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The glass industries of our country have reached a level wherein they must be considered as one of the major industrial activities of the present era. Glass production in general, centers in the Ohio Valley, but with subsidiary plants in other states, its scope reaches from coast to coast. The one-room glass houses of the Colonial Period contrast greatly in proportion to the industries of today. The total value of the product assumes a figure difficult for consumers to understand.

Because of its recent rise to importance, glass information of the present day has been disclosed mainly by government publications and sensational articles in magazines and periodicals. Two noteworthy summaries were written in 1880 and 1917, but these reports do not include the automatic processes induced by machine economy. Economic Geographers have given only brief mention of this industry, and future courses in Industrial Geography may give glass deserving credit.

The author, in this study, selects only the major factors that seem responsible for the advancement of glass culture. The early techniques adopted by the American Colonists were principally those used in Medieval Europe, therefore, a brief history of pre-American glass seems essential.

The author is deeply grateful to all who have contributed their assistance and suggestions toward the writing of this thesis, especially Doctor Edward E. Keso and Professor George S. Corfield of the Department of Geography, and the library staffs who so ably assisted him in procuring the desired information.

V. W. B.

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INTRODUCTION

1. Definitions of Glass

The industrial world, historically speaking, has passed progressively through a Stone Age, a Bronze Age, and a Steel Age. Glass experts believe that we are now entering a Glass Age. The world's oldest plastic has become a serious competitor in all phases of industry. From the finest of silks to the lowest grades of iron, glass has made its presence known as a rival. Technically speaking, it is difficult to define glass concisely because it possesses a wide range of characteristics. Most of it is transparent; on the other hand, it may be opaque or merely translucent. The major glasses as we know them are brittle, but they may be toughened by heat treatment until they become bulletproof. Glass is impervious to air, water, gases and most chemicals; it cleans easily; it does not soften or warp; it takes a high polish; it can be compounded so as to filter out or admit the infrared or ultra-violet rays of the sun.

The question frequently arises, what is glass? "The truth is," replies a chemist, "the constitution of glass is about as much of a mystery as the makeup of electricity. We know what we can do with both of them, which is plenty. When we find out what glass really is, we should go to town."[1] A physicist replies, "It's a misnomer, don't speak of 'glass', but of 'glasses'. There are more kinds of glass than there are of all the metals and alloys combined."[2] Glass science refers to it as

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[1] J. R. Hildebrand, "Glass Goes to Town," National Geographic Magazine, CXXXIII (January, 1943), p. 1

[2] Hildebrand, loc. cit.

a "super-cooled" liquid or an "amorphous solid," but these and other descriptions do not describe glass in the sense that H_2O describes common water. No true chemical formula for glass is known, because its chemical constitution and molecular structure are mysteries which not even the microscope and the x-ray have been able to solve.

2. Versatility of Glass

One glass is lighter than aluminum; another heavier than mercury. The Corning Glass Works of New York regularly melts some 300 different glass compositions.[3] Research men in the laboratories carefully analyze and study over 3,000 glass prescriptions. In huge stock piles 110 ingredients blend with sand in quantities varying from tons to a few grams. By comparing these figures with those of the early colonists of America, who used only the basic raw materials, four or five in number, and produced only three types of glass products, you have a fair estimate of the tremendous advance of the American Glass Industry since its early beginnings in 1608. Glass windows which transmit only the ultra-violet rays of the sun, possess such purity that one gram of improper material may make the product defective. Jewels or bearings for electrical indicating instruments, which formerly required polished sapphire, are produced with ease. Such a vital pin-point of glass weighs only three ten-thousandths of an ounce, and its diameter rarely exceeds seven-hundredths of an inch. At the other extremity, the Mount Polomar telescope disc, twenty tons in weight and nearly seventeen feet in diameter, took one year to anneal, and is still in the process of being polished to an

[3]Hildebrand, loc. cit.

accuracy of a millionth of an inch. Compare these two instances, and you begin to sense the versatility of the glass industry.

L. A. Stauffer, reporting on his trip through the research laboratories of the Pittsburgh-Corning Corporation, states the following, "In the laboratories of this company, I have seen glass that can be sawed and nailed like lumber; glass that will float; glass that bounces; glass that can be bent like rubber, twisted like yarn, tied into knots and woven like silk....One of its more recent uses is for artificial legs. The advantages appear to be the ease of molding to the exact contour of the natural leg and the lifetime resistance to wear!"[4]

Modern glass, therefore, finds its application in every type of industry, in every type of construction, and in every mode of living. From its early beginnings to the present day, glass proves its worth as a substantial product, and as an item of commercial importance. Small wonder that the present problem confronting research men lies not in the realm of finding new uses for glass, but in finding instances where they may avoid utilization.

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[4] Lewis A. Stauffer, "What Won't They Do Next with Glass?" Readers Digest, XLV (February, 1945) p. 54.

CHAPTER II

THE HISTORY OF GLASS

1. The Dawn of Glass Culture

Primitive man, regardless of what epoch or era of geologic time existed during his lifetime, had at his disposal, and frequently used, quantities of glass. This type of glass was not in the artificial state that we think of it today. Artifacts of obsidian, simply glass manufactured by nature through volcanism, have been found in nearly every country of the world. Savages of the Stone Age chipped knives and spearheads from fragments of this natural glass. In demand for thousands of years for weapons, jewelry, and mirrors, the importance of obsidian began to decline rapidly after the first appearance of artificial glass in about 8,000 B.C.

The exact person or persons credited with making the first artificial glass is an unknown fact, however, the discussion narrows to two peoples, namely, the Phoenicians and the Egyptians. At the present time, the opinions of glass historians do not agree. Ancient history records the story by Pliny and Tacitus, of the accidental discovery of glass by a group of storm-driven Phoenician mariners while cooking their food on the banks of the River Belus.[1, 2.] This tale or myth, as some writers refer to it, does not seem plausible, as the temperatures required to melt sand into a molten state range from 2600° F. to 2850° F.,[3] and a

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[1]Joseph D. Weeks, Census of 1880: Statistics of Manufactures, p. 1097.

[2]Belus: A river in Palestine near the Base of Mount Carmel.

[3]E. E. Pratt, "The Glass Industry," Bureau of Foreign and Domestic Commerce, Miscellaneous Series, LX (May, 1917) p. 68.

small fire constructed on an open beach would never contain such a concentration of heat. While it is true that the sands found in this vicinity have been used for the making of glass and later used by the Phoenicians, Joseph D. Weeks in his special report on Glass Manufactures, maintains that the Egyptions should receive the true credit for the discovery of the world's oldest plastic. The uncertainty of Egyptian chronology renders it impossible to determine the exact age of discovery, and inscriptions in the tombs offer only slight indications. Various inscriptions, paintings and even bits of glass itself, give evidence of its manufacture at least 4,000 to 6,000 years ago. Among the earliest traces of glass are those found in the ruins of Memphis, a city built by Menes, the first King of Egypt, whose reign ended approximately 5,000 B.C. The mummies found in the tombs of this city wear necklaces of paste-glass beads. Figures of glass blowing appear on the walls of the tomb of Mastaba of Tish, whose dynasty closed near 3,900 B.C.[4] Already, the art of blowing glass into bottles, pressing it into vases, cups, figures of sacred deities, coins, and emblems, and rolling it into beads and necklaces, seems to have been practiced with great skill. Such perfection could have been obtained only through centuries of practice, and the exact date of discovery must have been many years previous.[5] While under Roman dominance, Egyptian products found a huge market in the Imperial City. Egypt continued her glass industries as late as the 3rd century A.D., as Marcus Aurelius, the emperor, declared that part of the Egyptian tribute should be paid in glass and glassware. Quantities of

[4]Weeks, loc. cit.

[5]Francis Rogers, 5,000 Years of Glass, p. 25.

coins and tokens, as well as glass lamps, made by the Egyptians during the 14th Century, may be viewed in the National Museum of Paris. Crude in their designs, and containing numerous flaws, nevertheless, these antiques give rise to the fact that ancient civilizations knew much about the art of glass making.

The Phoenicians, previously mentioned in connection with the discovery of glass, gained early renown for their exactness in design and expert workmanship. Glass workers from Phoenicia spread their culture to other parts of the known world, and introduced its processes to Continental Europe. King Solomon, according to Biblical History, secured Hiram of Tyre, an artificer, for ornamentation work in his famous temple. The twin cities of Tyre and Sidon on the Mediterranean Coast, were noted for the making of artificial gems and hollow ware. The possibility that portions of King Solomon's temple was decorated with glasswares, may be accepted as a true fact. Not content with the production of crude colored glass, the Phoenicians possessed the initiative to experiment with various formulas other than the few already in use. Manganese was among the first agents to be introduced, and the resulting formula produced a clearer glass with fewer defects. Precious stones and gems could be imitated by the use of metallic oxides, and colored glass became an item of luxury. The famous "pillar of emerald" in the temple of Hercules of Tyre, has been deduced as a hollow tube of green glass in which a lamp burned perpetually.[6] Although the reign of the Phoenicians was short-lived, Sidon contained glass works until the 12th century; Antioch, until the 14th century and Smyrna as late as the 17th century. The city of Damascus became the chief

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[6] Weeks, loc. cit.

seat of glass-making in the East, but it too subsided about the year 1600 A.D., when the Venetians became the rulers of the glass industry. However, the glass-blowers of Damascus gave one contribution to the art of glass making; it lay in producing the first non-refillable bottles.[7]

Very little may be said concerning the glass works of the Assyrians. Among the ruins of Nineveh, destroyed in 625 B.C., were found specimens of glass bottles, glass lenses, and a small vase of transparent green glass with the title of the Assyrian Monarch, Sargon (722 B.C.). Other vases and gilded bottles have been found, but show little skill in workmanship or originality. Many of the relics are identical to Egyptian glass, and Egypt did export huge quantities of small glass items to Babylon.

The early Romans became acquainted with glass through their conquest of Egypt and the surrounding areas. Home manufactures began about 500 B.C., during the time of the Caesars, but the quality of the product was so inferior, that for many years the citizens of Rome were dependent on the Egyptians and the Assryians for their glasswares. Finally, under the reign of Augustus Caesar, production began in earnest after the secrets had been captured from Egypt, and a high degree of perfection ensued. Early Roman plate glass was formed by pouring molten glass on a flat surface of a stone that had been dusted with fine sand. It produced one smooth surface, but no transparency, and contained waves and numerous other defects. Recent excavations indicate that high quality plate glass had been produced. Portions of the streets in Pompeii and Carthage had been paved with plate glass blocks which had undoubtedly withstood great

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[7]Frances Rogers, 5,000 Years of Glass, p. 25.

amounts of pressure and possessed good wearing characteristics.[8] Along with the Greek contributions of art, Roman glass became one of the prized possessions of its citizens. Roman ladies had for vanity cases, two highly decorated vials, joined at the top by handles, through which passed a cord to carry them. One compartment contained rouge; the other, kohl for darkening the eyelids. Applications of the cosmetics were made with small glass rods.[9] In the year 220 A.D., history records the industry as being so important, that a special tax was levied on glass making as a source of revenue. Mr. Weeks in his report states that this fact may have been responsible for the transfer of the industry to Venice.

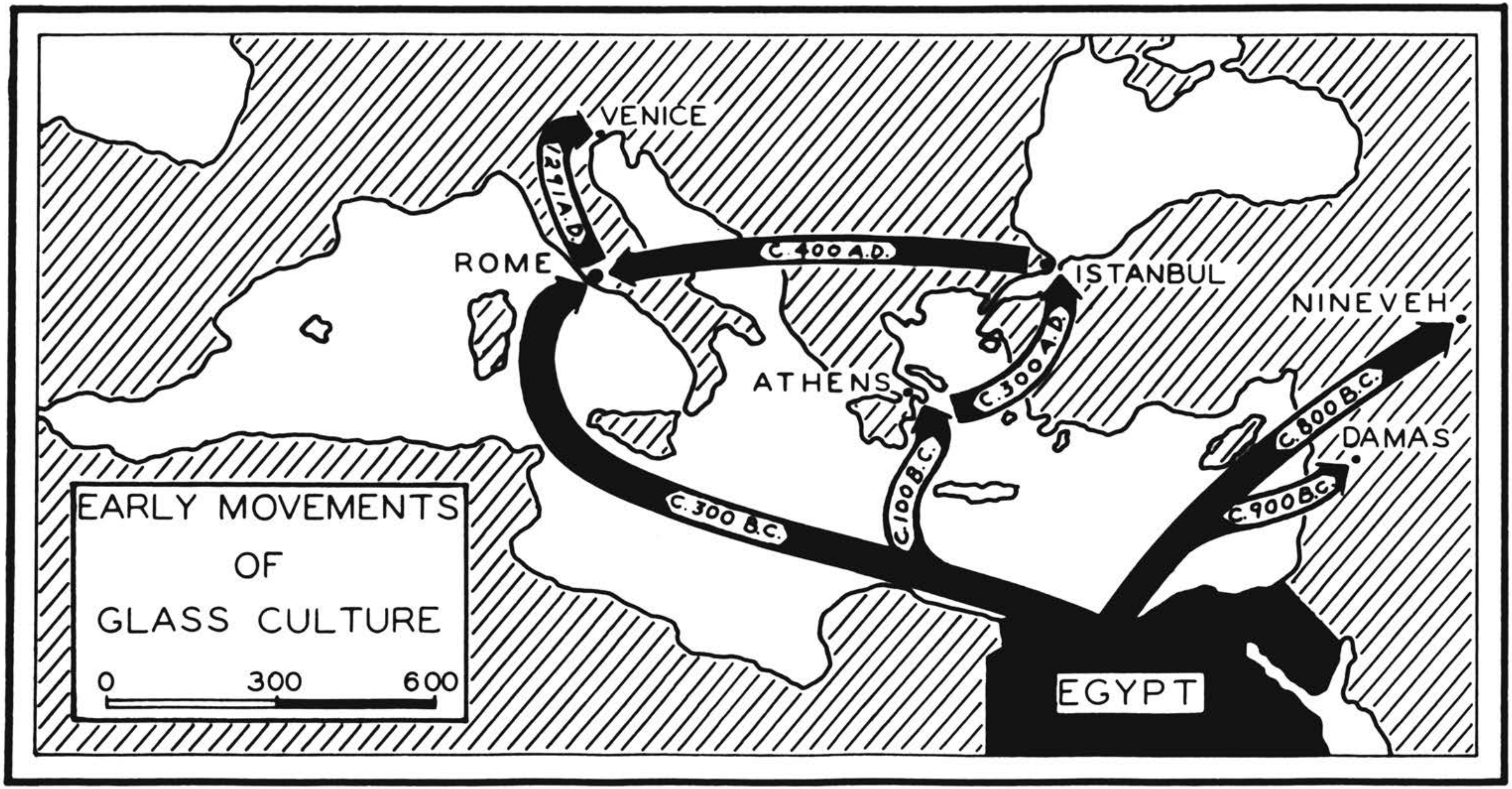
Constantine the Great, about the year 330 A.D., had in his command, nearly all the glass makers of the known world, and controlled the world market for the succeeding three or four centuries. Due to the corruptness of the empire, the Byzantine civilization disintegrated and with it went the glass secrets and the tradesmen. For the ensuing centuries, glass making seemed to be on a rapid decline and little of its developments are known or recorded in history. Not until the Venetians revived the industry on the island of Murano, did glass making assume the importance that it possessed at the time of the Phoenicians and Egyptians.

2. Glass Industries of Medieval Europe

The Medieval era of history, besides being the period of revival for education, religion, and fine arts, also stimulated industry. With

[8] R. T. Harding, "Pompeii's Streets Were Paved with Glass," Forum, CIV (October, 1945) p. 166.

[9] Rogers, op. cit., p. 27.



EARLY MOVEMENTS
OF
GLASS CULTURE
0
300
600
VENICE
1291 A.D.
ROME
C. 400 A.D.
ISTANBUL
NINEVEH
ATHENS
C. 300 A.D.
C. 800 B.C.
DAMAS
C. 100 B.C.
C. 900 B.C.
C. 300 B.C.
EGYPT

it rose the true beginnings of glass manufacture. Modern glass making dates from the city of Venice and its tiny isle of Murano.[10] From the glass houses of that gentile island, the art that produced the beautiful and exquisite forms of Roman glass was revived. From its entire street of glass furnaces came the workmen who carried its knowledge and inspirations into many of the European nations, and laid in these countries the foundations of the glass industry that has continued until the present time. Venetian glass did not, however, gain at once the full measure of its reputation. For many years after the establishment of the industry in that city about the 11th Century, Egyptian and Byzantine glasses dominated the markets of the world, and the early products of Venice suffered severe competition from foreign imports. Venetian glass did not gain world renown until the 16th Century.

Glass making, in conjunction with all the finer arts of culture, felt the influence of the barbarian deluge. Demands for glass, other than that in common use, ceased entirely when the tribal hordes conquered Rome and appropriated its wealth. The glass works of Rome were demolished and the workmen slain or scattered. Only in one phase of the industry did any of the former glory remain: the manufacture of mosaics and painted window glass. Here, as in many of the finer divisions of culture, the church preserved many of the secrets, and inevitably saved the industry from perishing from the earth. By the early 1200's, the great cities of Germany and Italy began their commercial enterprises, and the rising importance of Venice attracted many artisans, among them the decendants of the ancient glass workers. About the year 1250, the

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[10] Joseph D. Weeks, Census of 1880: Statistics of Manufactures, p. 1102.

art had grown to such magnitude that rules governing glass houses were established. In 1291 the Council of Ten, as a safety precaution against fire in the Imperial City, decreed that all glass furnaces should be demolished, but reestablished in the district of Venice. This later resulted in the growth of the industry at Murano.[11] The same council, in 1295, prohibited the exportation of glass making materials, and also issued a warrant imposing a heavy fine upon all glass makers who should leave Venice to practice their arts in other cities.[12] Later, this fine was abolished and a death penalty substituted. So closely were the secrets guarded that any worker who did escape was ferreted out by special agents, sent from Venice, and put to death. One glass blower actually reached the gates of Paris, only to meet his fate at the hands of the Italian agents.[13]

By this time, the fame of Venetian glass had spread throughout Europe. Other prosperous nations, such as England, Spain, and Holland, endeavored to secure workmen to advance their glass culture. As early as the 16th Century, twenty-four glass houses existed in Murano, each establishment having its own special type of product. Murano reached its peak about the year 1600, with a population of approximately 30,000. Approximately 8,000 laborers found employment in glass production alone.[14] An unbroken line of glass houses extended for one mile along one of the

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[11] Ibid., p. 1103.

[12] Weeks, loc. cit.

[13] Rogers, op. cit., p. 38.

[14] James J. Jarves, "Glass of Murano," Harper's Magazine, LXIV (January, 1882) p. 182.

streets in Murano. The actual manufacturing, conducted on a small scale, and using only the traditional blowpipe, produced a great variety of products, including vessels, window glass and mosaics, optical glass, mirrors and beads. Government control of industries forced the removal of the shops from Rome, but the guild system exercised a strict control over glass production, particularly in the field of labor. The following rules and regulations governed the workers: no apprentice could be admitted as a master craftsman without passing a strict examination; the candidate must prove his skill in the production of his particular shop; all candidates were elected into the body of masters by secret ballot; each factory to be subject to inspection day or night; whoever became a member of the guild must take an oath of fidelity; no strangers could be employed under any pretense; Venetians to be the only "outsiders" allowed as laborers; no employer could hire a master-craftsman in debt to another employer in the guild; and proprietors as well as master-workmen of ten years' experience, if they failed honorably, were entitled to an annual pension.[15] The Venetians took great pride in their work and the glass artisans of Murano were highly regarded as essential citizens of their communities. However, the monopoly they had enjoyed for over five centuries soon dimmed into oblivion. Countries of continental Europe began offering fabulous sums to Venetian glass workers to leave Murano, and in the later years small numbers of them escaped to Germany, France, England and the Low Countries, bringing with them the secrets that had been so ardently guarded.

Early glass workings did not fade entirely from the rest of the

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[15] Jarves, loc. cit.

continent during the dark ages, as products of Poitiers, France, date back to the Holy Roman Empire. Local production remained in a crude status until the latter portion of the 17th Century. In 1664, Colbert, the great finance minister of France, obtained eighteen Venetian glass workers and the manufacture of mirrors and mosaics began in Paris.[16] The secret of Murano had been captured, and its formulas and techniques spread rapidly over the balance of the continent. Bohemia became the foremost rival of Venice, and to the present day, produces glassware of high quality. Favored with unusually high quality raw materials, the Bohemians produced glasses of extreme purity and clarity. German initiative introduced the glazing and engraving of glassware, which became a product of great demand and greatly interfered with Venetian prestige. Cut glass entered the scene shortly thereafter, and so sharp and injurious did the competition become, that glass makers of Murano journeyed to Bohemia to learn the newer developments. One agent did return to Venice to secure patents on his findings, but the works of Murano began to decline, and the age of glory faded rapidly.

England and the Low Countries became the last of the great powers of Europe to master the techniques of the Venetians. The Belgians, near the city of Rotterdam, began successful operations about the year 1600, and the English followed with glass houses in London within the next decade.[17] English interest in the Venetian industry had begun prior to that time and after numerous frustrations for over two centuries, she finally succeeded in securing, by bribery, eight Muranese glass workers

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[16] Weeks, <u>op. cit</u>., p. 1104.

[17] <u>Ibid</u>., p. 1106.

and promptly imprisoned them in London. These artisans gained their freedom on condition they use their ability in the English glass houses, and from that time forward, English glass assumed a Venetian strain and the new industry prospered. Sea coal, used in place of wood for fuel, was effected by Sir Robert Mansel in 1635.[18] Britain's early products consisted of window glass and mirrors, but with the discovery of flint glass, huge vases and tableware appeared in great quantities. The revocation of the edict of Nantes, in 1685, drew a number of glass workers to England, and the manufactures began to improve. In 1700, many Englishmen considered their products superior to Bohemian glass, and second only to the royal Prussian glass houses of Potsdam.

3. The American Colonial Era of Glass

The earliest attempts of glass manufacturing in the United States are recorded in history as a series of failures, in which many industrialists lost whatever fortunes they possessed, and sought other fields for profitable enterprise. The colonists could not perceive the advantages of glassware, and even though the product could be successfully produced, little demand for home consumption existed, and severe competition from imported glass thwarted our early pioneers in the glass industry. Glass production began at different times in the various colonies, and a discussion of glass manufacturing by states would be more profitable than to attempt a chronological arrangement.

Glass has the distinction of being one of the first manufactured products of the United States. It is true that the majority of the

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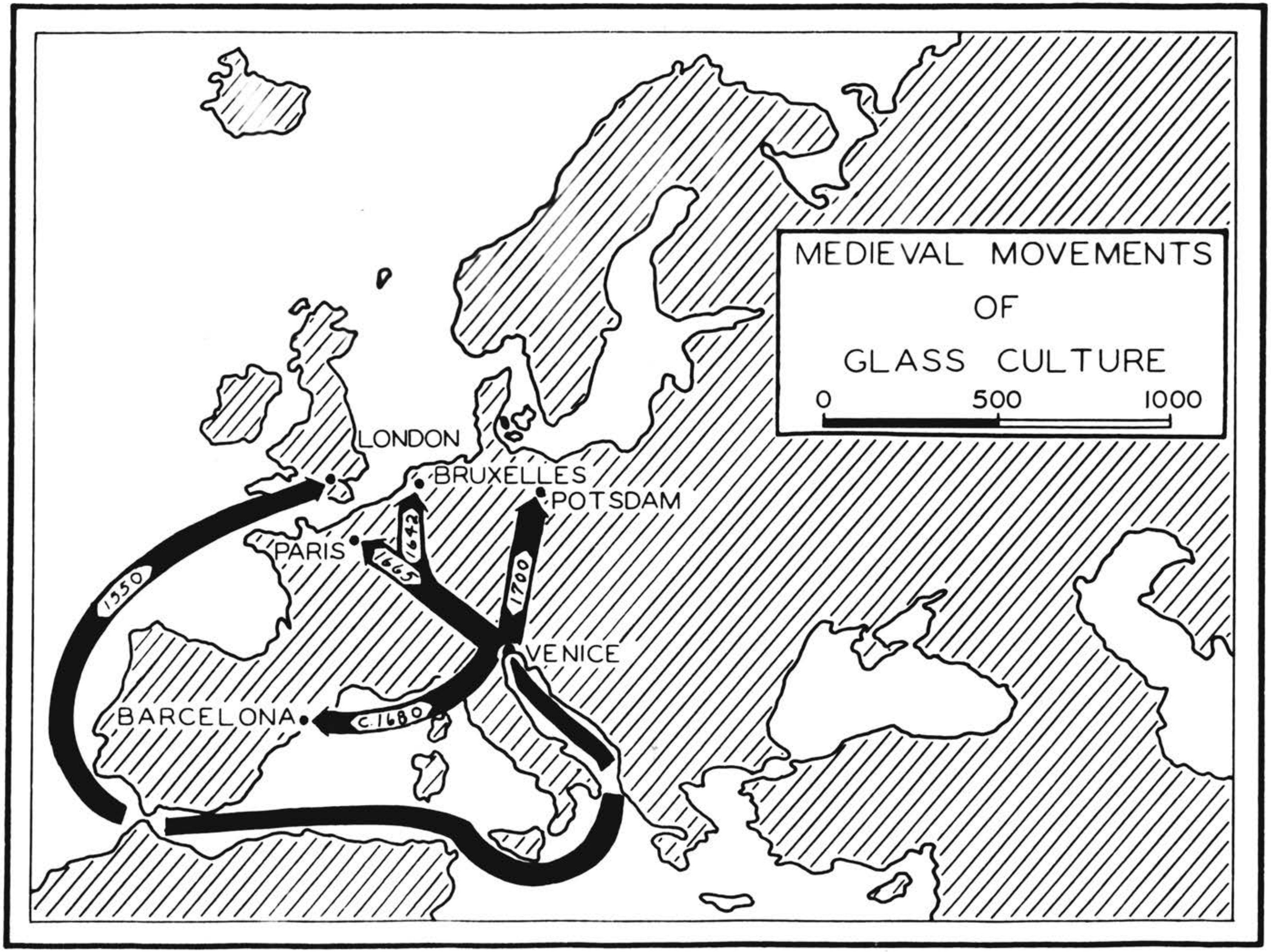
[18] *Ibid.*, p. 1107.



MEDIEVAL MOVEMENTS
OF
GLASS CULTURE
0
500
1000
LONDON
BRUXELLES
POTSDAM
PARIS
VENICE
BARCELONA
1550
1642
1665
1700
C.1680

first colonists' interests centered in obtaining fabulous wealth, but a few of the early settlers concentrated on commercial enterprises as well. History records the fact that Captain Newport, on his second voyage to Virginia in 1608, brought with him eight Poles and Germans to make pitch, tar, glass, and soap-ashes. Captain John Smith, in charge of the Jamestown settlement, therefore, deployed certain men to produce the aforementioned products. The first glass house was located in the woods near Jamestown and actually manufactured some crude flasks and window glasses during the next six or seven years. The Virginians added another product, an item for trade with the Indians, namely, glass beads. Unable to realize the limit of such articles of barter, over-production resulted and the colonists experienced America's first case of inflation. The surplus beads, shipped to England at less than cost price, resulted in a miniature depression and ruined the first successful industry in America. This fact, coupled with the craze for tobacco culture, caused the industry to decline and it eventually ceased to exist by 1617. An attempt, made in 1620 to revive the industry by importing Italian artisans from England, failed because of the Indian Massacre of 1622 which destroyed the newly erected glass house. Glass production of Virginia received no further mention until the year 1788. Discouraged by repeated failures and misfortunes, the Virginians resorted to other activities, and the scarcity and high labor costs of glass artisans, only furnished an added impetus to abandon glass production. Captain John Smith summed up the case by stating that the colonists' labor had been misdirected in the making of various articles, among them was the product glass.[19] In 1788, a plant existed in Alexandria, Virginia, and production for the year totaled 10,000 pounds, with an employment of over 500 laborers. Mention is made of a plant in Wellsburg in 1815, where flint glass as well as plate and hollow glass was produced. Wheeling, West Virginia, began glass operations in 1820,[20] and the city still contains numerous glass plants. Recognized as an ideal location because of cheap fuels and raw materials, it is the site of one of the first permanent glass centers of the United States. Blessed with industrious leaders and economists, the city withstood the trials and misfortunes of the early years of our country and has contributed numerous discoveries in the fields of pressed glasses and tableware.

America's leading producer of glassware for the past 100 years has been the state of Pennsylvania. It, too, as in the case of Virginia, possessed a very slow beginning and its early history is marred by frequent failures in glass production. Perhaps the earliest reference to glass was given by William Penn. He referred to a tannery, a sawmill, and a glass house in one of his reports to the Free Society of Traders.[21] For what purpose the glass house was maintained is not known, and its importance must have been relatively insignificant. O. W. Holmes, who wrote in 1689 concerning the various industries of Pennsylvania, speaks of the scarcity of glass in this fashion:[22]

> "The window glass is often here,
> Exceeding scarce and very dear.
> So that some in this way do take
> Isinglass windows for to make."

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[19] Weeks, op. cit., p. 1116

[20] Weeks, loc. cit.

[21] Ibid., p. 1117.

[22] Weeks, loc. cit.

From this time until the years preceeding the Revolutionary War, no mention of glass is recorded. The industry may have vanished completely or production may have been too small to even note. Many individuals attempted to establish plants about 1750, but their endeavors usually ended in bankruptcy. Caspar Wistar, a German immigrant, began his manufactures in Philadelphia about the year 1740. He imported four glass workers from Belgium and produced buttons and pieces of fine tableware. His failure occurred a few years later, and today, cautious collectors state that there are now no more than thirty authentic pieces of original Wistar glass in existence.[23] Another German, Baron Von Steigel, attempted a plant near Lancaster in 1762, but he too, suffered defeat. He later returned to Germany to study the Potsdam plants, but never did construct a successful glass house in America. Small establishments operated in the period following the Revolutionary War. The Society for Encouragement of Manufactures offered a $20.00 gold medal for the best specimen of flint glass produced in Pennsylvania. Glass manufacturing in western Pennsylvania was greatly influenced by the actions of two men, James O'Hara and Major Isaac Craig, as these gentlemen were the first manufacturers of glass to use coal for fuel. Under their guidance, a successful plant began in Pittsburgh in 1796, and from that time forward, the glass industry of the United States centered in the Pittsburgh district.[24] Two factors have been responsible for its phenomenal rise to prominence: (1) the abundance of coal and natural gas and (2) the vast supply of excellent sand — the Oriskany deposits, which

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[23]Rogers, op. cit., p. 57.

[24]E. E. Pratt, "The Glass Industry," Bureau of Foreign and Domestic Commerce. Miscellaneous Series, LX (May, 1917) p. 11.

will be discussed in the following chapter. By 1815, Pittsburgh alone employed 169 workmen and the value of the products totaled $235,000. Plants in Schuylkill, Philadelphia and Manheim, were greatly overshadowed by the Pittsburgh area.

Although aided by an early start in the manufacture of glassware, Massachusetts has since surrendered its distinction of being one of the leading producers. The first plant was erected at Salem in 1639, by Mr. John Concklin, who was aided in his efforts by the town council. Bottles and window glass were produced successfully, but severe competition from England forced the industry into abandonment. From this early effort until 1800, the story is the same as other areas, repeated failures and disappointments. The Boston Glass Works began shortly thereafter, and by 1810, the industry in Boston reached sufficient volume to produce products valued at $82,000.[25] The War of 1812 discouraged the industry, and by 1826, as a result of bad management, the company failed and the next fifty years saw numerous attempts to revive the Boston glass houses, but none were entirely successful, principally because of the lack of fuel.

The states of New York, New Hampshire, New Jersey and Maryland have similar histories concerning glass production. Until 1820, numerous plants were constructed and all resulted in disaster to the business men who financed them. Repeated efforts to secure aid from the state governments failed and the majority of the projects were discontinued. The commercial interests of the New England States allowed the importation of European glasses, and the new industry could not compete with them.

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[25] Weeks, op. cit., p. 1127.

While it is true that New York and New Jersey rank high in total production during the recent years, their rise to prominence came during the industrialization of glass which occurred during the late 1800's, and will be discussed in the latter portion of this chapter.

American glass production up to this point, with the exception of the Pittsburgh and Wheeling districts, has not afforded a record of which glass experts and historians can be proud. Repeated failures, the "hit and miss" type of production, and the scarcity of glass technicians have proven the point mentioned previously, that the early Americans were not ready for the new product, and whatever glass was needed, could easily be imported. The imported ware was of a higher quality and cheaper in price. The 19th century saw a complete change of events, and with the introduction of the shop system, glassware stood on the brink of becoming one of America's major products of industrial production.

4. Glass Developments of the 19th Century

The American Glass Industries made their greatest advancement during the 19th Century. As the westward movement of people progressed, all industries, including glass production, moved with them. The centers of production moved inland from the Atlantic Seaboard, and with the exception of Wheeling, West Virginia, located west of the Appalachian Mountains. As new states entered the Union and businessmen exploited the raw materials and fuels, glass plants became among the first to be established. The Midwest area rose to prominence shortly after the turn of the century and Ohio, Illinois, Indiana, Missouri, and Kansas entered the production columns. New York and New Jersey emerged during these years, and for a time threatened the supremacy of Pennsylvania. The use of petroleum and natural gas as fuel has caused a high correlation between the location of glass plants and petroleum fields. The discovery of natural gas in Indiana and New Jersey influenced the moving of glass plants to these states, and Illinois coal offered advantages for the industry in the Mississippi Basin.

From 1800 to 1870, the manufacture of flasks and bottles dominated all glass production.[26] Pressed tableware received its share of glory by being one of the first items to be produced by machinery. Deming Jarvis, a carpenter of Sandwich, Massachusetts, made the first pressed glass tumbler.[27] Up to this time, all glassware had been blown and cast, and the shaping of glass to the desired form by means of a mold provided a new technique for the glass workers of the nation. Although produced in large quantities, nevertheless, glassware still required the use of the blowpipe and constituted a slow and laborious process. Depression entered the glass industry from 1850 to 1860. This was followed by a great "boom" in the production of flint glass,[28] due to the making of coal oil from coal as a by-product. Lamp chimneys were in great demand by 1861 and the glass manufacturers responded accordingly. Approximately five years after the close of the Civil War, the glass industries of America went through a period of revolution in which machines began to rapidly displace the picturesque glass blower and his blowpipe.

The introduction of the shop system allowed greater production. The first profitable plate glass factory was established in 1881 at

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[26]Pratt, op. cit., p. 14.

[27]Ibid., p. 16.

[28]Ibid., p. 17.

Creighton, Pennsylvania, by Mr. John B. Ford. Previous attempts at Brooklyn, New York, Albany, Indiana, and Crystal City, Missouri, produced high quality plate glass, but resulted in financial failures due to high costs of operation. The Creighton plant is one of the original works of the present Pittsburgh Plate Glass Company. The wonderful progress and development of plate glass has continued until the present day. American plate glass surpasses European glass in clearness, finish, and freedom from flaws and defects. Closely associated with plate glass, the wire glass industry, successfully patented by Mr. Frank Shuman in 1892, allowed the two products to be produced on the same casting table.[29]

In 1880, following the invention of the incandescent lamp, glass manufacturers entered a new field, the making of light bulbs. From a meager beginning, the industry expanded by 1900, until it grew to an approximate production of 1,000,000 bulbs per day. Window glass, likewise, was increased in quantity by the introduction of new processes, the foremost being the use of a "bait member" to draw the molten glass from the pot furnaces.

S. P. Austin, in the Census Report of 1900,[30] states the following: "The Pacific Coast is attracting more and more attention as a field for glass manufacture, and the cheap fuel of Southern California, coupled with the growing demand for a glass package from the fruit packers, will probably lead to a decided increase in the glass production of that state within a short time!" The reasoning in this statement is sound and may seem foolproof, but the factor of securing a high quality sand, checked California's rise to prominence for many years. In 1930, the state

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[29] _Ibid._, p. 20.

[30] S. P. Austin, Census of 1900: _Statistics of Manufactures_, p. 958.

reached eighth place in the production columns. By the close of the 19th Century glass was produced in seventeen states. The industry as a whole, remained in a demoralized condition due to over-production and low retail prices. The European countries were closely allied as to price regulations and adjustments to production. Since the business of the United States had not extended beyond the home market, cooperation on that account was never considered by the European powers. Hence, the United States became a dumping ground for surplus foreign production, and exceptionally low prices were forced on American industries. The most severe problems lay in the shortage of workmen and the bids for higher wages. During 1900, American glass workers received wages two hundred per cent higher than England and three hundred per cent more than Belgium. The most noticeable trend of the year centered in the increased numbers of women employed, perhaps as a source of cheaper labor. The introduction of decorated glassware offered many positions that male labor would not accept.

Electricity, first used at the Ford Glass Works in Creighton, Pennsylvania, became the means of motive power for conveyors at the close of the century. Its nation-wide adoption followed within the next decade.

Although glass production in the United States soared to a value of $56,000,000 by 1900,[31] we were still dependent on foreign imports for the major portion of fine cut glasswares and chemical apparatus. Our position had not yet been established in the commercial world. Various experimental laboratories existed, but the necessity for new developments

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[31] Table IV of this report, page 46.

in glass was not yet at hand. The World's Columbian Exposition at Chicago in 1893, displayed a glass dress, and thereby demonstrated the first insight as to the future possibilities of glass.[32]

5. Glass Technology of World War I

Since the American glass industries established themselves securely in the industrial life of our country, the stress was now placed on world competition and the discovery of new products and new uses. Greater production became necessary with the use of glassware in commercial fields, such as, automobiles and the adoption of glass in the construction of buildings. The invention of new machines increased, and the United States Patent Office granted an unusual number of patents to glass experts in the early 1900's, among them Michael J. Owens, who invented the Automatic Bottle Machine in 1903. American exports of glass began to increase by 1915,[33] and the same year witnessed the largest output of glass up to that period. However, it remained for the first World War to give the glass industries their greatest boom. While the conflict raged in Europe, glass manufacturers faced the same problems as the users of dyestuffs. They had leaned upon foreign countries for many of the finer ingredients of glass, as well as machinery, specialists, and new techniques. Shut off from their usual supply, manufacturers began to search for new materials and a great impetus was given to chemical research. The chemist has since become as important to modern industry as the glass blower was to the primitive. Substitutions were fre-

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[32] R. T. Harding, "Pompeii's Streets Were Paved with Glass," Forum, CIV (October, 1945) p. 166-167.

[33] Pratt, op. cit., p. 378.

quently made for vital materials during World War I. The war forced many industrialists of glass to enter into fields which had been heretofore neglected. Laboratory and chemical glassware had been imported from Germany and had not been manufactured to any extent in the United States prior to the conflict. With its importation impossible, colleges, hospitals, and laboratories looked about for American-made goods, and the quick foresight of glass experts administered to the needs quite efficiently. After America entered the war, the acute shortage of range finders, field glasses, cameras, and surveying instruments placed a grave responsibility on the glass producers. All forms of optical glass were attempted and successfully produced with cooperation from the Federal Government. American glass sands possessed qualities for the production of the finest of lenses, glass tubing, and insulators, and from that time forward, the United States no longer depended upon foreign sources for such materials. At the close of the war, with many of the European glass houses idle, American products found a ready market in the commercial world, and today, the United States is the leading country in the exportation of glass and glassware.

CHAPTER III

GLASS SAND

1. Desired Properties of Glass Sand

Of the essential constituents in the manufacture of glass, silica, the oxide of silican, is the most important and the only material which enters all varieties of glass. This silica, generally in the form of sand, may be found in greater or less purity in nature as deposits of sand, as an easily disintegrated rock, or as a hard sandstone which necessitates crushing before use. Sand is the principle ingredient of all glass, comprising from 52 to 65 per cent of the batch, and from 60 to 75 per cent of the finished products.[1] The importance of sand may be illustrated by this simple definition of glass: "Glass is a transparent, impermeable substance formed by fusing sand or silica with fixed alkalies."[2] The quality of glass, however, depends chiefly on the quality of the sand used. The finest glasses, as flint, plate or cut glass, require freedom from color, absolute transparency, and exceeding brilliancy. Only the purest sand can be employed, as even slight impurities, especially small quantities of iron, tend to destroy these effects. Optical instruments and chemical equipment, which are practically colorless, require sands containing not more than 0.015 per cent of ferric oxide (iron). Plate glass of a poorer quality and window glass are commonly a pale green, and less absolute purity is required, but, iron content should not exceed 0.02 per cent.

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[1] R. W. Stone, Department of the Interior: Mineral Resources of the United States (1916) p. 335.

[2] E. E. Pratt, "The Glass Industry," Bureau of Foreign and Domestic Commerce. Miscellaneous Series, LX (May, 1917) p. 55.

Preliminary tests applied to sand to determine its value as a glass material, while giving a general idea, are inadequate without a complete chemical analysis of the sand. A test in the furnace to determine its melting and fusing characteristics is likewise essential. In general, the sand should be perfectly white, rather fine, uniform, even grained, and with angular, rather than rounded grains. The subject of using angular or rounded grains has been a disputed point for some time. Before 1900, manufacturers specified that sands must be angular because rounded grains were uncertain in results, did not fuse readily with other materials, and produced a glass of uneven texture.[3] Theoretically, an angular sand should melt faster and fuse easier because it has a greater theoretical chance of being more permeable and exposes more surface to heat in proportion to its volume than does the rounded sand. However, it has been determined that the shape of the sand grains is a comparatively unimportant factor in influencing the melting temperature; in fact, some glass manufacturers prefer sand with rounded grains.[4]

Sand that effervesces or loses color when heated with acid, is not good sand, as the effervescence indicates the presence of lime; and of clay by the change in color. The presence of iron may be detected by dissolving a portion of the sand in hydrofluoric acid and adding potassium ferro-cyanide, which will produce a blue color, if iron is present.[5]

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[3] A. T. Coons, Department of the Interior: Mineral Resources of the United States (1902) p. 1018.

[4] Illinois State Geological Survey, Geological Bulletin LIII (January, 1929) p. 12.

[5] Coons, op. cit., p. 1019.

Iron may be present in sand in numerous forms, chiefly as biotite, limonite, hematite or hornblende, and induces a green color to the finished products, providing decoloring agents are not used.[6] Alumina and clay render a cloudy appearance, while organic material of any sort will cause bubbles and stains in the finished product.

The removal of these foreign materials and the cost of the processes involved, frequently determines the final opinion as to the worthiness of the deposit in question. In some instances clay, copper, magnesia, and organic matter may be removed by washing. Iron content usually presents the greatest problem. Small particles of biotite or limonite can be removed by magnetism. Stains must be attacked by acid-leaching or the flotation process. The latter method resembles the froth flotation system used in the purification of copper. Various fluids, as alcohol, pine-tar oil, creosotes and finer oils are the mediums for extraction.[7]

The American Window Glass Company of Pittsburgh, Pennsylvania, submitted the following analysis of sands used in their glass works:

TABLE I

Analysis of Sand[8]

Constituent	No. 1	No. 2	No. 3	No. 4
Silica	99.990	99.714	99.659	99.579
Alumina	.008	.280	.310	.350
Oxide of Iron	Trace	.006	.011	.021
Lime and Magnesia	.002	.020	.020	.050
	100.000	100.000	100.000	100.000

[6]John Dasher, Department of the Interior: Bureau of Mines Report of Investigations, 3740 (December, 1943) p. 2.

[7]Ibid., p. 5.

[8]Coons, op. cit., p. 1013.

The experimental laboratories of the American Window Glass Company conducted the analysis and prescribed the following uses:

No. 1, the very highest grades of glassware and flint glass.

Nos. 2 and 3, tableware, plate glass and chimneys.

No. 4, window glass.

Sand containing more iron than shown in the table is used in making glass bottles and cheaper grades of window glass.

American glass sands, as a whole, outrank the glass sands of Europe in purity, but sands of France, Germany, and Belgium possess a lower content of iron which makes them more desirable. Modern science can combat the various impurities of glass sands, but in doing so, the cost per ton of processed sand exceeds the combined costs of mining and shipping of sand from other areas.

Glass sand possesses relatively little intrinsic value. The market value varies from $1.25 to $5.60 per ton, due chiefly to labor costs of extraction and preparation. Because of the high degree of purity required of glass sands, it is not too abundant in all localities, and is more expensive to prepare than other grades of sand. The cost of preparation of glass sand in proportion to its selling price frequently surpasses that of fire sand and molding sand, therefore, there have been tendencies to use glass sand for other uses throughout the entire history of glass production in the United States. The following factors determine the usefulness of sand as a glass making agency: (1) chemical purity, (2) Physical character, (3) quantity available, (4) location with respect of fuel supplies, (5) conditions of quarrying or mining, (6) location with respect to transportation routes, and (7) location with respect to markets.[9] The first two factors have already been discussed and a brief discussion of the remaining conditions appears to be rather essential. E. F. Burchard[10] maintains that a deposit as thin as twenty feet should have an areal extent of at least twenty acres of good sand in sight to warrant the erection of a mill and trackage. The majority of the deposits exceed a depth of twenty feet, but it would be safer to have a much higher ratio between areal extent and thickness, than the minimum given. When ledges of sand require stripping of overlying limestone, the limestone may, in certain cases, be of such purity to be used in glass making. If this is not the case, some other use should be sought for it as a by-product to reduce costs of extraction of the sand.

In regard to fuel, every plant producing glass sand in quantity sufficient to net a profit, must be equipped with power to move the sand and dry it, and in most cases, with equipment for cleaning it. Natural gas is the ideal fuel, particularly in the use of rotary driers. In respect to transportation routes, the general principle "the more available, the better" may be applied. Many plants that depend on one railroad for transportation lack cars at certain seasons. This fact seriously handicaps the company with its shipments and may lead to the cancellation of orders. As for markets, it must be considered that sand constitutes, per unit value, one of the bulkiest products. Therefore, distance possesses great influence on costs to consumers. At the same time, permanence of these markets must be taken into consideration, or the project becomes a useless investment.

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[9] E. F. Burchard, Department of the Interior: <u>Mineral Resources of the United States</u> (1911) p. 1009.

[10] Burchard, <u>loc. cit.</u>

2. Location of Sand Deposits

The deposits of sand applicable to the making of glass converge in three major regions of our country. The Mississippi Valley, with its St. Peter Sandstone, rivals the Northeastern Section of the United States wherein we find the Oriskany sand, though, known locally by various other names. The third major deposit consists of the California sands found principally in the California Trough near Oakland and San Francisco. It has been the strong competition of the Midwestern states that has kept the glass sand industry from spreading to other areas due to the pure quality of the St. Peter formations and the impetus of an early beginning.

The St. Peter Sandstone was named by L. Owen (United States Geological Survey - 1847) from exposures along the present Minnesota River, then known as the St. Peter River, near St. Paul, Minnesota.[11] Figure 3 denotes the location of the entire deposit as surveyed by C. L. Dake in 1921. It is interesting to note that the sandstone centers principally in the area drained by the Mississippi River and its tributaries, and also the area occupied by old Lake Chicago, the predecessor of Lake Michigan. The outstanding features of the St. Peter deposit and the ones best known, are purity, homogeneity, roundness of the grains, and the saccharoidal character of the sandstone itself. It possesses a high silica content and ranks low in impurities, especially iron. Repeated analysis of the sand give the silica content as being above 99.97 per cent. In general, the magnesia varies from a trace to about 0.01 per cent; the lime content from nothing to 0.02 per cent; the iron oxide

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[11] Illinois State Geological Survey, op. cit., p. 13.

from 0 to 0.02 per cent; and the alumina from none to about 0.05 per cent.[12] It is usually found in thick-bedded deposits, but the layers are not always so distinct due to the homogeneity and purity of the formation. Despite its loosely cemented character, the St. Peter withstands the effects of weathering when exposed to the agents of erosion. Covered deposits are commonly brown in color and case hardened to such an extent that they cannot be broken with hammers. This intensive hardness seems to have developed in areas where the sandstone has been subjected to moisture for long periods of time. In formations exposed to weathering, the stone is usually soft and loose. The color of the sandstone varies with the iron content. Many exposures, banded horizontally with yellow beds of iron-stained sand, have vertical or nearly vertical, ramifying, vein-like zones, colored by yellowish iron oxides. In other areas with the iron content negligible, the sand is buff, gray, or pure white in color. Limestone or dolomite underlie most of the St. Peter and the two materials often enter the glass furnace together. Maximum thickness averages nearly 100 feet, but extremes of 500 feet have been recorded near Joliet, in northern Illinois.

The question of the origin of the St. Peter Sandstone has been of much interest to geologists. Two theories have been advanced, the first depicting the St. Peter area as a great interior desert of drifting sand before being buried under glacial drift; and the second considering it as a sedimentary deposit, essentially marine in origin. C. L. Dake,[13]

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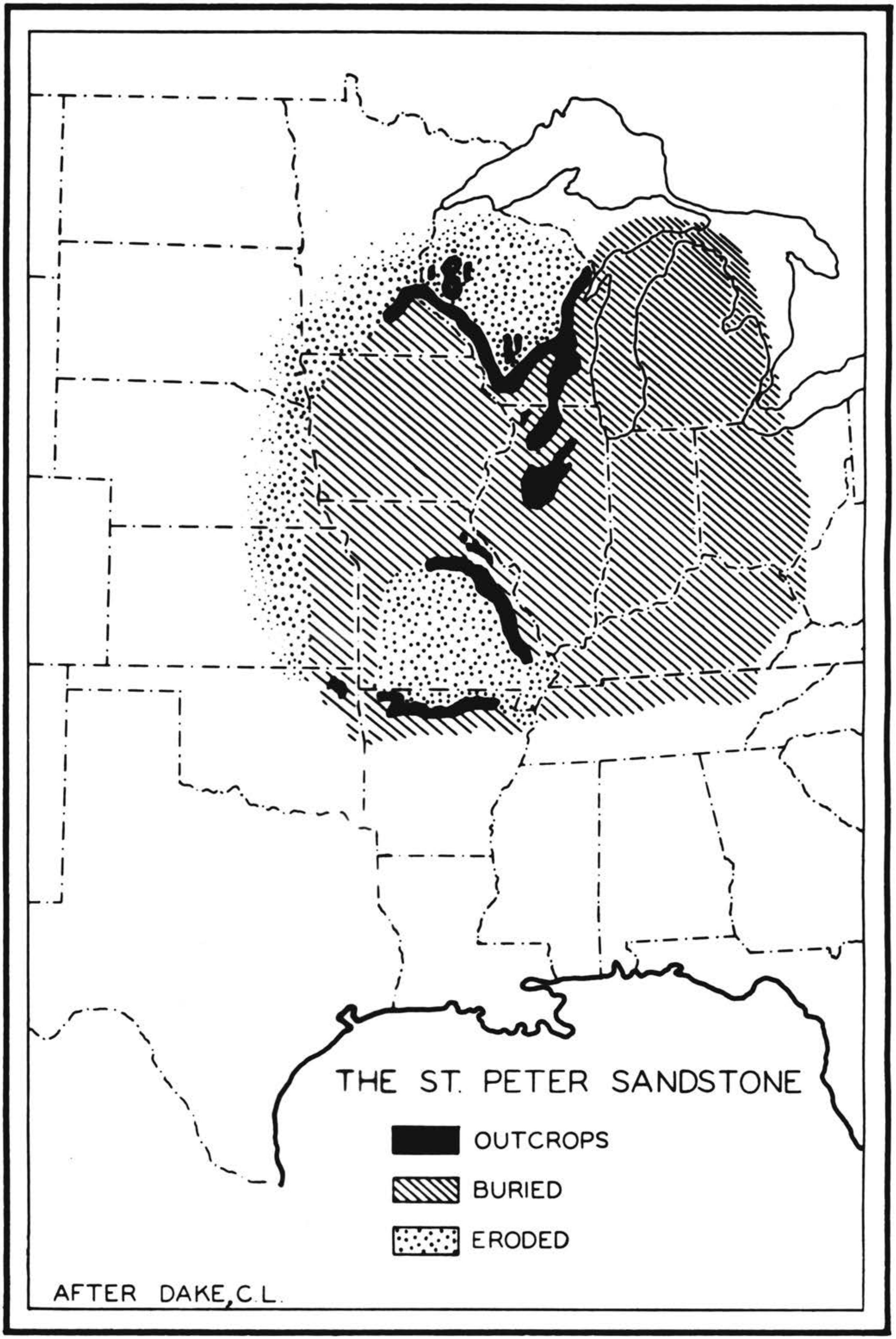
[12]Ibid., p. 14.

[13]C. L. Dake, "The Problem of the St. Peter Sandstone," University of Missouri School of Mines and Metallurgy Bulletin, VI (August, 1921) p. 15.


THE ST. PETER SANDSTONE
OUTCROPS
BURIED
ERODED
AFTER DAKE, C.L.

from a comprehensive study, concludes the stone to be principally of marine origin, except in certain areas near the borders of the deposit. His theory advocates the sources of sand as the Pre-Cambrian crystalline rocks and the Potsdam sandstone exposed in the Canadian Shield, north and northwest of the St. Peter Basin. The sand was then transported by streams from its source area to the great inland sea of Paleozoic time wherein deposition and distribution occurred. Whatever the origin may be, is not a question for the geographer or the industrialist to decide. This much may be accepted as true, that, desiring a high quality silica sand, one may effectively use the St. Peter. In regard to Figure 4, the eroded area of Southern Missouri and Northern Arkansas presents a fact of significance in the looseness in cementation of the sand particles. During the period of doming in the Ozark area, the strata of sandstone buckled up and exposed the layers to the agents of weathering. Consequently, the grains of sand eroded to the base of the dome or were washed by streams to the lower Mississippi area, where workable deposits of river sand facilitate the manufacture of green glass bottles. The outcrops, depicted by the solid black coloring, occur along the beds of streams where they protrude as bluffs or escarpments. In Southeastern Missouri however, the major outcrops reveal themselves as cuestas formed by the igneous intrusion of the St. Francis Mountains and the general doming of the area near the Burlington Escarpment, just west of the Mississippi River. Illinois, Missouri, Arkansas, and Oklahoma lead in the production of glass sand in the midwest area.

The second area of sandstone, used in the production of glass, is located principally along the Atlantic seaboard and inland to the Allegheny

Plateau. Our early manufacturers used sands of this region. However, the extent of the deposits remained unsurveyed until A. B. Cleaves edited the report on the Oriskany Sandstone in 1939.[14] H. D. Rogers recorded this particular formation as the Ridgely Sandstone in 1836.[15] The Ridgely has been recognized as part of the Devonian Age of clays, limestones and sandstones, bedded in the great Appalachian geosyncline of Middle Paleozoic time. Here, as in the case of the St. Peter Sandstone, the deposits are water-laid, compacted by the sediments deposited over them. In Upper Paleozoic Time, the Appalachian upland appeared and later folded into the various formations we now know as the Appalachian Mountains, the Ridge and Valley Country, and the Allegheny Highlands or Plateaus. The majority of the deposits exposed by the folding eroded away and streams carried the sand to the Atlantic Coast. Hence, nearly all the glass sands obtained in this region must be quarried and overlaying layers of limestones and clays removed before operations begin.

Figure 4 illustrates the approximate area occupied by the Oriskany formation. All states possessing this sandstone do not produce the product. Other factors such as nearness to markets, cheap production, and source of labor greatly influence the productivity of the deposits. New Jersey, Maryland, Virginia, Pennsylvania, and Tennessee constitute the major producing states of this area. The Ridgely formation, a part of the Oriskany system, centers in Virginia, West Virginia, and Southern Pennsylvania. This sandstone of exceptional purity, possesses character-

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[14] A. B. Cleaves, Pennsylvania Geological Survey: <u>The Oriskany Sandstone</u>, IV (1939) p. 92-130.

[15] Cleaves, <u>loc. cit</u>.

istics of white quartz. G. W. Stose diagnosed the Ridgely as a beach or near shore deposit of the sea.[16] Its high purity, freedom from mud, uniform size of particles, and sub-rounded character, indicate long-continued sorting action of sea or ocean currents. The grains, rather fine in texture, securely bound by lime, may be broken only by blasting or use of pneumatic drills and sledge hammers. The beds vary in thickness and maximums of 180 feet abound. In West Virginia, approximately 90 per cent of the Ridgely Sandstone produces sand of Number 1 quality, pure white, and containing over 98 per cent of silica. The choicest reaches 98.8 per cent and is used in the manufacture of fine cut glass. The comparative hardness of the silica, and its compressed cementation, does not facilitate the use of the hydraulic process commonly found among the pits of the St. Peter formation. The stone is quarried by blocks and sent to mills for crushing. Thereafter, the washing and cleansing processes resemble the sump-type of mining of the midwestern area. Pennsylvania uses this method exclusively. However, the glass plants, located near the quarries, withstand the added cost of crushing the sand because of a minimum of transportation. New York rates very high in the number of glass plants and value of products, with the major portion of the sand brought in from neighboring states, already processed and ready for use. Georgia and Alabama possess sands of the identical age and strata, but contain less purity resulting in green glass production. The Oriskany sands, the first to be used in our country for glass production, and possessing high quality, find extensive use in the plants of eastern United States.

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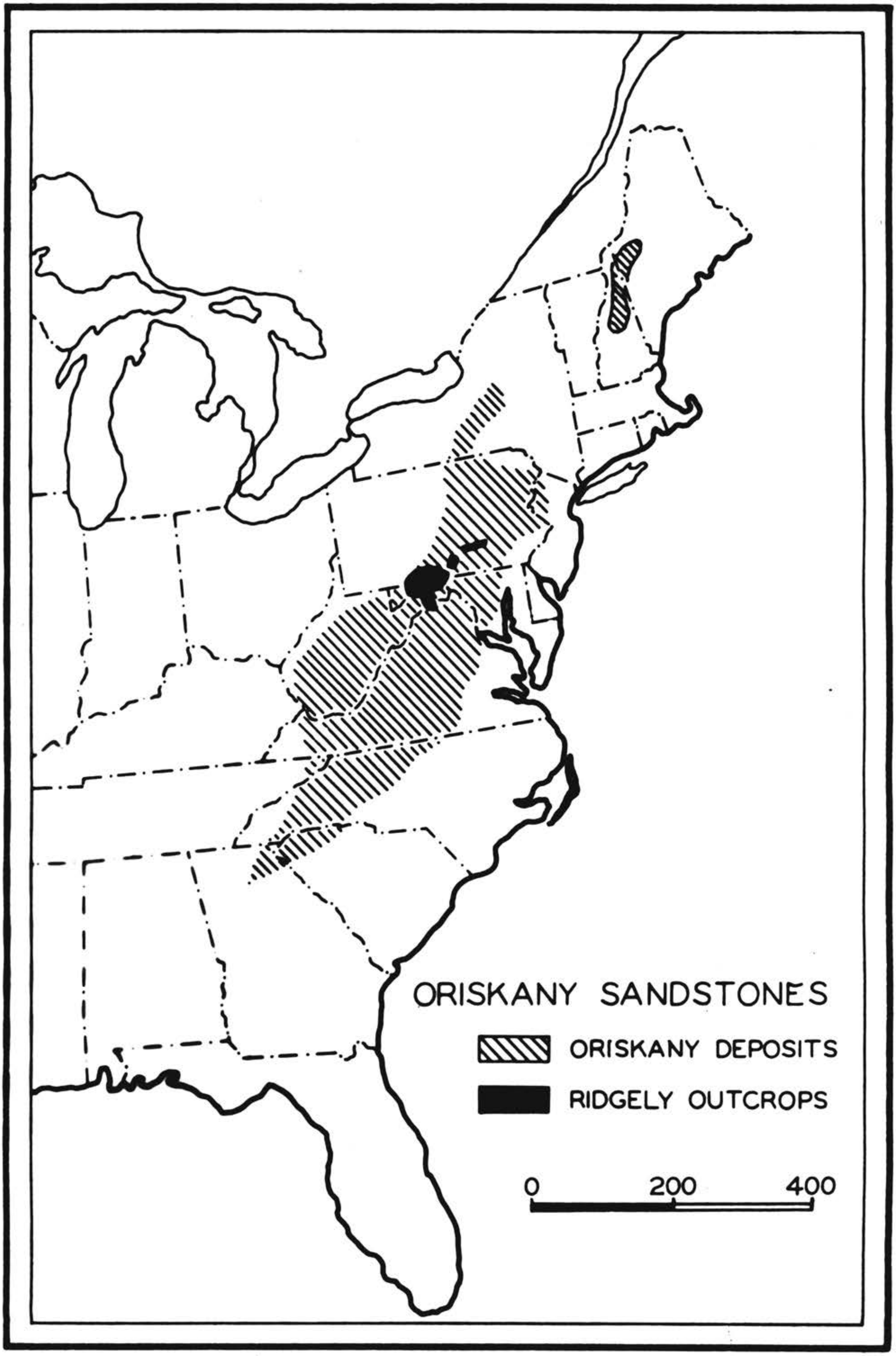
[16] G. W. Stose, "The Glass Sand Industry of West Virginia," <u>United States Geological Bulletin</u>, 285 (June, 1906) p. 473-475.


ORISKANY SANDSTONES
ORISKANY DEPOSITS
RIDGELY OUTCROPS
0
200
400

The third area of major importance, lies wholly within the state of California. It has just recently been developed and promises to remain rather important. The origin of these newer deposits has been attributed to the Pacific waters which occupied the California Trough during Mesozoic time. Production of glass sand in California has increased from 6,000 tons in 1924, to nearly 194,000 tons in 1942. The deposits center near the eastern edges of the Coastal Ranges in the San Francisco sector. Beach sands of the Del Monte Coast have been the most recent addition to the inland deposits.[17] Prior to 1924, California depended upon Belgium for the finer grades of glass sands. The sand could be imported at a low cost because of its use as ballast in ocean freighters.[18] The shift in production, from tableware to glass bottles, allowed the use of local sands containing a higher percentage of ferric oxide. Since 1936, the demand for finer grades of glassware has increased in the Pacific Coastal areas. Faced with the problem of impure sand, science developed the flotation method of removing iron stains and California ceased to import the grades of sand required for plate and window glasses. With the extra cost added by the purification process, the prices of plate glass are relatively higher than those of eastern United States. However, the total cost still remains somewhat less than if the finished product were transported cross-country.

Minor deposits of glass sand, other than those already discussed, are scattered throughout the United States. Florida has been producing

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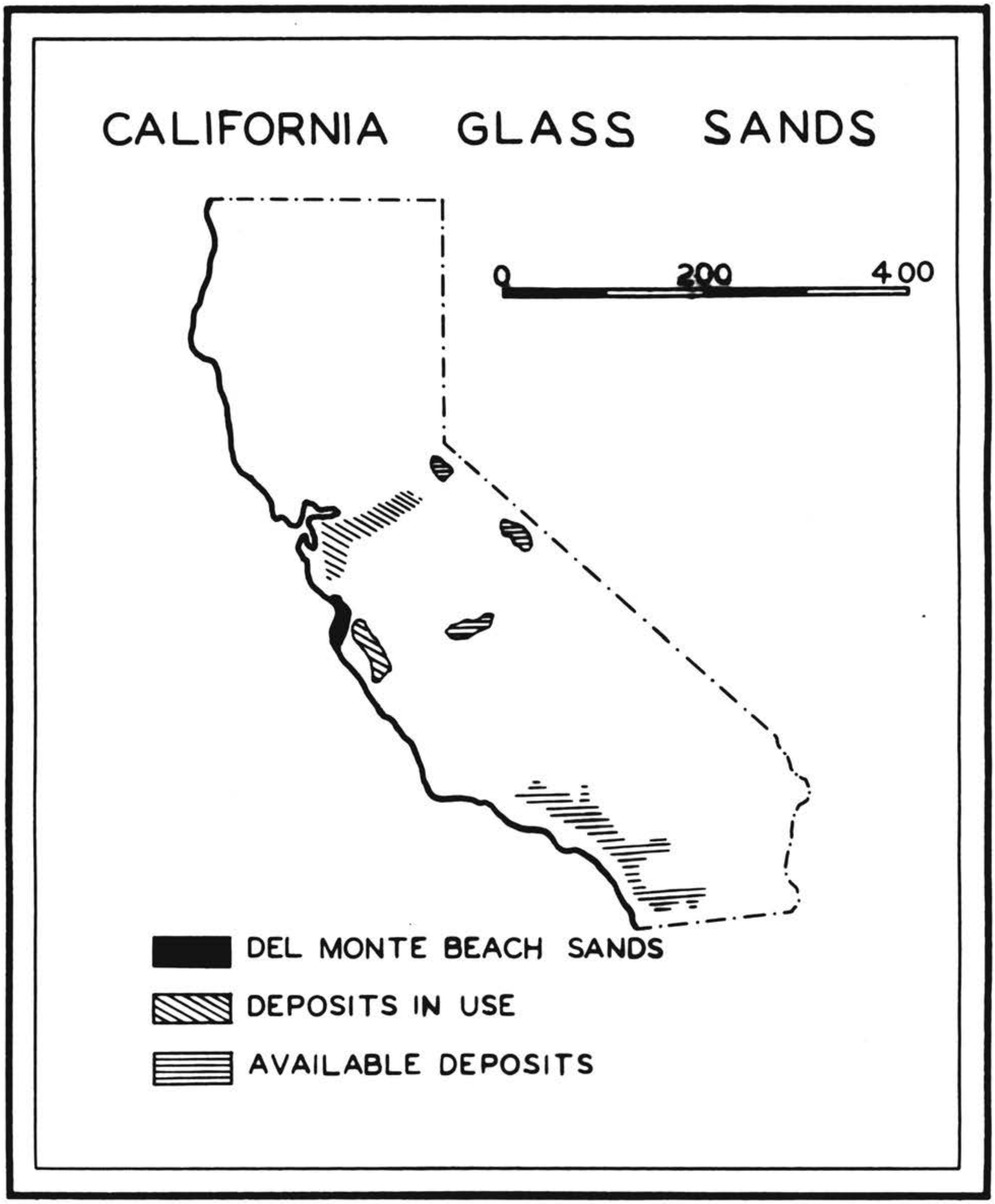
[17] Dasher, op. cit., p. 2

[18] Dasher, loc. cit.


CALIFORNIA GLASS SANDS
0
200
400
DEL MONTE BEACH SANDS
DEPOSITS IN USE
AVAILABLE DEPOSITS

glass containers for over a score of years, using beach sands of the Gulf Area. A goodly supply is available, but extensive screening must be used as the particles vary in size. Washington and Nevada produce small quantities of glass sand, but for local consumption only. Seattle, Washington, has two plants producing plate glass, but the sands must be extensively processed before being fused with the other materials. These sands, river and beach deposits, exceed the minimum content of iron. Nevada silica, found in drifted deposits, contains a high percentage of iron necessitating further processing.

3. Methods of Production

The complete process of transforming sand into a fusible product does not constitute a comparatively simple procedure. The various steps differ with respect to the type of sand or sandstone encountered. The bedded formations of the St. Peter Sandstone require the following preparations: quarrying or hydraulicing, screening, washing, draining, drying, and final screening for size.[19]

In the Oriskany deposits, a lengthened process consisting of the following steps must be taken, due to the cementation of the particles: quarrying, breaking, crushing, grinding, and then followed by similar methods of washing and drying. Beach sands, as in the case of California and Florida, require only the washing and drying processes, due to their type of deposit, and are relatively cheaper to obtain and transform into a usable product.

Hydraulic methods of quarrying dominate in the Midwestern area. A stream of water, directed against the face of the deposit, washes the

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[19] Burchard, op. cit., p. 1011.

sand to a sump or pit. From this sump, steam pulsometers pump the material to washing plants for further processing. Compact deposits, quarried by blocks, or drilled, or shot down by explosives, must be sent to the crushers or grinders for rendition to fine sand. Special quality sand is procured by hand selection at the quarry before shipment.[20]

Washing the sand consists of two methods:[21]

1. The sand, carried upward by a screw conveyor through a long narrow box, inclines against a descending stream of water, and proceeds downward by a second stream. This process, repeated three or four times, removes the foreign matter. Belt conveyors remove the sand to the draining pits.

2. The sand, dumped into a settling tank, receives the full impact of a stream of water. Fine mesh screens allow the various impurities to drain off but secure the sand in the tank.

After the silica has been washed and drained for several hours, rotary cylindrical driers or steam coils dry the sand. A flame, produced by natural gas and played over the contents, burns the existing amount of organic matter and furthers the drying.

The removal of quantities of iron has been previously discussed, but it is not extensively used whenever high grade sand can be procured in its natural state. After sufficient drying, the sand is placed in railway cars for shipment. However, plants in Pennsylvania, located near deposits of sand, receive the processed material directly from the

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[20] R. W. Stone, Department of the Interior: <u>Mineral Resources of the United States</u> (1916) p. 335.

[21] Stone, <u>loc. cit</u>.

quarries. Mechanical conveyors transport the sand to the stockpiles, thereby eliminating transportation costs.

4. Figures of Production

The production of sand has varied from year to year, depending, of course, on the demand of glass products. Glass sand produced in surplus quantities finds use as molding sand in foundries and in grinding and polishing operations. American production of sands used in glass industries has been kept on record since 1882. The United States Geological Service published these reports in the volumes of Mineral Resources of the United States. The following table denotes production in tons and total value:

TABLE II

Glass Sand Production[22]

Year	Tons of Sand (000) omitted	Total Value (000) omitted	Average Value Per Ton
1882	75	$ 168	$ 2.24
1892	221	507	2.29
1902	943	807	.85
1912	1,465	1,430	.97
1922	1,768	2,866	1.62
1932	1,370	2,267	1.68
1942	3,622	6,784	1.87
1945	4,682	8,374	1.79

The most noticeable feature of the table lies in the sharp reduction of the value of sand per ton in 1902. Two factors in particular caused

[22]United States Geological Survey, Department of the Interior: Mineral Resources of the United States, 1882, p. 489. 1892, p. 710. 1902, p. 1007. 1912, Pt. 2, p. 622. 1922, Pt. 2, p. 193. 1932, p. 603. 1942, p. 1268. 1945, p. 4.

the decrease; one, the opening of new areas of production in the lower Mississippi area and the upper reaches of the St. Peter formation; the other, the resultant boom in sand production because of high value in the preceding years. Values of glass sand vary consistently throughout the United States due to demands for certain qualities and types of sands, and in methods produced. Sand values soared in the years of the first World War, as glass experts were called upon to produce items formerly imported. Another increase in total production may be noted in the period from 1932 to 1942, and the fact itself seems self-explanatory. The production of sand has been centered in a minimum of states during the past sixty years. At various intervals, as few as five states have produced over 85 per cent of the nation's glass sands. In 1922, and again in 1924, Pennsylvania, Illinois, West Virginia, New Jersey, and Missouri supplied the aforementioned total. The following table presents the five leading states in glass sand production at selected intervals since 1882:

TABLE III

Leading States in Glass Sands[23]

States	1882	1892	1902	1912	1922	1932	1942	1945
Pennsylvania	1		1	1	1	2	1	1
Illinois	2		2	2	3	1	2	2
Missouri		(a)	3	5	5	4	5	5
West Virginia	3		4	3	2	3		
Ohio			5	4				
New Jersey					4	5	3	3
California							4	4
Virginia	4							
Maryland	5							

(a) Data not available

[23] Ibid.

The export and import trade on glass sand does not reach sufficient quantity to be of importance in the commercial world. In the early stages of glass manufacture, the United States imported the finer sands of Belgium and Germany. California still used sand from the Low Countries as late as 1924. During the years of 1942 and 1945, federal imports totaled less than one ton![24] Federal exports of sand are rather insignificant. Glass producing countries of the world do not depend upon the sands of the United States. They may either use their own, or purchase the finished glass products from us at a substantial low cost.

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[24] G. E. Tucker, "Sand and Gravel." Department of the Interior: Minerals Yearbook (1945) p. 16.

CHAPTER IV

ESSENTIALS OF GLASS PRODUCTION

The rise of the American Glass Industries has been rather sensational during the past fifty years. Prior to this period of rapid success glass was in an experimental stage. Numerous plants and companies endeavored for perfection, but complete success seemed entirely out of their grasp. Table IV on the succeeding page shows the gradual increase of plants since 1819 and the proportional totals of the value of the product. The advance in value of products since 1909 has been largely due to the mechanization of the industry. Automatic bottle machines, the continuous process of extraction for plate and window glass, and the assembly line type of production illustrate a few of the recent trends. During this same period, the amount of labor used did not increase proportionately. Numerous articles produced in the modern glass plants remain untouched by human hands until packed or stored by case lots.

Table V denotes the leading states in glass production per value of product. It is interesting to note the change from the Atlantic Seaboard to the Ohio River section. Since 1860 Pennsylvania has led the nation in glass production. Proximity to good markets, high quality sand, and an abundance of fuel have supplemented the impetus of an early beginning. The headquarters of the principal companies center in Ohio, Pennsylvania, West Virginia, New York, and Illinois. Small subsidiary plants, scattered throughout the nation, satisfy local needs. Transportation costs of glass products are relatively high. If the basic essentials of glass technology are available near a prospective market, production of the product in the market area is usually cheaper than to transport the finished product over great distances.

TABLE IV

General Statistics of Glass Production[1]

Item	1819	1839	1859	1869	1879	1889	1899	1909	1919	1929	1939
Number of Establishments	(a)	81	112	114	169	294	355	363	371	263	421
Persons Engaged	706	3236	9016	12,308	(a)	(a)	55,256	72,573	83,656	73,396	122,905
Wages (000) Omitted $	246	(a)	2904	5953	9144	22,119	29,877	44,293	100,890	87,795	152,601
Cost of Materials (000) Omitted $	122	(a)	2914	4377	8029	12,141	16,731	32,120	90,780	103,294	207,702
Value of Product (000) Omitted $	479	2890	8775	14,301	21,154	41,051	56,540	92,095	261,885	303,819	613,567

(a) Statistics not available.

(1) Source: United States Census of Manufactures. 1819. 1839. 1859, p. 736. 1869, p. 818. 1879, p. 1039. 1889, Pt. 3, p. 311. 1899, Pt. 3, p. 950. 1909, p. 875. 1919, p. 831. 1929, p. 868. 1939, pp. 28, 38.

TABLE V

Rank of States by Value of Product[2]

State	1819	1839	1859	1869	1879	1889	1899	1909	1919	1929	(a) 1939
Pennsylvania	2	2	1	1	1	1	1	1	1	1	
Ohio	4		7	7	4	2	4	2	3	3	
Indiana				5	8	4	2	3	4	4	
West Virginia							7	4	2	2	
Illinois					6	6	5	6	5	5	
New Jersey	6	1	4	4	2	3	3	5	6	7	
New York	1	4	3	2	3	5	6	7	7	6	
Missouri			5	8	5	8	8		8		
Maryland	3	7				7					
Kansas								8			
Virginia	7	5	6								
Massachusetts		3	2	3	7						
California										8	
Kentucky	8	8	8	6							
New Hampshire	5	6									
Vermont											

(a) Glass values of individual states totaled with Ceramics in Census of 1939.

(2) Source: United States Census of Manufactures. 1819. 1839. 1859. 1869. 1879, p. 1047. 1889, p. 315. 1899, Pt. III, p. 958. 1909, Vol. X, p. 883. 1919, Vol. X, p. 831. 1929, Vol. II, p. 869.

1. Usable Raw Materials

Generally speaking, the location of raw materials determines the location of industry. Glass manufacturing differs, however, as the cost of all material used rarely constitutes more than ten or fifteen per cent of the total cost of manufacture. Therefore, it may be ranked in the low cost bracket of the industries of the United States. During the early history of glass only the basic ingredients were used. A simple formula in common use by glass workers of the early 19th Century was as follows:

TABLE VI

Window Glass Formula

Raw Materials	Quantity Used
Glass Sand	100 pounds
Soda Ash	30 pounds
Pulverized Limestone	35 pounds

A comparison between the above and the modern formulas finds the same basic ingredients used, but the present day batch contains numerous metallic and basic substances unknown to the early glass experts. The principal raw materials used in the manufacture of glass, regardless of the process and the type of product, include sand, soda ash, lime, salt cake, and cullet, or broken scrap glass.

Sands used in glass production have been extensively discussed in the preceding chapter and no further mention need be made of their importance.

Sodium carbonate, or more commonly known as soda ash, is used to the amount of 500,000 to 700,000 tons annually as a flux to facilitate the

[3]Joseph D. Weeks, Department of the Interior: Mineral Resources of the United States (1885) p. 548.

mixing and melting of the other materials in the batch.[4] It is a chemically made product, resulting from the fusing of salt, ammonia, and carbon dioxide. The cost of this single item averages from eight to ten dollars per ton, resulting in one of the more expensive materials of glass production.

Lime and limestone together are used to the extent of nearly 200,000 tons annually. Its principal purpose lay in giving hardness, permanency, and ease of melting to the molten product. Frequently in the mining of glass sands, layers of limestone are found approximately at the same levels, and limestone becomes a secondary product of the sand pit. Thus, two major raw materials are procured in the same locality.

The amount of sodium sulphate or salt cake, used to lower the melting point or viscosity of the glass, has declined in recent years to a mere 40,000 tons annually, due to the automatic temperature control devices installed in the furnaces.

Broken or scrap glass, used for centuries in glass manufacturing, frequently supplies up to fifty per cent of the weight of the batch. Scrap shortens the melting time, reduces raw material, lowers fuel costs, and acts as a flux to combine the other raw materials.

The three common metallic substances used in glass production are lead, arsenic, and carbon. Lead imparts a brilliant color and increases the weight of the product. As an active flux, lead may be used in all glasses where a low softening point is desired. Such glasses may have quantities of metal actually welded onto the finished product. Arsenic is used chiefly as an oxidizing agent. It removes carbonaceous material

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[4] E. B. Alderfer and H. E. Michl, Economics of American Industry. p.203.

and assists in freeing the glass from gas bubbles. Added to the batch, carbon assists the salt cake in the decomposition of the sulphates, besides imparting a green color.

Nearly all glass sand contains a small quantity of iron oxide which imparts a pale green color to the product. Such agents as manganese, selenium, nickel or cobalt neutralize the effect of iron oxide and produce pure colorless glass.

Years ago, coloring was induced by the degree of heat to which the glass was subjected and the length of time the batch remained in the furnace. The modern glassmaker must respond quite frequently to the peculiar demands of the public for color schemes in glassware. The following metallic compounds produce the colors that are most common:[5]

Antimony	- Fine Yellow	Iron	- Olive Green
Arsenic	- Milky White	Lead	- Pale Yellow
Barium	- Deep Green	Manganese	- Pinkish Purple
Cadmium	- Rich Yellow	Nickel	- Violet
Carbon	- Dark Amber	Selenium	- Pale Pink
Chromium	- Sea Green	Silver	- Deep Orange
Cobalt	- Blue	Tin	- Copper Ruby
Copper	- Peacock Blue	Vanadium	- Vivid Yellow
Gold	- Ruby	Uranium	- Fluorescent Yellow

All the coloring agents are used in small quantities and in small batches of materials because of their individual value which increases the total cost of the raw materials.

2. Suitable Fuels

Until the 20th Century, the cost of fuel was, exclusive of labor, the largest single item of expense of glass manufacturing. Today, labor

[5] E. E. Pratt, "The Glass Industry," Bureau of Foreign and Domestic Commerce, Miscellaneous Series, LX (May, 1917) pp. 58-59.

claims the greatest expense with the cost of fuel ranking third. It is not surprising to find manufacturers influenced to a great extent in locating their plants near the source of the fuel supply. Fuel may be considered the primary reason for the location of glass plants. Early glass houses used woods of various types, but the material had to be dried or baked to expel all the moisture, so as to produce the greatest amount of heat. When a single pot was used for melting, charcoal was an effective fuel. If several pots were in one furnace, wood was more effective as it carried the flame directly to the crucibles. Sir Robert Mansel, an Englishman, is credited with being the first to use coal as a fuel. His adaptation occurred in the year 1635. Since the first settlers of the United States inhabited the Atlantic seaboard, dried wood was available in every locality and factories could be erected wherever the proprietor desired. With the adoption of coal as a fuel in Pittsburgh, the glass industry migrated westward. The discovery of natural gas in western Pennsylvania, Ohio, and Indiana caused further migration. Hundreds of small factories would spring up over-night near new oil fields. With the failure of natural gas, some plants moved to newer fields, but others refused to move, and, consequently, failed. The gas fields of Oklahoma, Texas, and California, influenced the glass industry to such an extent, that it has become a national industry instead of regional.

Free from ashes and dirt, giving an essential uniform heat, gas, either natural or artificial, furnishes an ideal fuel. Furthermore, it provides an almost perfect combustion which gives a flame, easily controlled and applied. Natural gas is preferred because it is cheaper and gives greater heat. However, limited supply and uncertainty of quality decreases reliability. In early days when plants followed the supply of natural gas, the establishments, cheaply constructed, could move whenever the occasion arrived. By 1920, factories became larger, equipment more costly, the buildings more substantial, and the industry adapted to specific locations. Whenever the supply of natural gas is exhausted, oil or artificial gas may be used without too great a revolutionary change. Electricity, as yet, has not proved to be an ideal fuel, although a few arc-type furnaces are in use for small special quantities of molten glass.

3. Types of Furnaces

The first glasses produced by man were melted in open pots. This process required great amounts of time and fuel, and the need for a furnace was soon realized. The earliest type of furnace was a fire-brick box in which stood the pot with the fire of wood on either side.[6] With the charge of raw material ready for use, the blower inserted the end of his pipe, picked up the right amount of molten material, and carried out his task of blowing it to the desired shape. Pot furnaces are still in use today, although they are of the regenerative type. By utilization of the waste gases of combustion to preheat the incoming gas and air, a uniform and a more intensive heat is obtained. As much as fifty per cent reduction in fuel costs result in this method. Pot furnaces may be of various shapes and sizes, depending on the scale of the industry. Pots usually number from six to twelve, although plate-glass furnaces may use as many as twenty. The pots are placed in two rows on either side of the fire. The flame, directed against the pots, melts the batch. An opening

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[6] *Ibid*. p. 60.

in the furnace wall opposite each pot allows for its hurried removal. The manufacture of individual pots is a tedious process which requires many months for completion. They are costly and their comparatively short lives range from twenty-five days to six months. Pot furnaces necessitate day production only, and special crews recharge the empty vessels each night. The chief argument against such production centers around their limited capacity. Each pot produces only one and one-half tons of molten glass per twenty-four hour period.

In 1861, Siemens, a German industrialist, introduced the first tank furnace.[7] From its crude beginnings, it has developed into one of the primary reasons for the tremendous advance of the glass industry in the United States. (First introduced into America about the year 1872, tank furnaces provide the most widely used type at the present time.[8] The tank furnace has proved successful where twenty-four hour production exists, as it allows a continuous melting and tapping of the product. The capacity, which averages near 1400 tons of raw materials becomes equally important among other factors. The tank is located inside an open hearth or combustion chamber lined with fire-clay. For a complete processing of raw materials, the tank requires three divisions.[9] The first compartment, a melting chamber, allows for the fusing of sand and the other materials; the second, a refining compartment, burns out the impurities; the third division, a working section, keeps the molten product at a uniform temperature for tapping. The major advantage of the tank furnace

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[7]*Ibid.* p. 12.

[8]Pratt, *loc. cit.*

[9]Alderfer and Michl, *op. cit.*, p. 204.

lies in its continuous operation. While raw materials are entering the first division, molten glass may be withdrawn from the third section.

4. Preparation of the Batch

The actual mixing of the raw materials in glass production is a relatively simple process. After the impurities, such as iron, lime, alumina, and vegetable matter have been removed from the sand, the quantity desired is weighed according to the formula and placed in a huge mechanical mixer. The other ingredients, after having been properly weighed, are added and mixed. Small quantities for special glasses are frequently mixed by hand on a clean surface. Cullet (broken glass) is then added and the batch transferred to the furnaces. Modern methods permit the mixture to be mechanically shot through tubes or pipes. The charging of pot furnaces usually takes place at night, while the tank furnace, continually fed, keeps the molten glass at a fixed level. Ingredients vary in quantity and number according to the type of glass being produced. Some varieties contain only five raw materials, others twenty. During the melting of the batch there is a loss of material due to evaporation. This loss seldom averages more than one-sixth the weight of the quantity mixed. The temperature necessary to melt the batch cannot be stated positively. That depends entirely on the type of furnace and the composition of the mixture. The average actual temperature required is about 2600° Fahrenheit, and in some instances, as much as 2850° Fahrenheit.[10] The glass, ready to be tapped, proceeds through the various processes for salable products.

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[10] Pratt, <u>op. cit.</u>, p. 68.

5. Costs of Labor

During the period of time from 1860 to 1920, labor was by far the outstanding expense in the glass industry. Table IV, on page 46, shows labor as totaling more than raw materials until the 1929 census, at which time the number of plants and number of laborers also decreased. In a special report of 1917,[11] labor costs ranged from 18.19 per cent to 71.69 per cent of the total costs of production, with an average of 42 per cent for all glass industries.

In the early period of American industry, glass blowers averaged $5.30 per day, which constituted the highest paid of all workers in industries of all types. As late as 1903, glass blowers still received $1.70 per hour and averaged a thirty-six hour week, giving them the highest income of any industrial workers for that year.[12] The introduction of machines greatly diminished labor and wage levels in proportion to the total value of products. The glass blower can no longer demand top wages. The unions of glass workers have stabilized the wages and the majority of men are now classed as machine operators and not as glass specialists.

In October of 1946, there were 105,000 glass workers. A summary of their earnings and hours in comparison with other industries follows:

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[11] Ibid., p. 242.

[12] Ibid., p. 246.

TABLE VII

Summary of Earnings and Hours[13]

Industry	Weekly Earnings	Weekly Hours	Hourly Earnings
All Manufacturing	$45.74	40.2	$ 1.14
Automobile	52.80	38.3	1.38
Iron and Steel	49.85	40.3	1.24
Glass	45.71	39.4	1.16
Leather	44.78	39.7	1.13
Furniture	42.59	41.8	1.02
Cotton Goods	35.57	40.2	.95

From the contents of this table, we may surmise that glass workers are near the average of all manufacturing labor in regard to salaries and wages. With specialization outmoded, higher wages have vanished, largely through the mechanization of the entire industry.

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[13] United States Department of Labor, Labor Review, LXIV (January, 1947) pp. 148-149.

CHAPTER V

TECHNIQUES OF GLASS PRODUCTION

Glass production has become a field of specialization. No longer do we find one plant producing all types of glass and glassware. The United States Bureau of Census lists glassware as either glass containers, flat glass, or pressed tableware, and miscellaneous glasses. The demand for higher quality of product, the increase in cost of raw materials, and larger amounts of capital invested must be balanced by means of unlimited production. As early as 1918, specialization invaded the countries of Europe with the following nations producing certain types of products:[1]

England: Beautiful, brilliant, lead flint-ware, cut, colored, and engraved glasses of excellent quality.

France: Polished plate glass, stained window glass, enameled and etched fancy ware, and optical lenses.

Belgium: Window glass of fine quality.

Germany: Mirrors, cheap tableware, and colored vases.

Austria: Cut, engraved and colored tableware, glass gems, beads, pearls, and buttons.

The United States now leads the world in glass technology. The Bureau of Standards in 1944, reported that the United States excels in the field of optical glass which had long been dominated by Germany. Appendix A and B at the conclusion of this study carries a complete summary of the exports and imports of glassware.

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[1] E. E. Pratt, "The Glass Industry," Bureau of Foreign and Domestic Commerce. Miscellaneous Series, LX (May, 1917) p. 23.

1. Window Glass

The earliest forms of window glass were blown by the professional glass blower. Securing the proper amount of molten material on the end of the blowpipe, he produced a cylinder of glass which was then cut with shears and rolled out on a flat surface with a metal roller. Window glass of this sort was of poor quality. Unevenness in thickness and impurities imparted by the metallic roller caused a demand for better products. The first improvement over this slow process, came in the use of a "bait" member to form the cylinder instead of the blower. An iron ring was dropped into the surface of the molten glass, and the material adherred to it by simple molecular attraction. The ring, when pulled upward, drew with it a cylinder of glass. The rate of draw, usually from one to two feet per minute, depended upon the temperature of the mass as well as the thickness of the desired product. The diameter of the cylinder was regulated by a jet of compressed air, introduced through the "bait." Later improvements introduced the air through an aperture in the center of the melting pot.[2] Cylinders of twenty-five and thirty-five feet could be drawn. Machine operators of this process frequently handled as many as three machines simultaneously, controlling their speed and air pressure with hand levers.

All modern flat glass, or window glass, is made on a continuous basis. This comparatively simple process had its introduction during the first world war. An iron bar, seven to nine feet in length, is inserted

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[2] Ibid. p. 65.

horizontally in a shallow batch of molten material. When withdrawn, the sticky glass adheres so firmly that a thin sheet flows after it at the rate of four or five feet per minute.[3] It continues to flow in an endless ribbon, since the amount of glass being melted is synchronized to the amount being withdrawn.

TABLE VIII

Window Glass Made by Continuous Process[4]

Year	Percent
1919	10
1923	38
1926	39
1929	80
1932	95
1935	100

In this branch of the industry, automatic production reduced the number of plants and companies. In 1941, only fifteen plants existed, as compared with eighty-two in 1917. Three companies produced more than three-fourths of the nation's supply, namely, the Libby-Owens-Ford Glass Company of Toledo, Ohio, the Pittsburgh Plate Glass Company, and the American Window Glass Company of Pittsburgh, which operate plants chiefly in Pennsylvania, West Virginia, and Ohio.[5]

Window glass is quite bulky in relation to its value, and transportation costs often reach 35 per cent of total factory costs. Hence, plants of this nature are located near markets and adjacent to cheap efficient

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[3] E. B. Alderfer and H. E. Michl. Economics of American Industry, p. 206.

[4] United States Tariff Commission, "Flat Glass and Related Glass Products," Report of the United States Tariff Commission. Section 332, Part 2., p. 123.

[5] J. Russell Smith and M. Ogden Phillips, Industrial and Commercial Geography, p. 257.

fuel. Although the complete mechanization of the industry brought about a marked reduction in total labor cost, fuels and raw materials, plus the increased overhead of machinery have caused an overall gain in costs of production. Special glasses, allowing certain health-giving rays of the sun to penetrate them, are being introduced in many homes. However, ordinary window glass will continue to be in demand due to its extensive use and the increasing population of the United States.

2. Plate Glass

For many years, plate glass was produced on a casting table. Within the past two decades, the continuous process, similar to that producing window glass, has taken complete charge of this branch of the glass industry. A complete description of the casting method was given by E. E. Pratt in 1917.[6]

> "As the door of the furnace is opened (pot furnaces), the pot, usually containing about one ton of molten glass, is removed from the furnace by means of wrought-iron tongs, and carried to the casting table. The casting table is made of iron with a smooth, highly polished, trued surface, and is 12 to $16\frac{1}{3}$ feet wide and 20 to $27\frac{1}{2}$ feet in length. The pot is tipped, and as the molten glass is poured or cast on the table in front of it, a heavy roller attached to the table, quickly passes over the glass. The roller of cast iron, about eighteen inches in diameter, covers the entire width of the table, and rolls the full length.... When the glass has been rolled, it is pushed into the leer. By means of mechanical appliances, it is made to successively travel from one position to another, thus passing through a gradually diminishing temperature. After sufficient cooling, the glass is then ground. It is secured to a revolving iron table by means of plaster of Paris, and in some cases is further secured by means of wooden blocks. As the table revolves, water and sharp river sand are applied to the glass, and revolving iron runners begin to grind....After the sharp sand, emery is used in the same manner....The glass, after being

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[6] Pratt, <u>op. cit.</u>, pp. 70-71.

> ground, is placed on a special polishing table. Rouge and water are applied and felt-covered oscillating blocks or discs polish the glass. After it has been ground and polished, the glass is about one-half the thickness of the original rough plate."

The making of rolled figure glass resembles the aforementioned method, with the desired pattern engraved on the roller or cut into the surface of the casting table.

This process remained in effect until 1922. At this time, the Ford Motor Company and the Pittsburgh Plate Glass Company developed the continuous drawing, rolling, grinding, and polishing process which greatly enhanced production. Henry Ford, discouraged by the high cost and breakage of automobile glass, conceived the idea of a cheaper product. In two years, his plant cut the cost of plate glass by 80 per cent.[7] His method centered around a continuous flow of molten glass across a moving platform at the rate of 53 inches per minute.[8] Careful study proved this to be the proper speed to allow sufficient cooling of the glass for cutting and polishing without stopping its movement. Other automobile manufacturers quickly entered this phase of the industry to assure themselves an adequate supply, as well as a low-cost product. Fisher Body Division of General Motors gained control of two plants for their supply, and Ford Motors obtained interest in several companies.[9] Since 1930, the compulsory use of safety glass in automobiles added another impulse to the industry as the amount of plate glass per car doubled. Automobile manufacturers require nearly three-fourths of all plate glass produced.

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[7] Smith, op. cit., p. 257.

[8] Ibid. p. 258.

[9] Alderfer and Michl, op. cit., p. 208.

Plate glass production rests largely in the hands of two great companies, the Libby-Owens-Ford Company and the Pittsburgh Plate Glass company. Together, with their six plants, these companies produce 95 per cent of the American supply of plate glass.[10]

3. Tableware

During the early part of the 20th Century the major portion of tableware was either blown or pressed in paste molds.[11] Pressed tableware required the use of a plunger mechanism instead of compressed air. Tumblers, dishes, goblets, and vases were efficiently produced. Blown tableware required the art of the picturesque blower. Gathering the proper amount of glass on his blowpipe, he proceeded with his usual routine and inserted the bulb of glass in the mold. As air pressure was applied, the blowpipe was rotated so that the ridges of the mold would not leave an impression on the finished product. Exclusive use of paste molds permitted the glass to be revolved. When the article was removed from the mold, it was annealed and sent to the finishing department where the rough edges were smoothed and the product glazed or polished.

In present day manufacture of tumblers, practically all steps are automatic and machines produce as high as forty tumblers per minute. Intricate designs for household dining rooms, kitchens, and restaurants are generally fashioned by hand and produced in smaller plants. In

[10] Alderfer and Michl, <u>loc. cit</u>.

[11] Paste mold: An iron mold coated with a thin film of oil or carbon.

1939, thirty-five tumbler plants were concentrated in Ohio, West Virginia, and Pennsylvania.[12] Fancy designs of every conceivable combination are patterned, and brilliant colors are used to stimulate sales.

4. Glass Bottles

The art of blowing glass bottles was considered the height of perfection by ancient glass blowers. With the introduction of paste molds, the operation was greatly simplified, and higher production was induced by the shop system. Three men formed a team, a blower, a gatherer and a finisher. A single team produced 300 dozen bottles per day. A single blower, without the aid of his assistants, rarely produced over 40 dozen per day. The shop system remained in effect until 1903, when Michael Owens invented the Automatic Bottle Machine.

The modern bottle glass industry accounts for over forty per cent of the total output of the entire glass industry. Due to the tremendous quantity desired, automatic machines produce over 7,000,000,000 containers annually, with a total employment of only 24,000 workmen.[13] Two types of machines have complete dominence of the field, the Owens Bottle Machine, and the Gob-fed Process of the Hartford Empire Company.

The Owens machine employs the so-called suction process.[14] Molten glass flows from the cooler section of the tank furnace into a shallow revolving pot. Molds, mounted on arms radiating from a central pillar,

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[12] Alderfer and Michl, op. cit. p. 209.

[13] Alderfer and Michl, loc. cit.

[14] Temporary National Economic Committee, "The Glass Container Industry," Hearings of the 75th Congress, (December, 1938) p. 738.

revolve so that each mold passes over the revolving pot. At this point, the mold lowers itself until the open end touches the pool of molten glass, sucks up a charge of glass, rises, and moves on. A second mold automatically moves into place and with the aid of compressed air, forms the finished product. At this point in the revolution, the arm swings over a conveyor and deposits the bottle which moves to the lehr for annealing. The primary mold of the arm of the machine swings back into position ready to renew the process. The machine consists of from six to sixteen arms, depending upon the type of product or the speed of operation desired. The process is an endless one and none of the bottles are touched by human hands.

Since 1917, the Gob-Fed Process of the Hartford Empire Company has offered serious competition to the Owens machine.[15] The Gob-Fed operations are less intricate and machines less expensive. A covered channel, known as a forehearth, conducts the molten glass from the tank furnace to the machine. The material is fed from a hole or orifice in the bottom of the forehearth by a plunger type of mechanism. The drops or gobs of glass fall into molds, and compressed air is applied to shape the bottles to proper size. An automatic "take-out" removes the product from the molds onto a belt conveyor. The circuit is completed with the molds returning to their former position at the forehearth.

From 1917 to 1924, sharp conflict arose between the two companies. Agreements reached shortly thereafter, created a form of cross-licensing, known as the leasing system. Neither of these companies sells its equipment outright to bottle manufacturers. Owens-Illinois restricts the use

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[15] Ibid., p. 742.

of its machinery to its own plants, and Hartford Empire merely licenses the use of its machinery.

The Hartford Empire Company, since its agreement with Owens-Illinois, has amassed sensational totals in the collection of royalties and license fees.

TABLE IX

Receipts from Royalties and License Fees[16]

Year	Royalties	License Fees	Total
1924	$ 637,692	$ 128,842	$ 766,534
1928	1,742,386	469,100	2,211,486
1933	3,114,590	197,179	3,311,769
1937	5,548,584	516,678	6,065,262

The combined production of the two companies totals approximately 96 per cent of all glass containers produced in the United States.[17] The remaining four per cent is produced by four independent organizations who have resigned themselves to hand-blown ware. Hartford Empire entered the world market and now has foreign patents in seventeen foreign nations, from which it collects no royalty. Figures for 1938 indicate the presence of 45 companies operating 90 plants in the glass container industry. Indiana, West Virginia, and Pennsylvania have 50 of these plants, with the balance scattered over fourteen states.[18] Container products have eleven classifications, of which food containers and milk bottles have greatest prominence in total production.

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[16] *Ibid.* p. 764.

[17] *Ibid.* p. 763.

[18] *Ibid.* p. 804

5. Miscellaneous Items

Modern scientific experiments have perfected numerous sensational products, many of which are not available to the consumer. Certain discoveries, if perfected, are capable of revolutionizing our entire mode of living. Artificially made materials, usually higher in cost to the consumer, cause the average layman to remain quite aloof to new scientific products, regardless of their advantages.

Foam glass, made by the Pittsburgh-Corning Corporation, has the appearance of an extremely porous, coal-black brick. One-third lighter than cork and far more buoyant, foam glass adapts itself to lifebelts, rafts, submarine nets, as well as insulation in homes.[19]

Glass-reinforced plastics, which have made possible a lightweight, bullet-proof body armor for soldiers, surpasses metallic armor in ballistic efficiency. Doron, as the glass-plastic armor is known, will stop missiles up to and including a 45-caliber revolver bullet.[20]

Doctors Alfred Badger and Roger Bray of the University of Illinois, have perfected a special glass fertilizer. Glass containing the principal plant foods is so mixed that it is soluble in water and dissolves slowly in the soil. As it dissolves, life-giving chemicals are released. By altering the glass composition, the rate at which it disappears may be controlled. In this way, an application of the glass fertilizer may serve over a period of years.[21]

Science not only has learned how to do new things with glass, but

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[19] "Glass in the Atomic Age," Popular Science, CXLIX (December, 1946) p. 127.

[20] Ibid. p. 128.

[21] Ibid. p. 129.

it has learned how to improve the older conventional forms of glasses. A transparent, durable, electricity-conducting coating may be applied to windshields of automobiles and airplanes to eliminate icing and fogging. Produced by the Pittsburgh Plate Glass Company, the product known as Nesa, does not distort vision nor does it reduce the transmission of light. The development of this material is attributed to extensive research for a satisfactory glass for use on radar equipment and other types of electronic instruments and dials. When untreated glass was used, static electricity would collect on the surface and cause deflection of the registering mechanisms. Hence, Nesa served as the necessary conductor for the accumulated electricity.[22]

Perhaps the most sensational development in glass technology lies in the production of glass that resists hydrofluoric acid. Developed by Doctor Alexis Pincus of the American Optical Company, the product contains no sand or any form of silica. A new material, phosphorus pentoxide, is the major constituent of this acid-resisting glass. This discovery is expected to simplify the handling of the important acid used in scientific experiments, as well as industrial operations. Previously, the use of hydrofluoric acid presented difficulties because it could be shipped only in lead or wax containers. Laboratory uses were restricted to gold or platinum retorts. Now, the sandless glass offers a more economic and less dangerous means of transport as well as working facilities. With melting and working properties nearly the same as ordinary glass, it can be cast or drawn into sheets or blown into bottles and

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[22] "Transparent Conductors," Scientific American, CLXXV (December, 1946) p. 275.

containers. It may also be ground and polished, tempered, or reused as cullet. Its potential uses are unlimited in chemical research as beakers, test tubes, and evaporation dishes.[23]

The Owens-Corning Corporation has been specializing in the production of glass fibers. A strand of this fiber may be fifteen times as fine as human hair, and yet contain the tensile strength of steel. Fireproof by nature, it is a popular drapery material for hotels, cafes, and public institutions. Owens-Corning states that glass fabrics will compete with satin, damask, and other fine quality materials in the near future. It will not compete with wearing apparel, as it is non-absorbent and irritates the skin. Fiberglass fabric is unsuited for tires because it breaks from repeated flexing, but finds use in belting and insulation for underground cables. The Navy consumes a large part of the present production as a substitute for kapok and for electrical insulation. Glass fibers are being tested by the United States Army in its new type Arctic clothing. Field jackets, parkas, boots, and mittens lined with the new product, give good lightweight protection against sub-zero temperatures. An experimental glass-lined parka, worn by an observer during Operation Musk Ox in Northern Canada, afforded complete comfort at temperatures as low as 40 degrees below zero.[24] Glass fibers compete with cotton in the insulation field. The competition is hardly direct, because cotton products cost only one-fifth as much as fiber-glass. Owens-Corning

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[23] "Acid Resistance Offered by New Glass," Scientific American, CLXXII (February, 1945) pp. 110-111.

[24] "Glass in the Atomic Age," Popular Science, CXLIX (December, 1946) pp. 127-129.

estimates that fiberglass, already used in fifteen per cent of all electrical equipment, may reach seventy per cent in the near future.[25]

[25] "New Glass Fiber, Fine Diameter Product." Business Week, (February 17, 1945) pp. 67-68.

CHAPTER VI

FUTURE POSSIBILITIES OF GLASS

The problem of discovering new uses for glass has been discarded and the major point in the minds of glass experts is to determine instances where it can not be used. Glass materials, with us in nearly every phase of human existance, find a place in all industries, and have recently been used by the medical profession in the human body. The American public hardly surmises the calamity that would exist if the manufacture of all types of glass were to cease. Industry could not function properly without a supply of the vital necessities afforded by glass manufacturers. Light globes, gauges, glass tubing, electrical instruments, and tiny jewels or bearings are but a few of the critical items supplied by glass technicians. Human lives would need adjusting to a glassless world. Homes, business houses, transportation, and commerce depend upon the facilities supplied by glass. Iron and steel dominate our present machine economy. However, considering the relative importance of glass, may we not add glass to the basic essentials of our economy?

It was stated earlier in this study that science can not specifically define the composition of glass.[1] At the present time, in a major glass-research program conducted at the University of Pittsburgh, Doctor Alexander Silverman, in charge of the chemistry department, aims to solve some of the age-old secrets of glass. He hopes to find out how the raw materials in glass melt; how the glass flows in melting; and what causes defects in glass. His findings may remove many of the "ifs" from glass

[1] Chapter I, "Introduction to Glass," p. 2.

manufacturing and open new fields for future research. Doctor Silverman prophesies the use of glass in defense against the atomic bomb. The same element that is used to make the bomb, can be used to produce a glass that provides good protection against harmful radiations. Garments and helmets made of cloth spun from uranium-glass or lead-glass fibers, would permit safe entry into atom-bombed areas. Special oxygen respirators, equipped with glass-insulated, high-frequency precipitators, would keep radio-active dust out of lungs of rescue workers.[2]

Of the basic types of glass, the production of glass bottles appears to be the least promising. The return of metal containers, since the close of the war, is expected to lessen the amount of glass used as a substitute for metallic packaging. Plate glass and window glass depend largely upon automobile manufacturers and construction agencies. The return to normalcy is expected to increase the total production in these types of glass products.[3]

The author of this study has been lead to believe that the future of the glass industry rests in the hands of the chemists and glass technicians of our country. The basic glasses have become a definite part of our standard of living, and science has devoted its recent efforts towards the improvement of these products. The near future may witness sensational developments of new products, however, science again holds the key for such speculation. Glass, as a material, may be thousands of years old, but glass as an industry, is just coming of age.[4]

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[2] "Glass in the Atomic Age." Popular Science, CXLIX (December, 1946) p. 127.

[3] "Outlook for Glass Isn't Too Rosy." Business Weekly, (February 5, 1944) p. 26.

[4] "Glass in the Atomic Age." Popular Science, CXLIX (December, 1946) p. 129.

BIBLIOGRAPHY

A. GOVERNMENT DOCUMENTS

United States Tariff Commission, "Cast Polished Plate Glass." Report to the President of the United States. Tariff Act of 1922, Section 315, pp. 1-59.

United States Tariff Commission. "Increasing Rates on Duty of Polished Plate Glass." Report to the President of the United States. January, 1929. Bulletin 1864.

United States Tariff Commission. "Flat Glass and Related Glass Products." Tariff Act of 1930. Section 332, part 2.

United States Tariff Commission. "Glass Industry as Affected by the War." Tariff Information Series V, 1918.

United States Tariff Commission. "Optical Glass and Glassware." Ways and Means Committee, House. Report of 1919.

United States Tariff Commission. "Minor Glass Manufacturing Processes." Bulletin B-9, 1921.

United States Department of Commerce. "The Glass Industry." Miscellaneous Series, No. 60, 1917.

United States Department of Interior. "Glass Sands of the United States." United States Geological Survey. Bulletin 285, 1906.

United States Department of Interior. "Glass Sands of West Virginia." United States Geological Survey. Bulletin 315, 1906.

United States Department of Interior. Bureau of Mines Information Circular 6937. 1937.

United States Department of Interior. "Benefication of Del Monte Sand." Bureau of Mines Report of Investigations 3740. 1943.

United States Department of Interior. "Marketing Silica." Bureau of Mines Information Circular 7202. 1942.

United States Department of Congress. United States Census of Manufacture. Washington: United States Government Printing Office. 1820, 1840, 1860, 1870, 1880, 1890, 1900, 1910, 1920, 1930, 1940.

United States Department of Interior. United States Minerals Yearbook. Washington: United States Government Printing Office. 1882, 1885, 1892, 1894, 1895, 1896, 1902, 1907, 1912, 1922, 1932, 1942, 1944, 1945.

Temporary National Economic Committee. "The Glass Container Industry." _Hearing of the Seventy-Fifth Congress._ Third Session, Part II. 1938.

B. STATE PUBLICATIONS

California State Geological Survey. "Sand and Gravel." _Mineral Products of California._ 1943.

Dake, C. L. "The Problem of the St. Peter Sandstone." _University of Missouri School of Mines and Metallurgy Bulletin._ No. VI (August, 1921).

Illinois State Geological Survey. "The St. Peter Sandstone of Illinois." _Geological Bulletin LIII._ 1929.

Pennsylvania State Geological Survey. "The Oriskany Sandstone." _Geological Bulletin IV._ 1939.

C. BOOKS

Alderfer, E. B. and H. E. Michl. _Economics of American Industry._ New York: McGraw-Hill Book Company, 1942.

Bengtson, Nels A. and Willem Van Royan. _Fundamentals of Economic Geography._ New York: Prentice-Hall, 1943.

Branson, E. B. and W. A. Tarr. _Introduction to Geology._ New York: McGraw-Hill Book Company, 1935.

Hinds, Norman E. A. _Geomorphology._ New York: Prentice-Hall, 1943.

Landon, Charles E. _Industrial Geography._ New York: Prentice-Hall, 1946.

Lehmann, Helen M. _Glass and Glassware._ New York: The Ronald Press Company, 1922.

Lippincott, Isaac. _Economic Resources and Industries of the World._ New York: D. Appleton-Century Company, 1929.

Morey, George W. _The Properties of Glass._ New York: The Reinhold Publishing Company, 1938.

Ostrolenk, Bernhard. _Economic Geography._ Chicago: Richard D. Irwin Incorporated, 1941.

Rogers, Francis and Alice Beard. _5,000 Years of Glass._ New York: Frederick A. Stokes Company, 1937.

Smith, J. Russell, and M. Ogden Phillips. Industrial and Commercial Geography. New York: Henry Holt and Company, 1942.

Thomas Register of Manufacturers. New York: Thomas Publishing Company, 1941.

D. PERIODICALS

Baum, A. W. "They Live in a Glass House and Like It." Saturday Evening Post, CCXVII (August 19, 1944), 26.

Cormier, L. W. "Cut Glass." Hobbies, XLVII (January, 1943), 58-62.

Harding, R. T. "Pompeii's Streets Were Paved with Glass." Forum, CIV (October, 1945), 166-167.

Hildebrand, J. R. "Glass Goes to Town." National Geographic, LXXXIII (January, 1943), 1-48.

Jarves, James J. "Glass of Murano." Harpers Magazine, LXIV (January, 1882), 181-183.

Killeffer, D. H. "Glass Made to Order." Rotarian, LXIII (July, 1943), 36-38.

Kinsey, J. R. "Clearer View Ahead." Popular Mechanics, LXXXVI (August, 1946), 96-101.

Lee, R. W. "Glass for Everyday Dining." American Home, XXXVI (June, 1946), 54-56.

Page, W. H. "Glass in Textiles." Scientific American, CLXXI (December, 1944), 266.

Phillips, C. J. "What Glass Is and Isn't." Scientific American, CLXX (January, 1944), 22

Rolfe, R. C. "Our Nineteenth Century Glass Industry." Hobbies, LI (January, 1947), 116-117.

Sanders, G. V. "Nonreflecting Glass." Popular Science, CXLVII (November, 1945), 94-96.

Shull, T. "Venetian Glass." Hobbies, XLVIII (March, 1943), 52-55.

Smith, P. H. "Glass Shatters Its Traditions." Nations Business, XXXIII (January, 1945), 62.

Sparks, W. J. "America's First Industry." Popular Science, CXLVII (December, 1945), 104-105.

Stauffer, L. "Miracles in Glass." Science News Letter, XLVII (January 13, 1945), 26.

Zeluff, V. "Glass and Electronics." Scientific American, CLXXIII (September, 1945), 165-167.

"Acid Resistant Glass." Scientific American, CLXXII (February, 1945), 110-111.

"Electric Glass Called Nesa." Life, XXI (September 16, 1946), 129-130.

"Glass, Oldest American Industry." Life, XVIII (March 12, 1945), 73-84.

"Glass Tomorrow Will Perform Strange Duties." Scientific American, CLXXII (January, 1945), 37.

"Glass That Floats." Scientific American, CLXIX (October, 1943), 172.

"Glass Outlook Isn't Too Rosy." Business Week, (February 5, 1944), 26.

"Glass: Now and Tomorrow." Fortune, XXVII (March, 1943), 122-125.

"Glass Standards to Stay." Business Week (October 12, 1946), 79-80.

"Glass in the Atomic Age." Popular Science, CXLIX (December, 1946), 127.

"Glass Fibers in Planes." Science News Letter, XLVII (May 26, 1945), 328.

"Glass Fibers Afloat." Business Week (July 14, 1945), 73.

"Glareless Glass Available." Science News Letter, XLIX (March 2, 1946), 132.

"New Glasses Contain No Silica." Science News Letter, XLIX (January 26, 1946), 59.

"New Glass Fiber." Business Week (February 17, 1945), 67.

"Nonfogging Glass." Business Week (August 10, 1946), 58.

"Protection from A-bomb Radiations." Science News Letter, XLIX (March 23, 1946), 185.

"Sandless Glass." Scientific American, CLXIX (August, 1943), 59.

"Transparent Conductors." Scientific American, CLXXV (December, 1946), 275.

APPENDIX

APPENDIX A

Glass Exports of the United States for the Year 1940

WORLD

Continent	Value
Europe	$ 218,495
North America	9,755,633
South America	2,901,539
Asia	944,735
Oceania	329,721
Africa	599,733
Total	$14,749,856

Types of products exported:

1. Plate Glass
2. Pharmaceutical Ware
3. Beverage Bottles
4. Table Glassware
5. Chemical Glassware
6. Electric Insulators
7. Glass Chimneys and Globes
8. Miscellaneous Decorated Ware

EXPORTS TO EUROPE

Country	Value
Belgium	$ 1,223
France	12,736
Iceland	16,714
Ireland	10,865
Italy	1,443
Netherlands	1,476
Norway	1,795
Portugal	7,562
Sweden	20,518
Switzerland	4,634
United Kingdom	137,659
Others	1,870
Total	$ 218,495

EXPORTS TO NORTH AMERICA

Country	Value
Canada	$6,043,608
Central America	887,053
Mexico	795,334
Newfoundland	58,174
Cuba	1,641,861
West Indies	339,603
Total	$9,755,633

EXPORTS TO OCEANIA

Country	Value
Australia	$287,733
New Zealand	40,790
Island	1,198
Total	$329,721

EXPORTS TO AFRICA

Country	Value
Belgian Congo	$ 39,692
British East Africa	7,313
Union of South Africa	489,572
British South Africa	14,217
Gold Coast	2,761
Egypt	24,396
Liberia	2,529
Mozambique	17,002
Others	2,251
Total	$599,733

APPENDIX B

Glass Imports of the United States for the Year 1940

WORLD

Continent	Value
Europe	$1,709,274
North America	27,525
South America	1,747
Asia	573,150
Oceania	26
Africa	36
Total	$2,311,758

Types of products imported:

1. Cylinder, crown and sheet glass
2. Bottleware
3. Decorated ware
4. Engraved tableware
5. Christmas tree ornaments
6. Lenses
7. Mirrors
8. Watch crystals

IMPORTS OF EUROPE

Continent	Value
Belgium	$ 569,438
Czechoslovakia	8,954
Finland	13,323
France	302,733
Germany	95,239
Hungary	37,006
Italy	90,548
Netherlands	10,283
Portugal	11,236
Sweden	75,022
United Kingdom	480,893
Others	14,599
Total	$1,709,274

IMPORTS OF NORTH AMERICA

Country	Value
Canada	$ 6,507
Mexico	20,278
Cuba	669
Others	71
Total	$27,529

IMPORTS OF SOUTH AMERICA

Country	Value
Argentina	$ 791
Brazil	830
Chile	55
Venezuela	71
Total	$1,747

IMPORTS OF ASIA

Country	Value
British India	$ 228
China	43,865
Hong Kong	298
Iran	19,714
Japan	508,695
Others	350
Total	$573,150

IMPORTS OF OCEANIA

Country	Value
Australia	$ 17
Fr. Oceania	9
Total	$ 26

IMPORTS OF AFRICA

Country	Value
Egypt	$ 21
Morocco	15
Total	$ 36

MARY R. THOMPSON, Typist