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REPORT OF INVESTIGATIONS—NO. 24

PROGRESS REPORT ON THE STUDY
OF SOUTHERN ILLINOIS SILICA
AS A POTTERY MATERIAL

BY
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URBANA, ILLINOIS

1932

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SCHNEPP & BARNES, PRINTERS
SPRINGFIELD, ILL.

1932

73377—1,500

ILBN
1-21-39
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PROGRESS REPORT ON THE STUDY OF SOUTHERN ILLINOIS SILICA AS A POTTERY MATERIAL

By C. W. Parmelee

INTRODUCTION

In extreme southern Illinois, specifically in the uplands of northern Alexander and southern Union counties, there are extensive deposits of a mineral substance known locally as "silica" because it consists almost entirely of this chemical constituent. The "silica" is a part of the Clear Creek formation of the Devonian system and has probably resulted from the weathering of chert or very siliceous limestone. It occurs in deposits that range in thickness from a few feet to almost 50 feet and is white, buff, brown, or pink according to the amount and character of the iron compounds present. The white "silica" is the chief commercial product. Analyses of this material are reported which show less than 1 per cent of oxides other than silica.

For many years this "silica" has been extensively mined and marketed for a variety of uses. It is reported that some of the output has been employed with gratifying success in the manufacture of pottery. This fact together with the extent of the deposits and the unusual physical and mineralogical character of the material seems to justify studies to determine in more detail its properties when used in pottery mixtures.

Accordingly investigations were begun in 1918 and considerable progress made. The data obtained, however, seemed to require further substantiation, and additional work to include studies in thermal expansion and petrographic examination was therefore undertaken in order to check and supplement earlier results. This brief report summarizes the more important results of both investigations.

In this report the terminology commonly used in the pottery industry is followed except that the southern Illinois material is designated as "tripoli", following the usage of Weigel¹ in order to avoid confusion with the use of the word "silica" as a chemical term. The silica produced by grinding quartz sand is designated in this report as quartz sand "flint" in order to distinguish it from French pebble flint or ground quartz rock "flint."

This report describes results of tests on three types of silica, each of which affects the conduct of the wares during firing as well as the properties of the finished products, namely, (1) southern Illinois tripoli, (2) quartz sand "flint", and (3) French pebble flint. The materials, in order of quanti-

¹Weigel, W. M., Technology and uses of silica and sand, U. S. Bureau of Mines Bull. 266, pp. 10 and 160, 1927.

tative importance as used by the potter, are quartz sand "flint," French pebble flint, quartz rock "flint", and tripoli.

The investigations included, (1) a study of the mineralogical characters of the raw material, (2) an estimate of the size distribution of the fine particles in the prepared material, and (3) a comparison of the effects produced respectively by the three varieties of silica in unburned and burned mixtures of typical pottery compositions selected as representative of the important kinds of wares produced in large quantities by the ceramic industry and involving the use of large tonnages of silica.

FIRST INVESTIGATION

The first investigation included a study of the size of the particles of one sample each of quartz sand "flint," pebble flint, and tripoli, and the determination of drying shrinkage and cross-breaking strength of three pottery mixtures used respectively in the manufacture of semi-vitreous or ordinary table ware, vitrified white floor tile or "ceramics", and hotel china. The compositions used were as follows:

	Semi-vitreous body <i>Per cent</i>	Vitrified white floor tile "ceramics" <i>Per cent</i>	Hotel china body <i>Per cent</i>
Flinta	40	15	37½
Feldspar	15	50	16
Ball clay	20	..	7½
Florida clay	15	8
Kaolin or china clay.....	25	20	29
Whiting	2
	100	100	100

^a That is, true flint, sand "flint", or tripoli.

When burned, these compositions gave products which had very different characteristics, of which the shrinkages, the resistance to abrasion by hard substances, and the degree of vitrification were of especial interest.

SECOND INVESTIGATION

The second part of the investigation which was continued in 1929 was similar in purpose and scope to the first portion but was extended to include three samples of tripoli obtained from various sources in southern Illinois. The tests of the raw material were made somewhat more detailed in order to determine, if possible, significant differences between the samples of

tripoli. The pottery mixtures used were a semi-vitreous body and a vitreous sanitary ware body of the following compositions:

	Semi- vitreous body <i>Per cent</i>	Vitreous sanitary ware <i>Per cent</i>
Flint ^a	36	30
Feldspar	12	26
Kaolin or china clay.....	32	26
Ball clay	13	10
Florida clay	7	8
	100	100

^a That is, true flint, sand "flint", or tripoli.

These compositions represent two important types of wares which are extensively manufactured. They are quite different in essential physical properties and seem to be as susceptible to the effects of variations in the nature of the silica as any other compositions which might be chosen.

Each of the body compositions shown was prepared with the following form of silica, (1) quartz sand "flint", (2) French pebble flint, (3) International Silica Company tripoli, (4) Olive Branch Mineral Products Company tripoli, (5) Isco-Bautz Company Incorporated tripoli.

The following examinations and tests were made:

(1) Drying shrinkages were determined.

(2) Samples of the mixtures were burned at pyrometric cones 6, 8, 10, 12, 14, which correspond to temperatures of approximately 2174°F., 2237°F., 2300°F., 2390°F., 2534°F. These samples, after burning, were examined for shrinkages and porosities.

(3) Thin sections were prepared for study with the petrographic microscope.

(4) The strengths of the mixtures burned at suitable cone temperatures were determined by transverse breaking tests.

(5) The thermal expansion characteristics of the burned bodies were determined over a range of temperatures from 79°F. to 1652°F.

(6) Inasmuch as a capacity to withstand sudden heating and cooling without breakage is a necessary characteristic for table ware, such compositions were subjected to thermal shock tests. The sanitary ware bodies were also subjected to these tests because their composition approximates that of certain types of table ware.

SUMMARY OF RESULTS

The following summary presents the salient results of the investigations of southern Illinois tripoli to date. Details concerning methods of experimentation and specific results of tests will be published subsequently together with the results of other studies of tripoli now in progress.

The results obtained in the second part of the investigation clarified and confirmed the results of the first part.

Specific gravity.—The specific gravity determinations showed that the calcination of the tripolis at 2462°F. for 24 hours lowered the specific gravity of the quartz sand "flint" 4 per cent, the French pebble flint about 13 per cent, and the tripoli about 11 per cent, which changes indicate a much greater similarity of conduct between the pebble flint and the tripoli than between the latter and quartz.

Drying conduct.—The differences in the drying conduct of the several compositions are not significant.

Unburned strength.—The strength of the unburned mixtures (semi-vitreous, "ceramics," and hotel china) as determined in the first part of the investigation by making transverse breaking tests varied with the different materials. The quartz sand "flint" gave values slightly higher than those of the other mixtures; French pebble flint, least in two cases; and the tripoli mixture an intermediate value. However the differences between the strength values of these three varieties of silica are small. It is possible that the distribution of the various sizes and shapes of the particles may be the important factors rather than the type of material in itself.

Vitrification.—The vitrification of the bodies containing French pebble flint showed a distinctly significant conduct. Such compositions reached maturity at lower temperatures than the others and also over-burned at lower temperatures. This was not true in all cases but it was clear in those tests which appear to be most reliable.

The samples of tripoli closely resembled the quartz sand "flint" in conduct.

Petrographic character.—The petrographic examination of bodies in the second part of the study shows that the semi-vitreous bodies containing French pebble flint contain the greatest amount of mullite ($3Al_2O_3 \cdot 2SiO_2$). The bodies prepared with tripoli contain more mullite than those to which quartz sand "flint" was added. The sanitary ware bodies gave similar results. These results are in conformity with observations made on other compositions during the first part of the investigation.

Burned strength.—The strength of the burned bodies showed consistently high results for the French pebble flint mixtures used as semi-vitreous and sanitary ware bodies. Some of the bodies containing tripoli are better

than and some are not as good as those containing quartz sand "flint". The reason for this is not yet understood but will be studied further.

Thermal expansion.—The thermal expansion studies show that all of the compositions irrespective of the nature of the silica additions have a well defined characteristic inversion of the alpha to beta quartz (i. e. low quartz to high quartz). The semi-vitreous bodies containing quartz sand "flint", pebble flint, and one sample of tripoli form a group that exhibits somewhat higher coefficients of expansion from 932°F. upwards. The bodies containing the two other samples of tripoli are rather similar to each other and show slightly lower coefficients of expansion.

The same properties are exhibited by the sanitary ware bodies with the difference that the coefficient of expansion of the bodies containing quartz sand "flint" rises sharply at the inversion point. Also the expansions of all are practically identical until the inversion is completed, then the bodies containing tripoli constitute a separate group having very similar coefficients which are distinctly lower than those of the quartz sand or pebble "flint." The difference, however, between the tripoli group and the other two varieties of silica is small.

Thermal shock tests.—The value of the thermal shock tests lies in their indications of the relative resistance which compositions made with these various silicas offer to sudden temperature changes.

The thermal shock tests of the semi-vitreous body show that the most consistent results were obtained when the heat cycle was within the range 932°F. to room temperature. Within this range the quartz sand "flint" showed the least loss of strength. The French pebble flint and the tripoli were similar in conduct and showed losses about twice as great as the quartz sand "flint". Another series of tests which was made with the range of 1292°F. to room temperature confirmed these results.

Similar tests on the sanitary ware within the range of 1292°F. to room temperature gave like results, excepting that one tripoli sample was quite superior to all other samples of tripoli.

It appears from the above data that (1) in semi-vitreous bodies quartz sand "flint" gave the best results, and (2) in vitrified bodies one sample of tripoli was superior to all other "flints"; otherwise quartz sand "flint" gave the best results. Inasmuch as investigations of the thermal shock resistance of pottery bodies is still in progress these conclusions are subject to some modification.

FURTHER STUDIES

Further studies of the effect of various types of silica on certain properties of pottery mixtures not covered by the previous investigations are now under way.

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