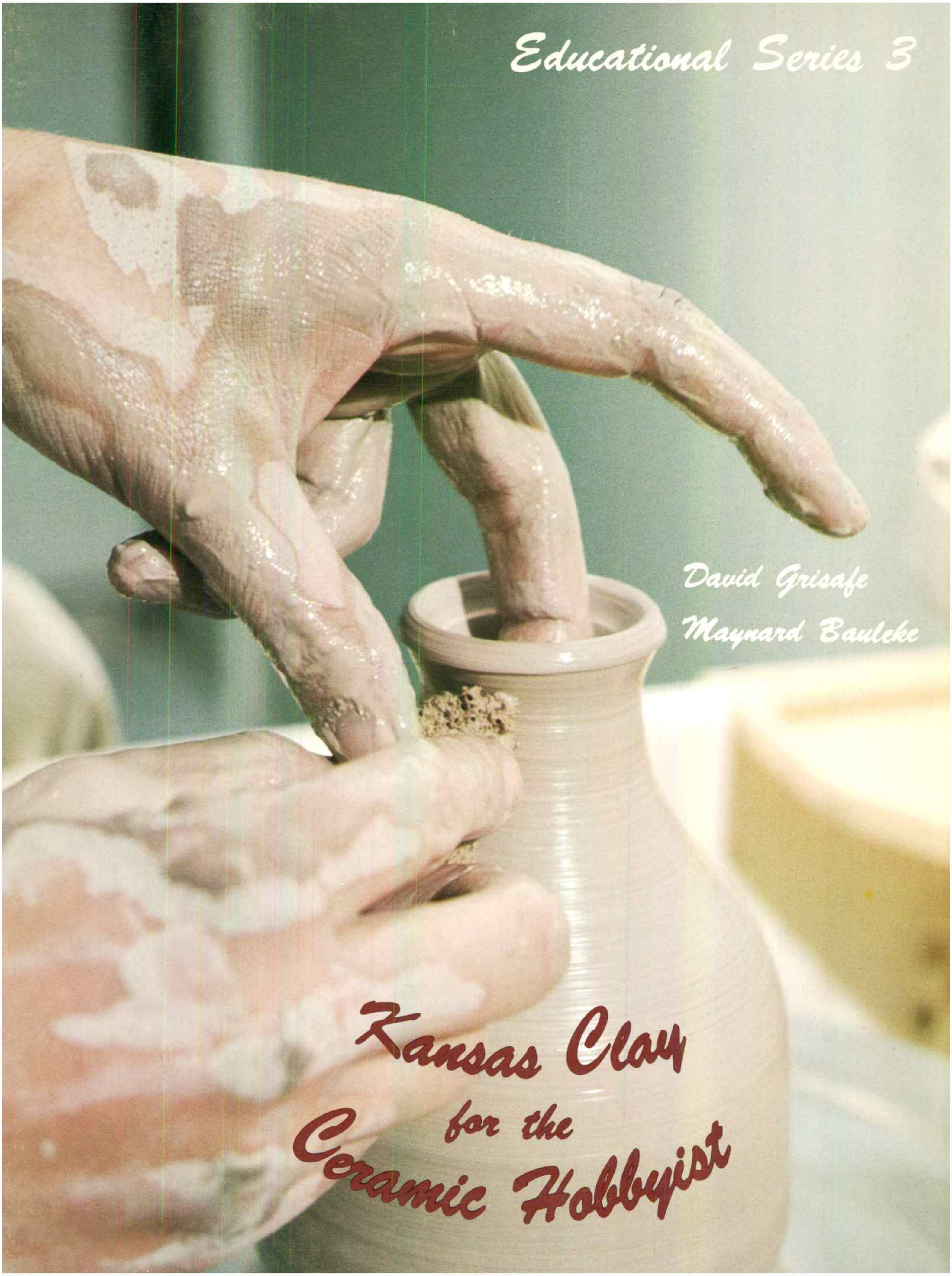

Educational Series 3

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Kansas Clay for the Ceramic Hobbyist

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Kansas Geological Survey, 1977

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Kansas Clay for the Ceramic Hobbyist

INTRODUCTION

Clays* are found almost everywhere. You walk upon them, scrape them off the bottom of your shoes during a wet spell, or sweep them off the dusty floor during dry weather. However, all clays are not alike. The characteristics of a good pottery clay are often completely different from those useful in the manufacture of cement. The potter wishes a clay to respond to the instructions relayed into it by the shaping fingers. The cement kiln has no interest in how a clay responds to human touch.

Kansas has a wide variety of clays and shales for many different applications. This publication is written as a simulated dialogue between a ceramic hobbyist and a member of the Geological Survey. The answers are intended to be general and only slightly technical. For more detailed information, the reader is referred to the list of reference books at the end of the publication. Undoubtedly, there will be some unanswered questions in your mind, but the aim is to develop your desire or curiosity to try some local clay or shale in place of buying from a supplier. It must be emphasized that the information in the paper is not applicable on a world-wide scale but rather describes the conditions for Kansas clays.

* An extensive glossary, which explains almost all of the terms used, is included at the end of this publication.

WHY SHOULD I DIG MY OWN CLAY?

Mainly for personal satisfaction. If you think you're going to save lots of money you are not properly valuing your own time spent locating and preparing the clay. Digging your own clay is a lot of work, but it will give you personal satisfaction to go through the complete process (finding, processing, and shaping your idea into the clay) over which you have had complete control. You will end with an item that is characteristic of the area and you. Using local clay affords a great learning experience not obtainable through your local hobby supplier.

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WHAT IS A CLAY MATERIAL?

A clay is usually defined as any fine-grained natural, earthy, argillaceous material. This category includes clays, shales, and other earthy mixtures containing a high percentage of clay material.

Clays from various locations behave differently because of differences in the composition and structure of clay minerals and impurities. There are three families of clay minerals, each having its own distinctive characteristics. For the potter, kaolinite clays are the best, montmorillonite clays the poorest, leaving illite clays in the middle.

A shale is a clay which has been consolidated as a result of pressure applied to it at some time during the geologic past. It has a layered appearance in exposures, tending to break into flat platey pieces. In most cases, the words shale and clay are interchangeable, the major difference being their degrees of consolidation, compaction, or lamination.

It is easy to take clay/shale for granted: everyone knows it is used to make pottery. It would be wise to remember that millions of dollars of non-pottery clay products are sold in Kansas each year. Such products include sewer pipe, brick, and expanded shale.

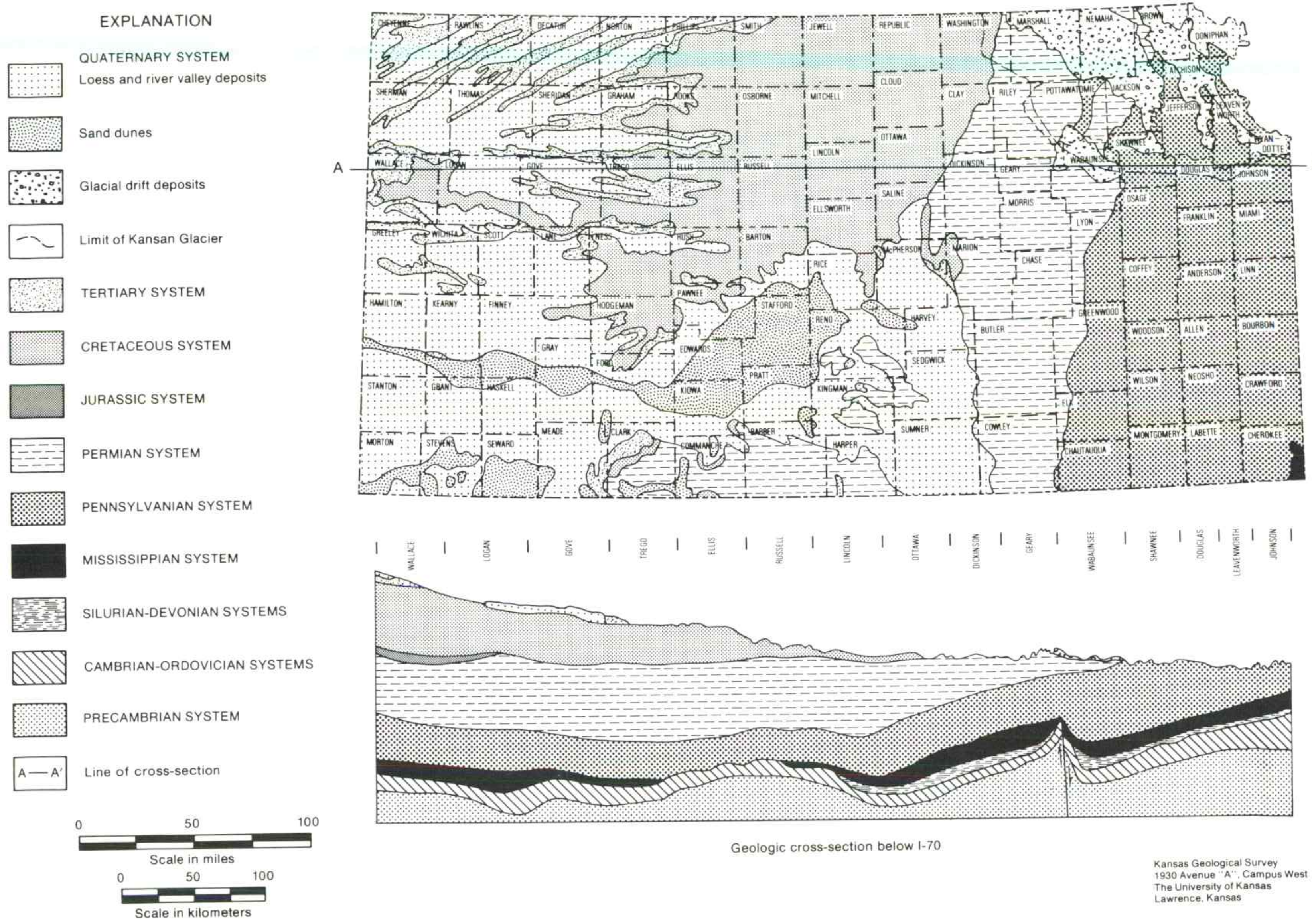
CAN I DIG ANY PLACE I SEE AN EXPOSURE OF CLAY?

Definitely not! Kansas does not have free public lands. All land is owned or controlled; hence no prospecting mineral claims can be filed in Kansas. Do not dig clay from any location without first receiving permission from the appropriate authority, usually a landowner. How would you feel about someone digging holes in your backyard? In certain parts of Kansas the backyard may be several thousand acres, but it is still someone's backyard and should be so treated. 'Always receive permission to trespass, i.e., walk upon another person's land. Often the landowner can give helpful directions as to where to look for good clay. Also, digging clay along road cuts and railroads is considered illegal.

HOW DO I KNOW WHETHER I AM DIGGING A CLAY OR SHALE?

Notice the structure of the deposit. If the material is hard, in thin layers within the bed and breaks out as a plate-like piece, it is probably shale. Shales tend to be harder than clays. Some clays may be extremely hard (claystone), but they will not have the plate-like structure observed in shales. In other words shales generally behave like a rock whereas pure clay acts more like earth or soil.

You may also consult a geologic map for the name of the formation in which you are digging.



GENERALIZED GEOLOGIC MAP OF KANSAS

WHAT ARE THE COMMON IMPURITIES FOUND IN KANSAS CLAYS?

SAND. Sand of varying particle size is almost a universal impurity in clay. It does little damage to the physical properties when present as fine-grained material in amounts of less than 25%. In fact, most pottery casting slips contain a certain percentage of silica. Sand, often called quartz, is a refractory material with the chemical composition SiO_2. Its high melting point increases the maturing temperature of a clay-sand mixture. It is non-plastic and decreases the drying shrinkage and the plasticity of wet clay. In Kansas, sand usually contains a small percentage of iron oxide which will affect the color of the fired ceramic body.

FELDSPAR. Feldspar is an alkali aluminosilicate which acts as a flux, i.e., lowers the fusion temperature of a clay body. This property is desirable in clay products that are to be vitrified; for example, nonporous paving bricks, stoneware or floor tiles.

MICACEOUS MATERIAL. Mica appears as a flat, platey, bright-sparkling material in the clay. Normally mica is not harmful in small amounts. The material acts as a flux, but it can also be a source of iron color, especially the dark colored biotite mica. In appreciable amounts, micaceous materials produce problems in casting, etc., which necessitate removal of the mica before using the clay.

GYPSUM. Gypsum is a hydrated calcium sulfate. It is not truly harmful, but it can produce a white surface scum which is detrimental to the appearance of a red-firing clay body. The scum is produced both during the drying period and again during periods of wetting and drying of the fired ware. Some people call this efflorescence instead of scumming.

The addition of small amounts of barium carbonate will usually eliminate the scum problem. Sometimes additions of a much cheaper chemical like soda ash (sodium carbonate) will reduce or eliminate scumming.

ORGANIC MATTER. Decomposed plant matter is not troublesome as long as the dry clay has enough porosity to permit combustion of the organic material during firing. If the organic matter does not completely burn out, the clay is referred to as a tight burning clay. Most Kansas clays do not have excessive amounts of organic material but notable exceptions are the very black shales which usually have a large hydrocarbon content, e.g., coal or oil.

LIMESTONE. This is predominantly calcium carbonate. However, limestone often is erroneously called lime, which is really the name for calcium oxide. Limestone is the source of much trouble because its presence alters the firing range of the clay and is the source of lime-pop defects. The way to test for the presence of limestone is described in questions about field testing. Limestone will react with iron compounds to form a light-colored material and thus has a bleaching effect on the fired color.

VANADIUM COMPOUNDS. These cannot be identified in the field, but if a green stain is found or develops on your fired ware a vanadium compound is probably in the clay. The presence of vanadium in the clay may also produce a yellow color on fired ware.

PYRITE. Pyrite is fool's gold, iron sulfide. As far as we know, no one has ever found a genuine gold nugget in Kansas clay, but fool's gold exists by the ton. Pyrite produces dark iron spots on fired ware. Large particles should be removed because they will produce "pyrite pops."

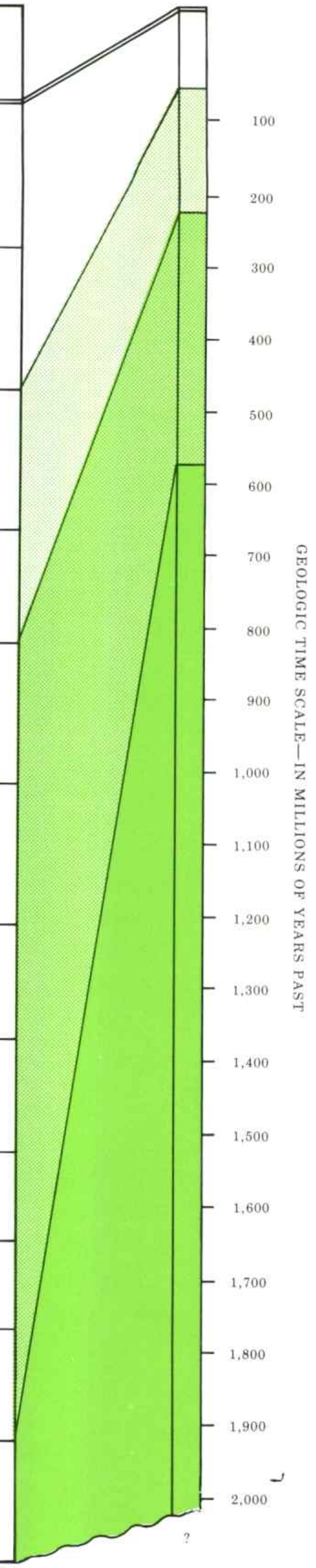
SIDERITE. Siderite is iron carbonate. Small particles produce black spots (sometimes desirable) or give an iron color to the clay. Both pyrite and siderite are sensitive to a reducing atmosphere since the compounds are reduced to metallic iron which usually causes setter problems (ware will become fused to setters).

SUMMARY. It is not at all unusual to find several impurities in a clay deposit. There are few deposits containing only a single clay mineral in the world. The probability of finding a high-purity small deposit is much greater than finding a large commercial size deposit.

GEOLOGIC TIMETABLE AND KANSAS ROCK CHART

(Not scaled for geologic time or thickness of deposits)

ERAS	PERIODS	ESTIMATED LENGTH IN YEARS*	TYPE OF ROCK IN KANSAS
CENOZOIC 65,000,000	QUATERNARY (PLEISTOCENE)	1,500,000	Glacial drift; river silt, sand, and gravel; dune sand; wind-blown silt (loess); volcanic ash.
	TERTIARY	63,500,000	River silt, sand, gravel; fresh-water limestone; volcanic ash; bentonite; diatomaceous marl; opaline sandstone.
MESOZOIC 160,000,000	CRETACEOUS	71,000,000	Limestone, chalk, chalky shale, dark shale, varicolored clay, sandstone, conglomerate. Outcropping igneous rock.
	JURASSIC	59,000,000	Sandstones and shales, chiefly subsurface. Siltstone, chert and gypsum.
	TRIASSIC	30,000,000	
PALEOZOIC 345,000,000	PERMIAN	55,000,000	Limestone, shale, evaporites (salt, gypsum, anhydrite), red sandstone; chert, siltstone, dolomite and red beds.
	PENNSYLVANIAN	40,000,000	Alternating marine and nonmarine shale, limestone, sandstone, coal; chert and conglomerate.
	MISSISSIPPIAN	25,000,000	Limestone, shale, dolomite, chert, oolites, sandstone and siltstone.
	DEVONIAN	50,000,000	Subsurface only. Limestone, predominantly black shale; sandstone.
	SILURIAN	45,000,000	Subsurface only. Limestone.
	ORDOVICIAN	60,000,000	Subsurface only. Dolomite, sandstone.
	CAMBRIAN	70,000,000	Subsurface only. Dolomite, sandstone, limestone and shale.
PRECAMBRIAN ERA		4,600,000,000 +	Subsurface only. Granite, other igneous rocks, and metamorphic rocks.



*Geological Time Table by F.W.B. Van Eysinga Elsevier Publishing Company, 1972

WILL ANY OF THE CLAYS MAKE GOOD SLIP?

Some will but you can't tell this property too accurately in the field. Kaolinite clay has the best slip properties; montmorillonite clay has very poor slip properties.

The presence of small amounts of montmorillonite or certain swelling illite clay minerals with the kaolinite mineral may cause the slip to gel while standing in the mold. Gelling is an unacceptable casting condition. Changing the type or amount of deflocculent may reduce this problem, but the cure may create new problems concerning casting rates. A good slip casting clay is harder to find than a good throwing clay. Usually a slip-casting clay will throw but a throwing clay may not slip cast. These properties must be evaluated in the shop.

IS THERE A RELATIONSHIP BETWEEN THE RAW COLOR OF CLAY IN THE FIELD AND THE FINAL FIRED COLOR?

Not as much as you might wish. However, one can be reasonably certain that a red clay (usually indicative of iron content) will fire to some shade of red, except when limestone is present. White clay should fire white but the presence of impurity minerals usually produces an off shade. The fired color from a black or gray clay is anyone's guess. The result can range from pure white to deep red. The fired color depends upon the impurities present which are masked by the dark organic matter. Only test firing in a kiln can accurately evaluate the fired color. Remember, many clays change their color with changing firing temperature or kiln condition. The color of iron-bearing clays is quite sensitive to the percentage of oxygen present in the kiln atmosphere.

WHAT IS MEANT BY A PLASTIC CLAY?

Evaluation of plastic nature is somewhat of a personal opinion, but it is that property that makes a clay workable. A good plastic clay can be mixed with the proper amount of water, called the water of plasticity, formed into a pencil-shaped rod, then formed into a tight figure eight without the formation of any cracks. Usually the more plastic the clay, the more water is required to bring the clay to a plastic condition. It is possible for a clay to be too plastic, which produces a variety of undesirable effects such as the slumping of wet ware and an extremely high drying shrinkage often accompanied by warping and cracking.

MY FRIEND LOOKS FOR GOOD SLAKING CLAYS. WHAT IS THE SLAKING PROPERTY?

Slaking refers to the reaction of clay with water . A cube of a good slaking clay will disintegrate within a few minutes when placed in water. A poor slaking clay will hold its shape for hours. The evaluation of slaking is quite simple. Place a one-inch cube of clay on a ¼-inch-opening screen. Lower the assembly into a pan of water until the clay is completely covered but does not rest on the bottom. Observe the time required for the clay to disintegrate and fall through the screen.

A good slip clay must be a good slaking clay. The faster a clay slakes, the easier it is to bring it to a workable condition. As an extreme example of an undesirable clay, calcareous (calcium carbonate rich) cement in the clay may cause the cube to be relatively unaffected by water: it may never be workable.

HOW LARGE A CLAY DEPOSIT DO I NEED?

It depends upon the size of your operation. For a one-person hobby a small pocket of clay can be a lifetime supply. The larger the operation, the more clay you need. You may find one location has your ideal clay or you may wish to blend clays from more than one location to produce distinctive characteristics in your ceramic body.

WHAT SHOULD I TAKE INTO THE FIELD TO HELP IN MY SEARCH?

A comfortable pair of shoes and appropriate "bumming" clothes are essential. A shovel of proper size to match the individual and a pick are needed to loosen the material. The clay is collected and placed in sacks, either plastic or cloth. Multi-walled paper sacks are also acceptable for storage if the clay is not too wet. Remember strings to tie the sacks.

Don't fill large sacks too full unless you can drive close to the digging area. A cubic foot of clay weighs about 120 pounds. Sometimes the best clay is found in remote areas and must be carried to the nearest road.

Take a map or draw a map for marking the sample location. Record the clay type and location on a piece of paper and place it in the sack. A soft pencil is a good recording media as it doesn't smear if the paper becomes wet. It is quite important to keep the sacks distinctly marked if you are gathering from several locations.

You might want to record descriptive information about the deposit and surrounding area in a "clay resource" note book.

Always take a small dropper bottle of 10% hydrochloric (muriatic) acid, obtainable at your local drugstore, in order to test for calcium carbonate content.

A plastic bottle, such as a liquid soap bottle, of water should be taken for evaluating the plasticity in the field.

It usually takes one trip into the field to establish sampling or collecting and testing routines. Different people have different requirements.

WHAT TYPE OF TESTS CAN I MAKE IN THE FIELD?

No one likes to spend his time digging non-usable clay. Therefore, if you are in a new area take only enough sample to make forming, drying, and firing tests in your shop. You can always come back for more if it proves itself. In the field, the following tests should be conducted before filling your sacks:

1. Grit characteristics.

Rub a small amount of clay between your front teeth. A pure clay will feel relatively smooth because the clay mineral has a smooth plate-like geometry which allows the plates to slide freely against the teeth. The common impurities produce a "grit feel" between your teeth because you're actually rubbing fine sand between your teeth. The more impurities, the more "gritty" it feels. The teeth method is much more sensitive to the presence of fine particle impurities than the "rubbing between fingers" method.

2. Plasticity test.

To test the plasticity take a sample of clay, slowly wet it, and work it in the hand until it has a smooth, stiff consistency. A good plastic clay containing the proper amount of water can be extruded between the fingers without sticking or tearing. You should practice with a known plastic clay before going into the field in order to develop the necessary feel for the situation. Also, feel for large grains and uncomfortable amounts of grit particles. If it doesn't feel comfortable in the field it probably will not feel any better on the wheel.

Sometimes a good kaolin clay will contain coarse sand in such amounts that the mixture is unusable. By methods of clay suspension and sand settling or else by screening, the clay can be separated and made usable.

A clay that is low in plasticity will first form a crumbly mass that does not hold together. As more water is added it will suddenly become liquid and slump. Such a clay is said to have no plasticity or too narrow a range of plasticity to make it useful. This behavior is often due to large amounts of non-plastic impurities in the shale or clay.

Clays that are too plastic become sticky and adhere to the hands during forming. A sticky clay is probably a montmorillonite clay; a good plastic clay is probably a kaolinitic clay or an illitic clay. Poor performing clays should be left in the field but make a note of the behavior because you might need these properties for blending with other clays.

3. Carbonate test (limestone or calcium carbonate).

Clay containing calcium carbonate will froth or bubble when wetted with dilute hydrochloric (muriatic) acid. The degree of bubble activity is usually proportional to the amount of carbonate present. Calcium carbonate, when heated above 1400°F, forms free lime, calcium oxide. Lime has two undesirable effects on clay. First, it shortens the firing range; second, lime reacts with the humidity to form hydrated lime. A large volume expansion accompanies the hydration reaction causing the ceramic ware to crack in the neighborhood of the lime particles. This is called "lime-popping" and makes any ware having it unsalable.

If you can feel limestone particles between your fingers, leave the clay in the field. It will cause nothing but grief in the shop.

There is a remote possibility that some clay might contain dolomite, a double carbonate of calcium and magnesium. Dolomite does not vigorously react with dilute hydrochloric acid. However, heat does change dolomite into calcium oxide and magnesium oxide, both of which can cause water reaction problems. If your ware develops lime pops and there is no "fizz" between raw clay and dilute acid, you probably have dolomite present. Find another clay.

4. Pyrite test (fool's gold, FeS_2).

Mix a small amount of clay and water to produce a suspension. If necessary you can do this in the palm of your hand. Pyrite is much heavier than clay and will sink. Wash away the dispersed clay. Examine the residue for small hard yellow particles. Often the particles look like cubes. If it looks like a poor grade of gold, it's probably pyrite.

Although very small particles aren't too troublesome, large particles will cause "pyrite pops" during firing, spoiling the ware. Furthermore, pyrite does contain sulfur which will form sulphur dioxide during kiln firing with a normal oxidizing atmosphere, and has a most unpleasant odor. The first whiff will make a lasting impression. We do not recommend pyrite-containing clays for you.

Leave the clay in the field if it fails any of the three tests: plasticity, calcium carbonate, or pyrite content. Look for a new source. Only when you are satisfied with the field tests should you sack large samples for shop tests.

ARE RATTLESNAKES, CRAWLING CREATURES, OR OTHER OBJECTS IN THE FIELD A PROBLEM?

Not if you let them know you are coming. Make some noise. Don't tip-toe around. Use caution if you must turn over flat rocks or move logs. You never know what may be underneath. Walk in the field as if you were crossing a busy street—carefully and watchfully!

Your problems in the field will be minimized if you apply common sense to your surroundings. Good shoes or boots are especially important in western Kansas where cactus and yucca plants are common. Remember that yucca is much tougher in the field than in the garden. Always present are poisonous varieties of ivy, oak, and sumac, as well as thistle and other miscellaneous thorny plants. Another reason for watching where you are walking is illustrated by the fact that people have been known to fall over cliffs or to break a leg by stepping in an animal burrow.

WHAT TESTS SHOULD I DO IN MY SHOP?

First, decide whether or not you can use the clay as dug. If you can, proceed directly to the drying, throwing, and firing tests.

If the clay appears suitable except that it contains sand or coarse impurities, the impurities may be removed as follows. Prepare a slurry of water-clay about 50/50 by weight. Actual ratio must be determined by experiment. Add a small amount of Calgon to help disperse (or defloc) the clay. Stir vigorously to separate the clay impurities. If sieves are available, one can screen the slurry. Otherwise, allow the slurry to stand for five minutes or longer. Pour off the suspended clay into a shallow pan. Set the pan in the sun and evaporate the water. If the clay is to be used for throwing, do not evaporate to dryness but only to the moisture content required for throwing. Store in air-tight bags.

Look at the coarse material before throwing it away. It will often give you a clue to the identity of the remaining impurities in the clay.

1. Drying test.

After determining how much water is needed to develop the clay to a plastic condition, form some test bars. It is a good idea to make several bars in case you decide to make firing tests. The bars should be a convenient size such as one inch wide, by one-half inch thick, by six inches long. Immediately after forming, place two parallel marks of a known distance, e.g., five inches apart, on the wet bar. These marks will be used to calculate drying and firing shrinkages. As the clay dries, the distance between the marks will decrease.

After marking, place the bars on a coarse screen (hail screen is excellent) which will serve as a drying rack. Often plastic ware is first dried in air and then in an oven around 200° to 210° F. Although an ideal drying clay will dry without warping or cracking, most clays will show some warping if rolled or pressed into thin bars and dried. Uniform drying of all surfaces lessens the chances of warping and cracking.

There is a related warpage during the drying of a clay, referred to as a memory effect; this means that the clay attempts to assume or remember a previous shape. To observe this effect, one can take a plastic clay bar, wrap it around a small jar and let it set for a couple of minutes. Remove the bar, straighten it, and let it dry on the coarse screen. During drying, most clays will tend to curl or warp in the direction they were molded around the jar. This interesting phenomenon has never been fully understood but fortunately does not restrict a clay's use by the hobby potter.

A clay bar will stop shrinking during the drying process before all the water is evaporated. Shrinkage occurs because the evaporation or removal of water between the clay grains allows the grains to move closer together. However, once the grains are in contact, shrinkage nearly stops, even though further evaporation of water from the pore spaces occurs. A slight additional shrinkage can occur as the last traces of water are removed. The last step involves removal of a tightly bound, difficult to remove, monolayer of water around each clay grain.

It is important to completely dry test pieces to obtain accurate drying shrinkages and to avoid destruction of green ware during rapid firing (the water may boil out of the ware). A fully dried bar does not feel cool when touched to the cheek. Measure the distance between the marks on the dried bar to obtain the drying shrinkage. Drying shrinkage is expressed as a percentage and is calculated from the formula—

$$(1)\quad \text{Percent Drying Shrinkage} = \frac{\text{Plastic Length - Dry Length}}{\text{Plastic Length}} \times 100$$

Break a dried bar between your fingers to get some idea of the dried strength. Ware made from weak clay is easily broken during handling whether it be made on a wheel or by slip casting. If the clay does not properly dry, there is no need for additional testing. Drying cracks cannot be successfully repaired. They generally will reappear and enlarge during the firing process.

2. Throwing test.

Bring the clay to your normal throwing plasticity. Form a shape on the wheel. Decide whether or not you like the manner in which the clay reacts. This involves a number of personal evaluations. What is satisfactory for one person may not be satisfactory for another.

If you aren't interested in numerical values for drying and firing shrinkage you may use your throwing test shapes to evaluate the drying and firing behavior.

3. Firing test.

Fire the dried bars to your normal kiln firing temperature. A 2000°F kiln is usually limited to the red burning shales. White firing bodies for the lower temperature kilns purchased at a hobby shop are mixtures of clays and fluxes. If you are fortunate enough to have a gas fired or high-temperature electric kiln, you will want to evaluate the clay at several firing temperatures. The important items to note after firing are the firing shrinkage, fired color, and percent water absorption.

A. Firing shrinkage. The change in length during firing is expressed as percent firing shrinkage. It is calculated in the same manner as drying shrinkage,

$$(2)\quad \text{Percent Firing Shrinkage} = \frac{\text{Dry Length - Fired Length}}{\text{Original Plastic Length}} \times 100$$

Note that we prefer to calculate the percent firing shrinkage based on the original size of the plastic piece. The dry size is only an intermediate size in the overall hardening process and should not be used as a reference base for calculations. Drying and firing shrinkage may be added to calculate the total shrinkage.

As an example, suppose one has a plastic clay bar exactly 10.0 inches long. After air and oven dryings the length of the bar is 9.5 inches, and after a kiln firing the bar measures 8.0 inches. Using the formulae given, the drying shrinkage would be (10.0-9.5) / 10.0 or 5 percent and the firing shrinkage would be (9.5-8.0) / 10.0 or 15 percent. Thus, the total shrinkage is 20 percent.

Obviously, formula (2) is meaningless in an industry where dry pressing is used. Since there is no drying shrinkage, firing shrinkage is based on the dry pressed specimen and is expressed as:

$$(3)\ \text{Percent Firing Shrinkage} = \frac{\text{Dry Length - Fired Length}}{\text{Dry Length}} \times 100$$

Although (3) is normally of little concern to the hobby potter, one should be aware of its existence, especially since many publications do not specify whether firing shrinkage figures are based on plastic or dry lengths.

There is no specific desired shrinkage value. You can learn to live with any shrinkage for most applications. Drying shrinkage is sometimes critical for slip casting because the amount of shrinkage will determine how long the green casting will remain in the mold. A casting with a high drying shrinkage must be removed from the mold much sooner than a clay with little shrinkage.

B. Fired color. Color varies with impurities, firing temperature, and kiln conditions. It is useful to develop some scheme for describing the colors. A Munsell or similar color system is helpful when describing color in written text. Your local library should have a book containing the Munsell system.

In Kansas clays, iron is the common coloring agent and in an air-fired kiln will generally give buff, salmon, or red colors depending upon the percentage of iron present. As one approaches the maturing temperature (higher temperatures), the color will become darker. If the clay contains a large percentage of iron, the mature ware may appear nearly black.

The reducing atmosphere (and high temperature) present in a gas-fired kiln will often create problems. As mentioned previously, reduction of iron compounds to the molten metal may cause the ware to fuse to the setter tile. Under these conditions, large amounts of iron might cause the ware to collapse (too much liquid phase). By contrast, a small amount of iron might give a desirable fluxing effect such as for the production of a black-spotted ware or a self-glazing body.

C. Percentage water absorption. Water absorption is directly related to the amount of open inter-connecting pore structure. If you want your ceramic item to hold water with no sign of leaking or oozing, it must have almost zero water absorption or be covered with a non-crazing glaze. The word vitrified describes the zero water absorption condition. It means that a sufficient amount of sintering or glass phase has developed to seal the pores from surface penetration by liquids. A qualitative method of evaluating the absorption nature is to moisten the tip of your tongue and touch it to the fired ceramic piece. You will feel a porous piece suck the moisture from your tongue with a slight sticking sensation. After a little practice, you will be able to distinguish different levels of water absorption.

Another test is to immerse the piece in fountain pen ink. Often a drop of ink is sufficient (it's best to use washable ink). If the piece is fully vitrified, the ink stain is only on the surface and can be wiped away by rubbing with a damp cloth. If it is not vitrified, the ink will enter the pore system, staining beneath the surface. Such a stain cannot be removed by wiping with a damp cloth.

If you have a balance, water absorption can be evaluated by determining the gain in weight when a piece is soaked for twenty-four hours in room temperature water. Express your results as percent. Percent terms are more informative because the percent value is independent of the size or shape of the test piece.

4. Slip test.

Substitute the local clay for the clay used in your slip. Adjust water and deflocculent as required. A few clays may have the proper impurity content to be a "natural slip."

WHERE IS A GOOD PLACE TO LOOK FOR CLAY?

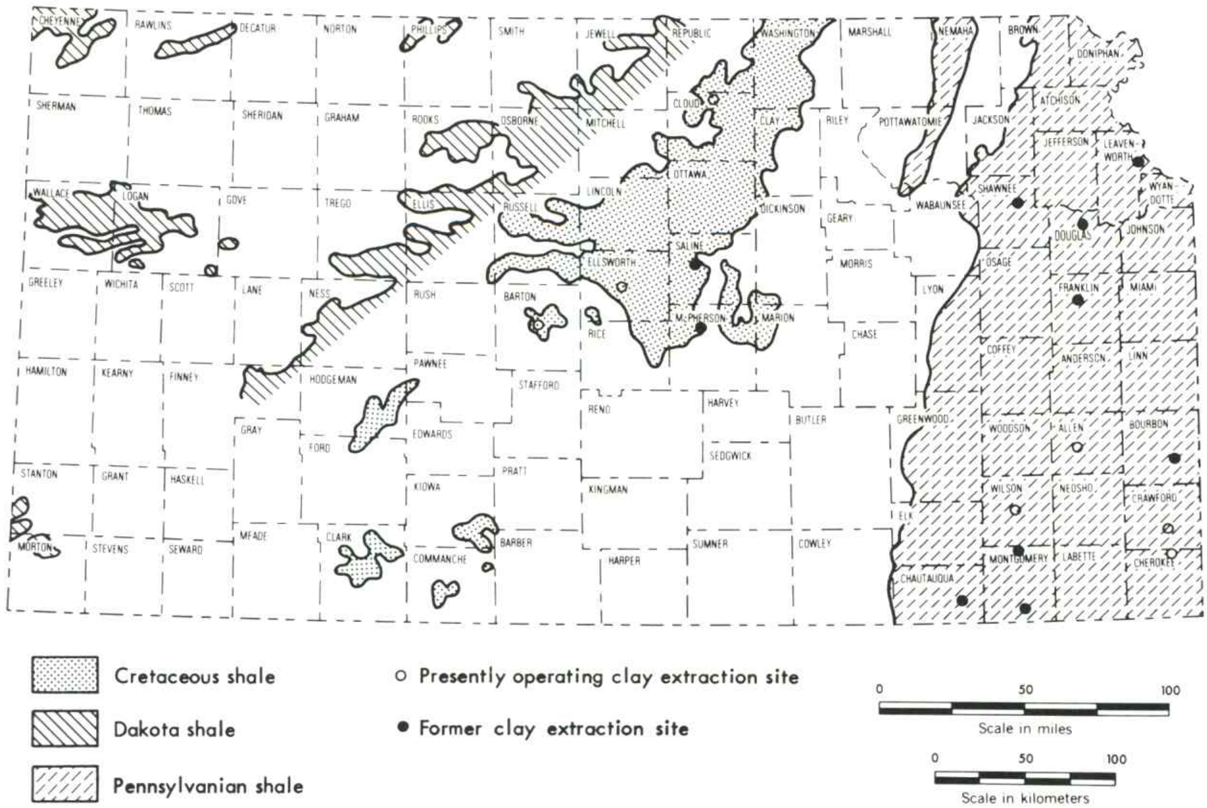
A good starting place would be in a region that has or has had known producers of brick, tile, pottery, etc. However, if this requires long travel, try looking around local streams, excavations, or road cuts. Remember, you don't need a big deposit. A one-foot seam could be a lifetime supply. If you happen to see wasps building mud nests, watch them and locate the source of their mud. Quite often this is a plastic clay of good throwing characteristics.

WHERE ARE THE BEST CLAY PRODUCING AREAS IN KANSAS?

Figure 1 (p. 4) is a generalized geological map of Kansas showing the outcrop areas of the various geological time periods across Kansas. Kansas is almost entirely covered by sediments of old sea bottoms and erosion materials from the slopes of the Rocky Mountains. Most of the usable pottery clays are sedimentary clays, meaning that they were transported and deposited by water. Moving water tends to sort materials into particles that respond in the same manner to flowing liquids. Particles that physically behave the same are deposited together regardless of their chemical composition; hence, most of the clay deposits contain impurities.

The geologists have mapped the rock structures of the state according to time of deposit and type of material. Unless geology is your hobby, you probably will not be able to tell one layer from another without the proper guide literature. Figure 2 presents a generalized picture of geological time spans (p. 7).

The best sources are in the Pennsylvanian shale and Dakota Formation clay regions as outlined on the map in Figure 3. Both regions support active ceramic industries using local shales or clays. Note that the Dakota Formation has suffered erosion and remnants remain in the counties southwest of the main body. The geologic age of the Dakota clay is much younger than the age of the



GENERAL AREAS OF CLAY AND SHALE EXPOSURES

Pennsylvanian shale. A difference in geologic age does not necessarily mean a difference in physical properties for ceramic use.

PENNSYLVANIAN SHALES, EASTERN KANSAS.

Usable outcrops of Pennsylvanian shales can be found in any county of eastern Kansas. Some general areas to look are listed below.

A. Cherokee, Crawford and Bourbon counties. Here we find the red-burning, maturing around 1800-1900°F, Cherokee shales. Also, beneath the southeastern Kansas coal seams is found a refractory clay called an underclay because of its location. It is used locally in the making of sewerpipes and pottery-stoneware. Many schools use these underclays for throwing in their ceramic art classes. Its fired color is buff and requires a higher maturing temperature than the red-firing shales. The impurity content of the underclay varies with location. Some areas have large amounts of pyrite; other areas have too much black organic matter to be usable. The black organic material will not burn out, causing a black interior (black-coring or carbon coring) in the piece. Furthermore, if not removed, some of this material may burn out during the glaze maturing operation and will produce a bubbled or other undesirable glaze texture. Do not use such tight burning clays unless you are able to mix them with an open burning clay which will open the clay's breathing structure and insure proper carbon burnout.

B. Montgomery County. Many years ago, excellent roofing tile and structural clay products were made from the gray and yellowish shales of the Pleasanton group. Good exposures still exist around Coffeyville. Vitrified paving bricks were made from the Cherryvale shale located in the northeastern part of the county. Paving bricks were made from shale having a wide firing range and capable of developing a large percentage of viscous glass within the fired brick. The viscous glass sealed the internal pore structure, making the brick impervious to water.

C. Franklin County. When heated very rapidly, the Weston shale expands to produce a light-weight aggregate. Under normal heating rates, the Weston shale does not expand and is quite usable for ceramic ware.

D. Allen County. The Lane-Bonner Springs shale is used for brick manufacturing although some locations contain limestone and pyrite impurities.

E. Other Counties. Brick plants have also operated at Lawrence and Lansing using the Pennsylvanian shales. Some of the shale layers within the Pennsylvanian rocks are extremely uniform in properties and chemistry throughout eastern Kansas. Usable outcrops of Pennsylvanian shale can be found in any county of eastern Kansas. Underclays are only found in regions having coal deposits.

DAKOTA FORMATION, CENTRAL KANSAS.

The Dakota Formation, Figure 3, contains some of our best pottery clay. Approximately one-third of the deposits are white-firing to buff-firing and two-thirds are dark buff-firing to red-firing clay. Kaolinite is the dominant clay mineral. Limestone impurities are generally absent. Three brick plants use the clays to produce a wide color range in face bricks. In the past, potteries have used the light-firing clays in their bodies.

Dakota clays are generally of the more refractory type requiring firing temperatures above cone 6 (2194°F) to produce proper fired strength and water absorption.

Dakota Formation deposits are of uneven thickness and often of a "pocket" nature. The beds are not continuous for long distances. Some of the white clay is associated with sandstone. Washing will separate the clay from the sand.

General types of clays available are kaolins, ball clays, fireclays, stoneware clays, terra cotta clays, and siliceous clays. Pyrite is a common impurity in the dark-firing clays. A full range of firing colors can often be found within a small area.

The Kiowa or Graneros shales of the region are not recommended as they have poor drying characteristics.

LOWER PERMIAN SHALES.

In McPherson County, south of Lindsborg, several exposures of Ninnescah shale are found along stream banks. The shale contains enough fluxes to become self-glazing or can be used in making slip glazes maturing around cone 5 (2151°F). This could be an interesting material. It fires a reddish brown.

CRETACEOUS SHALES OF WESTERN KANSAS

The Pierre shale and Blue Hill shale are of questionable value as a pottery clay. They have poor drying characteristics because of large amounts of montmorillonite clay minerals present. However, if mixed with a non-plastic material such as local volcanic ash, some interesting combinations might develop.

LOESS MATERIALS

Vast areas of Kansas are covered with a material called loess, a wind-deposited material consisting of a mixture of fine silica, varying quantities of clay minerals, mostly illite and montmorillonite, and usually some calcium carbonate. Any ware produced from loess usually will be of poor quality.

ALLUVIAL DEPOSITS

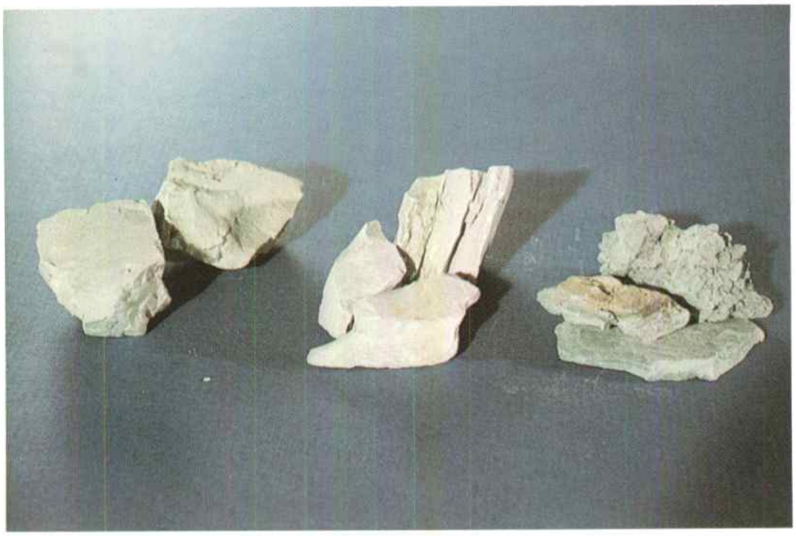
Alluvial clay deposits are water-deposited clays, often found along stream beds or in regions where the streams once flowed. Clay quality varies from excellent to worthless. Much of the early Indian pottery was made from alluvial clay, mainly because the clay could be dug in the moist condition ready for shaping.

SUMMARY

In conclusion, this paper has described some general rules of thumb to follow when searching for hobby potter clays. One should remember that various impurities may make the clay unusable or greatly affect the physical properties of the clay. Relatively fast and inexpensive methods have been suggested for both field and lab testing in order to evaluate a given clay. In addition, general areas have been suggested in which to find clays for your particular interests. If you look long enough, you will find a clay in Kansas that will suit your personality and requirements.

Illustrations

An early stage in the throwing process which led to the vase on the cover.



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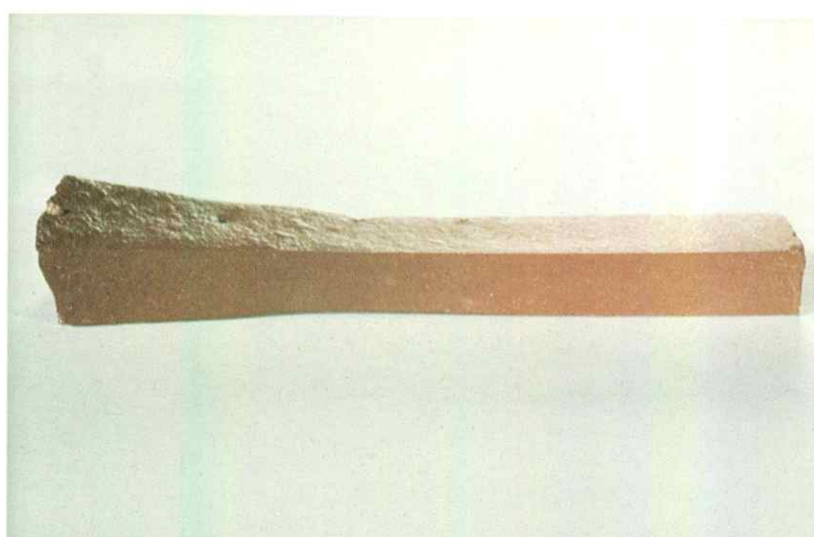
Clay versus shale. The sample on the left shows the texture of a typical clay while that on the right is a typical shale. The major difference shown in the photograph is the lamination or layering common to shales. The middle sample shows only a small amount of lamination and is also defined as a clay.

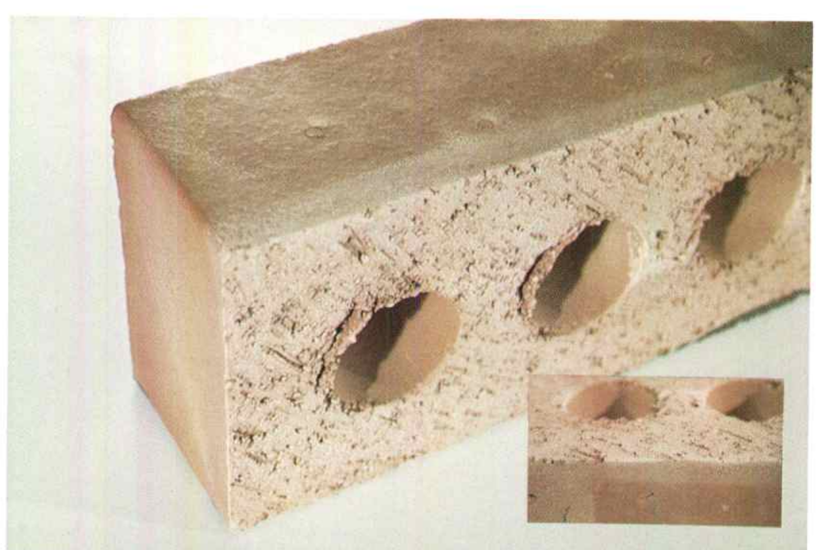
A sample of black Eudora shale (eastern Douglas County). The color is an indication of the shale's high organic content. Also shown are small white crystals of gypsum that occur between the layers of shale.

An example of unfired (upper left, lower right) and fired (lower left, upper right) clay colors. Despite the differences in color of the unfired samples, both produce a reddish fired color. This is a good example of how the unfired clay color cannot be used to predict the fired color.



A bar specimen which has been subjected to a gradient furnace firing. The middle of the bar shows the maximum shrinkage (as well as maximum strength and minimum porosity) and represents the maturing range or maturing temperature of the clay. The dark colored, highly expanded portion of the bar has been overfired and the clay has bloated. The opposite end of the bar has been underfired.

The effect of scum or efflorescence is obvious on sample I. Made from the same clay, a small amount of barium carbonate was added to sample II which effectively converted the soluble sulfate salts to insoluble barium sulfate. This procedure eliminated the migration of soluble salts to the surface and hence no scumming or efflorescence occurred.



Another example of scumming. In this case an abnormally high concentration of soluble salts coupled with an insufficient addition of barium carbonate produced the scum.

Glossary

The following terms are found in articles dealing with the hobby aspect of ceramics. Many of the terms are also used in the ceramic industry. The list of definitions or explanations is provided so that any reader will have a better understanding of the subject. The glossary will be especially helpful for the beginning hobby potter.

Any word in bold typeface in the glossary text indicates that this word is defined in the glossary.

Aging. The process of storing clay or a clay body containing water in a sealed container to obtain a uniform moisture content throughout the clay or body. The process can be accelerated by **tempering** in which a pan mill is used to help disperse the water. If the clay has a high organic content, bacterial action during aging may create a foul odor.

Alluvial Clay. A clay of variable composition found in past or present river valleys.

Ball Clay. A fine-grained, very plastic clay which is often added to a body or glaze and acts as a bonding or suspending agent. Such a clay fires to a white or off-white color and usually matures between cones 5 and 10.

Batch. A general term which describes any mixture used to form a ceramic body, glaze, etc.

Beneficiation. In ceramics, any process which increases the purity or quality of the clay. For example, a clay slip may be screened to remove all coarse particles or dry screening may be used to remove coarse particles of limestone or other impurities from a clay.

Bentonite. A clay formed by the weathering of volcanic ash and commonly found in the western and northwestern parts of Kansas. The Kansas bentonites usually expand when they absorb water and have a high **drying shrinkage.** Such properties make the pure clays poor candidates for ceramic bodies. However, they can function as bonding or suspending agents (see **montmorillonite**).

Binder. Any substance which is added to a relatively non-plastic ceramic body in order to increase the adherence of particles in the body and increase the strength of the body during shaping, pressing, etc.

Bisque Firing. The process of firing a ceramic object before it has been glazed. Such unglazed but fired ware is called bisque ware.

Black Core. The result of rapid firing a tight burning clay which contains appreciable carbonaceous material, thus producing ceramic ware with a black or dark gray interior.

Black Speck. Dark spots on ceramic ware, usually resulting from small particles of iron.

Bloating. A process accomplished in some clays by overfiring or rapid firing to the **vitrification** range of the clay body. The glassy phase is sufficiently viscous to trap air or gas bubbles which originate from entrapped air or the decomposition of impurities like sulfides or carbonates. The resulting body is permanently expanded and possesses a frothy or foamy texture.

Bond. A term of many uses. With regard to fired ware, the bond is the pore-filling material (glassy or crystalline) which gives the body its strength.

Burning. An alternative term for **firing.**

Calcareous Clay. A clay containing an appreciable amount of **calcium carbonate** and generally unsuitable for a ceramic raw material.

Calcite. The mineral name for **calcium carbonate,** $CaCO_3$.

Calcium Carbonate. $CaCO_3$ (see **limestone**).

Casting. 1) A piece which has been formed by casting.
2) A process for forming ceramic objects in which the **slip** is poured into a plaster mold and the latter absorbs water which in turn produces the build-up of the wall of the ceramic body. When the desired wall thickness is obtained, the excess may be poured out of the mold (**hollow casting**). **Solid casting** refers to the process of forming a solid object by continual addition of slip until the object is solid.

Ceramic. In terms of the fine arts, a ceramic is an object made from clay (s), or clay (s) with various additions, and fired.

Ceramic Whiteware. A white-burning ceramic body composed mainly of clay and other materials. This broad category of ceramics includes sanitary ware, tableware, tiles, etc.

Chalk. A soft rock composed of poorly bonded, fine grained **calcium carbonate.** Highly pure chalk is often called **whiting** and is added to certain bodies and glazes. The chalk beds common to Kansas are not pure enough to be classed as whiting.

Chert. A relatively light-colored, cryptocrystalline form of **quartz.** When such material is dark, it is called **flint.** Both **chert** and **flint** are common in Kansas, notably in certain beds of **limestone.**

China Clay. A white-burning, relatively pure **kaolin** whose best known locations include the southeastern United States and Cornwall, England. The term is now applied to all beneficiated **kaolin.**

Clay. A fine-grained, earthy aggregate of widespread occurrence composed primarily of hydrated aluminosilicates and used as the major ingredient in ceramic bodies.

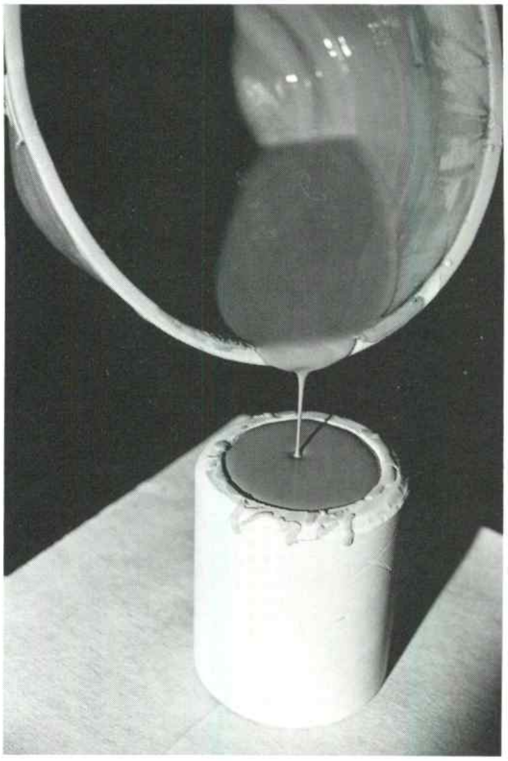
Crazing. Cracks which form in a glaze during or after cooling the glazed ware which result from the glaze having a higher thermal expansion than the body. Crazing can also result from stresses produced by the body upon absorbing moisture.

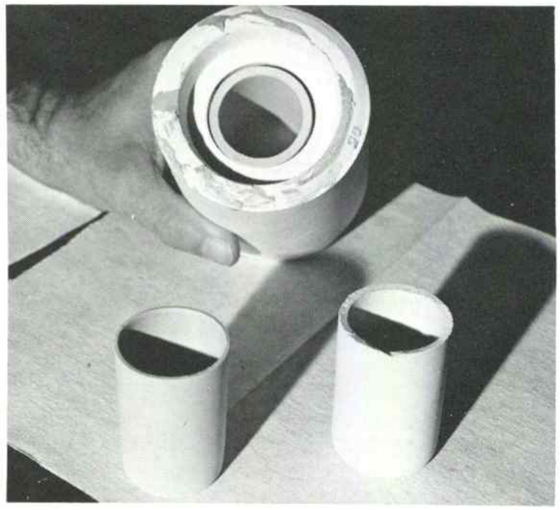
Deflocculation. The process of dispersing or separating particles of clay in a slip by adding an alkaline substance such as sodium silicate. Slightly acidic substances produce the reverse condition, **flocculation,** which causes clay particles to lump together and settle rapidly. For a uniform casting, it is always advisable to disperse or deflocculate the clay.

Dry Pressing. The process of pressing a ceramic batch (normally in a steel mold) which contains very little water, usually 10 percent or less.

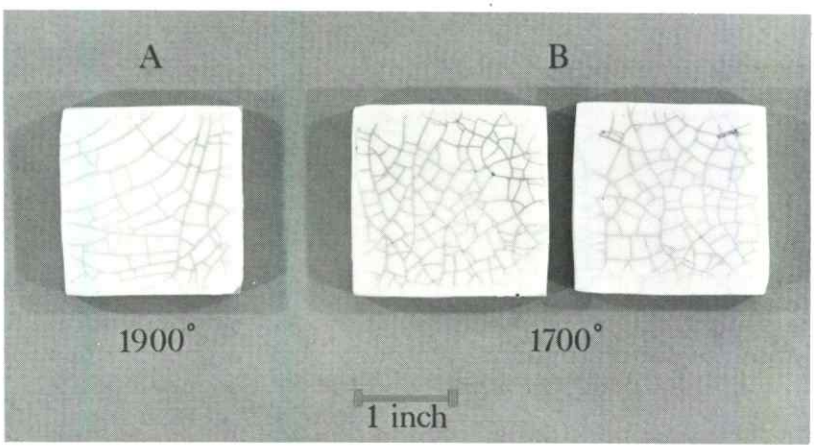
Dry Strength. The mechanical strength (usually flexural strength) of a dry, unfired ceramic body.

Drying Shrinkage. The shrinkage a ceramic body undergoes during drying. It is usually expressed as a linear percent based on the original or wet length.





The process of slip casting involves pouring a deflocculated mixture of clay and various additives (flint, feldspar, talc, etc.) into a plaster mold. The porous plaster absorbs the water and a layer or coating of the clay body is formed on the mold walls. After pouring out the excess slip and allowing a "drying" period, the clay body shrinks and begins pulling away from the mold walls. At this point, the ware can be gently removed from the mold. Remember, the ware is still very wet and easily deformed so it must be handled gently. Removing the ware too soon (still sticking to the mold) or allowing it to dry and shrink too much will normally ruin the casting.



Examples of crazing that has resulted from a mismatch in the thermal expansion of a glaze and the body to which it is bonded. The glaze has a much higher expansion. During cooling, the glaze wants to contract at a greater rate than the body but cannot since the glaze is bonded to the body. As a result, the surface of the glaze is thrown into tension and this stress is relieved by cracking or crazing. Ideally, the expansion of the glaze should be slightly less (5%) than the body so that the glaze is thrown into compression. Too great a compressive stress is also undesirable since the glaze may ripple, crack or in extreme cases, may pop off.

Earthenware. A category of non-**vitreous** ceramic ware commonly glazed and used as tableware.

Efflorescence. A **scum** of soluble salts, normally sulfates, deposited on the surface of a ceramic body by moisture which migrates from within the body to the surface. In industry the **scum** is normally eliminated by the addition of $BaCO_3$ to the raw material (insoluble $BaSO_4$ is formed). The terms scumming or **scum** are often used interchangeably with efflorescence. However, **scum** is a broader term which includes white deposits which form during the firing of ceramics (**kiln scum**) and areas of poor gloss on a normally glossy glaze or enamel.

Extrusion. The process of pressing or forcing a clay body with the consistency of stiff mud through a die (usually by means of an auger feed). Such a process is used in making brick and sewer pipe.

Feldspar. A primary constituent of most igneous rocks, feldspars are aluminosilicates (commonly of sodium, potassium and calcium) that are often added to ceramic bodies, especially pottery and whiteware bodies, to act as a **flux.**

Fireclay. A clay which has a **pyrometric cone equivalent,** P.C.E., of 19 or greater. A clay with a P.C.E. of $\geqq 27$ is called a **refactory clay** while a P.C.E. of 19—26 denotes a low duty fire clay.

Firing Shrinkage. The shrinkage a ceramic body undergoes during firing. It is expressed as a linear percent between the fired and original size (the latter may be the plastic or dry state and should be specified).

Flint. See **chert.**

Flocculation. See **deflocculation.**

Flux. Any substance in a material or **batch** which will lower the normal fusion temperature of the material.

Gel. A term which describes a slip that has set-up or developed a consistency resembling jello or gelatin.

Glazing. A term with several meanings but commonly used to describe the process of applying a glaze to a ceramic body (**greenware** or **bisque ware**). The glaze batch or raw slurry is usually applied with the aid of a brush, spray gun, or by dipping the ware into the glaze slurry. The ware is then fired to produce the glaze, a glassy layer covering the ware.

Greenware. Any unfired ceramic object.

Grog. A non-plastic material (often material which has been previously fired and crushed) which is added to batches to minimize their shrinkage during drying and firing. As an example, faulty brick may be crushed and added to the brick batch prior to extrusion.

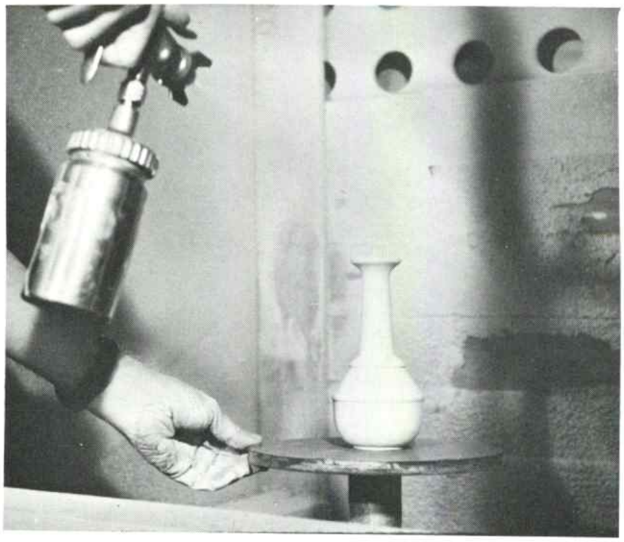
Gypsum. The dihydrate of calcium sulfate, $CaSO_4 \cdot 2H_2O$, which is used as a starting material for the production of plaster of Paris, $CaSO_4 \cdot 1/2H_2O$. The mineral occurs in Kansas. Forms of calcium sulfate are a common brick scum (see **efflorescence**).

Illite. One of the basic clay types (along with **kaolinite** and **montmorillonite**) common to Kansas. The category includes all of the micaceous clay minerals and thus illites have variable compositions.

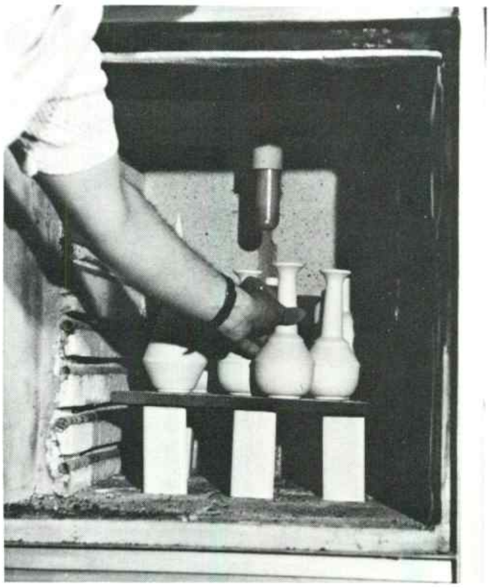
Jiggering. The process of taking plastic clay, placing it into a rotating mold and then shaping the clay to the mold by using a forming tool.

Kaolin. A light-firing clay composed primarily of kaolinite, $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$, and used to make a variety of products (especially china). In Kansas, kaolinitic clays are found in the Dakota Formation and are primarily used to make light colored brick.

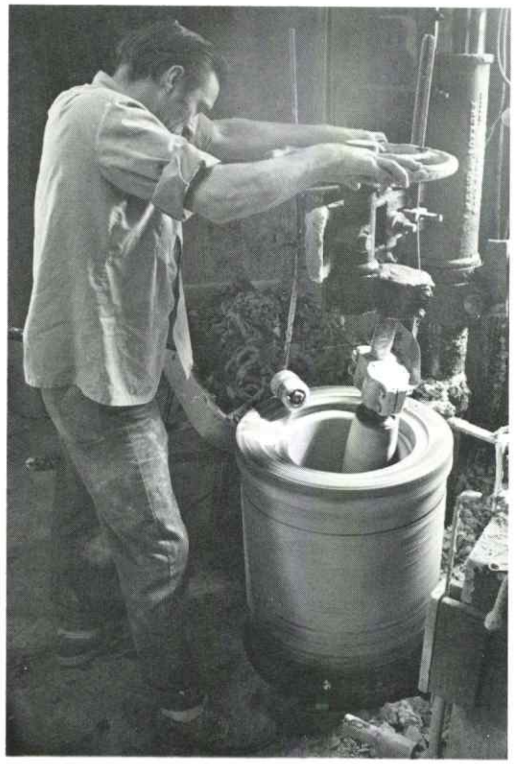
Kiln. A chamber used to fire ceramic bodies. A variety of kiln shapes are used but they are nearly always electric or gas-fired.



Using a spray booth to glaze a piece of bisqueware. Spraying normally produces a uniform glaze thickness. In this example, the undersides of the ware are first sprayed while rotating the ware by hand. The sides and top surface are then sprayed, rotating the ware on a handpotters wheel.



Looking inside a typical kiln heated by wire elements. The ware has been given a bisque firing and after removal from the kiln can be glazed. Note that the ware is not placed on the floor of the kiln but rather on a setter tile elevated by stilts. In this manner, the ware is located in the central portion of the kiln where the temperature is more uniform and the ware is exposed to approximately the same temperature as that recorded by the thermocouple (suspended from the roof or back of the kiln).



An example of jiggering. This photo was taken at Pittsburg Pottery (Pittsburg, Ks.) where jiggering is used to produce various sizes of stoneware crocks.

Kiln Furniture. The refractory pieces used to support the ceramic items in a kiln.

Lime. Calcium Oxide, CaO. It is produced by the thermal decomposition of calcium carbonate. It is an undesirable impurity in pottery since it may shorten or narrow the maturing range of the ceramic body and tends to "bleach" the iron-red color. In coarse pieces, it may produce **lime pops.**

Lime Pop. A hole on the surface of a ceramic product produced by the popping or falling out of small pieces as a result of expansions of lime pieces when they become hydrated by moisture from the atmosphere.

Limestone. A major type of sedimentary rock which is primarily composed of **calcium carbonate** and is especially common in Kansas. Although it is not a desirable component of some ceramic bodies, it is used extensively in cement production.

Loess. A wind-deposited material generally described as a clayey silt. It is common in Kansas but is normally not used for ceramic operations because of its variable composition.

Maturing Temperature. The temperature at which a ceramic body develops the optimum degree of **vitrification,** or melting. In general, a body fired at this temperature approaches zero water absorption and shows maximum shrinkage and strength properties. The **maturing range** refers to the range of temperatures over which the body can be fired to obtain maturity. Excessive fusion or melting will cause the ware to slump and/or **bloat.**

Modeling Clay. Any plastic clay used for modeling.

Montmorillonite. A category of clay mineral found in Kansas. It is the major constituent of **bentonite.** Chemically, it is a hydrated aluminum silicate of magnesium which often contains some sodium (swelling bentonite) or calcium (non-swelling bentonite).

Plasticity. The property of moistened clay which allows it to be shaped or permanently deformed without cracking.

Potter's Clay. Any plastic clay suitable for shaping on a potter's wheel.

Pottery. A general term for domestic ceramic ware which includes ware made by **slip casting** as well as that made by **jiggering** or on a potter's wheel.

Pyrometric Cone. A device used to monitor thermal treatment of ware or thermal gradient within the kiln. The cone is a slender, triangularly based pyramid of exact size and composition. The composition is such that at a specified temperature, the cone will bend into an arc and the tip of the cone will become level with the base. There are series of such cones (Orton Cones in the United States) which bend at different temperatures (each temperature has a specific cone number).

Pyrometric Cone Equivalent. A cone number which describes the refractory quality of a body.

Pyrite. The common mineral name for iron disulfide, FeS_2. It is often found as an impurity in Kansas clays.

Quartz. The mineral name for the common form of silicon dioxide or silica, SiO_2. This crystal structure is found in silica **sand, chert,** and **flint.**

Raku Ware. Single fired ware which is usually thick-walled and covered with a low firing glaze (700-800°C), nearly always a lead borosilicate glaze.

Sand. Quartz in loose granular form. In some cases the word sand is also used to define loose granular forms of other minerals.

Screen. A wire mesh of specified size used to collect or remove certain sized particles of a mineral. The process of screening is often used to beneficiate materials.

Scum. See **efflorescence.**

Setter. A piece of **kiln furniture.**

Setting Sand. Clean silica sand or alumina on which ceramic ware such as pottery is placed in the kiln.

Shale. Shales are **clays** which have undergone consolidation and consequently have become hard and laminated.

Sieve. A screen, generally used in the laboratory or for small samples (see **screen**).

Silica. See **quartz, chert.**

Siliceous Clay. A clay containing significant amounts of **silica,** either as visible grains, e.g. **sand,** or finely disseminated cryptocrystalline material, e.g. **flint** or **chert.**

Single Fired Ware. Ware in which the glaze batch is applied to the green or unfired body and then given a single firing (**bisque** and **glaze** firing done simultaneously).

Sintering. The process which produces shrinkage and the development of strength during the firing of ceramic bodies. The ceramic material or object (powdered, **slip cast,** pressed, or **extruded**) is heated below its fusion point but at a high enough temperature to cause solid state reaction or material transport into the pore spaces.

Slaking. The flaking or falling apart of clay when placed in water. A clay that shows no slaking is unsuitable for hobby potter use.

Slip. A suspension of clay(s) or ceramic materials in water.

Slip Casting. See **casting.**

Slip Clay. A clay which by itself acts as a natural glaze. In general, such clays fuse between cones 5 and 10. Kansas has one such deposit, namely the Ninnescah Shale near Lindsborg, Kansas.

Soaking. The term (in the preparation of ceramics) refers to holding the ware at some temperature to obtain optimum properties.

Soda Ash. Anhydrous (water free) **sodium carbonate.**

Sodium Carbonate (Na_2CO_3). Like **sodium silicate,** it is commonly used to deflocculate clay. The compound is also used as a major component in glass batches.

Sodium Silicate. As used in the field of ceramics, liquid sodium silicate is perhaps the most commonly used deflocculant of clay slips although it is often used with **soda ash.**

Soluble Salts. See **efflorescence.**

Stoneware. A **vitreous,** opaque type of ceramic ware which is typified by high strength and commonly used as tableware, cooking ware and studio type ware. A **stoneware clay** is very plastic, has a long maturing range (approx. cone 4-10) and a variable but light color when fired (buff or gray).

Tempering. See **aging.**

Terra Cotta. A general name for ceramics used as architectural shapes (unglazed or glazed building blocks and molded ornamental trim) or vases and statuary. A terra cotta clay must have sufficent plasticity for molding and is generally a **fireclay** or **stoneware clay.**

Thixotropy. A word used to describe the property of many clay **slips** which tend to become more fluid when stirred.

Throwing. The term describing the shaping of plastic clay on a potter's wheel.

Underclay. A clay which occurs directly beneath a coal bed. Such clays often contain appreciable carbonaceous material. In southeastern Kansas, such clay is used to make sewer pipe and stoneware.

Viscosity. Expressed simply, one can think of viscosity as the degree of thickness, fluidity or pourability of a slip.

Vitreous Ware. Ware of extremely low porosity as a result of extensive **vitrification.** Ware containing a considerable amount of a glassy phase is generally vitreous. Its porosity or water absorption is less than 0.5% (except for floor and wall tiles which can have up to 3% water absorption and still be termed vitreous). **Semi-vitreous** ware is whiteware possessing a water absorption of 0.5% to 10% (except floor and wall tile which have 3% to 7% absorption in their semi-vitreous state).

Vitrification. The process of developing a glassy bond in a ceramic material as a result of the partial fusion of the clay or other component in a body.

Water Absorption. Related to porosity, water absorption is simply a percentage figure describing the weight of water absorbed by a body as compared to the dry weight of the body.

Weathering. A physical and/or chemical breakdown of a material by prolonged exposure to natural elements. The process usually produces clay with a relatively uniform moisture content. It may also leach out undesirable soluble salts and oxidize any pyrite present.

Wedging. The process of repeatedly throwing a lump of moistened clay on a hard surface in order to obtain a more uniform moisture content and to remove considerable air and laminations in the clay. Sometimes tightly stretched wire is used to cut through the lump during throwing and the pieces can be rejoined in a random manner which helps to eliminate laminations.

Whiteware. See **ceramic whiteware.**

Whiting. A common term for relatively pure powdered calcium carbonate. See **chalk** and **limestone.**

Workability. See **plasticity.**

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Many of the earlier Geological Survey publications are now out of print. Please write the Kansas Geological Survey for information about the clay resources in specific locations.

Kansas Geological Survey
University of Kansas
Lawrence, Kansas