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SILICA SAND FROM SOUTH-CENTRAL KANSAS FOR FOUNDRY USE

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ABSTRACT

Tests and the opinions of foundry operators indicate that the Cheyenne sandstone of Barber, Comanche, and Kiowa Counties, Kansas, can be a satisfactory source of silica sand for making synthetic molding sand or cores.

This loosely cemented sandstone disintegrates readily into particles having an over-all average A.F.A. grain fineness number of 72. Depending upon the location, sands having grain fineness numbers of 49 to 102 can be found.

The Cheyenne sands are characterized by a low percentage of minus 140-mesh particles, and by a broad grain-size distribution.

Kansas foundries import silica sand from other states; Cheyenne sand can be found to parallel closely the grain-size distribution of these imported sands. However, the market for foundries alone is not now of sufficient size to justify any large-scale development.

INTRODUCTION

Silica sand is used extensively as a raw material for producing glass, and with suitable binders, to make molds for metal castings. The Cheyenne sandstone of Barber, Comanche, and Kiowa Counties, Kansas, is composed of loosely cemented grains of silica associated with approximately 2 percent other minerals. The grain size is favorable for utilizing the sand either in glass making or in the foundry industry.

Earlier investigations (Nixon, 1949, 1950) of the Cheyenne sandstone deposits in this area, sponsored jointly by the Kansas Industrial Development Commission and the State Geological Survey, were focused almost exclusively on the potential value to near-by glass industries. This report summarizes a study of the possible applications for the Cheyenne sand in foundries. The data presented in this report were compiled during the spring and summer months of 1949 as part of a comprehensive investigation of foundry-sand sources in Kansas now being made by the State Geological Survey.

Functions of Foundry Sands

Metal castings are made by pouring molten metal into a cavity of some predetermined shape, where the metal cools and solidifies. The part of the cavity that forms the external surfaces of the casting is called the *mold*. Hollow portions of the casting are formed by *cores*.

Foundry sands are used to make molds and cores. In each of these applications, the sand particles are held together by some material called a *bond*.

Molding sands may be either naturally or artifically bonded. The *naturally bonded sands* contain a variable amount of clay and silt found in the sand deposit. *Synthetic molding sands* are artificial mixtures of clean sand (called "sharp" sand) and a bonding agent such as fire clay or bentonite. In each type of molding sand, the workability of the sand is influenced by the presence of moisture, water being an essential ingredient.

Core sands are bonded with linseed oil, cereal flour, resin, or some other material that "sets" when it is baked. Cores contain very little clay and practically no free moisture.

Better sands are required constantly as the foundry industry develops. The trend today is toward an increasing use of synthetic sands, because these sands can be controlled to offer molding properties that are dependably uniform. This feature becomes increasingly important as the foundries become more and more mechanized, with a resultant scarcity of skilled hand molders who learned through years of experience how to make castings from whatever molding materials were available.

Silica sand, such as that available from the Cheyenne sandstone of Barber, Comanche, and Kiowa Counties, is the type of material most commonly used both as a base for synthetic molding sand and as a core sand.

Properties of Foundry Sands

It is difficult to define briefly the qualities essential for a good foundry sand. A great deal of study is being directed toward the development and standardization of tests to measure the desirable properties, but there is still considerable difference of opinion among foundrymen as to what should be tested and how the results should be interpreted. Even so, no alert foundryman will presume to ignore the value of some kind of sand control. A widely accepted manual on testing of foundry sands has been published by the American Foundrymen's Association (1944) and several firms catering to the foundry trade have released useful, informative material.

The three main requirements of foundry sand are refractoriness, grain size, and durability. A fourth requirement, workability, is influenced somewhat by the grain size and can be altered to a certain extent by adjusting the moisture content or by adding other materials.

An adequate degree of refractoriness is obtained if the sand particles do not fuse together when they come in contact with the molten metal. This is governed largely by the metal to be cast. Steel, which melts at about 2750° F., requires a much more refractory sand than aluminum alloys, which melt at about 1200° F. Steel foundries generally prepare a synthetic sand from grains of pure silica in order to secure the necessary refractoriness, but naturally bonded sands containing feldspar or other low-melting constituents are perfectly satisfactory for aluminum and brass.

Grain size, particularly the proportion of different-sized grains, controls the density and permeability of molds or cores. There must be sufficient permeability to allow the escape of gas and steam, but there must also be sufficient density to resist penetration by molten metal. Many of the common defects in castings can be prevented by properly adjusting the grain size, permeability, and density.

Foundry sands must resist the thermal shock and high temperature that result from contact with molten metal. If the grains break too readily, either from thermal shock or from abrasion, fine material accumulates rapidly and the permeability drops. Heat tends to destroy the binding power of the bond. When the sand is re-used, new bonding material must be added to replace that which has been ruined. This not only adds to the cost of the operation, but causes fine material to accumulate in the sand. Ultimately it reduces the permeability and strength of the sand so much that the sand must be replaced. Thus a low percentage of grain sizes smaller than 140 mesh is desirable.

Workability is especially important where molding is done by machines. The sand must flow readily from bins or hoppers. It must pack properly. It must be uniform because a machine does not have the ability of a skilled molder to compensate for variations in the sand.

Kansas Markets for Unbonded Foundry Sand

In 1949 there were approximately 50 foundries operating in Kansas. Most of these are small shops casting only a few tons per day. Less than half a dozen use synthetic molding sands, but these few include most of the large operators in the State. All the foundries use sharp sand (but not necessarily pure silica sand) for making cores.

As a rough estimate, the demand for sharp sand in Kansas probably does not now exceed 1,500 tons per month, and approximately half of this is consumed by the State's only steel foundry. However,

TABLE 1.—*Screen analyses of several unbonded sands now produced in Kansas for foundry consumption*

Sand	A.F.A. grain fineness no.	Percent retained on mesh 20	30	40	50	70	100	150	200	270	pan
E. S. Glynn core sand (KC)	45	1.1	3.0	14.0	41.0	31.3	6.2	1.1	0.2	0.4	1.2
Canfield no. 2 core sand (KC)	47	1.1	4.3	17.2	40.0	23.8	6.8	4.6	1.3	0.5	0.4
Rees core sand (KC)	61		0.1	0.8	13.0	48.4	27.4	7.0	1.2	0.2	0.9
Cochran core sand (Wichita)	78	0.1	0.5	2.9	10.4	25.4	28.1	20.2	6.6	1.8	1.8
Canfield no. 1 core sand (KC)	79		0.1	0.3	2.9	28.9	34.0	24.7	6.6	0.9	1.1
Dune sand (Hutchinson)	80		0.1	1.1	10.8	30.9	30.7	19.0	3.7	0.6	3.1
Arkansas River sand (Wichita)	82	0.4	0.8	4.1	12.2	27.8	29.2	17.2	5.2	1.0	0.7

several foundry operators either have decided to shift to synthetic sand or are considering the advisability of doing so.

ACKNOWLEDGMENTS

So many people have assisted in preparing this report that no attempt shall be made to mention each by name. The foundrymen of Kansas have been most generous in providing advice and information.

Special thanks are given to Earl K. Nixon of the State Geological Survey of Kansas, who directed the original field work, helped locate samples, and gave valuable help in preparing this report.

KANSAS PRODUCERS OF UNBONDED FOUNDRY SAND

The concentration of foundries in the Kansas City and Wichita areas, together with the abundance of clean river sand near at hand, has encouraged marketing of local sand for the foundry trade.

In the Kansas City area, sand excavated from the Kansas River flood plain or pumped from the river bed has been sold to foundries for many years. Although this sand seems to be quite satisfactory for nonferrous (chiefly aluminum and brass) castings and is adequate for most work in gray iron, it is not considered to be sufficiently refractory for steel castings. Similar conditions exist in Wichita where the sand used is produced from the Arkansas River and dunes along it. The source for a few foundries operating sand pits to supply their own needs is either a stream or dunes near by.

In summary, there has been no Kansas product on the market which could be described accurately as a high-purity silica foundry sand. This does not mean, however, that the sharp sands sold to foundries have been unsatisfactory; where their low fusion point is not a serious handicap, they perform well if they are handled properly.

Table 1 lists screen analyses for several typical Kansas sands.

OTHER SOURCES OF FOUNDRY SANDS USED IN KANSAS

Wherever special requirements have justified the additional cost, high-grade silica sand has been imported from the Ottawa district of Illinois; the Portage, Wisconsin, deposits; the glass-sand operations at Crystal City and Festus, Missouri; or from the Roff-Sulphur area of southern Oklahoma.

Screen anaylses for several of these foundry sands imported from other states are shown in Table 2. The Kansas sands parallel the imported sands except for the extremely coarse and the finest sizes, and these sizes undoubtedly could be supplied if there were sufficient demand for them.

Although the river sand and dune sand of Kansas compare favorably with other accepted foundry sands from the standpoint of grain size, these do not have a sufficiently high sintering point to make them completely satisfactory for casting iron and steel. Because of its high percentage of silica, with consequent refractoriness, the Cheyenne sandstone of southwestern Kansas may be used to make molds or cores that are more resistant to heat than those made of river or dune sand.

TABLE 2.—*Screen analyses of unbonded sands used in Kansas but produced elsewhere*

Producer	A.F.A. grain fineness no.	Percent retained on mesh 20	30	40	50	70	100	140	200	270	pan
Illinois sand (Ottawa)	34	1.2	30.2	55.8	5.7	1.6	1.4	1.6	0.8	0.6	1.1
Illinois sand (Ottawa)	47		0.1	11.6	43.8	30.8	10.2	2.6	0.5	tr	tr
Illinois sand (Ottawa)	51			3.8	41.4	40.0	11.6	2.6	1.8	0.6	0.2
Illinois sand (Ottawa)	51		0.6	29.2	33.6	15.8	9.8	6.8	2.6	1.2	0.4
Illinois sand (Ottawa)	52	1.0	6.6	32.4	24.6	13.6	10.2	7.2	4.0	0.8	0.6
Mo. sand (Festus)	60	0.1	0.3	5.4	27.2	37.0	17.6	9.2	2.5	0.7	0.7
Mo. sand (Crystal City)	62	0.1	0.2	3.4	23.0	37.7	19.9	10.9	3.4	0.8	0.6
Okla. sand (Roff)	84			0.6	3.4	9.4	38.4	38.0	9.6	1.0	0.4
Okla. sand (Roff)	100	0.1	0.1	0.4	2.3	7.4	21.8	45.6	18.5	3.2	0.7
Okla. sand (Sulphur)	111	0.2	0.4	0.6	0.8	1.5	23.3	48.2	16.8	3.4	4.8

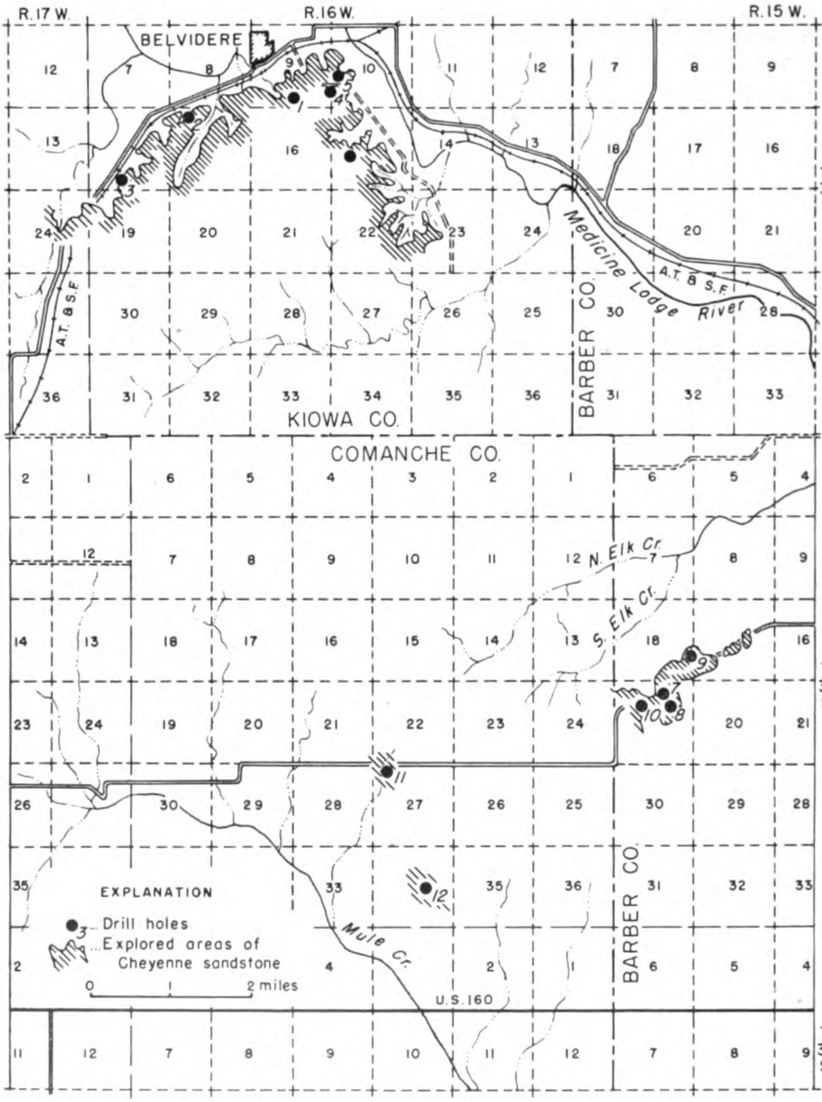

FIG. 1.—Areas of Cheyenne sandstone studied in Barber, Kiowa, and Comanche Counties, Kansas.

THE CHEYENNE SANDSTONE DEPOSITS OF BARBER, COMANCHE, AND KIOWA COUNTIES, KANSAS

Prominent outcrops of the Cheyenne sandstone occur in a triangular area bounded roughly by Belvidere, Wilmore, and Sun City at the corners. Because of the rough terrain and the importance of transportation to the economic value of the sandstone, exploration was confined primarily to locations near the highway between Wilmore and Sun City, and near Belvidere, where the Atchison, Topeka, and Santa Fe Railway passes within a mile of several of the outcrops.

The area explored and mapped lies approximately 100 miles southwest of Wichita between U. S. Highways 54 on the north and 160 on the south, within a 10-mile radius of the common corner of Barber, Comanche, and Kiowa Counties, in Ts. 30 and 31 S., Rs. 15 and 16 W.

Much of the area is covered by the Kiowa shale (Lower Cretaceous). The Cheyenne sandstone (Lower Cretaceous) is found immediately below the Kiowa. The rock is soft and commonly does not make bold exposures, but it may be seen in small buttes or in cut banks and gulches where it offers a strong contrast in color to the red Permian rocks beneath it.

Figure 1 shows the more important features of the area and the location of test holes from which samples were taken. More detailed descriptions of the location and history of the deposits is given by Nixon, Runnels, and Kulstad (1950), and geology of the area is discussed in detail by Lata (1946).

Character

The Cheyenne sandstone is soft and easily eroded; lumps of the consolidated material disintegrate when placed in water. Stream-cut exposures are often strongly iron stained, but the freshly dug sand is light buff in color, sometimes almost white.

Although the sandstone is generally of uniform grain, coarse fragments of a whitish mineral (possibly leached chert) and angular pebbles of quartz are fairly common in some localities. The amount of material coarser than 10 mesh did not exceed 3.5 percent in any of the samples, however.

The sand grains range in shape from angular to subangular types. There are many off-color quartz grains, but most are glass-

TABLE 3.—*Typical chemical analysis of Cheyenne sandstone from Barber County, Kansas* (Analysis by R. T. Runnels, State Geological Survey)

Component	Wt. percentage, air dried basis
Silica (SiO_2)	97.15
R_2O_3 (including alumina but not iron oxide)	1.44
Iron oxide (Fe_2O_3)	0.20
Loss on ignition at 1000° C.	0.54
Other (chiefly alkalis)	0.67
	100.00

clear, although many are covered with a thin film which is probably responsible for the buff color. It is not uncommon to find several grains rather firmly cemented together by iron oxide, but this seems to be confined to the finer grades of sand—those which are too fine for most foundry applications. The aggregates are bulky enough to be removed on coarse screens of 20 mesh or less. Table 3 gives chemical analysis from a 24-foot channel sample taken at the Cen. sec. 18, T. 31 S., R. 15 W., Barber County, in the vicinity of drill holes 7, 8, 9, and 10, which is fairly typical for all the Cheyenne sandstone.

SCREEN ANALYSES OF SAMPLES OF CHEYENNE SANDSTONE

Samples were taken at 5-foot intervals from the cuttings made by a rotary drill at the locations shown in Figure 1. Surface material and undesirable formations were cased off during drilling, and clean fresh water was used to wash out the cuttings. These samples, settled, saved, and dried, were sized by means of U. S. standard testing sieves in accordance with the procedure outlined by the American Foundrymen's Association (1944), to provide the data presented in Table 4. No tests were made for drill holes 2, 5, and 6, because the appearance of the sand or the location of the test holes was considered to be unfavorable for further development.

Analyses for each 5-foot interval in drill holes 1 and 9 indicated that the grain size is fairly uniform throughout the full section. However, an examination of the exposed beds reveals marked variations from one bed to another (each only 3 or 4 inches thick.) Also, there seems to be a tendency for the grain size to be coarsest at the bottom and finest at the top of the entire formation, which averages approximately 35 feet in thickness. This may account for the coarsest average grain size occurring in drill holes 7 and 9.

TABLE 4.—*Screen analyses of rotary-drill samples in Cheyenne sandstone*

Drill hole no.	County	Total footage of sand	A.F.A. grain fineness no.	20	30	40	50	70	100	140	200	270	Pan
				Percent retained on mesh									
1	Kiowa	35	70	1.5	1.1	5.1	15.2	23.3	25.0	23.2	4.0	0.7	0.9
3	Kiowa	29	77	8.6	2.0	5.6	10.8	14.6	21.3	23.9	8.4	2.4	2.4
4	Kiowa	35	77	2.2	1.0	3.6	12.1	24.7	23.5	21.7	6.8	2.6	1.8
7	Barber	25	61	2.1	0.9	4.8	16.4	36.3	25.3	10.6	1.7	0.7	0.8
8	Barber	27	75	2.2	0.6	2.4	9.4	28.3	31.1	16.6	5.4	1.8	2.2
9	Barber	16	55	1.5	1.4	6.9	20.8	41.8	21.0	6.4	0.5	0.2	0.2
10	Barber	34	76	1.2	0.7	3.2	12.0	24.9	23.4	24.3	6.7	1.6	1.4
11	Comanche	36	62	2.8	1.2	7.0	19.0	25.6	24.8	16.6	2.2	0.4	0.4
Composite of 11 drill holes			72		1.1	4.9	16.3	29.1	26.7	13.1	4.4		4.4

Fines and clay content.—Foundrymen commonly class sand particles smaller than 140 mesh (0.105 mm) as "fines." Fines are undesirable in molding sand for several reasons. They fill the pore space of the larger grains, thereby reducing permeability. Fine particles are more easily sintered; hence the castings may be harder to clean. Also, the total surface area increases rapidly as the particle size decreases. This increases the amount of core oil or binder needed to coat the grains. More core oil means more smoke; more binder (clay or bentonite) means lower permeability.

For these and other reasons, sharp sands are usually purchased in the washed and dried condition, primarily because such sand is relatively free of fine material. True clay in the natural sand is not harmful in small amounts if the sand, when ready for use, is to contain a clay binder, but there are no rapid shop tests that distinguish between true clay and sand grains larger than the clay particles but small enough to pass the finest screens (0.074 mm for a 200-mesh screen).

Figure 2 shows results of sizing tests made by screens and sedimentation pipette methods on a part of a channel sample taken from a 20-foot exposure of Cheyenne sandstone in a cut bank near drill hole 11. Crude Ottawa sands are reported to contain as much as 3.6 percent "A.F.A. clay" (particles smaller than 0.020 mm). This sample of Cheyenne sandstone contained less than 2.5 percent minus 0.020 mm material, and most of this, approximately 2 percent of the original sample, is true clay.

Standard A.F.A. clay tests (American Foundrymen's Association, 1944) carried out on a sample taken near drill hole 1 showed

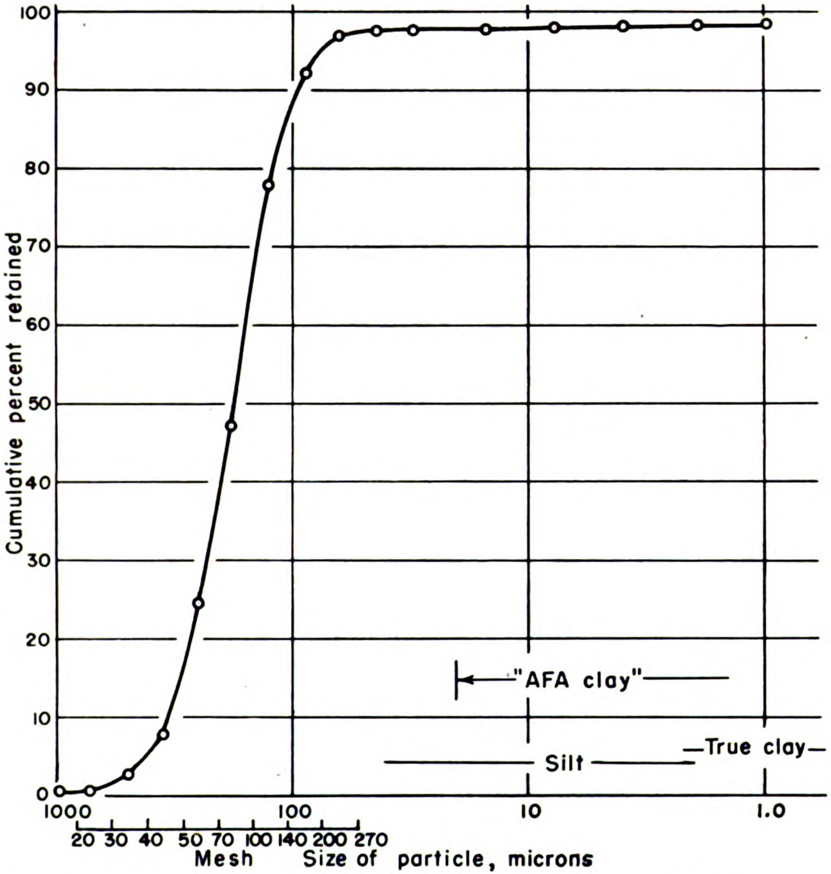

FIG. 2.—Cumulative grain size plot for sample of Cheyenne sandstone from cut bank near drill hole 11.

Mechanical analysis of sand shown in Figure 2

Grain size in mm	Percent retained	Cumulative percent retained
1.000	0.5	0.5
0.707	0.3	0.8
0.500	1.4	2.2
0.350	5.7	7.9
0.250	16.6	24.5
0.177	22.6	47.1
0.125	30.8	77.9
0.088	14.1	92.0
0.062	5.0	97.0
0.044	0.3	97.3
0.031	0.2	97.5
0.0156	0.3	97.8
0.0078	0.1	97.9
0.0039	0.1	98.0
0.00195	0.1	98.1
0.00098	0.2	98.3
0.00098-	1.8	

Tests made by Ada Swineford and Carrie B. Thurber of the State Geological Survey

3.5 percent A.F.A. clay. Another sample taken near drill hole 4 contained 2.5 percent clay.

Impurities.—Detailed petrographic studies of the sandstone are not yet complete. The original investigations were concerned primarily with iron minerals, which constitute approximately 0.2 percent Fe_2O_3 in the crude sand (Nixon, Runnels, and Kulstad, 1950).

It was suspected that the whitish, chertlike pebbles found in some localities might be gypsum, because gypsum and other allied minerals are found in adjacent formations. However, a qualitative chemical analysis showed no traces of sulphate. Inasmuch as the material shows no reaction with hydrochloric acid, it is not a carbonate. No further tests were made, because it was judged that elimination of sulphur and carbonates as possible contaminants leaves only compounds which would be relatively harmless in foundry sands.

COMPARISONS OF CHEYENNE SANDS WITH OTHER CLAY-FREE SANDS USED IN KANSAS FOUNDRIES

Methods of Defining Characteristics

It is not an easy matter to compare sands, because of the many factors that are needed to describe them. However, the following factors are employed in Table 5.

A.F.A. grain fineness number.—The A.F.A. (1944) grain fineness number represents the average grain size in terms of a square-mesh sieve that would just pass the sand if all particles were of the same size.

Screen analysis.—Two sands may have identical A.F.A. grain fineness numbers, yet differ vastly in particle distribution. This difference can best be determined by individual size analyses using standard sieves.

Fines.—The total percentage of a sample passing 140 mesh (0.105 mm) is classed as fines.

Grain distribution.—Although specialists generally agree that foundry sand should not be exactly uniform in size, definition of the optimum degree of uniformity is still influenced by personal opinion and experience. If 90 percent or more of the sand is retained on three adjacent sieves the permeability is high. However, a wider distribution, such as that obtained by having 90 percent or more of sand on five adjacent sieves, indicates a denser sand with higher

TABLE 5.—*Comparisons of Cheyenne sand with other sands used in Kansas foundries*

Sample no.	Sand	A.F.A. grain size no.	Percent retained on mesh 20	30	40	50	70	100	140	200	270	Pan	Total minus 140 mesh	Best percent on 3 adj. screens	Best percent on 5 adj. screens
1	Illinois sand (Ottawa)	34	1.2	30.2	55.8	5.7	1.6	1.4	1.6	0.8	0.6	1.1	2.5	91.7	94.7
2	E. S. Glynn core sand (Kansas River)	45	1.1	3.0	14.0	41.0	31.3	6.2	1.1	0.2	0.4	1.2	1.8	86.3	95.5
3	Canfield no. 2 core sand (Kansas River)	47	1.1	4.3	17.2	40.0	23.8	6.8	4.6	1.3	0.5	0.4	2.2	81.0	92.4
4	Illinois sand (Ottawa)	47		0.1	11.6	43.8	30.8	10.2	2.6	0.5	tr	tr	0.9	86.2	99.0
5	Cheyenne sand; depth from 9 to 15 ft. in drill hole 9	49	1.8	3.1	13.0	29.4	30.3	16.5	5.0	0.7	0.1	0.1	0.9	76.2	94.2
6	Illinois sand (Ottawa)	51			3.8	41.4	40.0	11.6	2.6	1.8	0.6	0.2			
7	Illinois sand (Ottawa)	51		0.6	29.2	33.6	15.8	9.8	6.8	2.6	1.2	0.4	4.2	78.6	94.2
8	Illinios sand (Ottawa)	52	1.0	6.6	32.4	24.6	13.6	10.2	7.2	4.0	0.8	0.6	5.4	70.6	88.0
9	Cheyenne sand; composite of drill hole 9	54	1.5	1.4	6.9	20.8	41.8	21.0	6.4	0.5	0.2	0.2	0.9	83.6	96.9
10	Cheyenne sand; channel sample from gulch near drill hole 1	54	1.4	1.2	7.6	23.5	39.3	19.6	5.3	1.1	0.3	0.4	1.8	82.4	95.3
11	Missouri sand (Festus)	60	0.1	0.3	5.4	27.2	37.0	17.6	9.2	2.5	0.7	0.7	3.9	81.8	96.4
12	Rees core sand (Kansas River)	61		0.1	0.8	13.0	48.4	27.4	7.0	1.2	0.2	0.9	2.3	88.8	97.0
13	Cheyenne sand; composite of drill hole 7	61	2.1	0.9	4.8	16.4	36.3	25.3	10.6	1.7	0.7	0.8	3.2	78.0	93.4
14	Cheyenne sand; composite of drill hole 11	62	2.8	1.2	7.0	19.0	25.6	24.8	16.6	2.2	0.4	0.4	3.0	69.4	93.0
15	Missouri sand (Crystal City)	62	0.1	0.2	3.4	23.0	37.7	19.9	10.9	3.4	0.8	0.6	4.8	80.6	94.9
16	Cheyenne sand; composite of drill hole 1	65	1.4	1.0	4.4	14.4	35.3	25.2	11.8	3.9	1.1	1.0	6.0	74.9	91.1
17	Cheyenne sand; channel sample of cut bank near drill hole 11	71	0.8	0.7	3.7	13.6	27.4	26.3	20.0	6.2	0.8	0.5	7.5	73.7	93.5
18	Cheyenne sand; composite of all samples	72		1.1	4.9	16.3	29.1	26.7	13.1	4.4		4.4	8.8	72.1	90.1
19	Cheyenne sand; composite of drill hole 8	75	2.2	0.6	2.4	9.4	28.3	31.1	16.6	5.4	1.8	2.2	9.4	76.0	90.8
20	Cheyenne sand; composite of drill hole 10	76	1.2	0.7	3.2	12.0	24.9	23.4	24.3	6.7	1.6	1.4	9.7	72.6	91.3
21	Cheyenne sand; composite of drill hole 4	77	2.2	1.0	3.6	12.1	24.7	23.5	21.7	6.8	2.6	1.8	11.2	69.9	88.8
22	Cheyenne sand; composite of drill hole 3	77	8.6	2.0	5.6	10.8	14.6	21.3	23.9	8.4	2.4	2.4	13.2	59.8	73.8
23	Cochran core sand (Arkansas River dunes)	78	0.1	0.5	2.9	10.4	25.4	28.1	20.2	6.6	1.8	1.8	10.2	73.7	90.7
24	Canfield no. 1 core sand (Kansas River flood plain)	79		0.1	0.3	2.9	28.9	34.0	24.7	6.6	0.9	1.1	8.6	87.6	97.1
25	Reno County sand dunes	80		0.1	1.1	10.8	30.9	30.7	19.0	3.7	0.6	3.1	7.4	80.6	95.1
26	Arkansas River sand (Wichita)	82	0.4	0.8	4.1	12.2	27.8	29.2	17.2	5.2	1.0	0.7	6.9	74.2	91.6
27	Oklahoma sand (Roff)	84			0.6	3.4	9.4	38.4	38.0	9.6	1.0	0.4	11.0	86.0	96.4
28	Oklahoma sand (Roff)	100	0.1	0.1	0.4	2.3	7.4	21.8	45.6	18.5	3.2	0.7	22.4	85.9	96.5
29	Cheyenne sand; channel sample from gulch near drill hole 4	102	tr	0.1	0.1	0.6	1.7	23.4	56.8	9.7	2.0	5.6	17.3	89.9	97.5
30	Oklahoma sand (Sulphur)	111	0.2	0.4	0.6	0.8	1.5	23.3	48.2	16.8	3.4	4.8	25.0	88.3	96.5

strength, greater hardness, and less metal penetration (Sanders, 1949).

Base permeability depends upon the shape and arrangement, as well as the size, of particles. Permeability values for the Cheyenne sand samples were not determined.

The data in Table 5 are arranged according to A.F.A. grain fineness numbers because this is the most convenient single characteristic to use in classifying the various samples.

A.F.A. grain fineness less than 40.—None of the samples of Cheyenne sandstone contained an appreciable amount of coarse quartz grains. The sand near drill hole 11 contained approximately 4 percent material coarser than 10 mesh, but this coarse material was a mixture of large cherty pebbles, shale fragments, and firmly cemented aggregates of smaller particles.

It would be possible to prepare a coarse sand by screening the fines from any of the Cheyenne sands but the yield would be rather low. Undoubtedly the coarse Ottawa sand (no. 1) listed in Table 5 has been screened from another sand of finer average grain size.

It should be pointed out, however, that screening would destroy the natural "five-screen" distribution which is one of the assets of the Cheyenne sands.

A.F.A. grain fineness 45 to 55.—This is a commercially important size range, because it is suited for heavy steel castings. Cheyenne sands from drill hole 9 and near drill hole 1 compare favorably with the other silica sands in this group. All three samples of Cheyenne sand contained a low percentage of fines and have good five-screen distributions.

A.F.A. grain fineness 56 to 65.—Sand in this range is used for cores in gray-iron castings. Three of the eight composite samples of Cheyenne sand fall in this group. The Cheyenne sands have a slightly broader grain-size distribution than the Missouri sand, but this is hardly great enough to be of any importance.

A.F.A. grain fineness 66 to 75.—Seventy might be taken as a fair average value for the fineness of the Cheyenne sands investigated. This corresponds to an average grain size of 0.210 mm (0.0082 inch).

Although Table 2 lists no imported sands in this size, one important gray-iron shop has been mixing Ottawa sand with Roff (Oklahoma) sand to give a blend of A.F.A. fineness number 70 for the base to their synthetic sand. The similarity between the blended sand and crude Ottawa sand from near drill hole 11 is evident in Table 6.

A.F.A. grain fineness 76 to 85.—Four of the composite samples of Cheyenne sands fall in this range, as does the bulk of the core sand now produced and sold in Kansas for light gray-iron and general nonferrous work. The percentage of fines is somewhat higher for the crude Cheyenne sand than for the dune or river sands. However, the Cheyenne sand should have better heat resistance because of its higher silica content.

A.F.A. grain fineness more than 85.—This is too fine to be of much importance except where excellent surface detail is needed and the foundryman requires a fine-grained sand. The Oklahoma sands are characteristically fine (Ham, 1945), but Cheyenne sand of equal fineness is available.

Foundry Tests on Cheyenne Sands

No large-scale tests using Cheyenne sand in foundries have yet been made. However, samples of approximately 100 pounds have been sent to a gray-iron foundry using synthetic sand and to a steel foundry. Both reported that the Cheyenne sandstone should be satisfactory for cores or as a base for synthetic molding sands. The steel foundry prefers a coarser sand (A.F.A. 50) than any of the composite samples of Cheyenne sandstone; in order to attract this potential user, it might be necessary to find workable deposits such

Table 6.—*Comparison of Cheyenne sand* with a blend of equal parts Roff sand and Ottawa sand.*

Mesh on which retained	Cheyenne sand	Blended sand
20	0.8	
30	0.7	0.5
40	3.7	8.3
50	13.6	17.8
70	27.4	20.4
100	26.3	27.3
140	20.0	18.3
200	6.2	5.9
270	0.8	1.4
Pan	0.5	0.5
A.F.A. grain fineness	71	70
Percent fines	7.5	7.8
Best 3-sieve distribution	73.7	66.0
Best 5-sieve distribution	93.5	92.1

* Sample 17, Table 5

as the interval between 9 and 15 feet in drill hole 9, or to screen the regular run and try to find a market for the finer cut.

At least a dozen other Kansas foundry operators have examined samples of the Cheyenne sand, and all of them expressed a desire to test it in their shops.

Possible Means of Developing the Deposits

Until a large market is available for the Cheyenne sand, any plans for mining the sand should be kept simple and free of extensive outlay for equipment. The crude sandstone probably could be broken by light blasting and loaded with a high-lift tractor shovel, but such a method could not be expected to disintegrate the sandstone into its individual particles.

Where water is available near suitable outcroppings of the sandstone, hydraulic mining should be considered. High pressure water would disintegrate the loosely cemented grains and provide a scrubbing action to loosen the clay. Hydraulic classification might then be employed to take out the fines, at least, and perhaps even to separate the coarse waste.

Where water is not easily obtained or must be pumped a considerable distance to the deposit, the sand might be loaded into trucks and hauled to a washing, sizing, and drying plant near a stream and railroad at Belvidere, Sun City, or Wilmore.

Mechanical screens and a dryer would be needed regardless of the method of mining.

CONCLUSIONS

The Cheyenne sandstone is a promising source of silica sand in the particle size suited for foundry uses. The deposits are, generally, so situated that development would be rather easy. Transportation should not be difficult, although it could easily become the most expensive part of the preparation costs.

Present freight rates would be a serious handicap in competing with Illinois or Missouri sand in the Kansas City—Atchison area, where there is a sizable potential market.

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