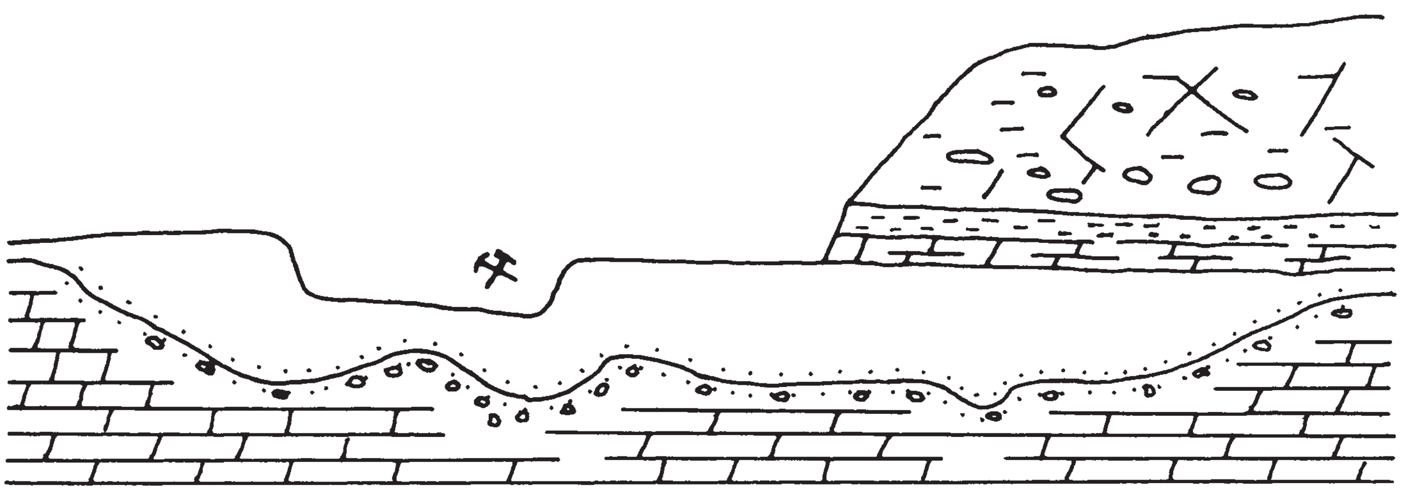
GUIDE BOOK

ASSOCIATION OF MISSOURI GEOLOGIST

FOR

21st ANNUAL FIELD TRIP

October 5, 1974



GEOLOGY OF EAST CENTRAL MISSOURI WITH EMPHASIS ON PENNSYLVANIAN FIRE CLAY AND PLEISTOCENE DEPOSITION

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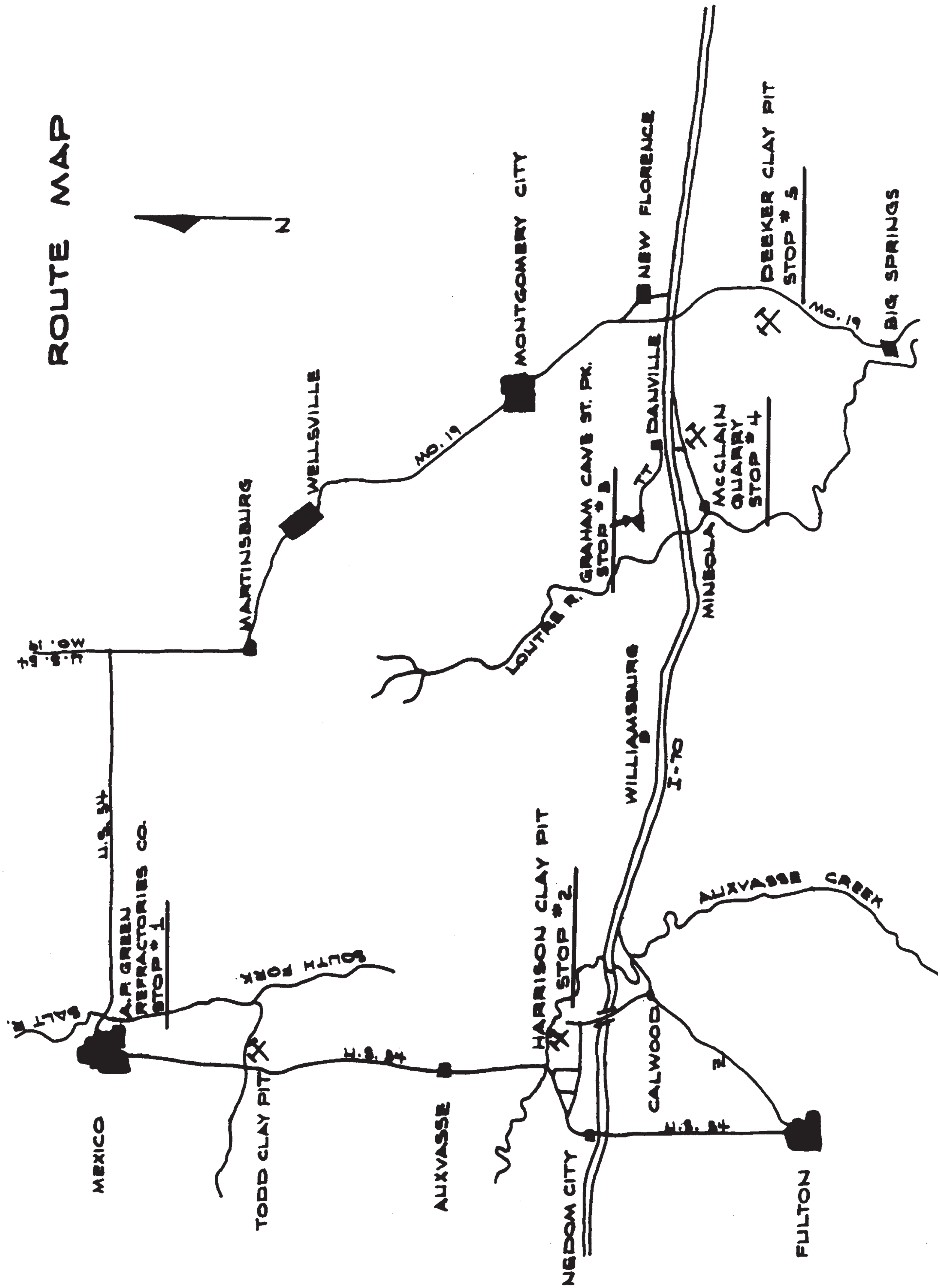
PREFACE

The Friday afternoon trip is to the Central Barite District to observe circle deposits in Cole County. Although the mines have been abandoned and partially filled with water, the nature of the deposits and the character of the mineralization can be seen.

The 21st annual field trip commences at the Mexico Plant of A. P. Green Refractories Co. With 27+ acres under roof, this is the largest plant in the world devoted exclusively to the manufacture of refractories. We will observe the manufacturing processes and equipment used to produce various types of refractories.

Additional stops include two large clay deposits. Excellent exposures of the Pennsylvanian fire clay and the overlying Pleistocene glacial till are present at each. Exposures of the underlying Ordovician and Silurian rocks will be observed at Graham Cave State Park and McClain Quarry. Graham Cave is in the St. Peter sandstone and is noted for its archeological significance. Joachim and Plattin formations are being quarried at the McClain Quarry.

The field trip committee wishes to acknowledge the cooperation and assistance of the A. P. Green Refractories Co., Kaiser Refractories Co., and McClain Lime Quarry. Permission to visit their facilities is greatly appreciated. The committee also thanks Richard B. Aylor, Missouri Highway Dept., and Lawrence T. Shelton, Chief Archeologist Div. of Parks and Recreation, Dept. of Natural Resources for valuable information supplied at the various stops.


ROUTE MAP
N
MEXICO
SALT R.
A.P. GREEN REFRACTORIES CO. STOP # 1
U.S. 54
MO. 15
U.S. 54
SOUTH FORK
TODD CLAY PIT
U.S. 54
AUXVASSE
HARRISON CLAY PIT STOP # 2
KINGDOM CITY
CALWOOD
U.S. 54
FULTON
AUXVASSE CREEK
I-70
WILLIAMSBURG
MARTINSBURG
WELLSVILLE
MO. 19
MONTGOMERY CITY
LOUTRE R.
GRAHAM CAVE ST. PK. STOP # 3
DANVILLE
NEW FLORENCE
MINEOLA
McCLAIN QUARRY STOP # 4
DEEKER CLAY PIT STOP # 5
MO. 19
BIG SPRINGS

INTRODUCTION

The area of Audrain, Callaway, and Montgomery Counties covered by this field trip ranges topographically from that of a moderately flat till plain in the north to the maturely dissected regions of southern Callaway and Montgomery Counties. The Mexico Plain is drained to the north by South Fork Salt River while the southern portion drains into the Missouri River by way of Auxvasse Creek and the Loutre River which are the main streams.

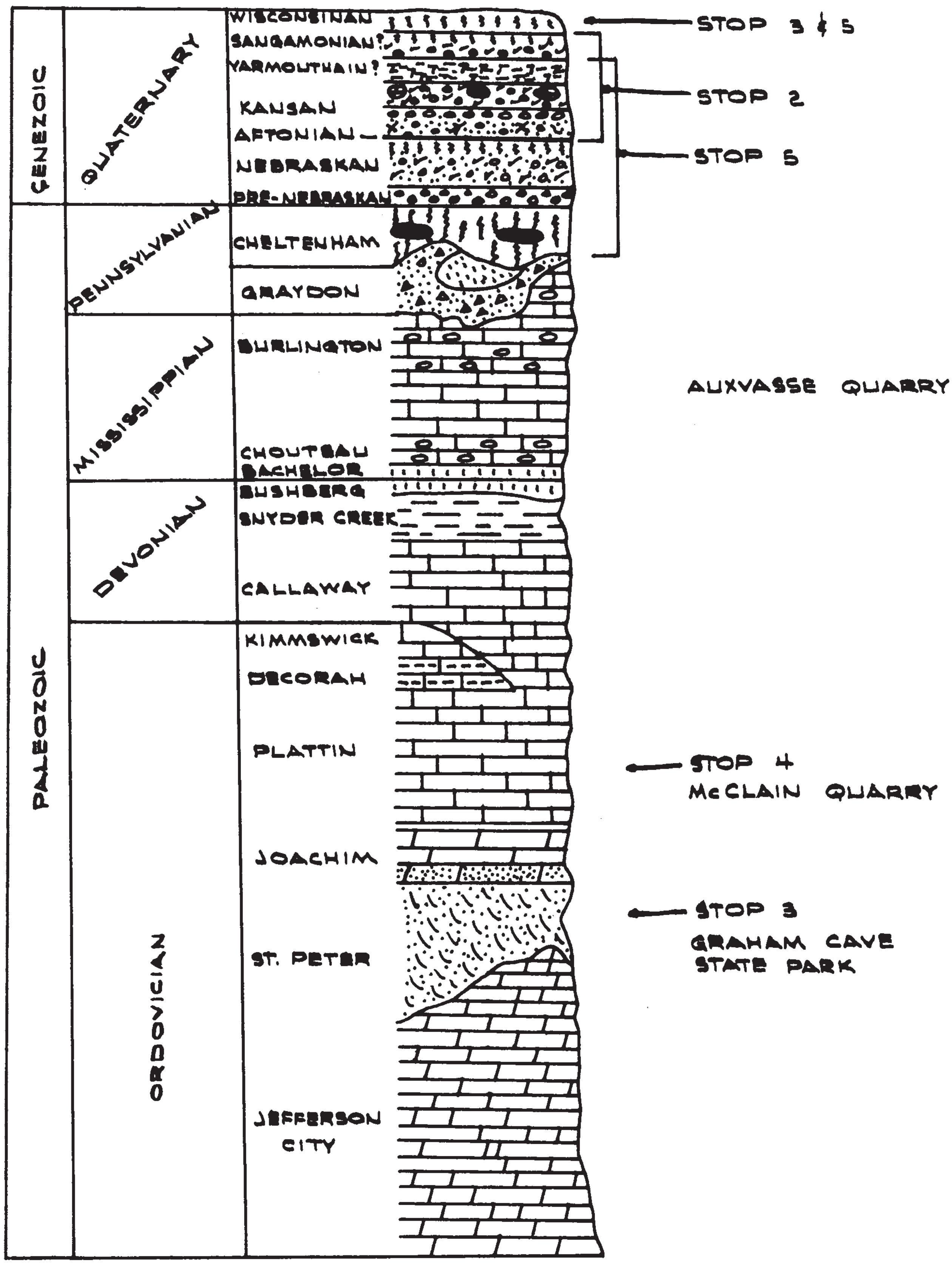
Most of the upland area is covered by a thin loess blanket and glacial drift where the total thickness averages about fifty feet. As the southern limit of till deposition is approached and the topography becomes dominated by the Ozark Pysiographic Providence the thickness of the till decreases to a feather edge and loess thickness increases. It is a generally accepted fact that a preglacial drainage network was well established in Northwestern Missouri; however, little attention has been focused on what was happening in the area adjacent to the Missouri River Trench. Preliminary evidence indicates that this area also had a well integrated drainage network. As the continental glaciers approached the ancestrial Missouri River the upland summits became more restricted in extent and the glaciers probably took the easier route - down into the valleys where occasional patches of discontinuous till are presently preserved. Erosion has since removed this material from the valleys where the underlying Paleozoic rocks are exposed. The oldest unit so exposed below the glacial cover are late Pennsylvanian sediments containing the vast commercial fire clay deposits.

The continental glaciers overrode the youngest Pennsylvanian deposits of the Mexico Plain and were slowed to a stand still as they rose up the north facing slopes of the Ozark Dome. This may account for the fact that there are no places where a pronounced terminal moraine can be found. Evidence of large scale outwash plains is nonexistant either north or south of the river; therefore, the most logical conclusion is that the Missouri River functioned as a giant sluceway, carrying most of the outwash material down river and out of the immediate vicinity.

A general stratigraphic column of the area is shown on the next page.

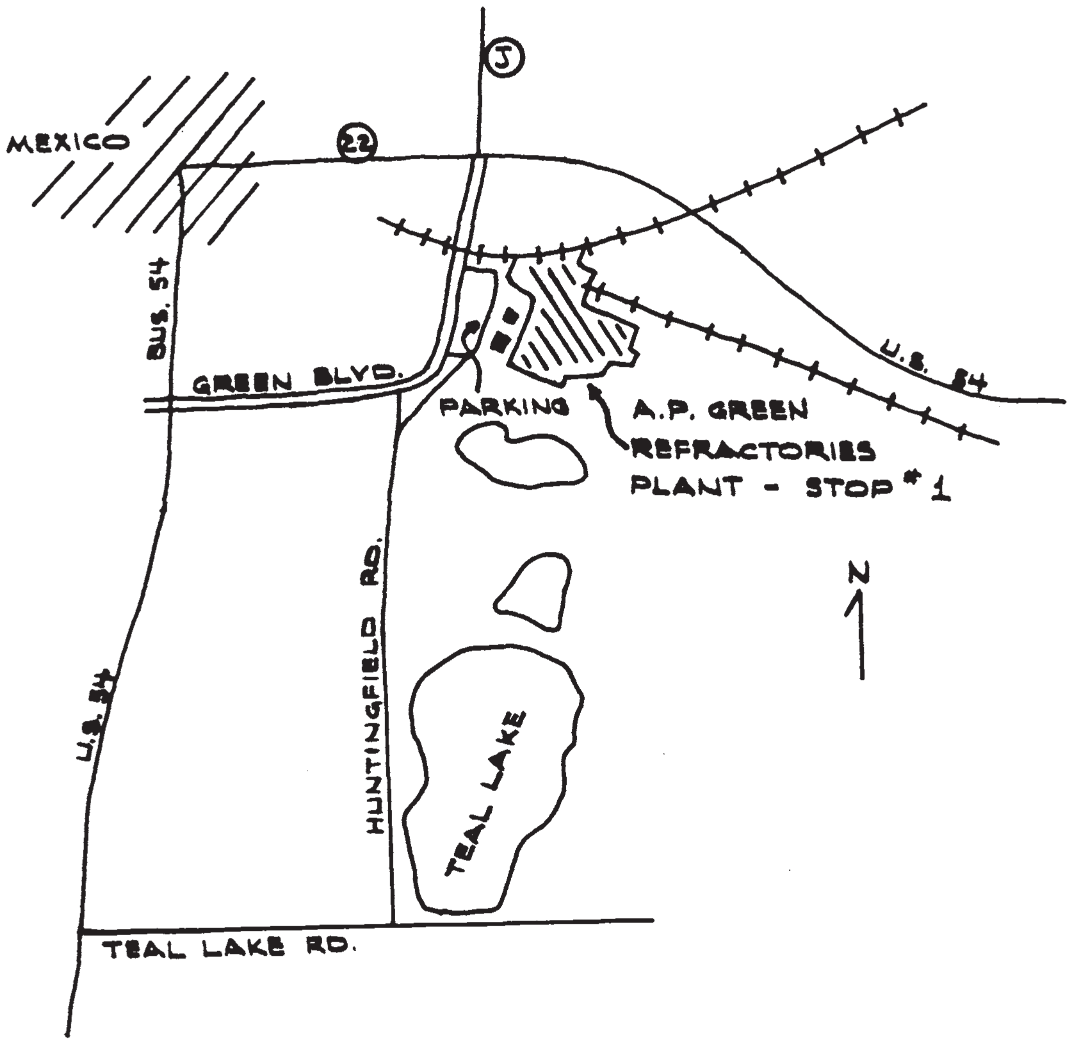
Bedrock in the field trip area is relatively flat lying. Regional strike is N 65° $\pm$ W and dip is to the northeast at 15 to 30 feet per mile. A number of small folds are present in the area and three of these will be crossed along the route. The dominant trend of folds and other structure in northeast Missouri is northwest-southeast, which is also the major direction of the Precambrian structural grain. Structures which will be crossed are the Mexico anticline, the Auxvasse Creek anticline and Mineola structure.

GENERAL STRATIGRAPHIC COLUMN



STOP #1 - A. P. GREEN REFRACTORIES CO.
Mexico, Missouri Plant

We will begin our field trip at Stop #1 at 8:00 a.m. Cars should be parked in front of the main office building. The buses will return to here at 4:00 p.m. From here, we can observe the area to the south and west which was strip mined for fire clays from 1910 to about 1930. The area has since been backfilled with overburden from previous pits and includes the playground and picnic



area south of Garfield School and the landscaped front on company property.

Part of the mined out area is also traversed by Green Boulevard, as well as part used for the Research Building, parking lot, and High Density Products Building.

The Mexico Plant was purchased by Mr. A. P. Green in 1910 and has since become the largest individual plant of this type in the world.

The following account is given by Roberts (1950).

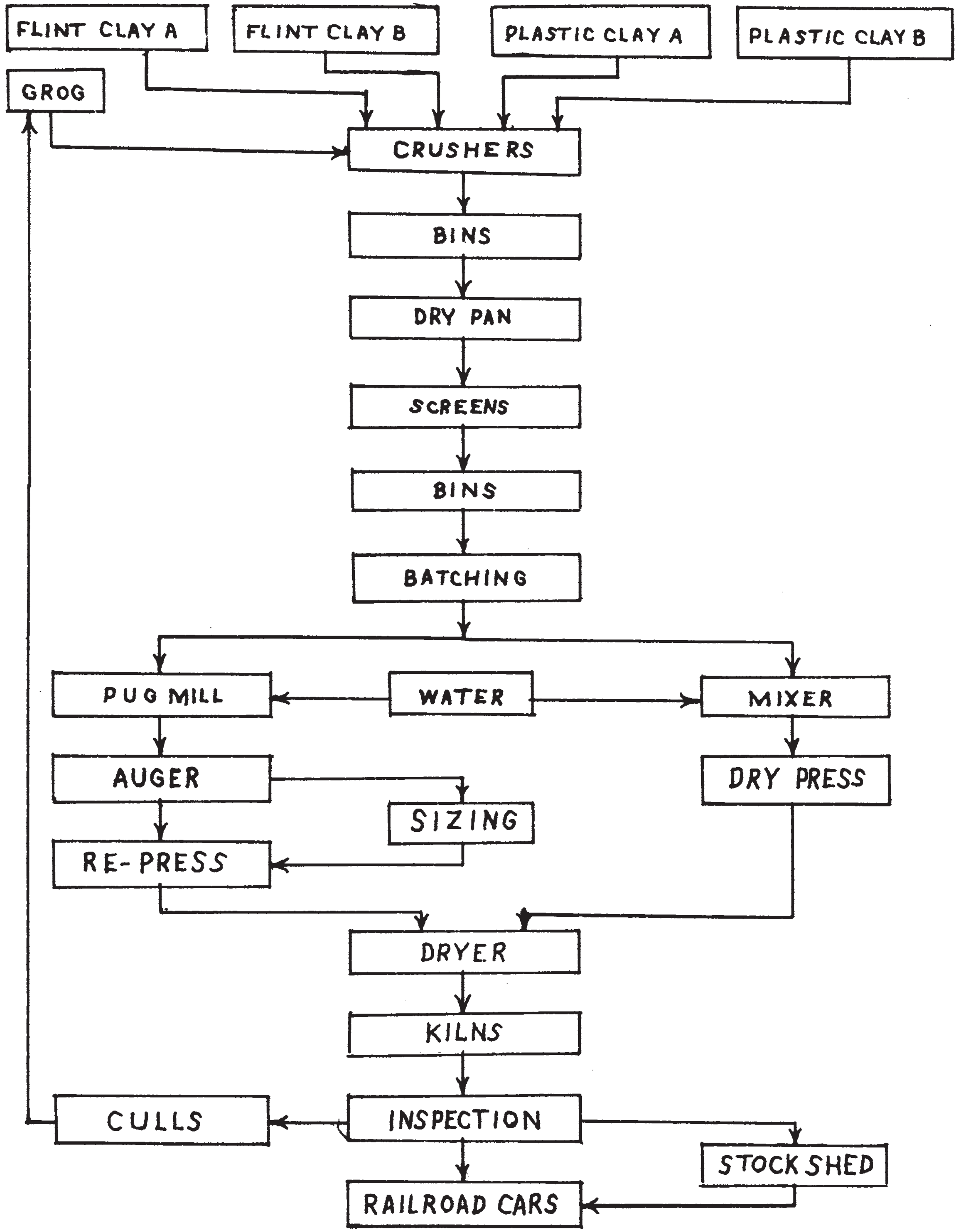
> "The organization that later developed into the A. P. Green Fire Brick Company was first known as the Mexico Brick and Fire Clay Company. This firm was incorporated in 1904 with all the stock held by local businessmen. The two leading stockholders were W. W. Harper and J. A. Glandon. The Harrison Brickyard and Works of East Mexico were purchased for the site of the factory. The plant began operations on April 20, 1905, with a capital investment of $100,000, two kilns, and a 250-horse power engine."

The principal products produced today include fireclay, high-alumina and mullite brick, insulating products, and a complete line of specialties. Various processes are employed including dry press, stiff mud, air hammer, and wood mould. The largest percent of brick is manufactured by the dry press process. A flow diagram of the stiff mud and dry press processes is shown on the next page.

The raw materials are brought into the local yard and stockpiled. The material is then brought into the plant by side-dump or bottom-hopper cars. They are dumped at the crusher house for primary crushing by an Eagle Roll Crusher. Materials are then transported to the Grinding Department. The majority of the material is ground in dry pans. A ball mill and Raymond mill are also used. The Raymond mill has a capacity of 9 tons/hour and is capable of grinding 95% to -325 mesh. After grinding, the material is sized and stored in bins before batching and transporting to the stiff mud, dry press, or other departments for forming into the finished product.

The Stiff Mud department contains two extruding machines, one tunnel kiln, and nine down draft kilns. The clay mix is fed into the auger machines where water is added to produce a stiff-mud column for extruding. The different mixes vary in moisture from approximately 15 to 20%. Some ware can be set directly on tunnel kiln cars while others are set on rack cars for humidity drying.

The Dry Press department contains 21 dry presses with a production capacity of 3,000,000 9" brick equivalent/month. The clay mixture is fed into the presses from the Acme mixers over each press and pressed



FLOW DIAGRAM FOR MANUFACTURE OF STIFF-MUD & DRY PRESS BRICK to the proper green density. The moisture content of the different mixes varies from 5 to 12% and is maintained at 1% variation. A dry press can exert approximately 400 to 1200 tons of pressure, depending on size. After pressing, the brick are set on tunnel kiln cars for firing.

The plant has a total of 12 tunnel kilns which are approximately 400 feet in length. The brick are charged into the kilns with less than 1% moisture. The brick are preheated, heat-soaked at maximum temperature, and cooled in the tunnel kiln. The brick are fired at approximately 2400 to 2700°F.

We will view these kilns as well as the air-hammer process used for intricate shapes or shapes too large for dry press. We will also visit the Specialties department where mortars, castables, and plastics are produced, as well as the palletizing and shrink-wrap operation.

C. N. Roberts, a history of the Firebrick and Refractories Industry in Missouri, School of Mines and Metallurgy, Technical Series Bulletin No. 75, p. 18, 1950.

10:00 A.M. Travel to Stop #2 - Harrison Clay Pit by bus. Enroute from Mexico to Kingdom City pass Todd Clay Pit and Auxvasse Stone Quarry.

MEXICO ANTICLINE -- The Mexico anticline is an anomalous feature in northeast Missouri as its axis (N35°E) is about normal to the northwest-southeast trend of the other folds in the area. Evidence for the structure is based on well logs which indicate about 200 feet of relief on the Mississippian surface. It is thought that movement took place at both the close of Mississippian and Pennsylvanian time. The structure is described by McQueen, 1943, in Fireclay Districts of East Central Missouri (MGS vol.28). The axis of the fold passes through the town of Mexico and on the ERTS-1 imagery a linear trace coincides with the known extent of the axis and extends well beyond it into Illinois.

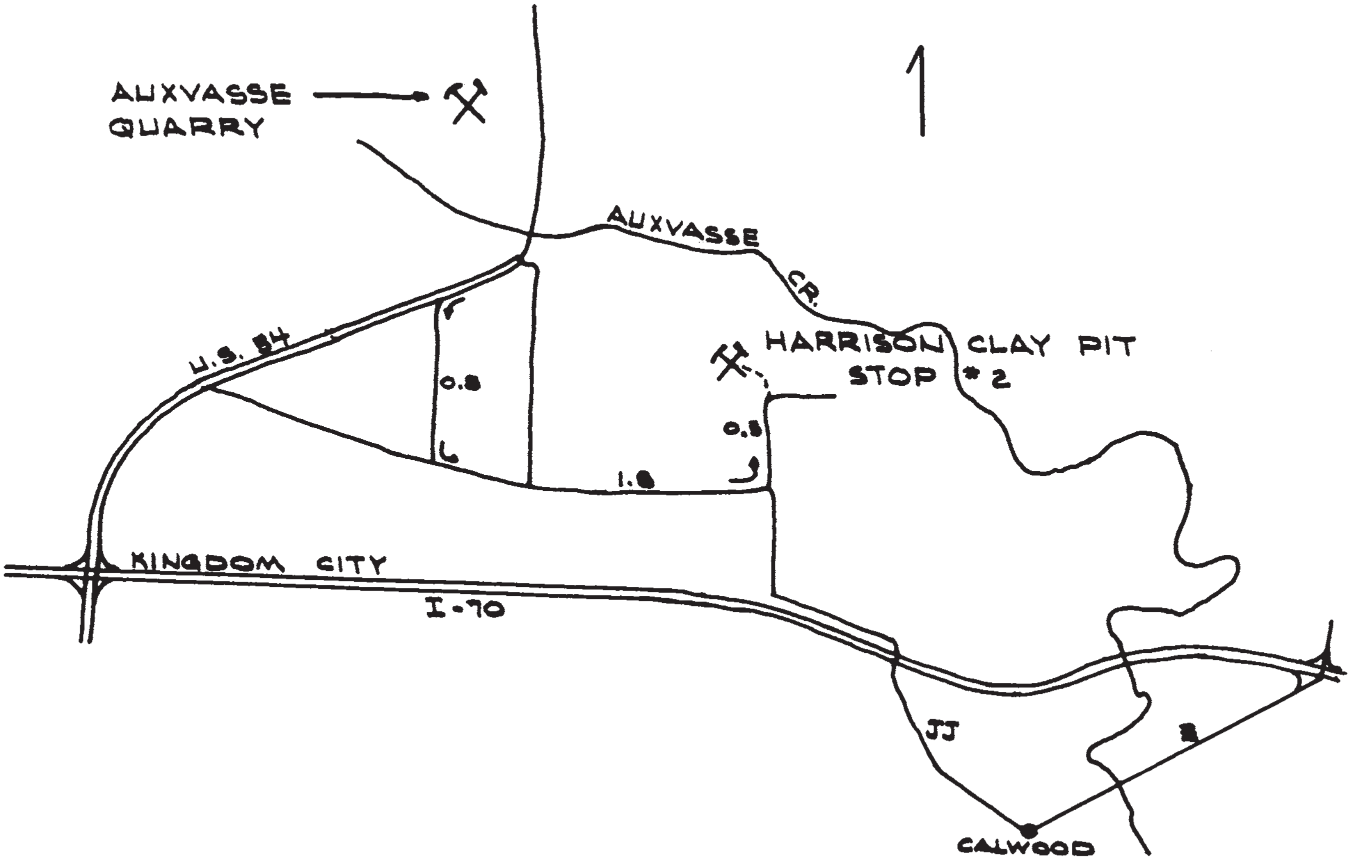
TODD CLAY PIT -- SW¼ Sec. 14, T 50N, R 9W, Auxvasse Quad, Audrain County. Five miles from the A. P. Green Plant and three miles south of Mexico on U. S. Highway 54 at crossing of Scattering Fork Creek. The Todd pit, opened in 1974, can be seen adjacent to the highway to the east. The Cheltenham clay in this area is very irregular in thickness varying from 0 to 25 feet. In general, the upper surface of the clay is nearly flat, whereas the lower surface undulates to produce the variation in thickness. There is some thinning in the immediate area of the pit due to recent erosion of the upper surface by Scattering Fork Creek. Over much of the surrounding area the clay is represented only by a marker bed of 6" to 1' in thickness on the underlying chert residuum of the Burlington limestone. The clay deposit on the Todd property averages about 10' in thickness. The overburden is relatively thin and is composed of approximately 12-15' of alluvial sand and gravel. As we proceed south on U.S. 54 toward Auxvasse, the surface elevation increases and the overburden composed primarily of glacial material increases in thickness. This pit is being mined under permit from the Missouri Land Reclamation Commission and will be reclaimed to pasture land and a recreational lake.

AUXVASSE STONE & GRAVEL COMPANY QUARRY -- SE¼ Sec. 34, T 49N, R 9W., Auxvasse Quad, Callaway County. The quarry is located three miles south of Auxvasse on the west side of U.S. Hwy 54. Stone being quarried is the lower Burlington limestone (20'±), the "Sedalia" dolomite (15'±) and the Chouteau limestone (20'±). The Bushberg-Bachelor-sandstone (1' to 2'), Snyder Creek shale (5' to 10') and Callaway limestone (20'±) are exposed in the quarry but the Callaway is not presently being quarried. The quarry was Stop #3 on the 3rd Annual AMG field trip (1956).

South of the quarry and on the north slope to Auxvasse Creek, the Burlington crops out in the ditch on the west side of U.S. Hwy 54. On the south slope to Auxvasse Creek, a large outcrop of Cheltenham clay is exposed in the road cut. The Harrison clay pit located about one mile down stream contains an excellent exposure of this clay which will be seen at Stop #2.

STOP #2 - HARRISON CLAY PIT

SW¼ Sec. 2, T 48N, R 9W, Fulton Quad, Callaway County



GEOLOGY OF THE MISSOURI FIRE CLAY DEPOSITS

The fire clays of Missouri occur in the Cheltenham formation (Pennsylvanian), and exhibit compositional and mineralogical variations indicative of lithofacies changes within the formation. As shown on the following page, different lithofacies belts can be delineated which are roughly concentric to the Ozark uplift. The Cheltenham fireclays range from dominantly semi-plastic and semi-flint clays in the northwest part of the fire clay district, through flint and finally mixed flint and diaspore clays as the Ozark dome is approached. Thus the plastic and semi-flint clays are found primarily to the north of the Missouri River in the area visited by this field trip.

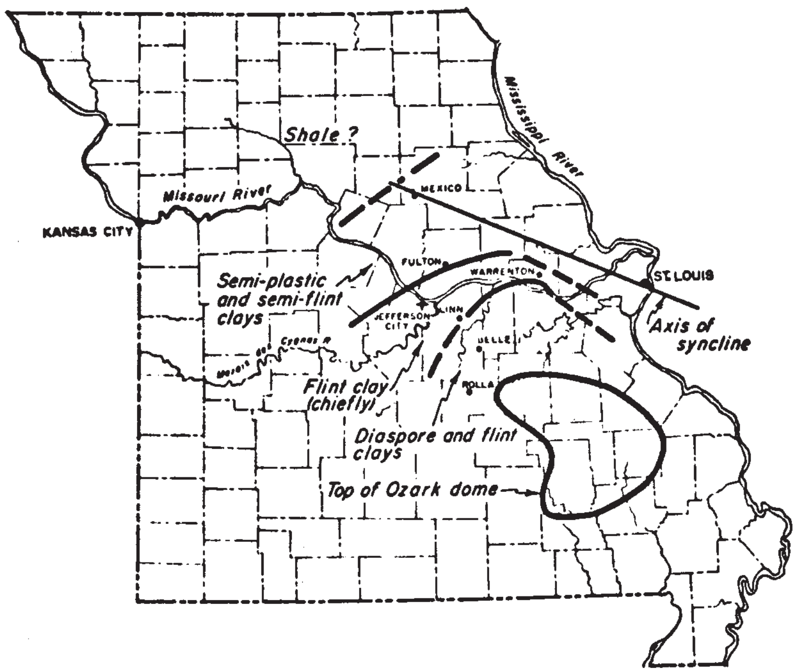


Figure 1, from

Keller, Westcott, & Bledsoe (1954)

The Cheltenham fire clays lie above an unconformity truncating sedimentary rocks ranging from Cambrian to Mississippian in age, dipping gently away from the Ozark Dome. The unconformity developed probably shortly after St. Louis (Miss.) time. North of the Missouri River the fire clays occur as a relatively continuous deposit, varying greatly in thickness and quality, the irregularity in thickness being due to deposition on a very irregular surface, resulting from intensive karst development on the Mississippian surface.

South of the Missouri River, clay deposits, particularly flint and diaspore clays, occur most often in isolated, circular pits, many of them representing solution basins and sinkholes developed in the underlying earlier Paleozoic carbonate rocks.

Generally the sediments immediately underlying the Cheltenham formation are quartzose, pyritic sandstones and cherty conglomerate-breccias of the Graydon formation, and are rather widespread in the north. South of the Missouri River the equivalent rocks are poorly consolidated, unsorted, highly contorted mixtures of quartz siltstones and sandstones, tripolitic chert, and variegated clays and shales. The jumbled, contorted nature of these rocks is taken as evidence of gradual solution of the underlying carbonates, with concomitant subsidence of the existing cover rock to become fill in many cases in so-called filled-sink structures.

Thus solution, subsidence, clay deposition and leaching were all part of the local continuing karst development during Cheltenham time.

Mineralogically the semi-flint and plastic clays consist of mixtures of moderately disordered kaolinite and variable amounts of illite. Quartz is also a common constituent along with variable, but minor amounts of chlorite and often some organic matter.

The flint clays are very fine-grained moderately to highly ordered kaolinite, the softer varieties containing minor illite. Flint clays may grade gradually or abruptly into higher alumina clays.

Mixtures of well-crystallized kaolinite, diaspore and/or boehmite are designated locally as burley clays. These commonly occur with oolites ("burls," a miners term) of diaspore in a matrix of kaolinite.

Essentially pure (mineralogically) diaspore clays occur, their Al_2O_3

contents approaching 75%. ($Al_2O_3 \cdot H_2O$ is 85% Al_2O_3 and 15% H_2O; the other 10% of the actual clay is silica, iron oxide, titania, alkali and alkaline-earth metals.)

At this stop and at the Deeker Pit (Stop #5) we will see occurences of plastic and semi-flint clay.

This summary was abstracted largely from the following two sources:

W. D. Keller, J. F. Westcott, and A. O. Bledsoe, the origin of Missouri Fire Clays,
Prec. 2nd Natn'l Conf. on Clays and Clay Minerals, p. 7-46, NAS-National Research Council Pub. No. 327, 1954.

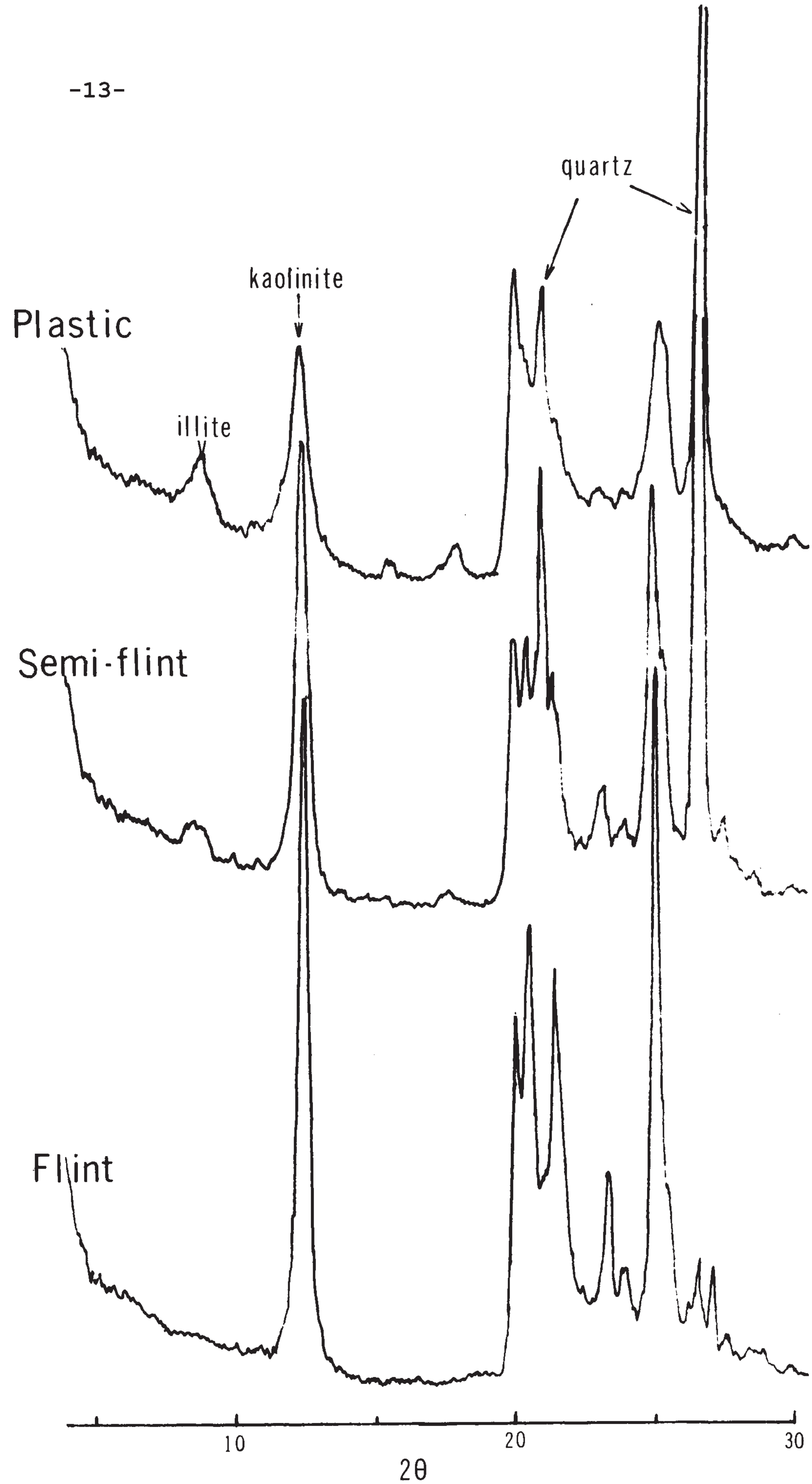
J. H. Bretz, Origin of the filled-sink structures and circle deposits of Missouri,
Bull. G.S.A., v. 61, p. 789-834, 1950.

Mineralogy of Missouri Fireclays

The fireclays we see today owe their refractoriness to their dominant kaolinite component. The central Missouri fireclay district contains the complete spectrum of fireclays, ranging from plastic through semi-plastic and semi-flint to flint clay varieties. We shall not see the high alumina, diaspore-bearing varieties. As we pass from plastic through semi-flint to flint clay, we see a gradual decrease in illite and quartz, the major non-refractory impurities. Flint clay is essentially pure kaolinite (See x-ray diagrams of typical clays on the following page).

Typical chemical analyses of plastic, semi-flint, and flint clays show a continuous decrease in silica, alkaliis, alkaline earths, and iron, with an increase in alumina. The flint clay approaches the composition of ideal kaolinite.

	Plastic	Semi-flint	Flint
SiO_2	56.10	45.92	44.42
Al_2O_3	24.47	35.79	38.63
Fe_2O_3	3.64	0.75	0.55
TiO_2	1.58	2.28	2.12
CaO	0.61	0.06	0.04
MgO	1.11	0.36	0.10
Na_2O	0.17	0.44	0.30
K_2O	2.89	0.41	0.12
H_2O	8.39	13.06	13.90
Total	98.96	99.07	100.18


quartz
kaolinite
Plastic
illite
Semi-flint
Flint
10
20
30
2θ

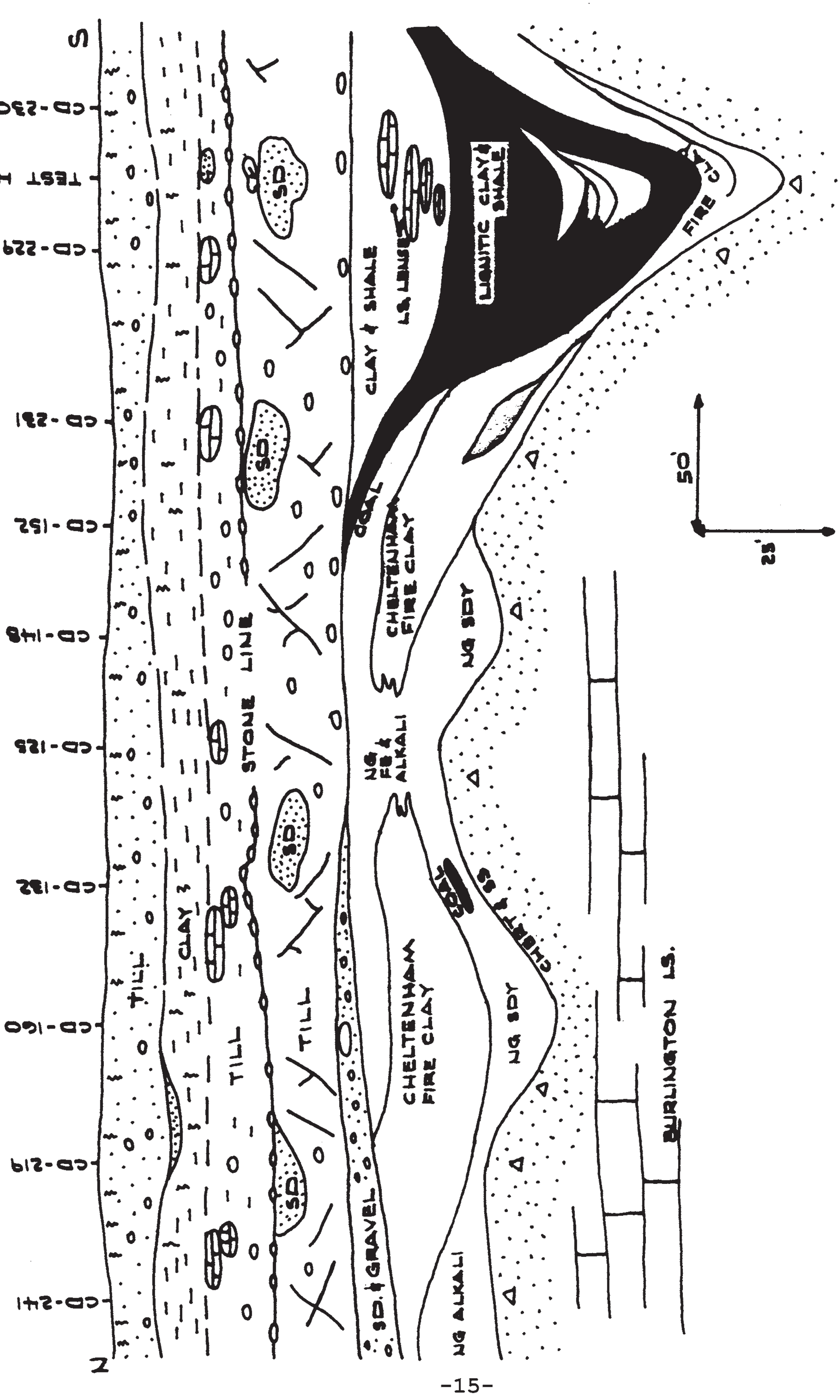
DESCRIPTION OF HARRISON CLAY PIT

Pleistocene section described by W. H. Allen and T. L. Thompson September 13, 1974. Pennsylvanian discussion by C. E. Stack and T. L. Thompson.

Except where eroded in the lower elevations, the clay occurs as a layered deposit under the entire Harrison property. The quality and thickness, as usual, vary considerably. The area immediately to the east of the present pit has been mined out by A. P. Green Refractories Co. since 1970 and backfilled as part of the planned reclamation. The present pit contains 37,000 tons of usable plastic and semi-flint and 13,000 tons of waste clay. The waste clay consists of clay with an excessive amount of impurities in the form of FeS_2, FeO, free SiO_2, or alkali materials. The overburden consisting entirely of soil and glacial till averaged 45' in thickness. A total of 160,000 cubic yards were removed prior to mining.

A cross section of the present pit (#5A) is shown on the next page. Clay thickness varies from 5' to 25' due to the irregularities of the underlying erosional surface. It is not unusual to encounter deep, sink structures similar to one located just south of the present pit. This sink structure is not exposed in the pit, but was delineated by core drilling and is shown in the cross section. The fill material, composed of coal, lignite, and pyritic clay, is about 80' in thickness. The clay occuring in these structures is most commonly flint clays, however, the clay in this structure is a semi-flint. This may indicate more extensive leaching in these deeper depressions.

There are three tills represented in this pit which are probably Kansan in age. The youngest one is relatively thin (maximum thickness 10 feet) and occurs as the surface deposit. It has a Yarmouth-Sangamon Paleosol developed to a depth of approximately five feet, which is also the depth of leaching. Underlying it is a thick (10 feet +) clay which is leached of carbonates. In the back and forth occilations which occurred during Kansan time along the glacial front, ice marginal lakes were formed, and it is assumed that this was the mode of deposition for this unit. It has many



CROSS SECTION HARRISON CLAY PIT 5-A

appearances of the Yarmouth-Late Kansan formation described as the Ferrelview Formation by Howe and Heim (1968). At the top of the middle till a marked concentration of limestone of the Fort Scott Subgroup occurs in an essentially level plane. Some of the boulders exceed 3x7x15 feet in dimension. The till averages 13 feet in thickness and is calcareous throughout. The lowest till is separated from the above by a marked stone line, which shows definite striations in the SW corner of the pit. The average strike of 8 measurements on the striations is S 43° E. This till is dominantly unoxidized and unleached. Incorporated in it is a large amount of wood that was growing on the pre-Kansan surface. It also has incorporated, as locally derived erratics, coal fragments from the Pennsylvanian section. At the base of the section there is a concentration of rounded gravels that contain a few northern erratics. The lowest till is thickest on the northern face of the pit and thins to the south as illustrated in the schematic cross section of the pit.

Ref: Howe, W. B. and Heim, G. E., 1968. The Ferrelview Formation (Pleistocene) of Missouri. Mo. Geological Survey and Water Resources R.I. No. 42.

11:30 A.M. -- Travel to Stop #3 - Graham Cave State Park
Via county roads JJ and Z through Calwood and east on I-70 (24 miles). Much of this route is on Burlington limestone with a thin mantle of residuum and isolated outcrops of Pleistocene materials. Isolated pockets of Pennsylvanian clay are preserved in depressions on the Burlington at the highest elevations. It is composed primarily of purple and red impure plastic clay. Scattered flint clay pits have been located to the south of I-70, as sinks and depressions in the Burlington. Many of these pits contain both flint and plastic clay and represent a transition zone between the plastic clay deposits to the north and the flint clay deposits in the Southern Fire Clay District located south of the Missouri River.

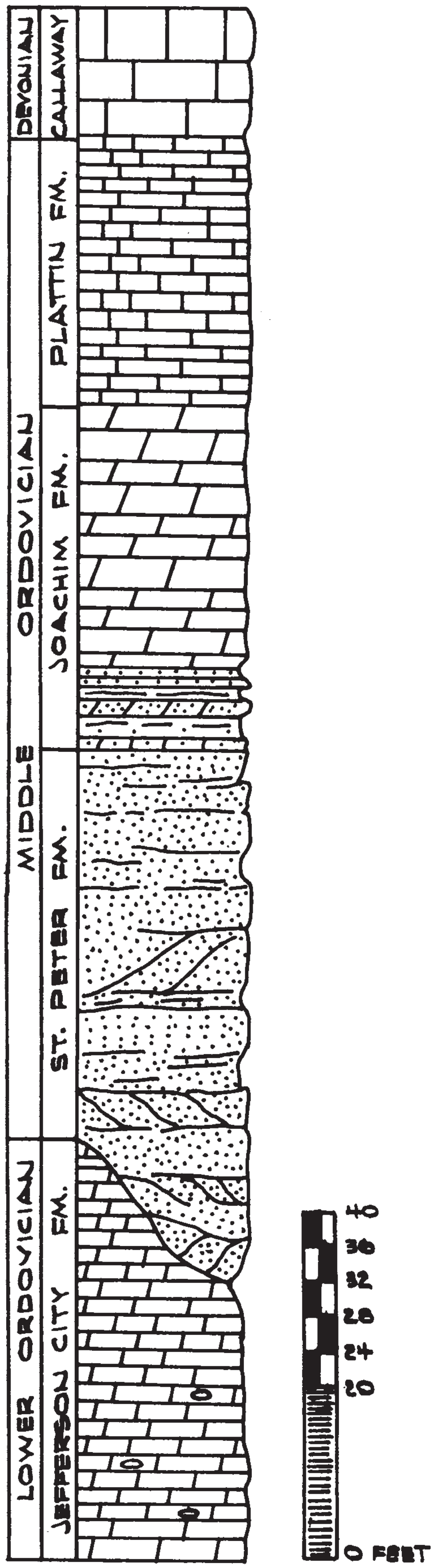
AUXVASSE CREEK ANTICLINE -- About seven miles east of Kingdom City, I-70 and Hwy Z crosses the northwest-southeast trending Auxvasse Creek anticline. The fold is asymmetrical with the steep flank (5° to 10° dips) to the southwest, which is often the case on folds that trend in this direction. The structure brings the Devonian to the surface and the structural relief is on the order of 175± feet. Movement may have been as early as Devonian, occurred during the Mississippian and probably continued into the Pennsylvanian. The fold is the subject of several thesis and is described by Unklesbay (1955) in the Fulton Quadrangle Reprint (M.G.S. Rept. Inv. 19).

MINEOLA STRUCTURE -- T 48N, R 6W, Montgomery County.

The Mineola structure is described as an asymmetrical closed fold or dome with the steeper flank to the southwest. The Loutre River roughly coincides with its northwest-southeast axis and I-70 is approximately normal to this axis as it crosses the Loutre valley. The following description is taken from Structural Features of Missouri by Mary H. McCracken, 1971, Mo. Geol. Surv. Rept. Inv. 49, p. 44.

> This(Mineola structure)was first mapped by Crane in 1912. His work, published as part of Dake's report (1918), showed a pronounced anticline in the vicinity of Mineola, with an east-west trend, and 10° to 20° dips on both flanks. Later work showed the structure to be closed with a short north-south axis. It is asymmetrical with a steep south-southwest dip and more gentle north-northeast dip. An additional closure was mapped in Secs. 13 and 14, T. 48N., R. 7 W. Barnes (1943) pointed to a number of closed anticlines or domes extending northwest from the Mineola area to the Browns Station anticline in Boone County. The Mineola dome brings Cotter (lower Ordovician) rocks to the surface in Loutre Creek, where they are surrounded by rocks ranging in age from Middle Ordovician (St. Peter) to Pennsylvanian (Cherokee Group).

Formations exposed in the roadcuts on either side of the Loutre valley are the Lower Ordovician Cotter (dolomite), Middle Ordovician St. Peter (sandstone), Joachim (dolomite) and Plattin (limestone) and the Devonian Callaway limestone. See fig. on next page.



5. Limestone (Callaway); light-to-reddish-gray; coarsely crystalline to fine-grained; thick irregular beds; predominantly fine-grained reddish-gray portions have relatively few fossils and are mostly confined to basal part; common fossils in the coarse gray limestone are corals and stromatoporoids; filled solution structures common; approximate thickness, as exposed in cuts west of Loutre River . . . . 15'
4. Limestone (Plattin); mottled light and dark gray, locally pink; sparsely cherty; thinly and evenly bedded; weathered surface honeycombed; locally highly fossiliferous with high-spired gastropods; contact with underlying Joachim not well defined; approximate thickness . . . . 30'
3. Dolomite (Joachim); dary gray to earthy, reddish-brown; evenly-bedded except lower part, which consists of sandy dolomite with shale breaks; contact with underlying St. Peter gradational; approximate thickness . . . . 40'
2. Sandstone (St. Peter); massive; thick to thin-bedded; some cross-bedding; several beds near top very friable, others very tightly cemented; uppermost bed contains small sandstone concretions; approximate thickness . . . 45'
1. Dolomite (Jefferson City); thin-bedded, fine-grained; distorted; thickness exposed approximately . . . . . 50'

SECTION BY: A. G. UNKLESBAY & R. B. AYLOR
THIRD ANNUAL A.M.G. FIELD TRIP 10/56

COMPOSITE OF EXPOSURES IN I-70 CUTS
SECTIONS 27 & 28, T. 48N., R. 6W

LOUTRE RIVER VALLEY, MONTGOMERY COUNTY

STOP #3 -- GRAHAM CAVE STATE PARK

NW¼ Sec. 27, T 48N, R 6W Montgomery City Quad, Montgomery County

The lower part of the basal archeological horizon (Zone IV) in the cave is dated as 9,470 ± 400 (M-1928) by Klippel (1971). He suggests that the upper horizons reflect loess deposition. However, these units are leached of carbonates, and reflect an influx of material that was previously leached and transported downslope as colluvium. Just outside the southern edge of the overhang, a probe hole penetrated one and one-half feet of calcareous loess and approximately eight feet of unconsolidated sand. Solid sandstone (St. Peter) was encountered at the base of the hole. This would indicate that the cave is developed entirely in the St. Peter formation. The unleached loess represents deposition prior to the basal date of 9,470 in the lower cultural horizon of the cave. It is suggested that the entire cave fill sequence reflects no eolian depositions but the colluvial accumulation resulting from downslope wash.

Ref: Klippel, W. E., 1971. Graham Cave Revisited, a reevaluation of Its Cultural Position during the Archaie Period, Mamoir No. 9, Missouri Archaeological Society.

STOP #4 -- McCLAIN LIME QUARRY

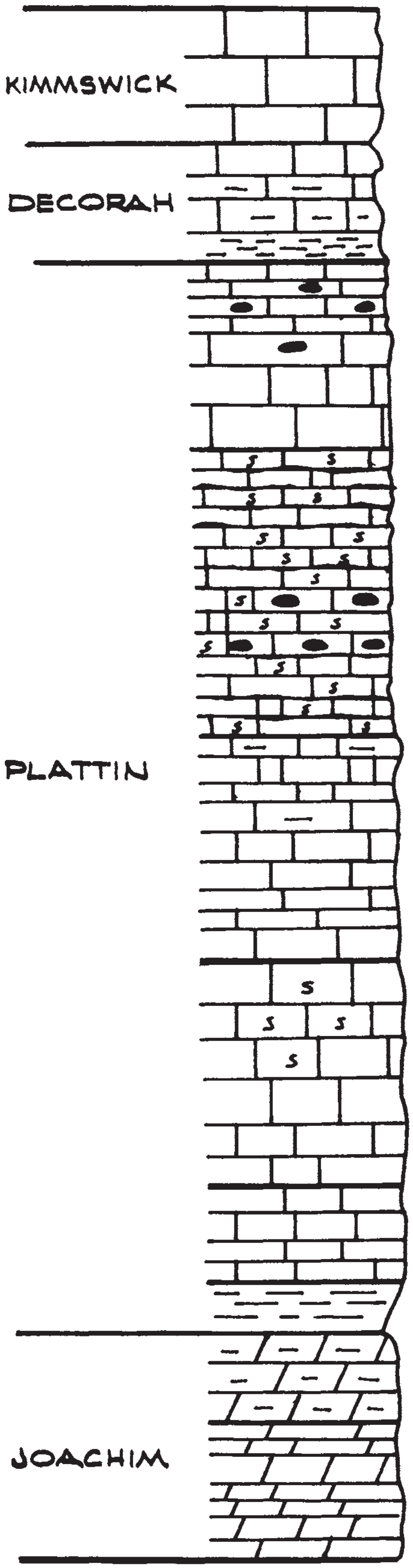
NE¼ Sec. 25, T 48N, R 6W, Montgomery City Quadrangle
Danville, Montgomery County

The quarry was opened in 1955 by H. E. McClain for production of construction aggregates and agricultural lime. Stone being quarried is the Plattin limestone (60' - 90') and Joachim dolomite (20'±). All grades of construction stone from concrete aggregate to crusher run are produced. Approximately 65 feet of the Plattin limestone is approved by the Missouri State Highway Department for portland cement concrete paving aggregate. The remaining 25± feet of Plattin has passed laboratory tests for asphaltic concrete aggregate and the Joachim dolomite has passed lab tests for surfacing. Agriculture limestone from this quarry has a calcium carbonate equivalent (CCE) of between 85 and 95 percent.

The most prominent feature in the quarry is the large number of solution "pockets" filled with green shale, tripolitic chert and limestone blocks. Prior to opening the quarry several cores were taken; however, neither the cores nor the outcrops along the valley (haul road) gave any indication of the presence of these shale and rubble-filled cavities and collapse features.

The number, size and random distribution of these shale and rubble-filled "pockets" result in a number of problems and add substantially to production costs. Blasting patterns have to be adjusted, fragmentation is unpredictable; scalping is almost a continual operating process; and pit development is a headache.

Four formations, Kimmswick, Decorah, Plattin and Joachim are exposed in the quarry area. The Kimmswick and Decorah are present only in a few places and appear to be preserved in depressions on the Plattin surface. The Plattin is the principal unit quarried. It ranges from about 60 to 90 feet and consists of light to dark grey, fine-grained to sublithographic limestone. Bedding ranges from thin and irregular to massive and blocky. Chert is present in the upper half but only in minor amounts. The middle portion is fucoidal and this gives rise to a "honeycombed" weathered surface. At the base is a prominent pink crystalline to coarse grained limestone and thick (3' to 4') green shale. The contact with the underlying Joachim dolomite is placed at the base of the shale which is fairly continuous throughout the quarry.



Limestone, medium crystalline to fine grained; medium to massive bedded.

Limestone, fine grained, argillaceous; shale partings; fossiliferous; 3' purple shale at base.

Limestone, gray; fine grained to dense thin bedded to massive in lower; chert nodules in upper half; fossiliferous.

Limestone, gray to dark gray; fine grained to sublithographic; thin wavy bedded; chert nodules; fucoidal.

Limestone, gray and greenish gray, mottled while and tan; fine grained to sublithographic; irregular thin and medium bedded; fossiliferous.

Limestone, gray to greenish gray; medium and thick bedded.

Limestone, gray and pink; fine to coarse grained; medium irregular bedded.

Shale, green

Dolomite, gray; fine grained; medium bedded; shale partings.

Dolomite, gray to brownish gray; fine grained; medium and thin bedded; shaly.

COMPOSITE SECTION - R. B. AYLOR MISSOURI STATE HIGHWAY DEPT.

McCLAIN LIME QUARRY NE¼ Sec. 25, T. 48N., R. 6W., MONTGOMERY CO.

STOP #5 -- DEEKER CLAY PIT

NW NW, Sec. 11, T 47N, R 5E New Florence Quad, Montgomery County

Pleistocene section measured and described 9/5/74 by W. H. Allen, Jr. and R. A. Ward. Pennsylvanian discussion by C. E. Stack.

The Deeker Pit is operated by M. W. Deeker of Montgomery City. The fire clay is trucked to Mexico for use by Kaiser Refractories.
The clay deposit covers a large agrea and originally outcropped in the valley to the northwest. During early mining, the overburden was quite shallow. Stripping has continued eastward under the heavy Pleistocene overburden where it ranges from thirty-five to eighty feet. Kaiser is using five different grades of clay from this pit ranging from hard flint to a soft semi-plastic clay. The average thickness of good clay in the area now being mined is ten feet. Overburden stripped from the new pit area is back filled in the old mined out pit as part of the reclamation program. Rye grass and fescue have been seeded on parts of the fill.
This pit is similar to many in the New Florence area where both flint and plastic clay occur together.
A 3 to 4 foot seam of low quality clay lies above the plastic clay. It represents the youngest Pennsylvanian unit in the pit.
Above the Pennsylvanian clay, but below the presently recognized Pleistocene sequence is an 8 foot unit of material that grades upward from a course sub rounded to angular patinaed chert set in a matrix of clay to medium grained angular, subrounded, and rounded patinaed chert pebbles set in a heavy clay to a light purplish clayey silt at the top. The unit at the base appears to be a residual lag gravel that was moved only a short distance off of a Mississippian high. The entire unit is leached of carbonates and represents considerable paleosolic modification of the original material. Long term stability is indicated by the thick paleosol which has its counterpart in very well developed modern day forest profiles.
The Early Pleistocene ice advance that deposited the thirty foot sequence immediately above the lowest paleosol was preceeded by an icemarginal lake for just below the till is a 3 inch thick varve unit. This marker bed is only slightly contorted and its relatively flat nature cannot be explained. It is highly calcareous and represents

the first recognized phase of Pleistocene deposition in this area.

During the past ten or fifteen years, a controversy has arisen in the Pleistocene literature regarding a correlation and age assignment of units. The older concept would relate to 4 glacial advances and 4 interglacials. Recent work has shown that interpretations based on the occurrence or absence of paleosols is not sufficient. Even those concepts regarding the Pearlette Ash as a single marker bed can no longer be accepted. Dating techniques are vastly improved; however, one must find the specific method that fits most of the conditions encountered in the field. C-14 methods are not appropriate to dating anything older than approximately 45,000 Y.B.P.; therefore, it is not applicable to any materials older than the latest major glacial advance (Wisconsinan). Fission track dates are no good if sufficient ash deposits don't exist with which to make correlations. Interglacial paleosolic development is the oldest method used and by far the most convincing field evidence. However, paleomagnetic dating has recently come to the fore front as an excellent means of corroborating field evidence. In correlating and assigning relative ages to those units observed on this field trip, we have used a combination of paleomagnetic data, gross lithologic differences, paleosols, and information gained from extensive investigation of the Pleistocene sequence in the Mark Twain Mine area north of Columbia.

The lower till unit here is thirty feet thick and contains a predominance of locally derived erratics (chert boulders) in the upper fifteen feet. The upper 2 feet is leached and has a high clay component indicating paleosolic development. Correlating with the Hinkson Creek Section and the Mt. Hope Section (Guccione, Davis, Allen, and Williams, 1973) the lower till is assigned an age of Late Nebraskan or Early Kansan on the basis of a negative paleomagnetic declination reading from silts overlying the till. The paleosol occuring at the top of the till (43 feet below the surface) is herein accepted as the Aftonian Paleosol which has long been used as the stratigraphic marker between Nebraskan and Kansan till, therefore this is the most southern local where Late Nebraskan Till has been recognized in the state. It is informally designated as the "Whippoorwill Creek" till and the

type section is designated as the Deeker Clay Pit Section.
Above the Afton Paleosol are two tills which are primarily differentiated by texture. They are tentatively assigned ages of Early Kansan and Medial Kansas. The lower (24 feet thick) of the two tills contains a higher percentage of coal (derived from the Pennsylvanian deposits to the north) than the upper till. The upper two tills are separated by a 6 inch sand lense which shows no signs of being leached. Unpublished laboratory data from M.G.S. Hole 92-38 in the western part of St. Charles County indicates that the textural differentiation between the two is real, but there was insufficient time between the advance, retreat, and readvance to permit weathering or formation of an incipient soil profile.
The Whippoorwill Creek till was contorted by the overriding Kansan glacial advance. However, the Early Kansan till does not appear to be contorted in this area. In other areas, such as north of Columbia, the two Kansan tills are separated by outwash sands and gravels. Incompletely developed paleosols are developed on the outwash. Contortions of the interglacial units are observed in that locality also.
At the top of the till sequence a Yarmouth-Sangaman Paleosol is developed. Depth of leaching is five feet. The total depth of carbonate removal is 9½ feet from the ground surface down.
Four and one-half feet of Wisconsin Loess lies above the till. The modern day soil profile extends to a depth of 2½ feet in this unit.
The exceptionally thick till sequence in this area is accentuated by the preservation of the lower till unit ("Whippoorwill Creek" till) which is virtually non-existant in the Mexico Plains area.
The probability is very good that it was deposited there, but later eroded up and incorporated in the Kansan tills that superseded it.

Ref: Guccione, M. J., Davis, S. M., Allen, W. H., and Williams, J. H., 1973 Pleistocene and Engineering Geology of North-Central Missouri, North Central G.S.A. Field Trip No. 2. Missouri Geological Survey Miscellaneous Pub. #26.

3:00 P.M. -- Return to Mexico via Mo. Hwy. 19 and U. S. Hwy 54.