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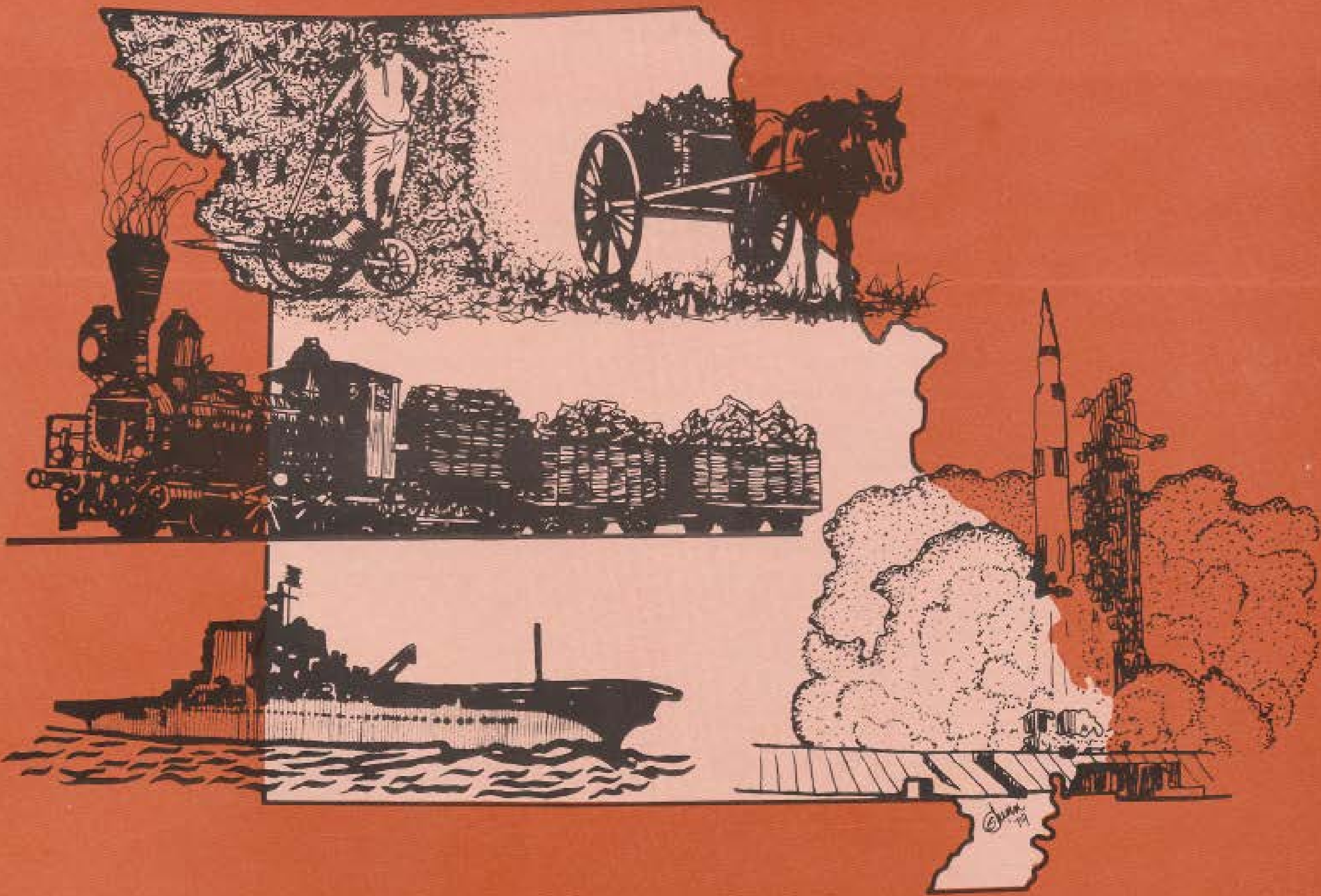

DIASPORE —

A DEPLETED NON-RENEWABLE MINERAL RESOURCE OF MISSOURI

W.D. KELLER

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A DEPLETED NON-RENEWABLE MINERAL RESOURCE OF MISSOURI

A Historical Overview Of Missouri's Most Basic Industrial Mineral.

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THE LURE of mineral wealth and prospecting for deposits have fascinated mankind for centuries.

INTRODUCTION

This is the story of the discovery and depletion of Missouri diaspore, a non-renewable mineral . . .

The lure of hidden, buried mineral wealth, and prospecting for mineral deposits, have fascinated mankind for as many years as there is historical record. Search for precious gems, gold, silver, uranium, and petroleum has generated book-long accounts. Unfortunately, less spectacular earth materials, although they may be the most basic of all industrial materials, have been relatively unpublicized. This account will call attention to such earth material — diaspore — of which the State of Missouri was for a short time the world-leading producer. It is appropriate that the story of Missouri diaspore be documented now while eyewitnesses to the events are still living.

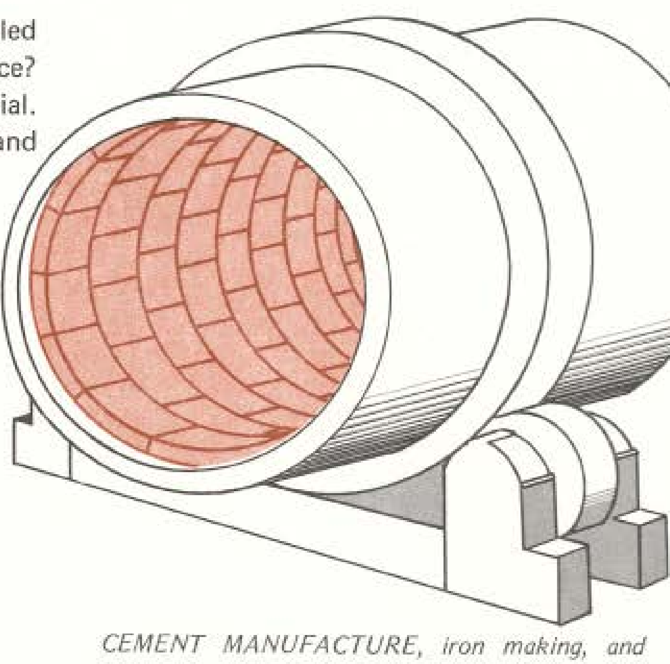
There is more, however, to this narrative than diaspore, *per se;* it cites an example of the discovery, waxing, peaking, waning, and depletion of a non-renewable mineral resource, all occurring within one generation. It is an example of the sequences and fates that presently are in the process of occurring with respect to other non-renewable mineral resources for the USA.

THE NATURE AND USE OF DIASPORE

Because the search for and finding of mineral wealth is the most exciting part of the event, prospecting for diaspore will be the approach used to guide this story. It will trace, in non-technical style, the prospecting tools and methods and accompanying technology evolved by Missouri ingenuity, from relatively primitive beginnings to now highly sophisticated operations.

Why was diaspore, also popularly called diaspore clay, of such basic importance? Diaspore is a superior refractory material. Refractories (also called "fire bricks", and

Prospecting for diaspore has evolved from primitive tools and methods to highly sophisticated operations . . . . .

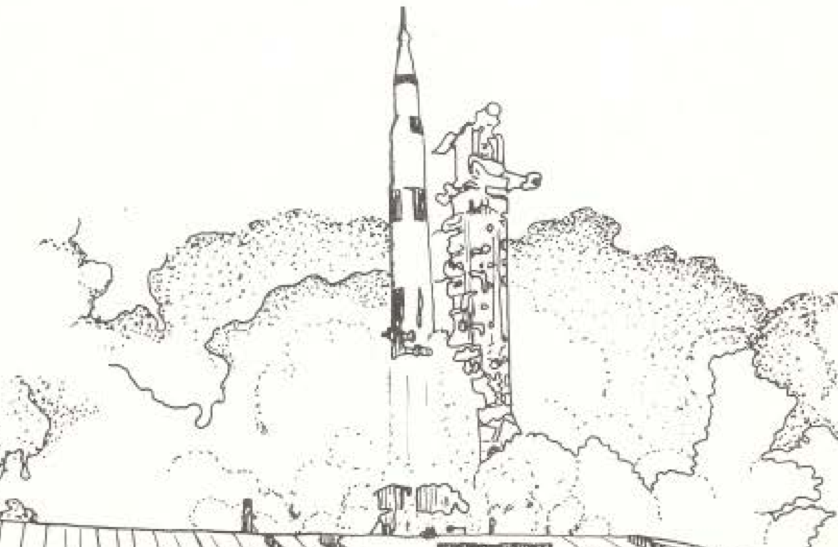


CEMENT MANUFACTURE, iron making, and other "basic industries" could not exist without refractories.

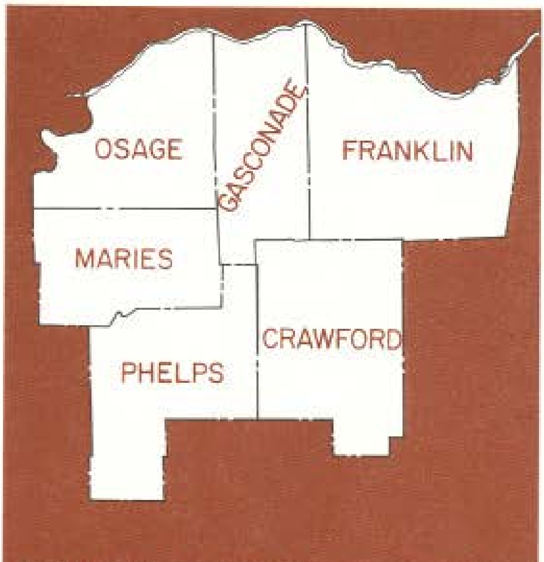
their accessories) are substances that remain solid, intact, and protective to dazzlingly high temperatures at which glass, iron, gold, and other metals are melted and refined. Whereas an iron pot contains and protects the "mess of beans" while they are cooking over a fire, refractories serve as the protective "pot" in which iron and glass are melted and contained within a hotter fire. Diaspore resists fusion to a temperature of about 3250° F (1800° C) whereas cast iron melts at about 2200° F (1200° C). Therefore, if there were not refractories, the more popularly publicized "basic industries" (iron making, metal refining, etc.) could not exist – hence refractories are more basic even than the vaunted "basic industries".

MANY BOILERS in Liberty Ships and U.S. warships were protected by diaspore refractories from Missouri (top). LAUNCH PADS used for Apollo lunar missions were surfaced with Missouri refractories also (bottom).

Missouri diaspore has been used and shipped worldwide, not uncommonly where transportation cost exceeded that of the raw materials. It played a significant role in the national effort during World War II, and in national history. Many of the boilers of Liberty Ships and U.S. Navy warships were lined, i.e., protected, by versatile, 60-percent, high-alumina diaspore refractories. More recently, the launching pads of Apollo lunar missions were surfaced by Missouri refractories, the successors to old diaspore bricks. Refractories are indeed basic to the industrial age.

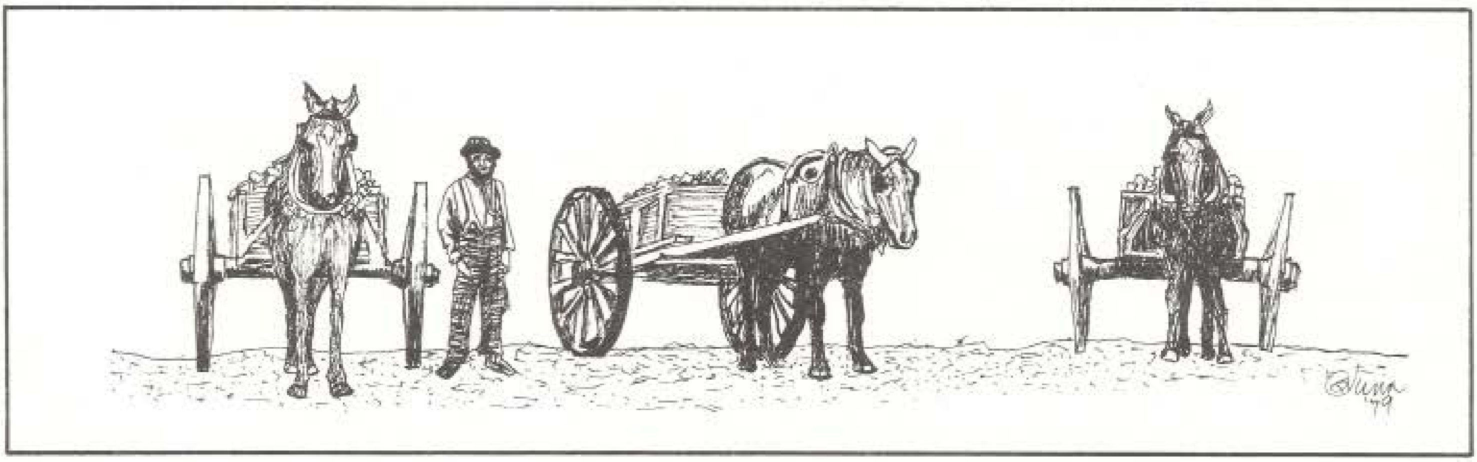


A half-dozen rural counties in east-central Missouri – Osage, Gasconade, Franklin, Phelps, Maries, and Crawford – were the scene of diaspore production which waxed and waned between 1920 and 1950. During its heyday, or "rush", the diaspore country had, only on a smaller scale, all the typical excitement, glamour, and human pathos that accompany a gold, uranium, or petroleum rush. A much longer historical narrative than this one (which documents only certain non-reenactable events and no-longer-existent equipment) awaits preparation by someone. It, likewise, should be written while eyewitnesses and participants are still living.



FROM 1920 TO 1950, diaspore was produced in a few east-central Missouri counties.

To understand the rationale used to prospect for and produce diaspore, a short description will be given of diaspore and its deposits. In Missouri, diaspore is an earthy, high-alumina mineral, $Al_2O_3 \cdot H_2O$; by weight ideally 85 percent Al_2O_3 (45 percent Al metal), and 15 percent water. It could have been a rich ore of aluminum, but diaspore produced in



DIASPORE CLAY was hauled from open mine pits by horse-drawn wagons in the early days.

A "STIFF-LEG" HOIST was used to lift clay to a stockpile and onto trucks at the rim of this pit near Belle, Mo. The power to lift the clay was generated by a motor salvaged from an automobile. Photo, about 1930.

Missouri was found to have greater value for refractory use, as was described. Although diaspore is technically not a member of the clay-mineral families, it has many times been popularly called diaspore "clay" because of its earthy appearance and close association with clay minerals.

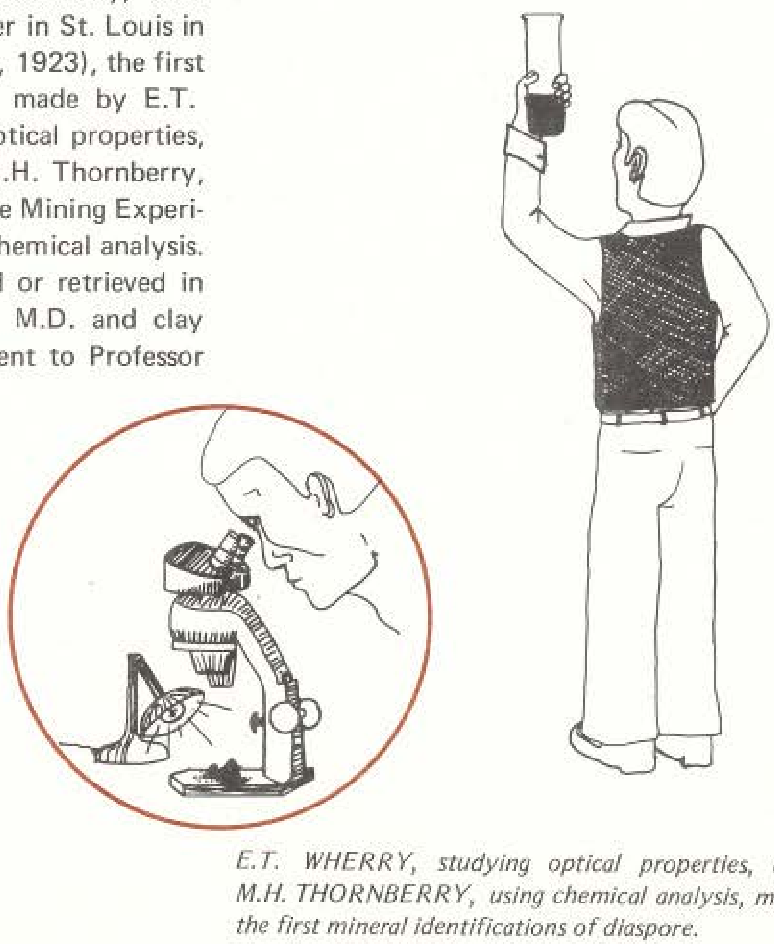
Diaspore occurs, intimately and genetically associated with flint clay (a true kaolin clay), in cone-shaped deposits that are exposed at the earth's surface and that taper downward. Typically, the deposits range from a few yards to perhaps 100 yards in diameter. The deposits, or "pits", may be as much as 100 feet deep, although most open mines were not more than 60 feet deep. As pits deepened, ramps or "runways" were left in the clay to provide truck access to the working faces of the mines. In the earliest days, some haulage was by wagon and horses. Ultimately, clay in the runways was recovered, and deep or steep-walled pits were worked by use of automobile-engine driven hoists, locally called "stiff-leg" hoists.

These pits or deposits are loci of geologically ancient (Pennsylvanian-age, 250 million years old) sinkholes that were dissolved from still older rocks (mostly Ordovician-age, deposited 450 million years ago). Sandstone typically lines the pit walls, enclosing a clay core composed of flint clay and diaspore which are usually mixed in large, irregular layers or lenses. The sandstone liner may be more resistant to erosion than are flint clay and diaspore, and therefore may physically stand out as a partially preserved "rim rock" surrounding the deposit. This feature aided in finding pits early in diaspore exploitation.

IDENTIFICATION OF DIASPORE

The first formal identification or "official discovery" of diaspore as a mineral (alternatively once called diasporite) in Missouri was about 1917. Although some of the "clay" had been adventitiously, and successfully, used by a refractories manufacturer in St. Louis in 1908 and in 1914 (Crawford, 1923), the first mineral identifications were made by E.T. Wherry in 1917, based on optical properties, and in the same year by M.H. Thornberry, chemist in charge of the State Mining Experiment Station at Rolla, using chemical analysis. A sample, presumably found or retrieved in 1917 by Dr. W.S. Cox, an M.D. and clay shipper of Cuba, Mo., was sent to Professor Thornberry for analysis.

The first official discovery of diaspore as a mineral in Missouri was about 1917 . . . . .



E.T. WHERRY, studying optical properties, and M.H. THORNBERRY, using chemical analysis, made the first mineral identifications of diaspore.

THE LATE A.O. BLEDSOE is pictured by a tombstone, carved from Missouri diaspore, in a small cemetery on the Dube Stockton farm near Belle, Mo. Circa 1940-45.

It was an entertaining experience to hear Thornberry, a kindly, deep-voiced, gruff speaker, who typically used expressively colorful language directed straight to the point, narrate his frustrating first bout with the unidentified material. Thornberry, observing the clayey nature of the sample sent to him, pulverized it, mixed it with sodium carbonate (the conventional flux), and heated it routinely in a platinum crucible. After the routine fusion period, he poured out the melt, but to his consternation (superlatives deleted), the "clay" had not dissolved. He prepared a new mix with twice the amount of flux and put it back over a hotter flame for fusion. Again, believe it or not, the stubborn (refractory!) "clay" did not dissolve. He left it over the fusion burner for the remainder of the half day, but still it did not succumb ("goodness gracious!"). By now it had become a professional challenge to this expressive Show-Me Missourian.

He recalled the use of sodium hydroxide to dissolve and analyze Arkansas bauxite, and transferred the Missouri "clay" to a nickel crucible containing the new flux, and all went well. The technique, but without Thornberry's personal narrative, is described in a publication (Thornberry, 1925).

Prior to its mineralogic identification, diaspore had been discarded by farmers (and possibly by geologists?) as an essentially worthless rock, although occasional use of it had been made on farms for foundation stones for buildings. Certainly it would resist weathering processes and it could be worked to dimension. At least one tombstone in a local cemetery was carved from diaspore, probably a unique use in the entire world (see photo, this page).

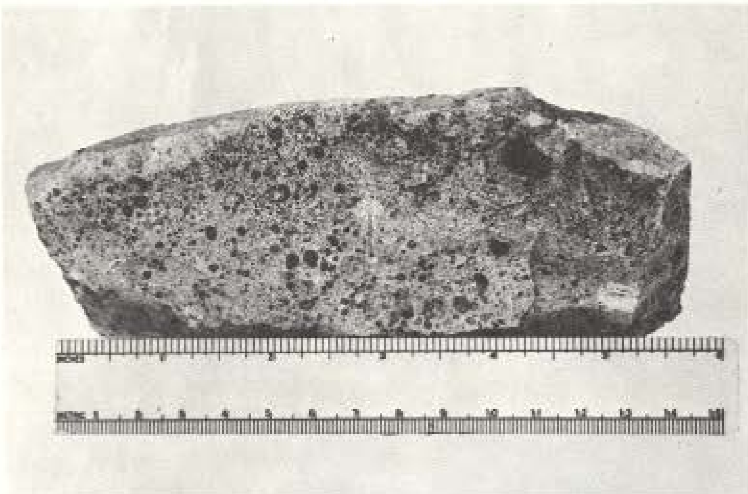
After identification of the material, which was followed by immediate realization of its technologic and economic value as a refractory substance, commercial demand for diaspore quickly rose. Refractories companies found it more easily processed and less costly than bauxite (now being used again in 1978) transported from Arkansas, Alabama, or the Guianas in South America. Premium prices, double to quintuple (or even higher) those paid for other high-heat duty refractory clay, were offered. Immediately diaspore became a highly-sought, profitable, cash-producing, aristocratic earth material in rural counties, previously long characterized by the agricultural life-style of their residents.

A new local industry sprang up, with diaspore being shipped from such towns as Bland, Belle, Owensville, Hermann, Chamois, Rosebud, Gerald, Rolla, and Cuba. Clay shippers rose in the social hierarchy. Clay scouts, or prospectors, originated a new profession. Many of them became "instant" amateur, self-trained "diaspore geologists". They more or less knew, from prior acquaintanceship with the rocks, such varieties as sandstone (rim-rock), limestone (mostly dolostone in the diaspore area), flint clay, plastic clay, "rough clay or diaspore", "kaoleen" (tripolitic chert), and hardpan gravel, and recognized the local topography simply as prairie and creeks. Their terminology was entirely unencumbered with "geologese" jargon.

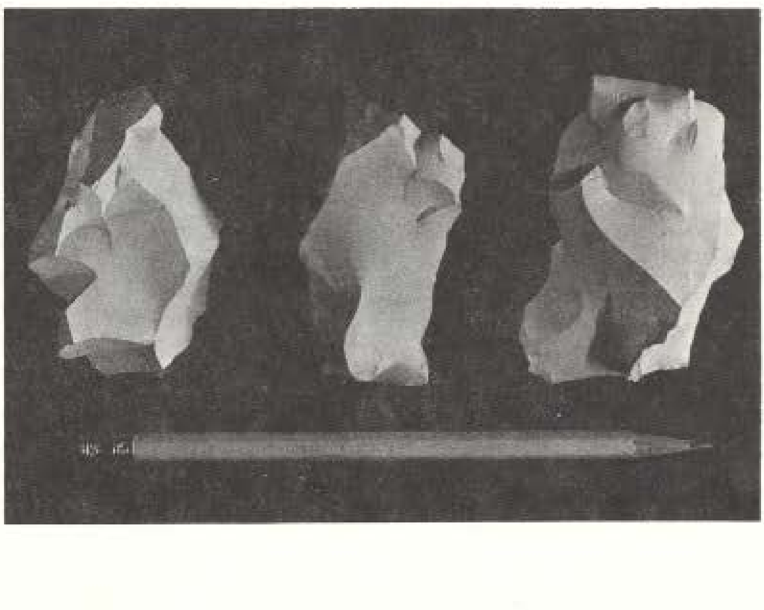
One of the first deposits of diaspore to be mined was on the old Gigg farm, 8 miles northwest of Belle, Mo. I am indebted to Willard M. Bledsoe for an anecdote about its history which reveals how a newly useful earth material has to find a dollar value for itself, and also gives insight into some rural personalities in the Belle area during the early 1920's. Willard Bledsoe's grandfather, Jerry Meyer Bledsoe, an adventuresome, literally horse-and-buggy mail carrier in 1920, had discovered the diaspore on the Gigg farm during his off-hours. Erosion had worn away the overlying Pennsylvanian-age rocks and essentially all overburden as well, exposing the fresh clay surrounded by limestone (dolomite) at the surface.

Mr. Bledsoe convinced Mr. Gigg that he should sell the clay to a refractories company for a cash sum bordering on affluence to augment the income from his farm. Mr. Gigg invited a representative of the General Refractories Company to examine the clay and make an offer. The representative countered by asking Mr. Gigg how much money he wanted for the clay. Mr. Gigg said, "Two thousand dollars". When the representative, an experienced businessman from St. Louis, indulged in ominous silence, Mr. Gigg, who

DIASPORE of first-grade quality (contains 70%, or more, Al_2O_3 in the raw, unfired material). Note the rough texture compared to the flint clay. Diaspore miners commonly called this 'rough' clay in contrast to 'slick' flint clay. Diaspore is the name for both rock and mineral.



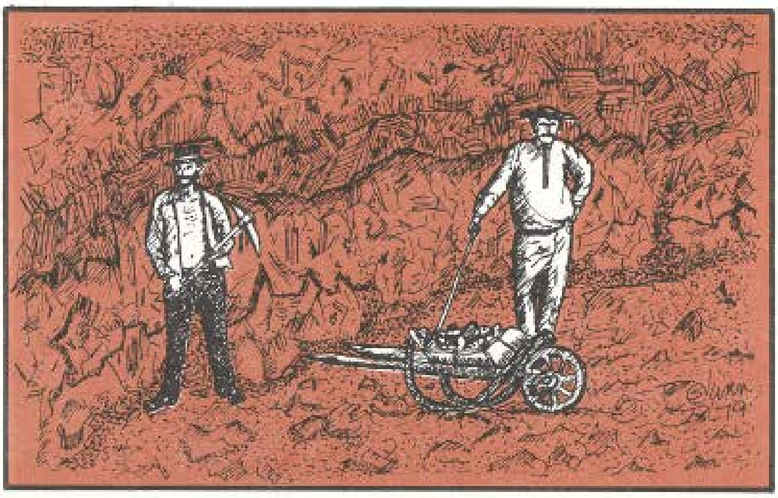
BURLEY CLAY, so named from the small, shot-like spherical shapes, called 'burls' by the local miners. The 'burls' are rich in diaspore whereas the fine-grained clay is flint clay (kaolinite) typically enriched with some fine-grained diaspore.



FLINT CLAY. Note the curved, conchoidal (shell-shaped) fracture surfaces and the very fine-grained clay which produces a 'slick' textural surface. The clay mineral in flint clay is kaolinite.

was a frugal German farmer in that relatively isolated, rural central Missouri community, became apprehensive that he was going to lose a sale and all of the extra money he wanted. He too quickly lost his poise and blurted out, "If that is too much, I will take ONE thousand dollars". They do not bargain that way in Belle today – 1979!

The diaspore pit was purchased for $1,000, and the mine opened in 1922. It was mined by hand, using shovels and wheelbarrows, with essentially no waste overburden being encountered. Within a few years, other pits were opened: the Brown Pit, southeast of Belle, in 1925; and the Tappmeyer Pit, southeast of Owensville, in 1927.



A DIASPORE PIT, opened in 1922 near Belle, Mo., was mined by hand using shovels and wheelbarrows.

EARLY PROSPECTING FOR DIASPORE

Royalties and fees for locating deposits encouraged many novices to become skilled clay prospectors . . . . .

As the dollar mark became attached to diaspore, the keenness of perception and differentiation between rock boulders by novices sharpened with astonishing rapidity to professional resolution. I recall even an eminent member of the judiciary who prided himself and boasted of his ability to recognize diaspore in the field.

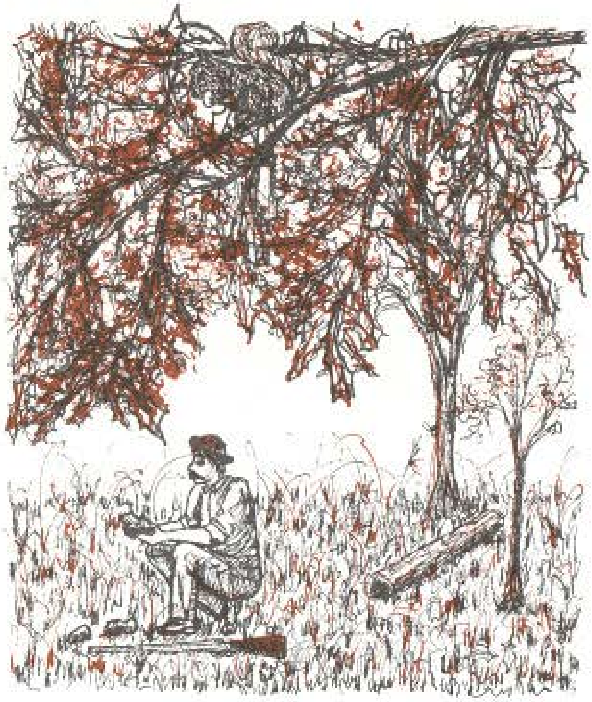
One farmer turned up a diaspore boulder while plowing his field, found the pit beneath, and harvested the highest-paying crop ever "reaped" from that field. A stock-watering pond, or small fishing and recreation lake (depending upon your ecological terminology) now graces the former meadow, while the farmer has the funds and time to fish.

Clay scouts quickly learned to walk creeks and look for tell-tale, erosion-resistant diaspore "float", i.e., boulders which had been dislodged from a deposit in the valley wall or the hill top and had rolled downhill.

THE BOULDERS at the head and handle ends of the hammer are diaspore. Are they easily differentiated from boulders of other "common" rocks?

The sport of squirrel hunting was combined with diaspore hunting, or vice versa, to rationalize a jaunt away from more conventional work. Squirrel hunting also became a ruse to walk over a neighbor's farm, looking down at the ground with one eye for diaspore, and up into the trees with the other for rifling down some variety in the meat diet. A typical fee for finding a pit (deposit) and disclosing it to a landowner was $25.

Of course, once alerted that a deposit had been scouted on his farm, a landowner might turn down the offer to reveal the location of the pit and decide to look for it himself. This might become complicated, however. Tales have been told how a shrewder than high-principled prospector would carry float (evidence) away, or to another valley to misdirect search, and then come back to a landowner promising to reveal the location of a pit on his farm for a bargaining sum. Too many more shenanigans than can be included in this paper were dreamed up by clay prospectors, especially by clay miners as they ate lunch, or sat in shelters when it was raining too hard to work in the open mines.



SQUIRREL HUNTING became a ruse to walk over a neighbor's farm looking for diaspore.

In the heyday of production, the royalty to a landowner ran $1 or more per ton; it was worth knowing if one had a deposit on his farm. A 10,000-ton clay pit was a $10,000 windfall to a landowner – and remember there was not much income tax to be paid in those days, and a popular automobile could be purchased for $1,000 or less.

A second clue, or another simultaneously followed while looking for diaspore float, was to hunt for sandstone "rim-rock" that completely or partly outlined a clay pit. However, just as "not all is gold that glitters", neither was every sandstone exposure a rim-rock. It was a frustrating experience to dig, drill, sweat, and end in tears when sandstone was just a layer, not a rim.

SANDSTONE "RIM ROCK". The deposit or "pit" lies to the right.

HAND DRILLING FOR DIASPORE

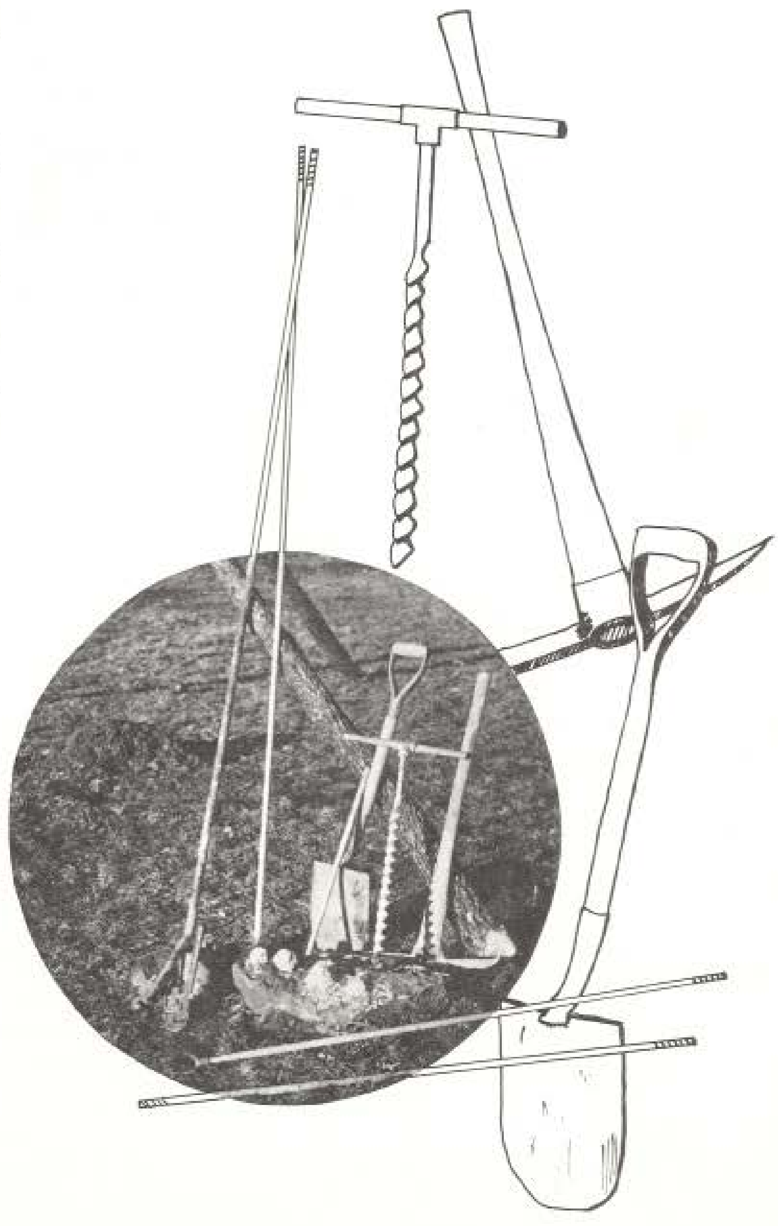
Early hand clay augers were developed to determine the thickness or depth of clay deposits . . .

To actually find or prove clay, it was necessary to dig a pit or a trench, or to sink a post hole into solid clay. To determine the thickness or depth of clay, the hole had to be deepened. To sink a "post hole" to considerable depth, was essentially impossible. As a practical alternative, an auger such as a soil-surveyor's auger was adapted to use. In the 1920's, soil augers were definitely not a regular item in the local, general-merchandise country stores that did, however, stock almost everything from home-cured bacon to blue denim overalls and jumpers (jeans, that is; unwashed and new, however). The ingenuity of rural Missourians quickly solved the need for many hand-manipulated clay augers.

Leaves from discarded or worn-out flattened springs of Model-T Fords were taken to blacksmiths. These leaves were heated, then one end was clamped in a vise and the spring-leaf was twisted. One end was sharpened, and the other was welded to a short length of 3/8-inch or 1/2-inch pipe. A T-fitting with short transverse extensions screwed on became the handle, and a clay-prospector's auger had been "invented". To lengthen the drill stem, sections of pipe were simply added between the auger bit and T-handle.

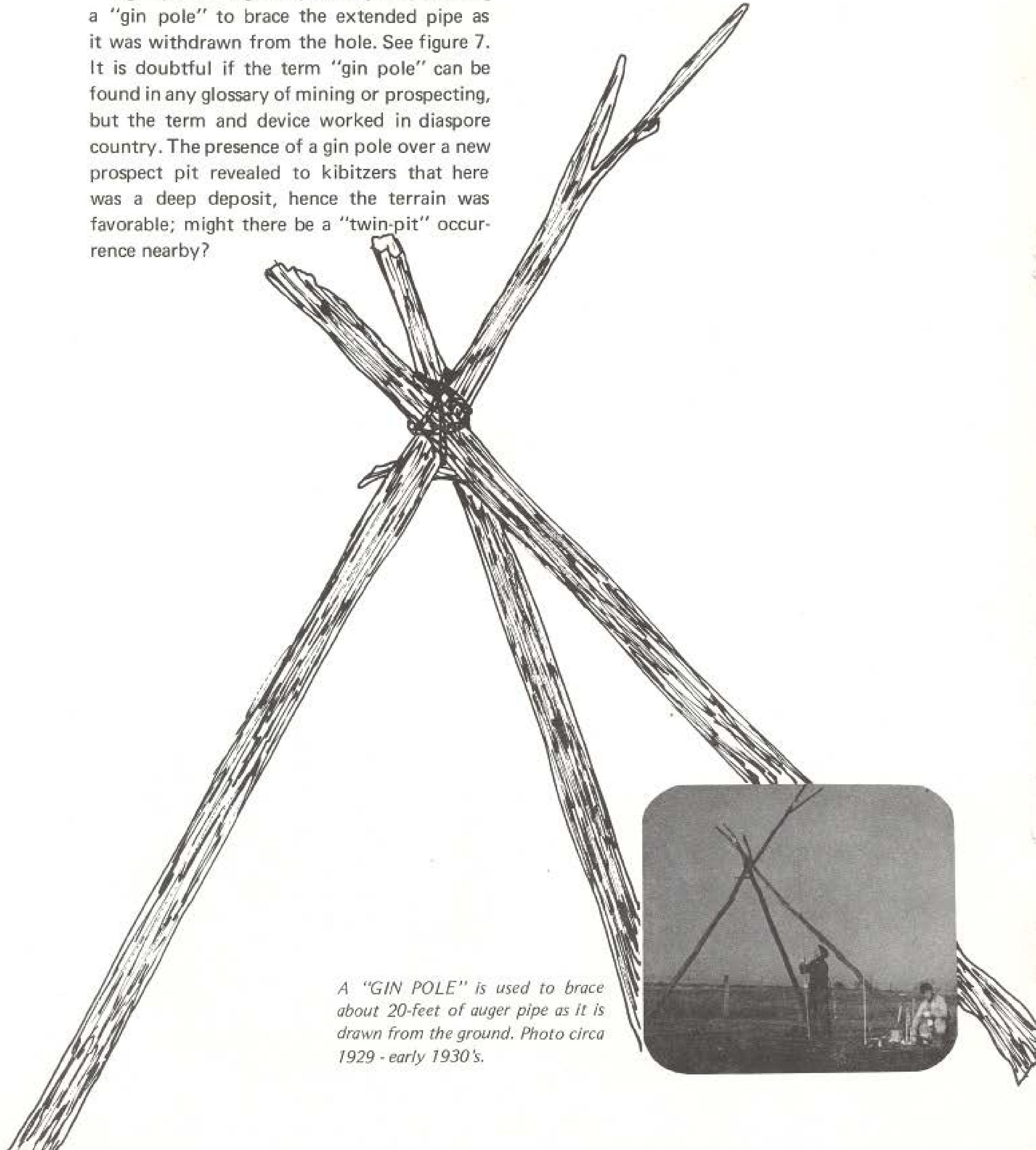
Standard equipment of a drilling prospector included an auger bit with extra pipe, a file to sharpen the auger, pipe wrench, a pick and shovel to dig through soil and gravel cover, a can to carry water to wet down cuttings, sample bags, and a "jalopy" to carry the gear. Most clay scouts knew one another's automobiles, and if one of them was observed parked along the road over near Second Creek, competitors rushed into the business of counterintelligence. News travelled fast over one-wire, grounded, hand-crank telephones and grapevines. The oil and uranium rushes had nothing on diaspore for competitive scouting and leasing practices.

If and when a clay pit was discovered, augering would be continued to considerable depth; a 100-foot deep, hand-augered hole was considerable. After several turns in clay, the auger filled with chips and had to be bored out. This clay had to be removed: (1) to permit more drilling, and (2) to recover the clay for testing or analysis. When hole depth and length of pipe exceeded about 15 feet, augering devices would become unwieldly if allowed to wiggle about in the air above.

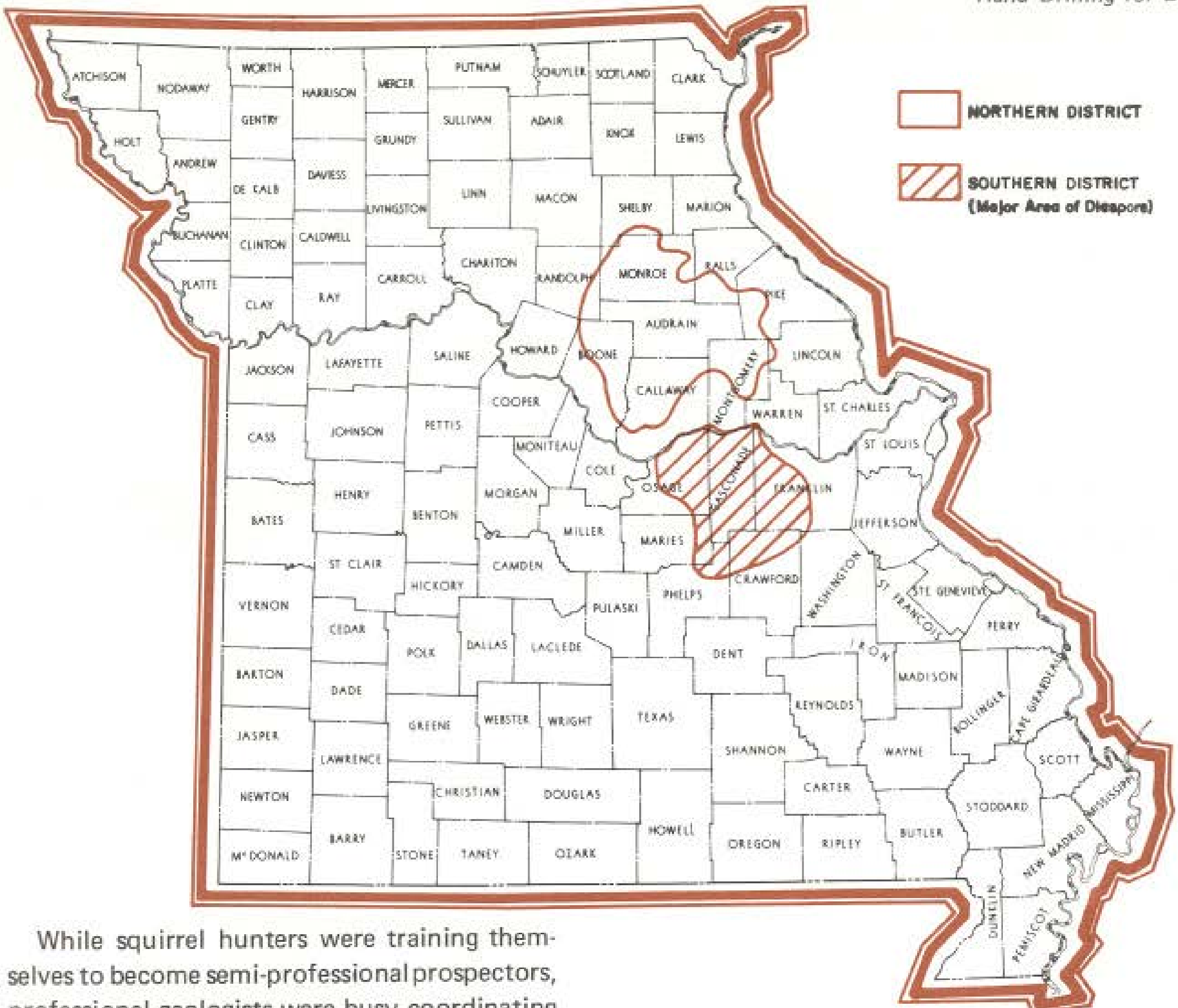


EQUIPMENT FOR DIGGING through overburden and drilling in clay was not sophisticated. Usually included were a hand auger, a pick, a shovel, an auger bit with extra pipe, a file to sharpen the auger, a pipe wrench, a can for water to wet cuttings, and sample bags.

Again, local ingenuity triumphed, devising a "gin pole" to brace the extended pipe as it was withdrawn from the hole. See figure 7. It is doubtful if the term "gin pole" can be found in any glossary of mining or prospecting, but the term and device worked in diaspore country. The presence of a gin pole over a new prospect pit revealed to kibitzers that here was a deep deposit, hence the terrain was favorable; might there be a "twin-pit" occurrence nearby?



A "GIN POLE" is used to brace about 20-feet of auger pipe as it is drawn from the ground. Photo circa 1929 - early 1930's.



MAP OF EAST-CENTRAL MISSOURI FIRE CLAY DISTRICTS. Adapted from McQueen, 1943.

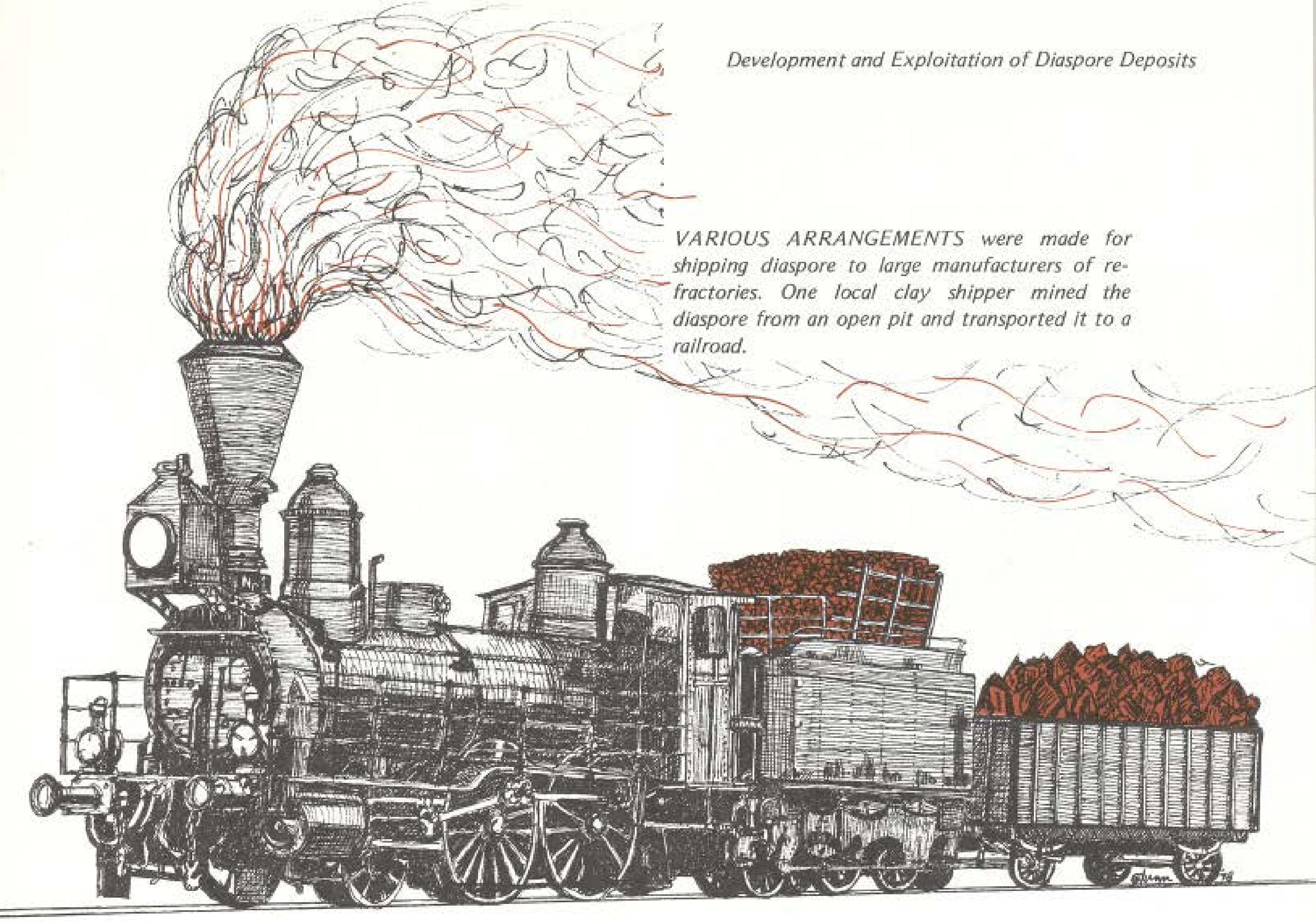
While squirrel hunters were training themselves to become semi-professional prospectors, professional geologists were busy coordinating observations from clay pits with the general knowledge of the state, and providing a base map outlining fundamental information on the areas where diaspore might be found. Apart from geologists employed by companies, the staff of the Missouri Geological Survey was notably active. H.S. McQueen, later Assistant State Geologist, published a useful map of Missouri's fire clay districts in 1926; an informative report in 1929; and a well-done, authoritative, comprehensive report devoted to the topic in 1943. Ries and Bayley had visited diaspore and flint clay pits prior to 1920, and included accounts of them in Bulletin 708 of the U.S. Geological Survey, 1922. Allen published on the mineralogy of diaspore in 1935, and Forbes discussed the winning of Missouri diaspore and associated clays in 1928.

DEVELOPMENT AND EXPLOITATION OF DIASPORE DEPOSITS

After the deposits were proved, the diaspore was usually mined and shipped to large manufacturers of refractories . . . . .

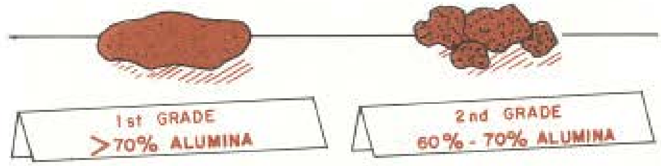
After a diaspore deposit was found, and proved out by hand drilling and partial uncovering, the contents were ordinarily sold to large manufacturers of refractories in Mexico (Mo.), Vandalia, St. Louis, or out of state. Alternative arrangements for sales were adopted under different circumstances. In many instances, a local clay shipper bought and mined the diaspore from an open pit and transported it to a railhead. In other cases the user company leased the clay land, paying an advance royalty to the landowner and an additional royalty for each ton of clay which exceeded the advance, and contracted with a local shipper for the mining and hauling. For general identification purposes, diaspore pits were most commonly named after the landowner. Occasionally, the name of the shipper was used and, more rarely, the geographic locality was used, e.g., the Aud pit, near the Aud, Mo. store and post-office.

At first, largely because of the Topsy-like growth of diaspore production, the responsibility for finding, developing, and grading (dignified in current parlance by the term, "quality control") gravitated to the local clay shippers. There were as many different



VARIOUS ARRANGEMENTS were made for shipping diaspore to large manufacturers of refractories. One local clay shipper mined the diaspore from an open pit and transported it to a railroad.

standards for clay products as there were shippers. Variability in raw material created intolerable difficulties in manufacturing uniform refractories. To remedy the situation, one company in 1929 began to systematize quality standards based on alumina content and to introduce them at the mines. This was done (organized by this writer) by assembling standard samples that were typical of the varieties of diaspore and clay in a pit, having them analyzed chemically, and displaying them with labels indicating the numerical percentage of alumina contained in each. In effect, distinctive physical properties previously recognized in the clays by miners were thereby expressed in terms of specific numbers. Miners were thus trained to confidently convert qualitative differences long observed in clay into quantitative values. First grade (> 70% alumina), second grade (60% - 70%),



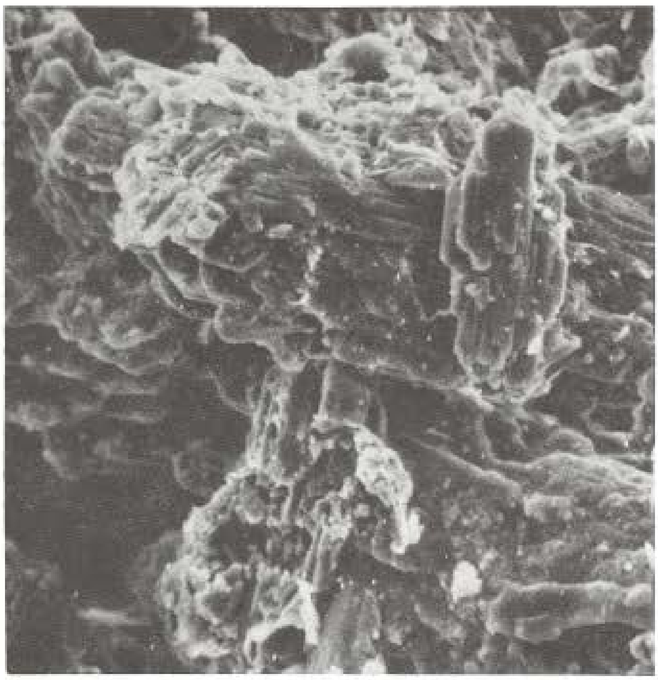
QUALITY STANDARDS based on alumina content were developed in 1929 for use at the mines.

THESE PHOTOGRAPHS were made at magnifications of 2,000 to 5,000 times using an electron microscope. The extreme detail is far beyond the capability of optical microscopes.

FLINT CLAY, 5,000X; Bueker Pit north of Owensville, Mo. (3682)

FLINT CLAY, 10,000X; Bueker Pit north of Owensville, Mo. (3680)

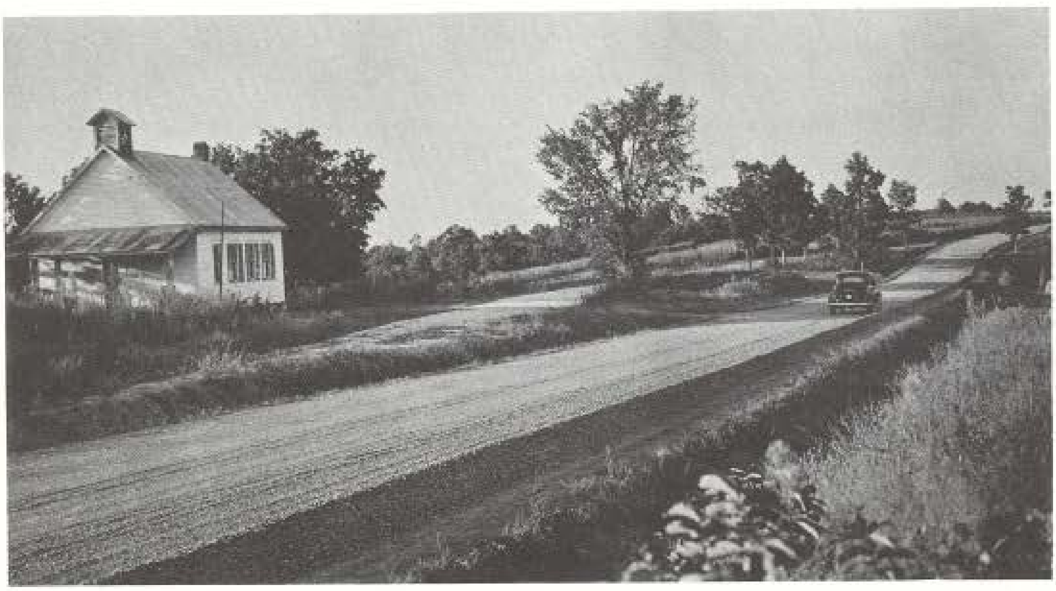
FIRST-GRADE DIASPORE CLAY 70% Al_2O_3, 3,000X; Forbes Pit, Rolla, Mo. (2759)



SURFACE-BOULDER DIASPORE, 2,000X; Gaume Pit, near Aud, Mo. (3403).

and burley varieties were soon uniformitized (Forbes, 1931; McQueen, 1943). Burley clay, to explain, is a natural, variable mixture of flint clay (described below) with diaspore, the latter commonly occurring within the clay as oolites (bird-shot size pellets) locally called "burls" – hence "burley" clay. See photo on page 9.

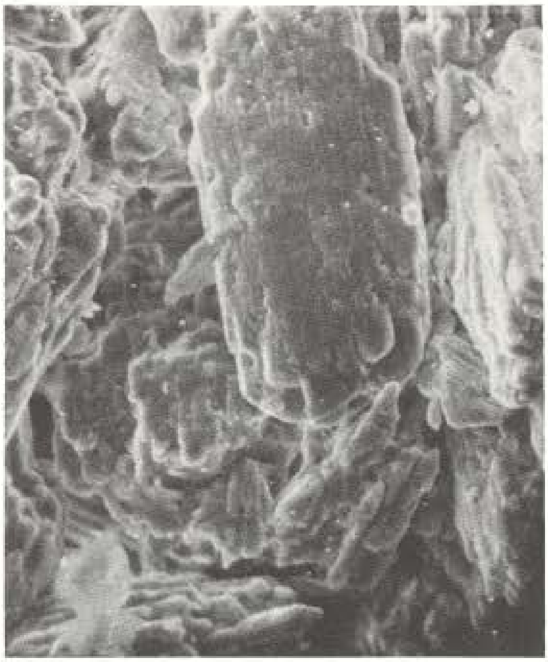
Flint clay, composed of the clay mineral kaolinite (40 percent alumina), was a poor relative of diaspore during the reign of the latter, but today it, too, is a valuable refractory clay (page 20). Because flint clay resists slaking in water, and was an unsalable by-product that had to be removed from a diaspore pit, it was used as a road-surfacing material at one time. It withstood horse-drawn wagon travel and light auto traffic in the 1920's, but is now superseded by gravel on county roads (see photo below).



PART OF AN ABANDONED COUNTY ROAD surfaced with flint clay lies between the school house and a newly constructed gravel road. This was one of the few public roads in the world surfaced with flint clay. Circa 1929-early 1930's.

Another variety of diaspore that is worthy of special mention is "surface boulder", a term that refers to boulders derived from the exposed, upper surface of a deposit. These unprotected boulders, long exposed to the weather, were intensely leached of non-aluminous constituents by the action of innumerable rains and possibly organic (plant) acids, thereby increasing both their porosity and their relative alumina content. They were oxidized, usually to a tan or brown color; hence they represented the ultimate residue after the most intense surface weathering in Missouri. As would be expected, their temperature of fusion (Pyrometric Cone Equivalent, or PCE) was highest, and they were prize material.

A NEARBY BRASS PLAQUE identifies this diaspore boulder (at A.P. Green Refractories Co., Mexico, Mo.) as follows: "This is the largest 'surface boulder', weight 10,400 lbs., of diaspore found in the Missouri diaspore fields lying south of the Missouri River. It was taken from the Gaume diaspore pit near Aud, Osage County, Mo., 1926. Diaspore is a high alumina "clay" occurring in this form with a fusion point above 3300°F." Photo courtesy A.P. Green Refractories Co.



SCALE: 1/1000 inch (25.4 micrometers)

CRYSTALS OF DIASPORE from a "surface boulder" magnified 2,000 times by scan electron micrography. From Keller, 1978.

The A.P. Green Refractories Company displays the traditionally largest diaspore surface boulder ever mined in a place of honor at their major plant in Mexico, Mo. (see photo on page 22).

Recently developed scan electron microscopes show that the diaspore mineral comprising them might be exceptionally well recrystallized to relatively coarse and well-formed crystals (for clayey rocks). See photo, left.

SCIENCE AND ART IN SELECTION OF DIASPORE QUALITY

Experienced miners could identify first-grade diaspore and estimate the alumina content without an analysis . . . . .

It is amazing – almost incredible – to one outside the diaspore district, how an experienced miner, after having been shown samples of diaspore and burley clay with their analyses, could estimate the alumina content and grade clay so as to furnish a freight car load to a given alumina composition, plus or minus 2½ percent alumina. More income was paid for more tonnage of high-analysis clay shipped, but if the clay quality dropped below specifications, the entire carload was docked in price to a lower rate; the two objectives had to be kept in balance.

The physical properties most revealing of alumina content were texture and the darkness to which the diaspore "marked" when abraded by a steel tool. Highest alumina content, e.g. 70 percent Al_2O_3, was indicated by texture described as "rough", mealy, porous, and oolitic, in contrast to the "slick" texture characteristic of flint clay, 40 percent Al_2O_3. "Marking" referred to a gray to black streak left on moist, high-quality diaspore where it had been struck or abraded by a steel pick, or a wedge (locally called a "gad") used to split boulders of diaspore.

The reason for this property is basically sound scientifically (Keller, 1930). Diaspore mineral has a hardness (on the Mohs' scale) of 6.5 to 7, whereas the Mohs' hardness of steel is about 5.5. Diaspore, therefore, will scratch and abrade steel as it is driven into the diaspore. The abraded mark, or "streak" (the scientific term), of the steel is left on the diaspore.

Flint clay, which is composed of kaolinite, has a Mohs' hardness of less than 3 – hence, it is not blacked ("marked") by steel. Many of the miners in the diaspore country, who were of German-Swiss extraction, admiringly described first-grade diaspore (70 percent Al_2O_3) by saying, "Dot placks gut". Chewing clay was another method of differentiation. Flint clay, when chewed, "goes to water in your mouth" (so described by miners), whereas diaspore maintains grittiness. Diaspore miners laughingly said that their ages (years in the mines) could be determined from their front teeth, as in a horse – long-time miners had test-chewed so much harsh clay that their front teeth were shortened by abrasion.

A STEEL WEDGE (called a "gad") was used to split boulders of diaspore. Gray to black streaks were left on moist, high-quality diaspore where it was struck or abraded. Diaspore is so hard, it will scratch steel.

CHEWING CLAY was one early method for identifying flint and diaspore clays. Flint clay "goes to water" when chewed, whereas diaspore maintains its grittiness.

A different crystallographic form of $Al_2O_3 \cdot H_2O$, named boehmite, occurred in some diaspore deposits. It was finer-grained than diaspore (although equally high in alumina content) and appeared "slicker", as in flint-clay, but yielded a dependable, tell-tale, high-alumina dark "mark" with steel.

In passing, it may be noted that laboratory analyses for aluminum in the 1930's had to be made by time-consuming and costly wet chemical methods, since newer spectroscopic instrumentation had not been developed. Silica could be determined more quickly and at less cost than alumina. A relationship between silica content and alumina content was worked out so that, within the diaspore-flint clay system, the alumina content could be estimated for practical purposes from a silica analysis (Holmes and Keller, 1932). Professor Thornberry's laboratory ran many more "silicas" than "aluminas" after this short cut was devised.

WET CHEMICAL METHODS for determining alumina content were time-consuming and costly, so a short cut was devised in the 1930's.

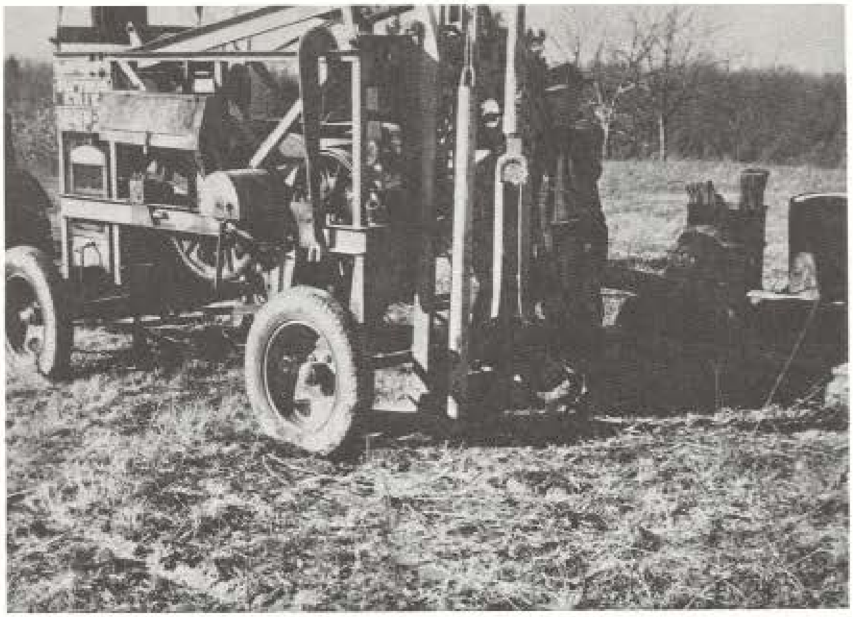
INCREASED ROLE OF DIASPORE USERS IN PROSPECTING

Use of a churn drill by an independent clay shipper alerted companies to mechanized prospect drilling. . . .

Besides the move by user-companies to uniformitize quality in raw materials around the 1930's, more attention was given to geological prospecting and to increasing the in-ground reserves of diaspore. Professional geologists began to enter the picture. The State Geologic Map and McQueen's maps formed the basis for delineating the areas which were potential producers of diaspore — i.e., those where Pennsylvanian rocks unconformably covered Ordovician rocks south of the Missouri River.

Earth resistivity methods of prospecting were introduced by Farnham (1931), and further examined by Keller (1934). A mass of buried clay rocks could be located by electrical means, but the quality of the clay could not be discriminated without the use of a drill; earth resistivity methods did not become popular.

An independent clay shipper, Stanton Roberts of Hermann, Mo., used (first, to my knowledge) a churn drill equipped with a slotted barrel, or bit, to mechanize prospect



A CHURN DRILL equipped with a slotted bit is pictured here. The clay was pierced by the bit and became packed within the hollow bit during drilling. The bit was withdrawn from the hole periodically and the clay filling was recovered for testing. Circa 1929, early 1930's.

drilling (above). Such a machine greatly speeded up prospecting. It would penetrate overburden such as "gravel hardpan" that had all but prevented hand drilling and, equally important, its use alerted companies to more sophisticated thinking about prospecting for diaspore. Hand drilling as a prospecting method was on the way out.

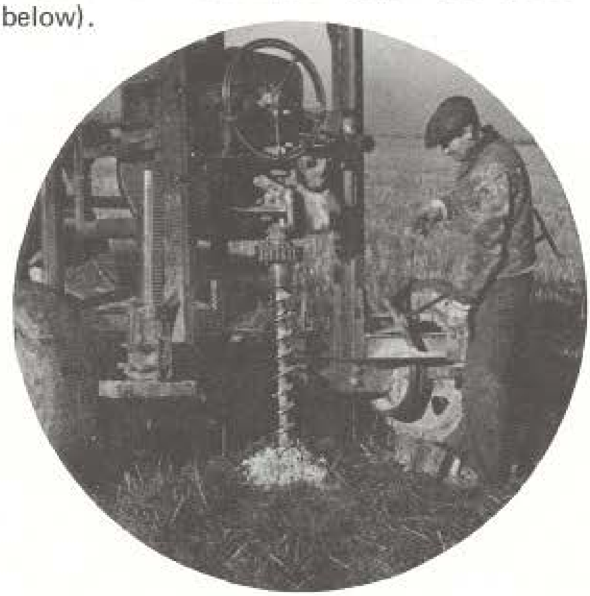
In the meantime, technological progress in ceramic research by manufacturing companies stimulated further demand for diaspore-based refractories. The first type of refractories made from diaspore, although they characteristically resisted fusion at very high service temperatures, did tend to shrink in size where exposed to hot flames in service. Volume shrinkage of brick permitted further penetration by hot gases into the refractory, whereupon a vicious circle of refractory deterioration was set up. This failing by shrinkage in service had restricted a potentially greater general demand for diaspore refractories. Intensive laboratory research formulated a "non-shrinking" (in service) high-alumina (diaspore) refractory. Immediately the demand for diaspore increased. The price of first-grade diaspore eventually went up into the $10- to $15-per ton range — at a time when ice cream cones, hot-dogs, and soda pop were a nickel each.

Manufacturing companies now sent professionals from the home-plants into the clay fields. Companies dealt directly with land owners to lease clay on a royalty basis, to buy mineral rights, or to buy the clay in the ground. Payment for unexposed clay in the ground, or high sums of advance royalty demanded a more precise knowledge of both quantity and quality of diaspore and burley clays in the deposit than had ever been known before. A new demand was placed on prospect drilling.

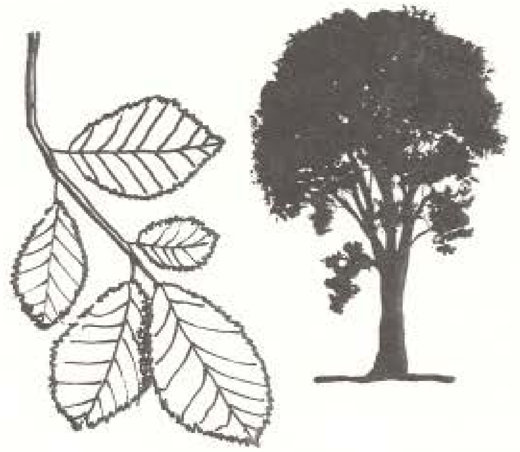
PROSPECTING IN A GRID PATTERN WITH A POWER AUGER DRILL

A power auger drill, developed in the coal industry, was adapted to prospecting for diaspore and associated clays . . . . .

Fortunately, a power-driven auger drill, soon made portable and then auto-portable, had been undergoing development in the coal industry where open-pit mining was supplanting underground mining. It was easy to adapt this power auger to prospecting for diaspore and associated clays (see photo below).



A POWER-DRIVEN AUGER DRILL penetrates the clay which is raised by the screw action of the drill. Circa 1940.



CHEWING SLIPPERY ELM BARK was an old-time method of very dubious validity for locating diaspore deposits. Some prospectors claimed that bark from trees growing over clay deposits tasted bitter.

Contemporaneously, a new rationale and approach was taken to finding diaspore deposits. Presumably all the deposits that could be located by hunting surface float or rim-rock, or chewing slippery-elm bark (some chewers dreamed up an idea that it tasted bitter from trees growing over a clay pit) had been found. Less consistent than with other nonferrous heavy metals, Al was found by spectrographic methods to be occasionally higher in oak leaves and twigs of trees over clay pits than in those elsewhere (Keller, 1949). Terrain that was potentially productive on a geological basis had been clearly delimited.

It was time to move in by prospecting with power drills, beginning first with the land deemed most favorable on the basis of geology and topography, and by using an organized, statistically spaced grid pattern that permitted thorough and complete testing of all of the ground. The cost of drilling many closely spaced prospect holes was counterbalanced

MANY FARMS were drilled in a statistically spaced grid pattern to increase the prospects of finding deposits.

A CORE-DRILL BIT is pictured with a core of clay that was recovered after the bit was unscrewed. A core of this type yields a truly representative sample of the clay being prospected. Circa 1940-45.

against spreading the spacing of the grid and by considering the maximum-size pit that the prospector was willing to miss finding. Many farms were grid drilled in this manner. Statistical probability had supplanted the "by-guess and by-gosh" of earlier days.

Power-drill bits (above) were equipped with hardened alloy teeth and/or diamonds, and penetration went to "bottom" in sandstone. Some areas, geologically favorable but blanketed with thick gravel hardpan, were bypassed because of difficulty in drilling. In the meantime, other geophysical methods such as magnetometry, gravimetry, and shallow seismic vibration were tried. As with earth resistivity methods, distinction of useable refractory clay (apart from shale or other non-refractory clay) could not be made. The drill always had to be brought in; therefore, the drill has not been supplanted.

A second-generation power auger drill, equipped with two-speed gears, permitted drilling through formerly impenetrable gravel. Moreover, it was found that, on rare occasions, a thin layer of sandstone might overlie clay; so, it was recognized that the first appearance of sandstone, without some deepening of the hole, should not invalidate the test. A sandstone cover was observed over flint clay north of the Missouri River (Keller, 1938), and an uneroded, original limestone cover was found over a diaspore pit, the Bueker Pit, in the clay-rich Gurley (Goerlich) Ridge region (Keller, 1952; Keller, Westcott, and Bledsoe, 1954). A two-speed auger drill could penetrate some of these harder rocks. Advances and economics of drilling simultaneously brought a conventional, portable core drill into competition with the two-speed auger drill. Core drills are the "last word" in prospect drilling. Several farms in the diaspore country have been prospect drilled so many times with so many holes, either by new-generation machinery or by competitive-company prospectors, that some of them are called "Swiss-cheese" farms.

PITS AND PEOPLE

Scores of clay pits produced diaspore of various qualities and in various quantities. Every pit employed from a few to perhaps a score of workers. It is beyond the scope of this narrative to name all, or even many, of the pits or the people. For historical perspective, a few will be cited. In the region of Swiss in Gasconade County, the relatively small Helmer Krull Pit (landowner) produced a sample of diaspore found by the Clay Testing Laboratories in Rolla to contain 79.2 percent Al_2O_3, the highest on record in that laboratory. Nearby was the Andrew Fleutsch Pit, not the largest, but famous because it was one of the richest in first-grade diaspore; it contained a core of about 30,000 tons of "first grade" so uniformly rich that it required little sorting. The Klossner Pit, within the town limits of Swiss, first produced commercial quantities of fine-grained, quasi flint-like, high-alumina boehmite clay. The Ochesky Pit, out of Linn, contained a remarkable mixture of diaspore and boehmite (Keller, 1952).

Scores of clay pits produced diaspore of various qualities and in various quantities . . . . .

On Gurley (or Goerlich) Ridge, a topographic high but structurally lower area, several deposits of special interest occurred.

The Aufderheide Pit was very large areally, and the bottom surface of the Farnberg complex of connected shallow and deep pockets probably best represented an exhumed topography of this region as it occurred in the Pennsylvanian Era, some 250 million years ago. The Bueker Pit, also on Gurley Ridge, was a geologic hallmark which exposed the first and only unequivocal geologic evidence that the complete process of deposition of clay and alteration to diaspore had occurred within Pennsylvanian time. Diaspore and flint clay, the upper part of which was decomposed by ancient weathering, are here directly overlain by fresh, green Excello shale, and then by Ft. Scott Limestone, both of Pennsylvanian age (Keller, 1952; Keller, Westcott, and Bledsoe, 1954). McQueen, with notable perception, had astutely suspected a limestone cover for the diaspore deposits from fragmentary evidence at a pit near Belle, but the Bueker Pit had not been discovered or opened when his investigation was made in 1943.

The Brandhorst Pit, a few miles north and west of Drake, exhibits in its "runway" (ramp) an unexcelled, typical cross section of the rocks involved in the formation of sinkhole-type clay pits. Ordovician Jefferson City dolomite, showing Pre-Pennsylvanian weathering, is tilted and slumped inward from the rim of the pit. It is unconformably overlain by Pennsylvanian-age siliceous sediment grading into a clay-diaspore clay.

The Forbes Pit outside of Rolla was a large, long-lived, typical diaspore pit, closely observed by investigators in Rolla, and shown to many "visiting firemen" geologists. It was a

HARD ROCK-LIKE, finely porous high grade diaspore clay interbedded with thin seams of "mealy" clay at the Aufderheide pit in Gasconade County. Photo from McQueen, 1943.

trap-door type collapse-structure, a form even more dramatically displayed in an almost forgotten nameless (?) pit on the east of Gurley Ridge. The pit at Aud occurred notably low in elevation and in the stratigraphic section. Unfortunately, the initial discovery location of diaspore near Cuba, Mo. is nameless now.

A commentary on diaspore pits should include a description of the haulage roads out and in to them. Pits located on flat land near highways usually were connected with the highway by an easily passable truck road. It was typically surfaced with slaking-resistant, "irony", "alkali", or sandy flint clay (occasionally with now-merchantable flint clay). On the other hand, pits that were located in the hinterland, in hillsides eroded by active streams, or in the "back-forty", were accessible only with great difficulty. They might be served by deep-rutted, high-center, tortuous, tree-dodging mud roads, occasionally pole-surfaced, that tested old-style trucks and drivers to the utmost.

A traditional description to an outsider who wished to visit such a pit went something like this: "Drive down the highway to the second bridge, turn right down the creek road (impassable during high water), go as far as a 4-wheel drive vehicle will take you. Then get out and walk down the trail, and swing in the last 30 yards on a grapevine to the pit." As diaspore increased in value, and larger trucks were used in transport, haulage roads likewise were improved.

Difficult as it is to select pits for mention, it is far harder to limit the number of persons for mention in diaspore history. Many individuals made names for themselves by discovering deposits, or by longevity in the industry, or as personalities. All cannot be cited, but when conversation turns to diaspore in that area, one cannot help but hear such names as Bledsoe, Branson, Dillon, Gray, Jones, Roberts, Roussett, Sassman, Turner, Wehmeyer, and others.

SWAN SONG AND A WARNING

Essentially no more diaspore is to be found in Missouri. All geologically favorable areas have been honey-combed by drills. Exceedingly high demand during the World War II era, and following, depleted Missouri deposits. Even the lower grades of burley clay, which earlier had been rejected because of uncontrollable, high service-shrinkage, were made useable by research discoveries which remedied their deficiencies (Lesar, Krinbill, Keller, and Bradley, 1946). The diaspore event and saga can never be reenacted in Missouri.

The depletion of diaspore gives mankind pause to think about the approaching exhaustion of other minerals . . . . .

This State has been privileged to witness the discovery, waxing, peaking, waning, and depletion of a non-renewable mineral resource within its boundaries in one generation. The history of diaspore in Missouri may well be a prototype for the waxing and waning exploitation of petroleum and natural gas (now prominently in the public eye) and later for copper, gold, and almost any other non-renewable mineral resource.

When this is observed on the local scene, mankind is given pause to think about approaching exhaustion within larger scenes and reserves of minerals and metals having more diversified and more popular uses — "it can happen here, it did in Show-Me Missouri!"

ACKNOWLEDGMENTS

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