ILLINOIS STATE GEOLOGICAL SURVEY
John C. Frye, Chief Urbana, Illinois

March 1968

INDUSTRIAL MINERALS NOTES 32

SILICA SAND BRIQUETS AND PELLETS AS A REPLACEMENT FOR QUARTZITE

H. P. Ehrlinger III, M. L. Schroder, L. R. Camp,

and H. W. Jackman

ABSTRACT

Several industries in or near Illinois have indicated a need for a near-by source of high-purity silica rock. The known deposits of consolidated silica rock in Illinois are not sufficiently pure to meet the chemical specifications, but the silica sand produced in the state easily meets requirements. However, it does not meet size specifications.

In the Illinois State Geological Survey laboratories, silica sand was bonded to make pellets and briquets of the size required. When tested, the briquets and pellets proved to be a suitable replacement for the quartzite at present used by the industries.

SILICA SAND BRIQUETS AND PELLETS AS A REPLACEMENT FOR QUARTZITE

H. P. Ehrlinger III, M. L. Schroder, L. R. Camp,

and H. W. Jackman

INTRODUCTION

An inquiry was received by the Illinois State Geological Survey in 1966 regarding the possibility of obtaining in Illinois a very high-purity quartzite that could be used as a source of silica in the production of silicon alloys or silicon metal. Specifications called for a siliceous material in pieces less than 4 inches and more than 1 inch in diameter that contained more than 99 percent silicon dioxide (SiO_2) and less than 0.05 percent iron oxide (Fe_2O_3). Although no material meeting all these specifications is available in the state, novaculite, which is a comparatively white chert containing about 98 percent silica, occurs in thick deposits in southern Illinois (Lamar, 1953). Illinois also has large deposits of silica sand that, after preparation, contains more than 99 percent silica, but the particle size of the material is well below that indicated by the inquiry.

The Geological Survey decided to attempt to make a synthetic quartzite that would meet the specifications by bonding high-silica Illinois sand with small amounts of sodium silicate. An additional requirement considered was that the product be able to compete economically with natural quartzite being shipped from mid-eastern states.

At about the same time, correspondence and conferences were conducted with another company that requires similar raw materials. This company wanted organically bonded briquets having a silica-to-fixed-carbon ratio that would allow them to be fed directly to an electrically heated reducing furnace with no further addition of carbonaceous material. The company felt that a self-reducing briquet might increase the efficiency of the reaction in the furnace and so increase capacity or reduce costs.

The Survey laboratories consequently undertook the project of making artifical quartzite briquets of specific size and strength with a silica-to-fixed-carbon ratio of 5:2 and the lowest possible costs for basic materials and fabrication. Thus both silicate-bonded pellets and self-reducing briquets were studied.

AVAILABLE RAW MATERIALS AND BINDERS

Silica Sand

Illinois has a prime source of silica sand in the St. Peter Sandstone (Lamar, 1928) in the north-central portion of the state. Seven commercial operators produced 3,853,000 tons of silica sand from the St. Peter in 1966. The extensive McNairy Formation (Pryor and Ross, 1962) in the southern part of the state is a potential source of silica sand, but at present it is not known to be worked commercially.

The sand from the St. Peter Sandstone is mined, washed, dried, and closely sized before being shipped in bulk or in bags to consumers. The sand from the McNairy Formation would need further preparation to remove the mica it contains before it reached the desired purity.

Locations of the plentiful silica sand reserves of Illinois are shown in figure 1. At present, all producing plants are in northern Illinois.

Binders

An infinite number of inorganic and organic materials might have been used as binders for the pellets and briquets made in this study. Those selected were sodium silicate, coker feed stock, and petroleum coke.

Sodium Silicate

Sodium silicate was chosen to bind the sand pellets because it is comparatively low in cost and has a high silica content. As a binder it would not significantly reduce the silica content of the pellets nor would it add any elements deleterious to the ultimate use of the product. Commercial sodium silicate is readily available in bulk quantity in the state of Illinois. The only known manufacturer is at Utica, LaSalle County (fig. 1).

Coker Feed Stock

Coker feed stock was selected as an organic binder because of its low cost and its low content of undesirable constituents. It is a residue from petroleum refining, has the consistency of tar, contains valuable hydrocarbons, and is readily available (Kemnitzer and Edgerton, 1965) in the Chicago metropolitan area, the East St. Louis metropolitan area, the Joliet area, and in southeastern Illinois (fig. 1). It contains about 24 percent fixed carbon and 76 percent volatile matter.

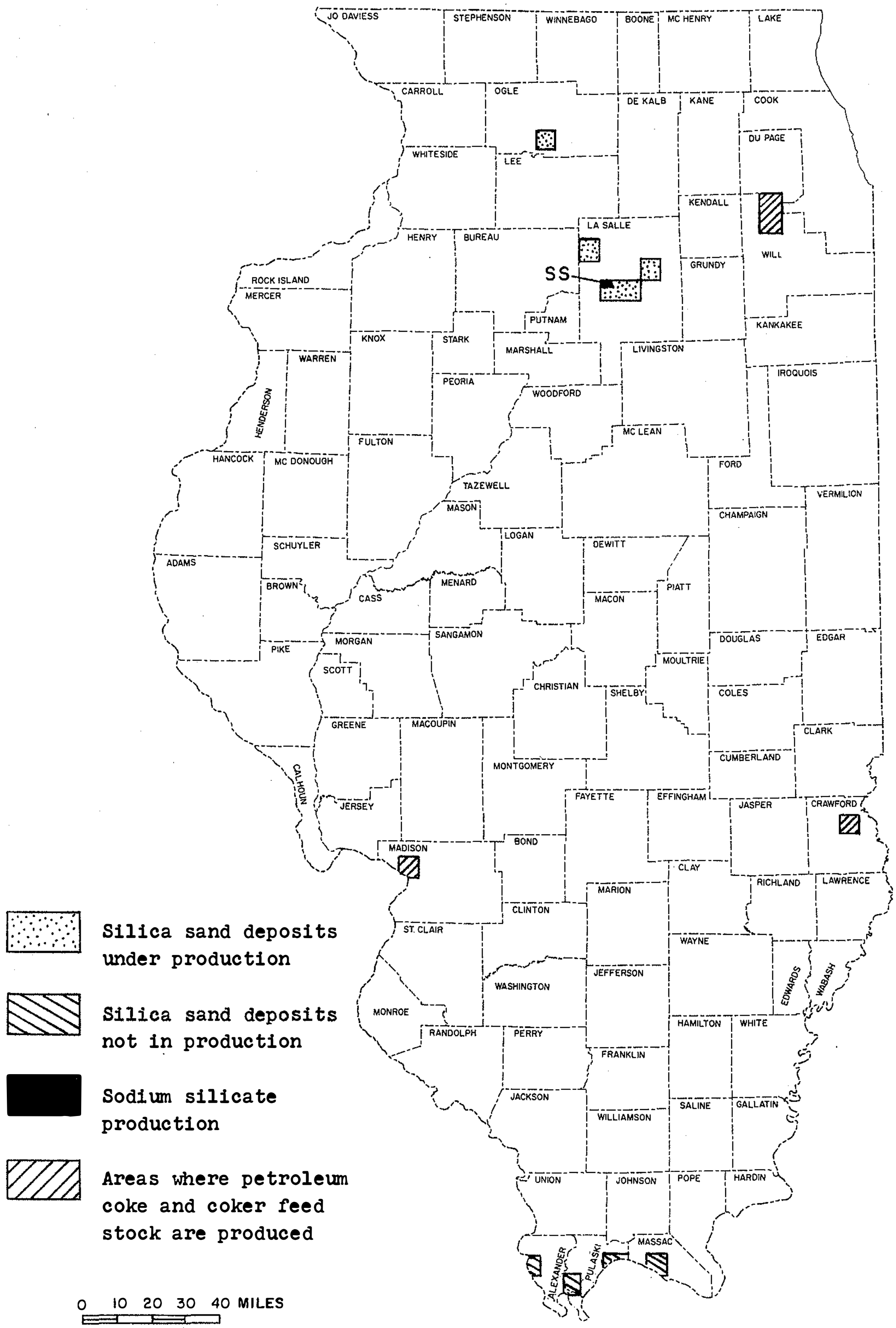


Fig. 1 - Location of silica sand deposits and areas producing silica sand, sodium silicate, petroleum coke, and coker feed stock.

Petroleum Coke

When coker feed stock is carbonized, a petroleum-based coke of from 80 to 90 percent fixed carbon is produced. It is less expensive than coker feed stock and does not contain elements that would affect the use of the briquets. The petroleum coke is available in the same areas (fig. 1) as the coker feed stock (Kemnitzer and Edgerton, 1965).

LABORATORY PROCEDURES AND RESULTS

Synthetic Quartzite

To produce synthetic quartzite of suitable quality, silica sand of exceptionally high purity must be used, a standard that may be obtained by washing, flotation, or other means of beneficiation. Sufficient sodium silicate is added to the sand to bond it, and the mixture is molded and dried. Pellets so made must be strong enough to resist decrepitation or popping when subjected to intense heat.

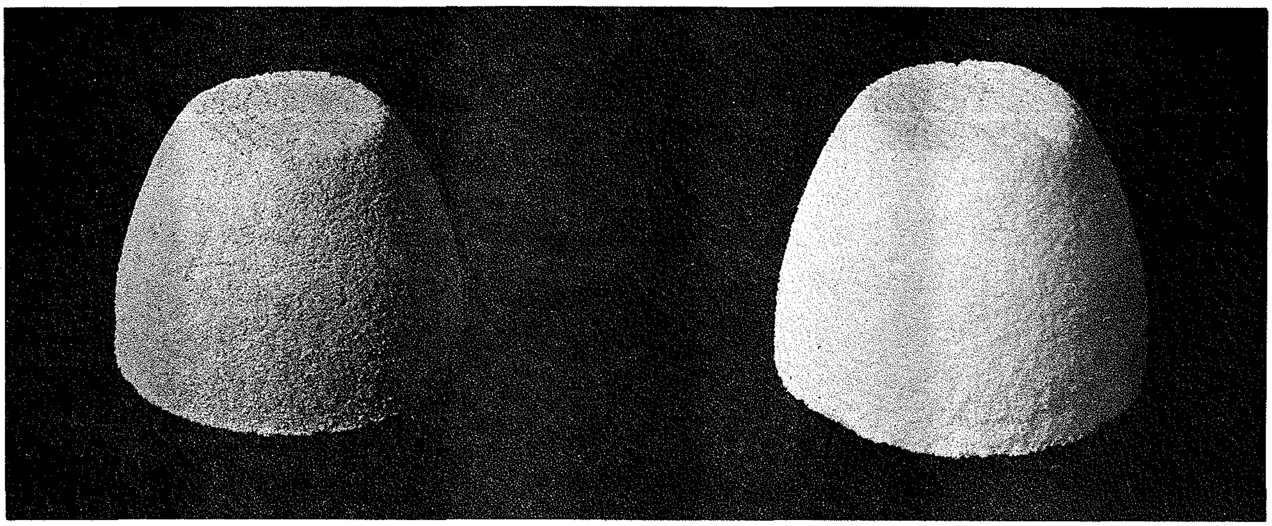
In our tests, 90 percent silica sand, 5 percent water, and 5 percent sodium silicate were thoroughly mixed and pressed into pellets in porcelain or iron molds. After removal from the molds they were dried at 220° F (105° C). The sample pellets were then tested for compression strength and heat reaction. They withstood a compressive load of over 280 pounds and did not decrepitate, even when the temperature was raised to 2000° F (1093° C). At that high temperature, however, the silica underwent a phase change from quartz to tridymite in the presence of the sodium ion. This transformation is indicated in the top photograph on plate 1 by the change in the color of the fired pellet.

Organically Bound Silica

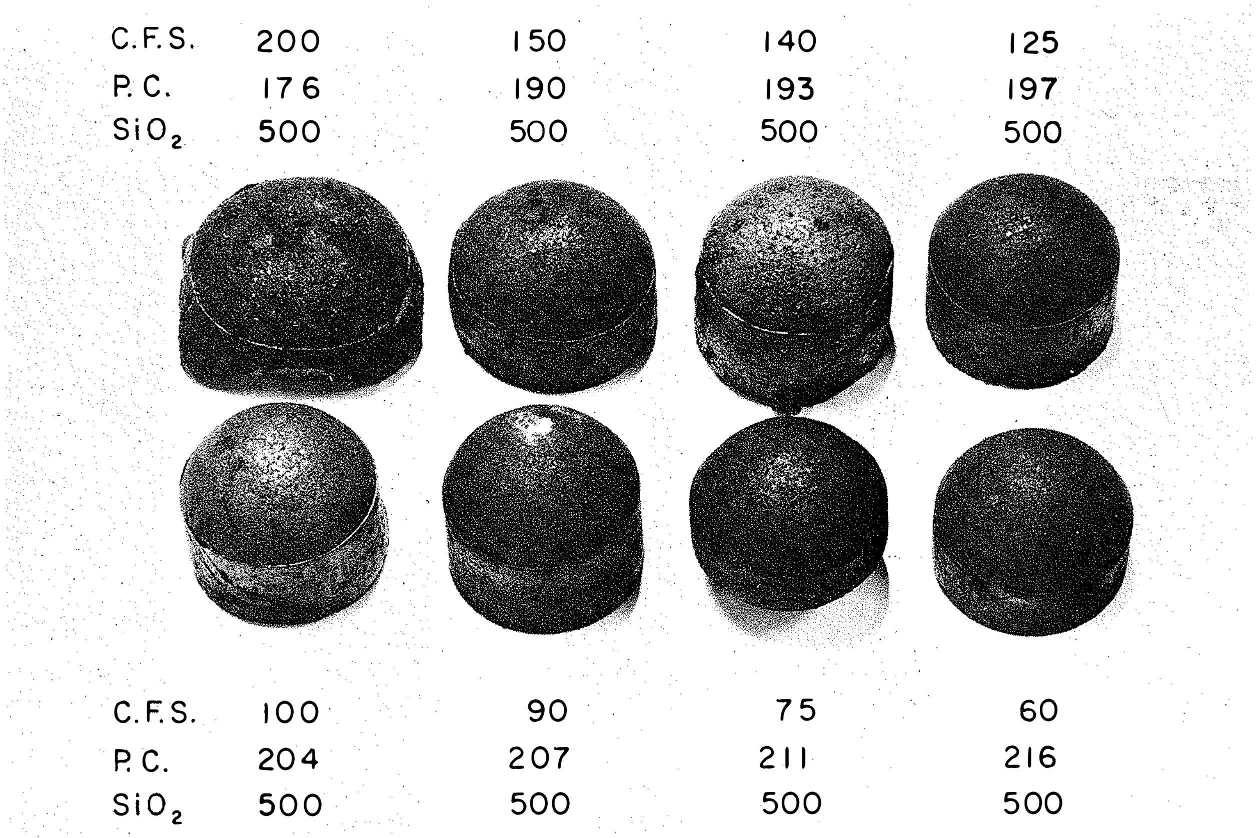
The first method tried for producing organically bound silica briquets was the blending of the proper quantities of high quality silica sand and coker feed stock to produce a mixture that would contain the ratio of five parts silica to two parts fixed carbon that the manufacturer had suggested. When the resulting mixture was coked slowly in a neutral or reducing atmosphere, a solid product resulted that met the required analysis and had adequate compressive strength. This material, however, was impractical because it was gummy to handle and too costly to produce.

A modification was attempted by partially coking the coker feed stock to drive off most of the volatile material but retain the plastic quality of the binder. Silica sand was then mixed into it, briquets were made, and the coking process continued. This reduced the problems of handling, but did not reduce the raw materials cost.

The final modification involved the selection of the optimum combination of silica sand, coker feed stock, and petroleum coke that would give the desired 5:2 ratio of silica to fixed carbon.



Silica sand pellets bonded with sodium silicate. Dark pellet is unfired; light pellet has been fired to 2000° F. Pellets vary in size, but average approximately 2 1/2 inches in diameter.



Organically bonded silica sand briquettes. Numbers show various proportions of coker feed stock, petroleum coke, and silica sand used. Briquettes vary in size, but average approximately 2 1/2 inches in diameter.

PLATE 1 - PELLETS AND BRIQUETS MADE WITH ILLINOIS SILICA SAND

An isocarbon line graph (fig. 2) was prepared that showed the various combinations of coker feed stock and petroleum coke that would produce the 200 grams of fixed carbon needed to mix with 500 grams of silica sand. As the petroleum coke contains about 86 percent fixed carbon and is less expensive than the coker feed stock containing 24 percent fixed carbon, the ideal briquet obviously should contain as much petroleum coke and as little coker feed stock as possible without lowering the binding qualities or the strength of the briquet.

Eight mixes were made in which the amounts of coker feed stock and petroleum coke were varied according to the possible combinations indicated on the graph (fig. 2). The briquets are shown in the lower photograph on plate 1, with their compositions given in the caption. Briquets containing the highest percentage of coker feed stock slumped or lost their shape when heated (pl. 1), while those containing the lowest percentage of coker feed stock crumbled when handled.

A significant characteristic of the briquets was discovered during firing. If the finished briquets are "tempered," or held at a temperature of 425° F (218° C) for about 30 minutes, there is no weight loss but a definite increase in compressive strength is recorded. The increased strength appears to be caused by an oxidizing effect on the carbon.

The best briquets developed in this study were made from a mix of 500 grams of silica sand, 211 grams of petroleum coke, and 75 grams of coker feed stock. The tempered briquets withstood pressures of 1000 to 1200 pounds and had a calorific value of 5100 Btu per pound.

GENERAL REMARKS

The feasibility of substituting silica sand for quartzite has not been the only facet of the project considered. The pellets made with the extremely high-purity Illinois silica sand bonded with sodium silicate proved to be a furnace feed that had a lower iron oxide content than most commercial quartzites, usually in the range of from 0.02 to 0.03 percent. Although the pellets are not as durable as natural quartzite, they do withstand reasonable attrition and compression.

The pellets made were sent to the inquiring company, which responded, "...this pellet has strong possibilities in the metallurgical field and the annual usage would exceed 200,000 tons....We can only recommend that you pursue this further."

The organically bonded briquets have a high resistance to abrasion and compression after they have been tempered. The intimate mixture of the silica and the fixed carbon should offer metallurgical advantages in the furnace because the charge would be complete within the briquet. At present six or seven different constituents must be added to make up the charge. The reaction of the briquets within a high-temperature furnace has not been tested and runs should be made in a semi-commercial electric-arc furnace capable of developing an electrode temperature of 6000° F (3315° C).

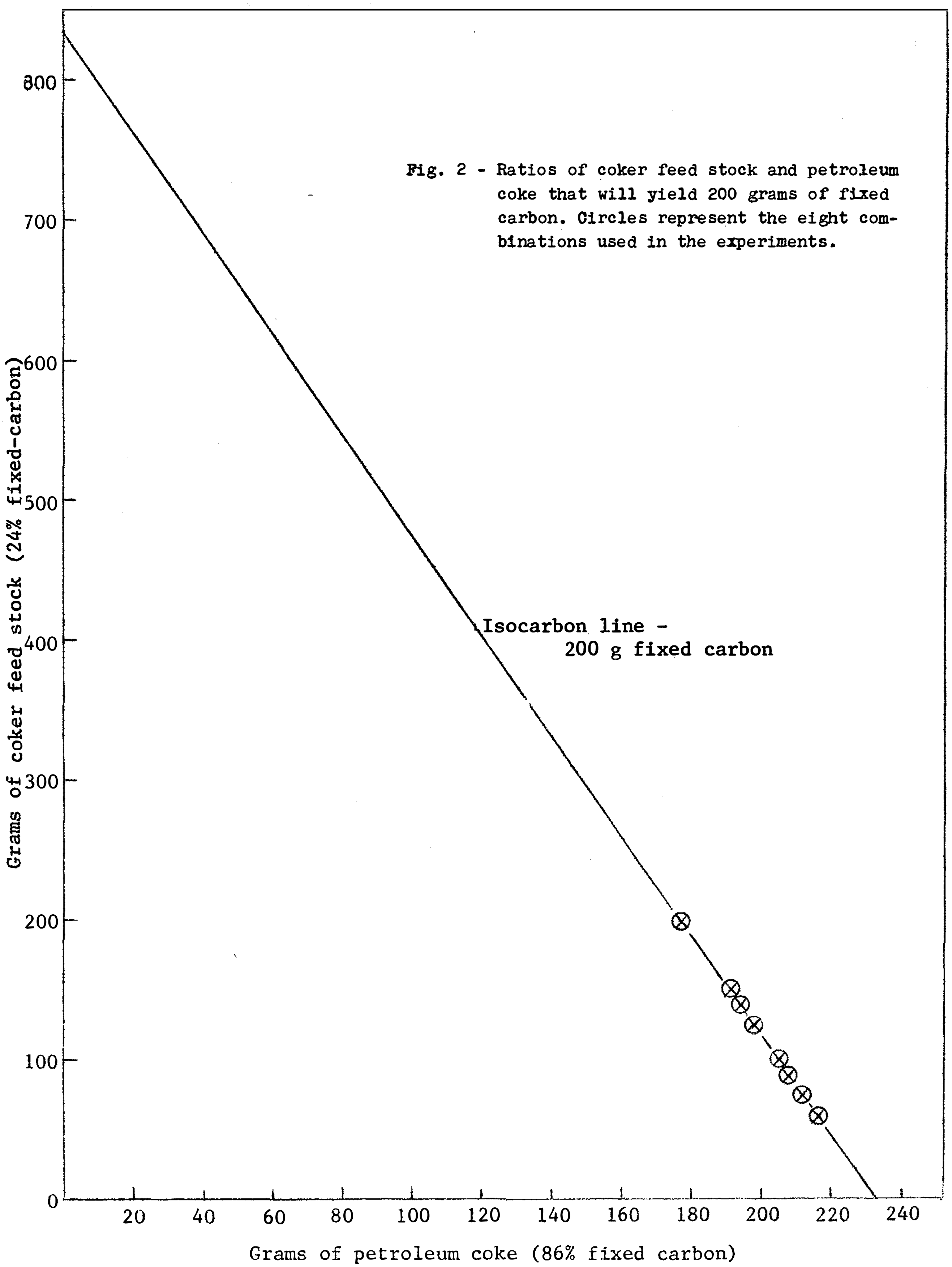


Fig. 2 - Ratios of coker feed stock and petroleum coke that will yield 200 grams of fixed carbon. Circles represent the eight combinations used in the experiments.

The studies reported here are, of course, of a preliminary nature and are not presumed to have covered all angles of commercial production. They do, however, indicate that Illinois silica sand is adaptable for special industrial uses, not only as a substitute for quartzite but as a component with definite advantages of its own.

REFERENCES

Lamar, J. E., 1928, Geology and economic resources of the St. Peter Sandstone in Illinois: Illinois Geol. Survey Bull. 53, 175 p.

Lamar, J. E., 1953, Siliceous materials of extreme southern Illinois — silica, novaculite, ganister, calico rock and chert gravels: Illinois Geol. Survey Rept. Inv. 166, 39 p.

Kemnitzer, W. J., and C. D. Edgerton, Jr., 1965, Petroleum coke on the west coast of the United States: U. S. Bur. Mines Inf. Circ. 8259, 80 p.

Pryor, W. A., and C. A. Ross, 1962, Geology of the Illinois parts of the Cairo, LaCenter, and Thebes Quadrangles: Illinois Geol. Survey Circ. 332, 39 p.

INDUSTRIAL MINERALS NOTES SERIES

*1. Heavy Minerals in Illinois Glacial Sands: R. S. Shrode. 1954.
*2. Lightweight Brick from Clay and Peat or Shredded Corncobs: J. E. Lamar. 1955.
*3. (1) The Industrial Minerals Industry in Illinois in 1955: W. H. Voskuil and W. L. Busch. (2) Trace Elements and Potash in Some Illinois Gravels: J. E. Lamar and R. S. Shrode. 1956.
4. Subsurface Dolomite in Lake, McHenry, and Part of Northwestern Cook Counties: M. E. Ostrom. 1956.
*5. (1) Gypsum and Anhydrite. (2) Fluorspar for Controlling Vanadium Staining. (3) Relation of Sulfate and Chloride to Ore Deposits in the Ordovician Rocks of Jo Daviess County: J. C. Bradbury. (4) Possibilities for Calcitic Limestone Underground in Kankakee and Iroquois Counties: J. W. Baxter. 1957.
6. Trend in Fuel Used in Selected Industrial Mineral Products, 1947 and 1954: W. H. Voskuil 1957.
7. Outlying Occurrences of Galena, Sphalerite, and Fluorite in Illinois: J. C. Bradbury. 1957.
8. Origin of Illinois Sand and Gravel Deposits: J. E. Lamar and H. B. Willman. 1958.
*9. Shales as Source Material for Synthetic Lightweight Aggregate: W. A. White. 1959.
*10. Recent Price and Cost Trends Relating to Stone, Sand, and Gravel Production in Illinois: H. E. Risser. 1959.
*11. Rare Earth and Trace Element Content of an Unusual Clay on Hicks Dome in Hardin County, Illinois: J. C. Bradbury. 1960.
*12. A Survey of Some Illinois Materials Possibly Useful as Pozzolans: W. A. White and J. S. Machin. 1961.
13. Summary of Illinois Mineral Industry, 1951-1959: W. L. Busch. 1961.
14. Illinois Stone Production in 1959: W. L. Busch. 1961.
*15. Black and Brown Terrazzo Chips from Southern Illinois Limestones: R. D. Harvey. 1962.
*16. Refractory Clay Resources of Illinois: W. A. White. 1962.
17. Pelletizing Illinois Fluorspar: H. W. Jackman, R. J. Helfinstine, and Josephus Thomas, Jr. 1963.
18. Permanent Expansion in Bricks: W. A. White. 1964.
19. Binding Materials Used in Making Pellets and Briquets: G. R. Yohe. 1964.
20. Chemical Composition of Some Deep Limestones and Dolomites in Livingston County, Illinois: J. W. Baxter. 1964.
21. Illinois Natural Resources — An Industrial Development Asset: H. E. Risser. 1964.
*22. Illinois Clays as Binders for Iron Ore Pellets: H. W. Jackman, M. B. Mirza, W. A. White, and R. J. Helfinstine. 1965.
23. Limestone Resources of Jefferson and Marion Counties, Illinois: J. C. Bradbury. 1965.
24. Thermal Expansion of Certain Illinois Limestones: R. D. Harvey. 1966.
25. Annotated Selected List of Industrial Minerals Publications: Compiled by J. E. Lamar. 1966.
26. Binders for Fluorspar Pellets: H. W. Jackman, M. B. Mirza, R. J. Helfinstine, and D. R. Dickerson. 1966.
27. High-Purity Limestones in Illinois: J. E. Lamar. 1966.
28. Illinois Clays as Binders for Iron Ore Pellets — A Further Study: H. P. Ehrlinger III, M. B. Mirza, L. R. Camp, and H. W. Jackman. 1966.
29. Clay and Shale Resources of Clark, Crawford, Cumberland, Edgar, Effingham, Jasper, and Vermilion Counties: W. A. White and W. E. Parham. 1967.
30. Lightweight Bricks Made with Clay and Expanded Plastic: H. P. Ehrlinger III, B. F. Bohor, L. R. Camp, and Suresh Khandelwal. 1967.
31. Clays as Binding Materials: G. R. Yohe. 1967.

* Out of print