstate trade barriers. Federal influence is much greater; many acts of the Federal government may have some effect upon income in certain areas and thus may influence the location of consuming markets (and hence the location of industry). Frequently, more direct and deliberate actions are taken. The following outline gives an over-all picture of the many ways in which the Federal government may influence industrial location:

A. Means which alter the relationships among industrial costs in various areas:
1. Those altering labor costs:
   a. Minimum wage standards
   b. Encouragement of union organization
   c. Social insurance
   d. Work relief and direct relief
2. Those altering material costs:
   a. Import duties
   b. Government competition in purchasing
3. Those altering power and fuel costs:
   a. Public power developments
   b. Regulation of the price of (and freight rates on) coal
   c. Regulation and indirect encouragement of the petroleum and natural gas industries.
4. Those altering transportation costs:
   a. Railway subsidies
   b. Highway and waterway expenditures
   c. Regulation of common carriers
   d. Land settlement policy.

5. Those altering capital costs:
   a. General monetary and banking policies
   b. Use of Federal credit.

B. Means which alter income relationships among areas:
   1. Revenues and expenditures
   2. Customs duties
   3. Price-fixing and regulation of price policies
   4. Land settlement policy.

C. Means which help or hinder certain industries and thus influence industrial location:
   1. Protective tariffs
   2. Excise taxes

D. Other means of influencing the location of Industry not owned by the government:
   1. Attitude toward basing points and market sharing
   2. Industrial research
   3. Educational and informational agencies.

F. Federal ownership and operation of industry.

**Locational Shifts**

The locational pattern of industries is constantly changing as adjustments to new conditions take place. Locational shifts most frequently occur as a result of changes in markets, new discoveries of raw materials or fuels or depletion of old sources, new technological developments, labor-cost differentials between areas, or attempts to consolidate production.

Most of the changes in the industrial location pattern are brought about by the establishment of new plants and the liquidation of old ones. Actual relocations of plants (physical transference of production

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*Ibid., p. 318.*
facilities) are quite rare, because of the heavy expenses involved. Branch plants are more easily involved in locational shifts than are single independent plants.

A shift in one industry, of course, produces shifts in others. Repercussions in the form of added or declining demand for materials, land, labor, and various services, and in the location of population and consumer markets accompany such a change.

Industrial development in the United States since 1940 has been characterized by a trend toward more equal interregional distribution. The heavily industrialized areas of the eastern United States have received relatively less new investment while the South and the West received a proportionately greater share. 9

In 1939, of total expenditures for new plant and equipment, 8.2 per cent was expended in New England, 24.7 per cent in the Middle Atlantic States, 33.7 per cent in the East North Central States, and only 7.7 per cent in the eleven Mountain and Pacific States. In 1951, 5.8 per cent of total expenditures was in New England, 22.4 percent in the Middle Atlantic States, 31.6 per cent in the East North Central States, and 10.7 per cent in the Mountain and Pacific States. 10

Among the industries in which the locational pattern shifted to include western development was the elemental phosphorus industry.

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9Edgar M. Hoover, _loc. cit._, p. 163.

IV. THE ELEMENTAL PHOSPHORUS INDUSTRY

IN THE UNITED STATES

Elemental phosphorus is a yellow or white, waxlike substance produced by the reduction of phosphate rock in electric furnaces.

In the electric furnace process, the phosphate rock is reduced in the presence of coke and silica. Free phosphorus is given off as a vapor, together with carbon monoxide. The phosphorus is condensed from the mixture and liquefied under water. When exposed to the air, elemental phosphorus is highly combustible at ordinary temperatures. It requires special equipment for storage and shipping. In shipping, the phosphorus is heated to keep it molten and pumped into water-filled tank cars, the phosphorus displacing the water and solidifying as it cools. Upon unloading, steam is pumped into the outer jacket of the car, thus melting the phosphorus so it can be pumped from the car to storage tanks.

Two other processes of making phosphorus have been used in the past. One method was to produce phosphoric acid by the wet process of applying sulfuric acid to the phosphate rock and then converting the phosphoric acid to phosphorus. Another method was by the blast furnace process, which used coke to provide heat for the melting of the charge. Use of both these methods was abandoned when the electric process proved to be the most satisfactory from the standpoint of economy and ease of production.

Most of the elemental phosphorus produced in this country is made into phosphoric acid and salts for use in the manufacture of food products,
textiles, dentrifices, cosmetics, pharmaceuticals, paints, soaps and detergents, and water softeners. Large quantities of phosphorus are also used in heavy industry and the production of armaments. By-products of the electric furnace process are carbon monoxide gas, lead off to be used as fuel for the process, and slag, used for ballasting railroads and in the construction of roads and fabrication of building materials.

**Growth of the Industry**

The elemental phosphorus industry in the United States has been characterized by rapid growth. Commercial production by the electric furnace method first began in 1896, at Niagara Falls, New York. A second plant was built in Alabama about 1920, but it was not until 1934, when the Tennessee Valley Authority constructed its first furnace at Wilson Dam, Alabama, that large-scale production got underway. With the defense and war efforts as an impetus, production increased rapidly from 1936 to 1944. (Table 1, page 25.)

A slight decline in production occurred in 1945 as military demands for phosphorus decreased, but by 1947 output was exceeding that of the war years, and a tremendous expansion program was underway to meet the demands of growing civilian markets for phosphates. Between 1946 and 1953, rated annual capacity increased from 92,800 short tons to 285,000 short tons, or 207 percent. The aggressive nature of the industry, evidenced in intensive research and market development programs, played an important role in this growth. Existing outlets were expanded, new markets developed for products already manufactured, and many new products brought to light. According to trade sources, present facilities appear adequate to fill the existing demand and little further expansion is
Table 1

NUMBER OF PRODUCERS, NUMBER OF ELECTRIC FURNACES, RATED ANNUAL CAPACITY, AND ANNUAL PRODUCTION, ELEMENTAL PHOSPHORUS INDUSTRY, 1930, 1935-1950, and 1953

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Producers</th>
<th>Number of Electric Furnaces</th>
<th>Rated Annual Capacity (short tons)</th>
<th>Annual Production (short tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1930</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1935</td>
<td>5</td>
<td>5</td>
<td>29,200</td>
<td>10,500</td>
</tr>
<tr>
<td>1936</td>
<td>5</td>
<td>5</td>
<td>31,200</td>
<td>21,500</td>
</tr>
<tr>
<td>1937</td>
<td>5</td>
<td>9</td>
<td>59,800</td>
<td>26,000</td>
</tr>
<tr>
<td>1938</td>
<td>5</td>
<td>9</td>
<td>53,300</td>
<td>27,250</td>
</tr>
<tr>
<td>1939</td>
<td>5</td>
<td>11</td>
<td>61,900</td>
<td>36,750</td>
</tr>
<tr>
<td>1940</td>
<td>5</td>
<td>13</td>
<td>63,900</td>
<td>43,000</td>
</tr>
<tr>
<td>1941</td>
<td>5</td>
<td>14</td>
<td>73,900</td>
<td>48,500</td>
</tr>
<tr>
<td>1942</td>
<td>5</td>
<td>15</td>
<td>83,600</td>
<td>56,500</td>
</tr>
<tr>
<td>1943</td>
<td>5</td>
<td>15</td>
<td>83,600</td>
<td>72,500</td>
</tr>
<tr>
<td>1944</td>
<td>6</td>
<td>16</td>
<td>88,100</td>
<td>80,000</td>
</tr>
<tr>
<td>1945</td>
<td>6</td>
<td>16</td>
<td>88,100</td>
<td>86,500</td>
</tr>
<tr>
<td>1946</td>
<td>6</td>
<td>16</td>
<td>92,800</td>
<td>80,000</td>
</tr>
<tr>
<td>1947</td>
<td>6</td>
<td>18</td>
<td>112,500</td>
<td>92,500</td>
</tr>
<tr>
<td>1948</td>
<td>6</td>
<td>20</td>
<td>118,000</td>
<td>83,500</td>
</tr>
<tr>
<td>1949</td>
<td>7</td>
<td>23</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1950</td>
<td>7</td>
<td>24</td>
<td>156,000</td>
<td>-</td>
</tr>
<tr>
<td>1953</td>
<td>7</td>
<td>27</td>
<td>265,000</td>
<td>154,000^4</td>
</tr>
</tbody>
</table>

1Includes Tennessee Valley Authority.
2Includes phosphorus equivalent of H₃PO₄ produced in one-step process.
3Operating capacity.
4Approximate figure.

planned for the immediate future.1

**Location of the Industry Prior to 1947**

At the present time, there are seven companies operating thirteen elemental phosphorus plants in the United States. They are Victor Chemical Works, Monsanto Chemical Company, Westvaco Chemical Division of Food Machinery and Chemical Corporation, Virginia-Carolina Chemical Company, Oldbury Electro-Chemical Company, Shea Chemical Company, and American Agricultural Chemical Company. The Tennessee Valley Authority also produces elemental phosphorus. The industry’s big three—Victor, Monsanto, and Westvaco—account for about 75 per cent of total production.

The location of plants producing elemental phosphorus in the United States is shown in Figure 1, page 27. Prior to 1947, all of the plants were located east of the Mississippi River, with the bulk of productive capacity near the Tennessee phosphate fields.

The single most important raw material in the production of elemental phosphorus—from the standpoint of both quantity and cost—is phosphate rock. The other two most important materials are coke and silica sand. Sand of a satisfactory quality is generally available everywhere (Weber would call it an ubiquity) and adds no weight to the product. Thus it is of little significance locationwise. Neither is coke important enough to be a major locational factor. However, approximately seven tons of phosphate rock are required to produce one ton of elemental phosphorus. With such a significant weight loss, it is to be expected that a strong locational pull toward the source of the rock would exist. In Chapter II, it was noted that in production processes

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Figure 1
LOCATION OF ELEMENTAL PHOSPHORUS PLANTS IN THE UNITED STATES

where one material is predominant, the industry is frequently drawn
toward the material source, and that in general industries engaged in
the early stages of production tend to be material-oriented. Thus most
of the phosphorus plants built before World War II were located near the
extensive Tennessee and Florida phosphate deposits. (Figure 2, page 29.)
Victor Chemical Works operated plants at Mt. Pleasant, Tennessee, and
Tarpon Springs, Florida; Monsanto Chemical Company at Columbia and Monsanto,
Tennessee; Virginia-Carolina Chemical Company at Nichols, Florida; and
the Tennessee Valley Authority at Wilson Dam, Alabama. In 1952, Shea
Chemical Company, a new entrant into the industry, constructed a plant
at Columbia, Tennessee.

In addition to phosphate rock, huge quantities of electric power
are necessary in the production of elemental phosphorus by the electric
furnace method. Power costs normally represent 30 per cent of the total
manufacturing cost; thus the availability of power at reasonable rates
probably plays an equally significant locational role in the establish-
ment of an elemental phosphorus plant. The first commercial electric
furnace was constructed at Niagara Falls, New York, to take advantage of
low-cost hydroelectric power. The rapid development of the industry in
the South was possible because of the cheap power available there in
conjunction with the phosphate rock deposits. In fact, the Tennessee
Valley Authority was instrumental in perfecting the electric furnace
method for commercial use, and established the first plant in the South
in 1934.

Elemental phosphorus is not marketed as such, except in very small
quantities. Producers of elemental phosphorus consume most of it in
further processing, mostly in the production of chemical phosphates.
All of the dry process phosphoric acid plants (plants producing phosphoric acid from elemental phosphorus) are located in the East, with the exception of the Victor Chemical Works plant at South Gate, California, and the Westvaco plant at Newark, California, which has been built since World War II. All are located near industrial markets, although in some cases at considerable distances from the elemental phosphorus plants. It is cheaper to ship concentrated elemental phosphorus than commercial grades of phosphoric acid or other derivatives.

It would appear that these were the two major factors in the establishment of the industry in the South: the availability of phosphate rock and low-cost electric power. The location of phosphorus plants in that area in conjunction with eastern phosphoric acid plants also afforded some proximity to the major industrial markets.

It is also significant that impetus to the development came from the Federal government, through its industrial research activities and the construction of the Tennessee Valley Authority dams. Because the Authority had perfected the electric furnace method at Wilson Dam, Alabama, there may have been advantages in locating near its plant, from the point of view of securing technical advice.

The fact that the South is a low wage area was not an important factor in the location of the industry there. Labor costs are not a significant part of total processing costs in phosphorus production. The industry is highly mechanized and the majority of jobs in the plant do not require highly skilled labor.

Size of plant does not appear to be so significant a factor in the phosphorus industry as in some others. Plants may be operated with one, two, or more furnaces; however, each is a separate producing unit.
Advantages occur chiefly in lower management costs and single-furnace plants are few. The tendency in the industry, however, seems to be toward several medium-sized plants operated by the same firm.

The entrance of two new firms since the end of World War II—Westvaco Chemical Division of Food Machinery and Chemical Corporation and Shea Chemical Company—indicates that some degree of competition exists in the industry. There is no evidence of monopoly influencing location. Insofar as price policies are concerned, little is known, since nearly all the elemental phosphorus produced is processed further into phosphates by the same firms. It is notable, however, that while the chemical industries, including the phosphate industry, are renowned for the "orderliness" of their marketing and price policies, there is keen competition cost-wise between producers of elemental phosphorus.

The primary item of cost in the secondary phosphoric products is the cost of producing elemental phosphorus; consequently, those producers who can most economically produce phosphorus have a considerable advantage.

The Shift West

In 1947, Westvaco Chemical Division of Food Machinery and Chemical Corporation began the construction of a new two-furnace plant at Pocatello, Idaho. By 1952, two additional furnaces had been added to the operation. In 1950, Victor Chemical Works began construction of a single-furnace plant at Silver Bow, Montana; the following year Victor began work on a second furnace at Silver Bow. In 1951, the Monsanto Chemical Company also moved west, building an electric furnace at Soda Springs, Idaho.

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A second furnace is now under construction. Thus, since 1947, three plants with a combined capacity of over 115,000 tons a year, or more than one-third of total United States capacity, have been constructed in Idaho and Montana. These developments represent an important shift in the locational pattern of the phosphorus industry.

In Chapter II, it was noted that such shifts generally occur as a result of changing markets, changes in labor-cost differentials between areas, new sources of raw materials (including fuels), technological developments, or efforts to consolidate production. In the case of the phosphorus industry, new sources of electric power and growing industrial markets on the Pacific Coast, together with the presence of huge quantities of phosphate rock in Idaho, Montana, Wyoming, and Utah, appear to have been the dominant factors in the westward movement.

The phosphate rock deposits in the Northwest were discovered before the turn of the century, and although the extent of the reserves still is not fully determined, more than half the known United States reserves are located in these states. (Table 2, page 33.) Most of the western deposits are on public domain, with leases obtainable from the Federal government. Comparatively little development of western phosphate fields had taken place by 1947. Several large fertilizer manufacturers and a number of western chemical concerns and small mining companies were mining rock in the area, but for the most part the huge reserves were virtually untouched.

The development of new low-cost hydroelectric power resources by private and public agencies after the war made the utilization of the western fields for the production of phosphorus feasible. The cost of electricity for industrial use in the Northwest is generally slightly
Table 2
PHOSPHATE ROCK RESERVES OF THE UNITED STATES

<table>
<thead>
<tr>
<th>State</th>
<th>Long Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total, United States</td>
<td>13,290,860,000</td>
</tr>
<tr>
<td><strong>Eastern States</strong></td>
<td></td>
</tr>
<tr>
<td>Florida</td>
<td>5,061,839,000</td>
</tr>
<tr>
<td>Tennessee</td>
<td>194,468,000</td>
</tr>
<tr>
<td>South Carolina</td>
<td>6,796,000</td>
</tr>
<tr>
<td>Kentucky</td>
<td>863,000</td>
</tr>
<tr>
<td>Arkansas</td>
<td>20,000,000</td>
</tr>
<tr>
<td><strong>Total, Eastern States</strong></td>
<td>5,305,968,000</td>
</tr>
<tr>
<td><strong>Western States</strong></td>
<td></td>
</tr>
<tr>
<td>Idaho</td>
<td>5,736,335,000</td>
</tr>
<tr>
<td>Montana</td>
<td>391,323,000</td>
</tr>
<tr>
<td>Utah3</td>
<td>7,741,480,000</td>
</tr>
<tr>
<td>Wyoming</td>
<td>115,754,000</td>
</tr>
<tr>
<td><strong>Total, Western States</strong></td>
<td>7,984,892,000</td>
</tr>
</tbody>
</table>

1All grades as differentiated, plus results of government prospecting to date.
2Including material better than 60 per cent tricalcium phosphate.
3Including material better than 40 per cent tricalcium phosphate.


lower than in the Tennessee area and considerably less than in Florida. Bonneville Power Administration's rate per kilowatt hour to large industrial users in Montana is 2.2 mills, compared to the Tennessee Valley Authority's rate of 3.1 mills per kilowatt hour, and a private utility rate of 7.0 mills at Tarpon Springs, Florida. This saving in power costs apparently helped to offset the slightly higher cost of mining phosphate rock in some parts of the Northwest. The average values of

phosphate rock at the mines in Florida, Tennessee, Idaho, and Montana from 1947 to 1953 are given in Table 3, page 35. These values are not entirely comparable because of variations in the quality of rock. According to the data, the average value per ton of phosphate rock mined in Montana during the first half of 1953 was $6.60, compared to $5.96 in Florida. Average value of Tennessee rock was $7.60. Idaho, where large quantities of low-grade rock are produced, had a low average value of $2.85.

The decade of the forties had witnessed a tremendous expansion of industrial activity on the Pacific Coast. As the demand for phosphates in the area increased, it was natural that the industry's attention should be drawn toward the possibility of utilizing the phosphate rock and power resources of the Northwest in the production of elemental phosphorus. In Tennessee, where the bulk of the productive capacity of the industry is concentrated, few new phosphate rock sources were available; in Florida, power costs were high. In addition, a location in the Northwest offered greater proximity to the western markets.

The three companies which have built phosphorus plants in Montana and Idaho are large corporations with ample resources. Their movement into the Northwest was slow and deliberate and accomplished only after several years of investigation. It is reasonable to assume, therefore, that these firms found it possible to produce phosphorus at a competitive cost in the Northwest, at least for further processing in the West.

To date, two of the three companies producing in Montana and Idaho—Victor and Westvaco—have phosphate manufacturing plants in California. Victor purchased the A. R. Maas Chemical Company at South Gate in 1949, and Westvaco constructed a plant at Newark. Both companies ship phosphorus from their Northwest to their California plants, because rates on elemental
<table>
<thead>
<tr>
<th></th>
<th>Florida</th>
<th></th>
<th>Tennessee</th>
<th></th>
<th>Idaho</th>
<th></th>
<th>Montana</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Long Tons (000)</td>
<td>Value at Mines (000)</td>
<td>Ave.</td>
<td>Long Tons (000)</td>
<td>Value at Mines (000)</td>
<td>Ave.</td>
<td>Long Tons (000)</td>
</tr>
<tr>
<td></td>
<td>6,482</td>
<td>$32,920</td>
<td>5.06</td>
<td>1,412</td>
<td>$7,779</td>
<td>5.51</td>
<td>845</td>
</tr>
<tr>
<td></td>
<td>6,539</td>
<td>37,733</td>
<td>5.77</td>
<td>1,308</td>
<td>8,231</td>
<td>6.30</td>
<td>434</td>
</tr>
<tr>
<td></td>
<td>6,816</td>
<td>37,856</td>
<td>5.55</td>
<td>1,344</td>
<td>9,068</td>
<td>6.74</td>
<td>471</td>
</tr>
<tr>
<td></td>
<td>6,086</td>
<td>45,378</td>
<td>5.61</td>
<td>1,384</td>
<td>10,028</td>
<td>7.24</td>
<td>573</td>
</tr>
<tr>
<td></td>
<td>8,497</td>
<td>50,263</td>
<td>5.92</td>
<td>1,420</td>
<td>10,605</td>
<td>7.47</td>
<td>695</td>
</tr>
<tr>
<td></td>
<td>8,761</td>
<td>51,542</td>
<td>5.67</td>
<td>1,453</td>
<td>10,875</td>
<td>7.49</td>
<td>621</td>
</tr>
<tr>
<td>(first half):</td>
<td>4,615</td>
<td>27,520</td>
<td>5.96</td>
<td>826</td>
<td>6,275</td>
<td>7.60</td>
<td>468</td>
</tr>
</tbody>
</table>

Note: Figures on average value per ton not strictly comparable because of variations in quality of rock. is particularly true for comparisons between Idaho and Montana, for more low quality rock is mined in Idaho.

phosphorus are lower than transportation costs for phosphoric acid or other derivatives.
V. THE LOCATION OF THE VICTOR CHEMICAL WORKS ELEMENTAL
PHOSPHORUS PLANT AT SILVER BOW, MONTANA

In the preceding chapter, the chief factors responsible for the location of three elemental phosphorus plants in the Pacific Northwest appeared to be the expansion of western markets and the availability of sufficient phosphate rock and power. These considerations determined the regional location. Once the decision to locate in the Northwest had been made, however, a further locational problem as to area and specific site must be solved.

Victor Chemical Works chose to locate its electric furnace plant near Silver Bow, Montana, seven miles west of Butte. The plant was built at a total cost of approximately $10 million. This was a significant development for Silver Bow County, inasmuch as it had been heavily dependent upon one industry (mining), and for the state of Montana, which has long been desirous of attracting new manufacturing industries in an attempt to diversify its economy. This chapter will deal largely with the factors involved in Victor’s choice of Silver Bow as the site of its new Northwest plant.

Silver Bow County

Silver Bow County differs in population and in industrial makeup from the greater part of Montana. Agriculture is of much less significance than in the state as a whole, with Silver Bow ranking 54th among
Table 4

PER CENT DISTRIBUTION OF URBAN, RURAL-NONFARM, AND RURAL-FARM POPULATION, MONTANA AND SILVER BOW COUNTY, 1950

<table>
<thead>
<tr>
<th></th>
<th>Montana</th>
<th>Silver Bow County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>43.7</td>
<td>79.3</td>
</tr>
<tr>
<td>Rural-nonfarm</td>
<td>33.3</td>
<td>19.6</td>
</tr>
<tr>
<td>Rural-farm</td>
<td>23.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

1Persons living in cities and towns of over 2,500 population.
2Persons living in rural communities of less than 2,500 population, but not on farms.


the 56 counties in value of agricultural products sold in 1949. By far the most important industry is metal mining. Considerable concentration also exists in the trade and service industries.

The population of Silver Bow County is predominantly urban, with 79.3 per cent of its residents living in the urban areas of Butte and the Silver Bow-Floral Park district. Only 1.2 per cent of the population of Silver Bow County is classified as rural-farm, with the remaining 19.6 per cent listed as rural-nonfarm. (Table 4, above.)

The median income for families and unrelated individuals in the county in 1949 was $3,050, 12.2 per cent above the $2,718 median income in the state and 17.4 per cent above the $2,599 median for the United States.

Table 5
DISTRIBUTION OF THE EMPLOYED LABOR FORCE, MAJOR INDUSTRY GROUPS, SILVER BOW COUNTY MONTANA,
APRIL 1, 1950

<table>
<thead>
<tr>
<th>Industry Group</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total employed</td>
<td>18,632</td>
<td>100.0</td>
</tr>
<tr>
<td>Agriculture</td>
<td>252</td>
<td>1.4</td>
</tr>
<tr>
<td>Mining</td>
<td>6,006</td>
<td>32.2</td>
</tr>
<tr>
<td>Construction</td>
<td>781</td>
<td>4.2</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>1,195</td>
<td>6.4</td>
</tr>
<tr>
<td>Trade</td>
<td>4,324</td>
<td>23.2</td>
</tr>
<tr>
<td>Service and finance</td>
<td>4,151</td>
<td>22.3</td>
</tr>
<tr>
<td>Transportation, communication, and other public utilities</td>
<td>1,710</td>
<td>9.2</td>
</tr>
<tr>
<td>Other, not elsewhere classified</td>
<td>213</td>
<td>1.1</td>
</tr>
</tbody>
</table>


States\(^2\), due largely to the higher-than-average wage rates paid by the mining industry.

A breakdown of employment by industry groups indicates the degree of Silver Bow County's dependence upon the mining industry. (Table 5, above.) Over 32 per cent of the total employed labor force was employed in mining in 1950. Wholesale and retail trade establishments employed

23.2 per cent of the employed labor force and another 22.3 per cent was at work in the service industries, including finance.

Only 6.4 per cent of the employed labor force, or 1,195 persons, were at work in manufacturing industries, and most of the goods produced were for local consumption. Three industry groups accounted for about 73 per cent of total manufacturing employment: food and kindred products, printing, publishing, and allied products, and primary metals. The bulk of the workers in primary metals were employed in the smelter at Anaconda and commuted from residences in Butte and its vicinity. To this extent, the employment figures overstate manufacturing employment in Silver Bow County itself. Those manufacturing industries producing chemicals and allied products were of minor significance in 1950, with only 32 employees, or 2.7 per cent of the county's total manufacturing employment.

The community of Silver Bow is a small, unincorporated settlement about seven miles west of Butte, with a population of perhaps 100. Victor is the only industry in the immediate vicinity.

**Victor Chemical Works**

Victor Chemical Works was founded in 1877 at Chicago Heights, Illinois. Originally, there were only two employees; with the steady growth of the company, this number has increased to well over 2,000. Today, Victor is one of the three largest producers of phosphorus and phosphates in the world.

The first Victor plant was constructed for the production of monocalcium phosphate from phosphoric acid, produced by the reaction of sulfuric acid on animal bones, which contain calcium phosphate. The raw material was changed to phosphate rock in 1912 to eliminate certain
undesirable impurities. In 1920, another plant was constructed at Nashville, Tennessee, to meet the increased demand for monocalcium phosphate by the baking industry. In 1928, a blast furnace plant was constructed at Nashville to produce phosphoric acid from phosphate rock, coke, and silica sand.

In 1937, due to increasing coke costs and demands for phosphorus, Victor constructed an electric furnace plant at Mt. Pleasant, Tennessee, utilizing Tennessee phosphate rock and low-cost surplus electric power from the Tennessee Valley Authority. This plant supplied all of the company's phosphorus needs from 1939 to 1947 and was expanded several times in the interim.

Victor undertook a large expansion program in 1947, constructing an electric furnace plant at Tarpon Springs, Florida, that year and a phosphate products plant at Morrisville, Pennsylvania, in 1948. The location of the phosphate plant in Pennsylvania provided freight savings and expedited deliveries to the firm's East Coast customers. Also during 1948, Victor's processing plants at Chicago Heights and Nashville were expanded to provide for additional capacity.3

On June 30, 1949, Victor acquired the A. R. Maas Chemical Company of South Gate, California, near Los Angeles. This division is an important producer of phosphates, phosphoric acid, and photographic chemicals, well located to serve the western states. As a final step in its immediate postwar expansion program, Victor in 1950 announced plans for the construction of an electric furnace plant at Silver Bow, Montana, to supply phosphorus to the South Gate division. Construction began in

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August of that year. The project was scarcely underway before it became clear that combined industrial and governmental requirements would tax even the firm's expanded facilities, and in March 1951 the company announced that it would construct a second furnace at the Silver Bow site. Officials state that the plant is so constructed that additional furnaces could be added if market conditions justified further expansion.

At the present time, then, Victor Chemical Works operates three electric furnace plants— at Mt. Pleasant, Tarpon Springs, and Silver Bow—and processing plants at Chicago Heights, Nashville, Morrisville, and South Gate. Compared to some of the giants in the chemical industry, Victor is a small company. However, it is one of the fastest growing chemical producers in the United States. Between 1940 and 1952, gross sales increased from $8 million in 1940 and $17 million in 1945 to almost $36 million in 1952, or about 350 percent.4

The food industry is one of the largest users of Victor phosphates and derivatives. The widening popularity of prepared cake, cookie, and biscuit mixes has strengthened the demand. An increasingly important customer is the soap and synthetic detergent industry, which uses sodium tripolyphosphate. The manufacture of such new drugs as penicillin and the anti-histamines requires phosphorus, and a Victor product, diammonium phosphate, goes into most varieties of tooth paste and tooth powder.

Research has widened the market for many of Victor's products. Phosphoric acid pickling of steel, for example, is now commercially feasible through a process which recovers the spent acid and permits its re-use.

A relatively new Victor product, phosphoric anhydride, can be added to asphalt so that it will not buckle or crack.

**Location in Montana**

Sufficient quantities of phosphate rock for an elemental phosphorus plant are located in all four of the Northwestern states of Montana, Idaho, Utah, and Wyoming. The electric furnace process does not require a high grade rock and thus deposits not economical for industries such as fertilizer may be utilized. There are, of course, variations among fields in the cost of extracting the rock. The most economic sources for conversion to elemental phosphorus are believed to be available in Idaho, where two of the three new phosphorus plants are located.

Victor Chemical Works, however, chose to locate its plant at Silver Bow, Montana. The major reason for this decision was undoubtedly the availability of cheaper electric power. At the time the Victor plant was being built, Hungry Horse Dam in northwestern Montana was also under construction and scheduled for completion in the fall of 1952. With its completion, Bonneville Power Administration, the distributing agency for Federal power in the Northwest, would have larger quantities of power available for industrial use. The Bonneville rate for large industrial users not located at the dam site is 2.2 mills per kilowatt hour. Idaho Power Company, the chief power producer in southern Idaho, offered a rate of approximately 4.5 mills per kilowatt hour. It seems clear that this saving in power costs was expected to more than offset the higher

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6Telegram from Donald Benedict, Assistant to the Power Manager, Bonneville Power Administration, Portland, Oregon, June 15, 1953.
cost of rock in Montana and constituted the major factor in the Victor
decision to locate in the state.

Selection of the Silver Bow Site

Transfer Costs

Once the decision had been made to locate the plant in Montana,
the selection of a specific site became the next step. Montana's phos-
phate rock deposits are located in the southwestern part of the state,
and in 1947 and 1948 Victor had acquired leases on two public domain
properties—the Maiden Rock and Canyon Creek deposits, involving some
2,500 acres—in the Melrose district in Beaverhead County, on the route
of the Union Pacific railroad. Bonneville Power Administration plans
included a transmission line from Hungry Horse to Anaconda, Montana.
Possible locations for the plant, therefore, included Anaconda, the
Melrose mining district, or some point between the two. The final
choice was Silver Bow, where the lines of the Northern Pacific, Chicago,
Milwaukee, St. Paul, and Pacific, and the Union Pacific railroads converge,
about 22 miles east of Anaconda and 30 miles north of Melrose. (Figure 3,
page 45.) Location at this point offered advantages in procurement of
materials and shipment of the product. Rail service to the East and
West via the Northern Pacific and the Chicago, Milwaukee, St. Paul, and
Pacific, and south to California on the Union Pacific is available from
Silver Bow. Phosphate rock is hauled the 30 miles from Melrose by the
Union Pacific. The necessity of reloading or switching from one railroad
to the other is eliminated. No other location between Melrose and Anaconda
except the seven-mile route from Silver Bow to Butte offered such trans-
portation facilities. Anaconda must have been immediately ruled out as
Figure 3

LOCATION OF VICTOR CHEMICAL WORKS ELEMENTAL PHOSPHORUS PLANT AT SILVER BOW, MONTANA

[Map showing locations and routes]
a possible location because it has no transcontinental railroad service.

**Processing Costs**

**Labor.** Labor requirements of elemental phosphorus production are low compared to other industries, because of the high degree of mechanization. However, the company anticipated a need for 250 employees at the plant and it was necessary that the availability of such a labor force be assured. Special skills were not required.

Because of Montana's small population, the availability of labor became a factor in the selection of a plant site. A location at the source of the phosphate rock was ruled out. The company's mining operations required 100 workers at Maiden Rock and Canyon Creek. An attempt to recruit another 250 workers from the area, which is sparsely populated, would probably have failed. The nearest towns of any size are Butte, about 30 miles north, and Dillon, about 30 miles south—too far for workers to commute during the winter. Another consideration mitigating against the establishment of the plant at the mines was the company's desire to avoid becoming involved in providing housing for its employees, and this would have been necessary in the Melrose district.

The location of the plant at Silver Bow, on the other hand, gave ready access to the Butte labor market just seven miles away. Butte has traditionally been an area of surplus labor, and experienced considerable out-migration of population to defense production areas during the decade of the forties. However, the male labor force of Butte and the Silver Bow-Floral Park areas adjoining it numbered 12,200 in 1950 and thus an ample labor supply for the Victor plant seemed assured. The fact that labor costs were somewhat higher than in other areas of the state was not significant enough to deter the company from locating near
Capital. The financial position of Victor Chemical Works and its prospects for future growth were such that little difficulty was encountered in financing the new plant. This was accomplished largely through use of the firm's own funds and a loan from the Equitable Life Assurance Society of the United States on promissory notes bearing 2 3/4 per cent interest.\(^7\)

Management. The firm brought its key personnel and managerial talent from other company plants. The plant superintendent came from Chicago Heights; the master mechanic and general foreman from the Victor plant at Mt. Pleasant, Tennessee; and most of the other lesser officials and foremen from various Victor plants. Personnel hired locally included for the most part only workers in the plant and clerical help in the office.\(^6\)

Isolation of Site.

A phosphorus furnace, with a certain amount of dust and smoke, and with flames belching from its stacks, is not the type of plant which a residential or business community would enjoy having in its midst. At the Silver Bow site, the plant enjoys a fair degree of isolation, and ample space is available for the dumping of slag and stockpiling of phosphate rock. It is also true that such a site is less costly than land in an urban development.

Governmental Influences

According to company officials, Silver Bow County offered certain property tax concessions to the firm, and this may have offered some


\(^6\)Letter from J. F. Jefferson, Jr., Personnel Manager, Victor Chemical
inducement for the location of the plant within the county borders. Victor also received a certificate of necessity as a defense industry from the Federal government, providing for accelerated tax amortization.

The influence exerted by the Federal government through the construction of Hungry Horse Dam may again be emphasized. When the final decision on the Silver Bow site had been made by Victor, Bonneville Power Administration began construction of a substation at Silver Bow and a tapline to Montana Power Company's Butte-Anaconda line. Arrangements were made for Montana Power to serve Victor until Hungry Horse Dam and the Bonneville transmission line were completed. Early in 1953, Bonneville began delivery of power to the plant from Hungry Horse.
VI. SUMMARY

The theory of industrial location was long neglected by economists. Johann Heinrich von Thunen, a German, made a notable attempt to explain the location of agricultural activity in the early 1800’s, and Alfred Weber undertook the analysis of industrial location in his *Über den Standort der Industrien*, published in 1909.

Weber defined locational factors as advantages in cost, and considered transportation and labor costs the only two factors which affect the regional location of industry. All other factors are part of the agglomerative or deglomerative forces determining the distribution of industry within a region. Agglomerative forces are advantages of lower cost of production or marketing resulting from the fact that production is carried on to a considerable extent at one place. Deglomerative factors are defined as counter-tendencies to agglomeration, all following from the rise of land values or labor costs which accompany agglomeration.

The principal statements of Weberian location theory are still widely used as the basis for the development of a modern theory. As economic activity has become more complicated and interrelated, however, location theory has necessarily taken on many new aspects. Since location problems arise chiefly in connection with manufacturing industries, it is this area to which the most study has been devoted.

When a private business enterprise sets about to select the location of a manufacturing plant, the primary objective is to choose a site where its operations may be performed at minimum cost. The producer is concerned
with procurement of raw materials, processing, and distribution of the
finished product.

Transfer costs play a major role in both the procurement and distri-
bution functions and frequently may be the decisive factor in location.
Advantageous locations from the standpoint of transfer costs are found
sometimes at material sources, sometimes at markets, and sometimes at
specially situated intermediate points. For example, industries in which
a large weight loss occurs in the initial processing may be attracted
toward the source of the material; finished products industries are apt
to be market-oriented because distribution costs are usually higher per
ton of product than procurement costs per ton of raw material; or, since
most industries utilize more than one material and produce several
products, the ideal location is frequently at a junction point. In any
case, the configuration of transfer routes and the geographical sequence
of sources, junctions, and markets plays an important role in location.

In some industries labor costs are an important part of total costs,
and as a result areas with low wage rates may prove attractive. Other
industries require specific skills or seasonal labor which may be available
only in certain locations.

New ventures or those ineligible for listing on a major stock
exchange may be dependent for capital upon a limited group of investors
with personal preferences as to location. Management personnel of the
required capabilities may be concentrated in particular localities.

A firm may achieve lower production costs by building one large
plant rather than several small ones, or economies may be effected by
integration of two or more processes. Advantages may be gained by locating
in an established production center for the industry in question.
Other, less tangible factors may influence location. Monopolistic influences reduce the number of producing units and concentrate production. Price policies may prevent the entry of potential producers into an industry, with the same effect. The Federal government may influence location in a multitude of ways. Its activities may alter cost or income relationships between areas; it may help or hinder certain industries through tariff and tax policies; or it may itself own and operate industries. State and local governments sometimes exert influence through promotional activities, tax concessions, regulation of public utilities, development of transportation facilities, or the erection of trade barriers.

Rarely is one locational factor strong enough to influence the location of a manufacturing plant alone; in most cases the choice of a site is influenced by several factors and theoretically at least represents the point where the necessary functions may be carried on at lowest cost.

Shifts in the location of an industry may occur as a result of changes in markets, new sources of raw materials or fuels or the depletion of old sources, labor-cost differentials between areas, new technological developments, or attempts to consolidate production. Most changes in the industrial location pattern are brought about by the establishment of new plants and the liquidation of old ones. Actual relocations of plants are quite rare, because of the heavy expenses involved.

Prior to 1947, the elemental phosphorus industry was located east of the Mississippi River, with the bulk of productive capacity near the Tennessee phosphate fields. The rapid development of the industry in the South was possible because of the cheap power available there in conjunction with huge phosphate rock deposits. Approximately seven tons of phosphate rock are required to produce one ton of phosphorus. With such
a weight loss, a strong locational pull toward the source of the rock exists. Electric power is also very important, normally representing about 30 per cent of total manufacturing costs.

There is no established market for elemental phosphorus; producers consume most of it in further processing, chiefly in the production of chemical phosphates. Processing plants were also located east of the Mississippi River, near the major industrial markets (although in some cases at considerable distances from the elemental phosphorus plants).

After World War II, the elemental phosphorus industry experienced a westward shift in its locational pattern. Industrial markets on the Pacific Coast, particularly California, were expanding rapidly. Huge phosphate rock deposits—estimated at 8 billion long tons—had long been known to exist in Montana, Idaho, Wyoming, and Utah, and the post-war development of new hydroelectric power generating facilities by private and publicly-owned utilities made their utilization feasible. These three factors—expanding western markets for industrial phosphates, the availability of phosphate rock, and low-cost electric power—were chiefly responsible for the location of three elemental phosphorus plants in the Northwest. Two of the plants were located in southern Idaho, Westvaco Chemical Division of Food Machinery and Chemical Corporation at Pocatello and Monsanto Chemical Company at Soda Springs.

Victor Chemical Works, however, established its phosphorus plant at Silver Bow, Montana. Attracted by the growing California markets and the phosphate deposits in the Northwest, the company appears to have located in Montana because of the availability of power from Hungry Horse Dam. Bonneville Power Administration, Federal power distributing agency, offered lower power rates than did other Northwest utilities.
and the saving in power costs apparently offset slightly higher phosphate rock costs in Montana. The state’s phosphate deposits are located in the southwestern part of the state and in 1947 and 1948 Victor acquired leases on two public domain properties in the Melrose district in Beaverhead County, on the route of the Union Pacific railroad. In 1949, Victor purchased the A. R. Mass Chemical Company phosphate plant at South Gate, California.

In 1950 company officials announced that the firm would build its phosphorus plant at Silver Bow, seven miles west of Butte, to supply the California phosphate plant. The specific location at Silver Bow seems to have been selected chiefly because of the transfer facilities available there. The Union Pacific railroad, coming into Silver Bow from the south, is available to haul the phosphate rock from Melrose to the plant. In addition, two major east-west railroads, the Northern Pacific and the Chicago, Milwaukee, St. Paul and Pacific, pass through Silver Bow. Thus excellent transportation facilities were assured.

A location near Butte seemed to insure an adequate labor supply for the plant, a consideration in a state so sparsely populated as Montana. The plant required approximately 250 workers.

Other lesser factors in the choice of the Silver Bow location probably were the availability of ample space and a fair degree of isolation for the plant and, according to company officials, property tax concessions offered by Silver Bow County.
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