GEOLOGICAL SCIENCES

I. A LABORATORY PROGRESS REPORT ON OKLAHOMA CLAY STUDIES

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Under a cooperative agreement between the Oklahoma A. and M. College and the University of Oklahoma, a survey is being made of the clay deposits of Oklahoma. The Geological Survey is collecting clay samples throughout the state, and the clays are tested in the Ceramic Laboratory at Oklahoma A. and M. College. At the present time some two hundred samples have been received at the laboratory, and the tests are being completed as rapidly as possible.

A geological classification of the samples received show the largest number are of Pennsylvanian age, with the majority of the samples from the McAlester, Pontotoc, Cherokee, and Coffeyville formations. A number of other horizons are represented. Of Mississippian age are samples from the Chattanooga, Boone, Fayetteville, and Stanley formations. Of Permian age the Hennessey formation gives the largest number of samples with Garber and Clearfolk well represented. The Cretaceous age is represented mainly by Purgatoire and Washita formations. Ordovisian, Cambrian, and Tertiary ages are also represented.

No attempt is made to discuss all the clays from each geologic age, but physical properties of representative samples from the important formations will be presented.

Laboratory Tests

The methods of testing used for this report followed the standards of the American Ceramic Society, in so far as it was possible to do so with the equipment available.

Preparation of Samples

The samples were crushed to pass a twenty-mesh screen, by passing through a laboratory jaw-crusher, followed by passing through a Braun pulverizer. Sufficient water was added to permit the mixture to be worked into a plastic mass. As far as possible a uniform consistency was maintained so that all determinations of water of plasticity and drying shrinkage would be comparable.

Test Pieces

The test pieces were made in wooden molds, 1⅛x1⅛x12 inches. Each bar was then cut in twelve 2-inch pieces and marked with steel dies one to twelve. Two 6-inch bars were made for transverse strength tests. The plastic weight and volume of the test pieces were determined as soon as possible. All volume measurements were made in a Schurecht overflow type Volumeter.

Drying

The test pieces were air dried in the laboratory, then heated in a constant temperature electric oven at a temperature of 74° C. for five hours and then at 105° C. for at least twelve hours. The pieces were then placed in a dessicator until dry weight and volume measurements were made.

Plastic and Dry Properties

Plasticity.—Notes on plasticity and molding properties were made at the time of molding. The clays were classified as poor, fair, good, and excellent.

Water of Plasticity.—The water of plasticity is the amount of water required to render the clay plastic or workable, and is calculated as the percentage of the weight of the dry clay bar. For example, if a clay has a water of plasticity of twenty-five percent, a one hundred-pound sample of the clay would require twenty-five pounds of water to develop the plasticity.

Shrinkage Water.—The water removed from the clay while it is shrinking from the plastic to dry state is called shrinkage water. Clays having a high shrinkage water are generally sticky and require care in drying.

Pore Water.—The amount of water retained by the clay after shrinkage ceases is called the pore water. The value is the difference between the percent water of plasticity and the percent shrinkage water.

Shrinkage.—Drying shrinkage was determined by calculating the volume of shrinkage, and from this value calculating the linear shrinkage. Drying shrinkage was calculated as percent of dry volume.

Firing Properties

Firing Treatment.—Each series of tests pieces were fired to Cone 7 in a gas fired laboratory kiln. Temperature was controlled by a pyrometer and checked by cones. A series of test pieces were drawn starting at Cone .010 (1742° F.) and at each alternate cone. Approximate cone temperatures are as follows:

Cone .010	1742° F.
Cone .08	1814° F.
Cone .06	1886° F.
Cone .04	1958° F.
Cone .02	2030° F.
Cone 1	2102° F.
Cone 3	2174° F.
Cone 5	2246° F.
Cone 7	2318° F.

The rate of firing was approximately 100° F. per hour to 1000° F., and 50° F. per hour to point where clays stuck to the muffle in the kilns.

Firing Shrinkage.—The shrinkage in firing is expressed in terms of volume and linear strinkage on the dry basis. All volume measurements were made in the Schurecht overflow type Volumeter, after saturating the test pieces with water and weighing then for absorption and apparent porosity determinations.

Absorption.—The absorption was determined by noting the weight of water absorbed by boiling the piece in distilled water for two hours.

Apparent Porosity.—Apparent porosity is the ratio between the volume of the pores and the volume of the whole piece.

Apparent Specific Gravity.—Apparent specific gravity is the relation between the weight of the mass and that of an equal volume of water equal to the volume of the solid material.

Softening.—After the burning tests showed that all the clays overburned at Cone 5, it was considered unnecessary to determine the softening points of these clays.

Texture, Structure, and Hardness

Texture.—The texture was expressed as fine, medium, or coarse grained.

Structure.—The structure of fired test pieces is reported as granular, stony, homogeneous or hetrogeneous.

Hardness.—The hardness is reported as greater or less than fingernail or steel. Hardness of dried clays is reported as very soft, soft, medium, equal to finger-nail or greater than finger-nail.

Color

With one exception all previous clay reports have expressed the natural and fired colors of clays in indefinite terms which could not be duplicated. Since the fired color of clays is a very important property in many cases, it is desirable to have some standard method of judging colors, so that any investigator may duplicate the various colors. For this reason the Ridgeway System of Color Classification has been chosen.

To express a color three variables are used: (1) Hue or series of spectrum colors; (2) tone or value used to distinguish light from dark colors; and (3) chroma as distinguishing strong from weak colors.

In the Ridgeway charts three symbols are used: (1) an arabic numeral to designate hue; (2) the superscript (' to ''''') to indicate chroma, and (3) a lower-case letter to distinguish tone. Thus a brick-red color is represented by 5'k. The Ridgeway system classifies 1115 named colors.[1]

Relation of Physical Properties to Uses

Clay for common brick should be capable of being molded into brick, should burn hard below Cone 1 (2100° F.) and develop a fair color. Stiff mud brick require a more plastic clay than soft mud.

Clay for face brick should be more plastic, and should retain good corners and smoth faces. A good color is essential, and face brick are usually burned steel hard, necessitating a good range of vitrification to prevent losses from deformation.

Building block and fireproofing require a clay of good plasticity that will work well in an auger machine. The material should possess good burned strength with high porosity. Color is immaterial, but strength and durability are more desirable.

Paving brick require a very tough material with extremely low porosity to prevent loss from spalling due to freezing and thawing.

Drain tile clays require properties similar to those required for stiff mud brick, with excellent drying properties to prevent warping and cracking.

Wall and floor tile are usually made from buff clays or porcelain mixtures with special attention to color.

Sewer pipe clays must burn dense and strong, and must take a good salt glaze to prevent leaking. High plasticity with good drying properties are essential.

Pottery, china, and porcelain clays require a high purity that is usually obtained by washing. They must be plastic, retain their shapes with low shrinkage, and burn to a white or light color. The product should be tough and strong.

The most desirable property of refractory clays is a high melting point and the ability to withstand changes in temperature without excessive loss in strength. Such clays must necessarily be low in fluxes and high in alumina and silica.

Clays for paper manufacture, paint fillers, and slips all require special properties.

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[1] Color Standards and Nomenclature, by Robert Ridgeway.

Physical Properties of Oklahoma Clays

SAMPLE NO. 5.
Laboratory No. E.
Section 18, T. 3N, R. 7E.
County: Pontotoc.
Geological formation: Wetumka.
Water of plasticity: 18.7%.
Dries easily.
Air shrinkage: 11.1%.
Soluble salts: trace.
Apparent specific gravity.

Cone No.	Cone temp. deg. F.	Porosity	Volume shrinkage	Hardness	Color
010	1742	28.1	20.2+	Fingernail	17'''f
08	1814	25.0	14.5+	Soft	17'''f
06	1886	22.9	18.7+	Soft	17'''f
04	1958	17.0	13.8+	Steel	21'''f
02	2030	12.4	9.75+	Steel	13'' f
1	2102	1.01	4.53+	Steel	13' f
3	2174				

This clay is from the quarry of the Ada Pottery Company in the vicinity of the Ahloso Fault and Boggy. Ironstone concretions are numerous, 2'' to 5'' diameter. The burning test of this clay shows it to differ from most clays in that there is an initial expansion up to Cone 010 with shrinkage starting at Cone 08. The clay is suitable for stoneware or low grade pottery.

SAMPLE NO. 46.
Laboratory No. TT.
Section 36, T. 6N., R. 14E.
County: Pittsburg.
Geologic formation: McAlester shale.
Water of plascitey: 23.10%.
Air shrinkage: 16.92%.
Soluble salts: None.

Cone No.	Cone temp. deg. F.	Porosity	Volume shrinkage	Hardness	Color
010	1742	30.8	5.92	Soft	7'd
08	1814	32.0	8.25	Soft	7'd
06	1886	24.8	12.90	Soft	9'b
04	1958	13.05	22.55	Steel	9'i
02	2030	10.00	26.43	Steel	7'k
1	2102	6.83	30.40	Steel	11'm
3	2147				

This sample was taken from the pit of the McAlester State Penitentiary. It is very plastic with a fine texture. It is good material for red tile or brick. Its best burning range is 010 to 04.

SAMPLE NO. 53.
Laboratory No. AB.
Section 9, T. 5N., R. 1E.
County: Cimarron.
Geologic formation: Purgatoire shale.
Water of plasticity: 29.98%.
Average air shrinkage: 30.40%.
Soluble salts: Trace.

Cone No.	Cone temp. deg. F.	Porosity	Volume shrinkage	Hardness	Color
010	1742	34.5	8.52	Medium	9'f
08	1814	32.3	9.15	—Steel	9'f
06	1886	32.8	10.62	—Steel	9'f
04	1958	32.0	7.40	Steel	11'd
02	2030	25.4	15.80	+Steel	[illegible]
1	2102	6.86	28.40	+Steel	25''i
3	2174				

Light gray shale works well and molds easily, warps slightly in drying, and burns to a buff color with some discoloring at high temperature. Steel hardness develops at Cone 04. Best burning range is Cone 010 to 02.

SAMPLE NO. 27.
Laboratory No. AA.
Section 31, T. 12N., R. 3W.
County: Oklahoma.
Geologic formation: Hennessey shale.
Water of plasticity: 23.67%.
Air shrinkage: 18.7%.
Soluble salts: Trace.

Cone No.	Cone temp. deg. F.	Porosity	Volume shrinkage	Hardness	Color
010	1742				
08	1814				
06	1886	28.2	18.7	Soft	7'b
04	1958	26.2	18.8	Soft	7'd
02	2030	23.8	22.4	Medium	9'i
1	2102	19.6	33.7	Medium	11 m
3	2174	5.3	33.8	Steel	11'm

This material from the pit of the United Brick and Tile Company, 2700 W. 10th, Oklahoma City, Oklahoma, Estimated thickness is 60 feet. Brick, flue, and drain tiles are manufactured from it. It has good plasticity with smooth texture. The best firing range Cone 06 to Cone 02. Overburning occurs above Cone 1.

SAMPLE NO. 93.
Laboratory No. BQ.
Section 24, T. 16N., R.
County: Kingfisher.
Geologic Formation: Hennessey shale.
Water of plasticity: 23.77%.
Air shrinkage: 11.34%.
Soluble salts: None.

Cone No.	Cone temp. deg. F.	Porosity	Volume shrinkage	Hardness	Color
010	1742	31.8	3.7	Soft	13''
08	1814	32.3	3.96	Soft	11''
06	1886	32.9	4.44	Steel	11''
04	1958	32.2	5.55	Steel	9''
02	2030	28.0	11.11	Steel	9''k
1	2102	15.6	24.60	Steel	11''k
3	2174				

This hard red shale contains numerous nodules of white shale. Material is gritty and lacks bending power when mixed with water. Excellent face brick color is present over four cones, 010 to 04, with the burning range in this area. It is a good material for face brick.

SAMPLE NO. 6.
Laboratory No. F.
Section 36, T. 3N., R. 5E.
County: Pontotoc.
Geologic Formation: Sylvan shale.
Water of plasticity: 32.12%.
Air shrinkage: 20.9%.
Soluble salts: Abundant.

Cone No.	Cone temp. deg. F.	Porosity	Volume shrinkage	Hardness	Color
010	1742	37.2	.37	Soft	15''d
08	1814	27.4	.0	Soft	15''d
06	1886	19.8	15.3	Medium	15''d
04	1958	16.5	16.5	Steel	13'''
02	2030	6.75	15.3	Steel	17'''
1	2102	7.30	8.45	Steel	17''k
3	2147				

This material is from the quarry of the Oklahoma Portland Cement Company at Lawrence, Oklahoma. This gray shale has good plasticity. Its burning test shows a large quantity of soluble salts which discolor the pieces.

SAMPLE NO. 133.
Laboratory No. DG.
Section 8, T. 25N., R21E.
County: Craig.
Geologic formation: Fayetteville.
Water of plasticity: 24.62%.
Air shrinkage: 15.08%.

Cone No.	Cone temp. deg. F.	Porosity	Volume shrinkage	Hardness	Color
010	1742	26.7	4.65	+Steel	17''f
08	1814	22.9	7.34	+Steel	17''d
06	1886	21.5	7.04	+Steel	15''d
04	1958	18.67	8.86	+Steel	15''f
02	2030	17.55	12.62	+Steel	15''f
1	2102	12.70	15.58	+Steel	15''f
3	2147				

This material crushes and grinds easily and has good molding properties. Steel hardness develops at Cone 010. High porosity at Cone 1 indicates that this clay may stand higher temperatures without deformation.

Relation Between Geologic Horizon and Physical Properties

It is practically impossible to classify a given clay by its physical properties as belonging to a particular geologic age or formation. The wide variation of physical properties of different samples taken from the same pit support this conclusion. It is possible that clays from a particular horizon may show similar characteristics, such as the presence of free quartz from sandstones, lime from limestones, or other minerals from a particular strata in the formation.

The curves in Figure 1 and Figure 2 show the porosity and shrinkage in percent plotted against cone temperatures.

Fig. 1.

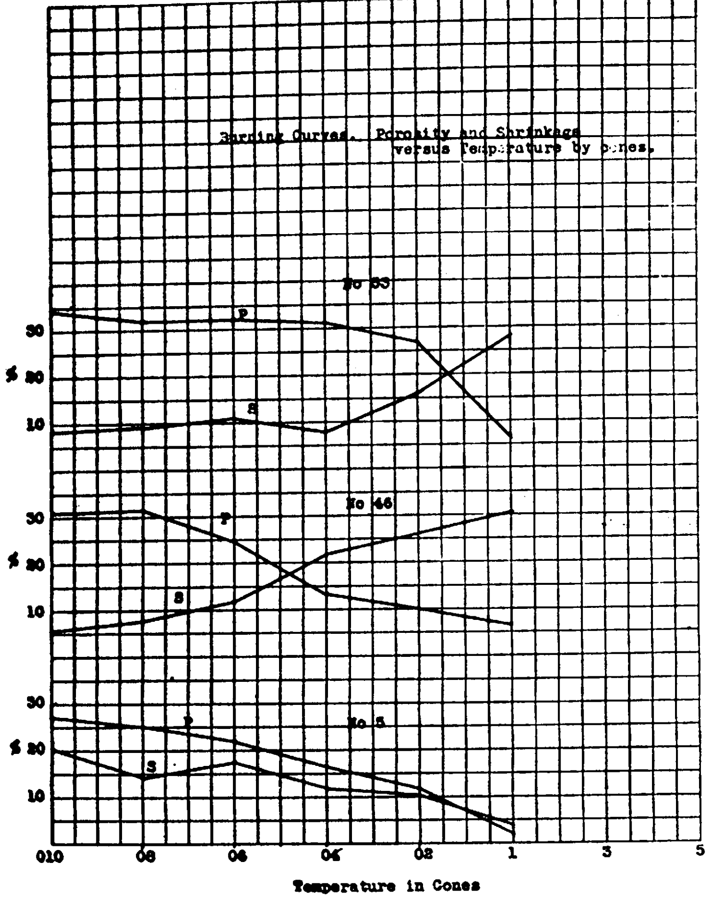
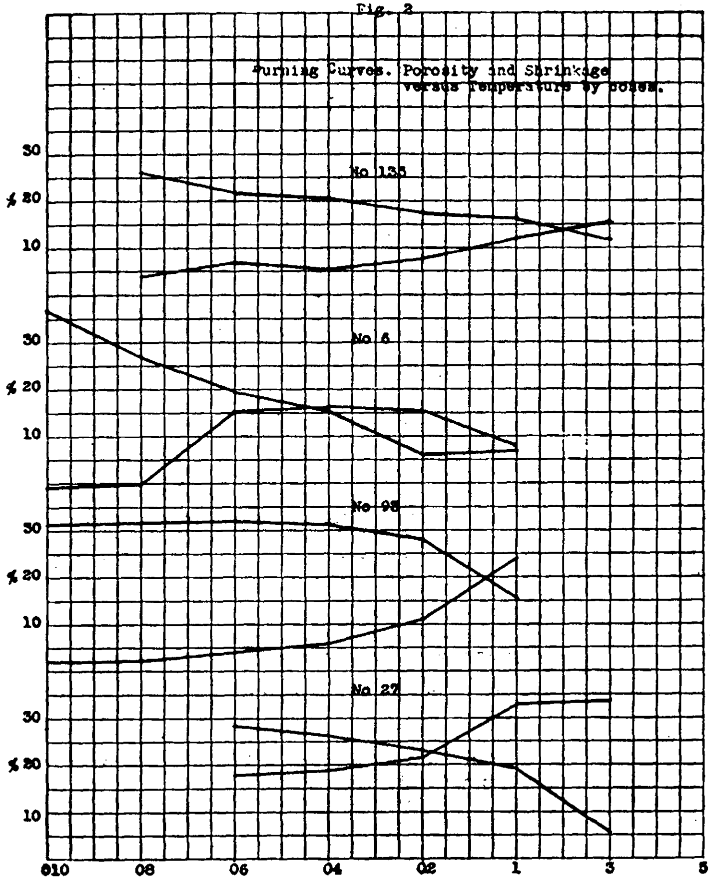

Burning Curves. Porosity and Shrinkage
versus Temperature by cones.
No 53
P
S
No 46
P
S
No 5
P
S
30
% 20
10
010
08
06
04
02
1
3
5
Temperature in Cones

Fig. 2


Burning Curves. Porosity and Shrinkage versus Temperature by cones.
No 135
No 6
No 98
No 27
30
% 20
10
010
08
06
04
02
1
3
5
Temperature in Cones