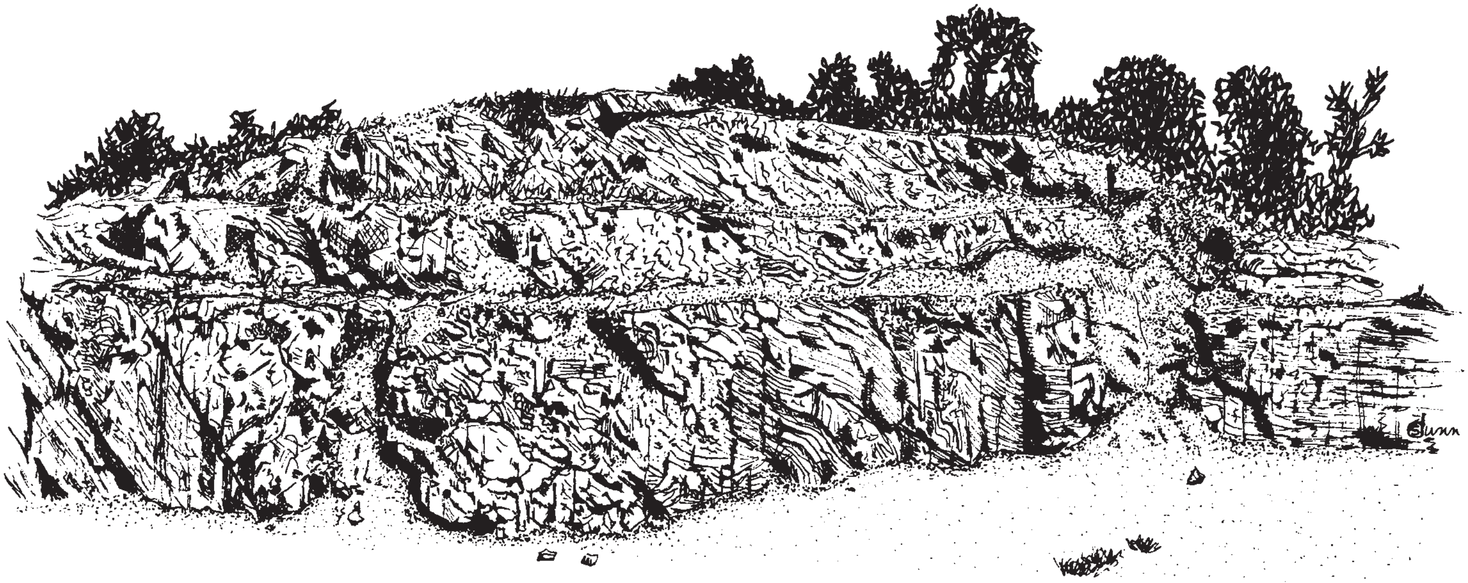
Association of Missouri Geologists

# Guidebook

24th Annual Field Trip
October 1, 1977



geology in the area of the

# Eureka-House Springs Anticline

with emphasis on stratigraphy—
structure—economics

Co-sponsored by: Missouri State Highway Department and St. Louis Community College at Meramec

ASSOCIATION OF MISSOURI GEOLOGISTS

24th ANNUAL MEETING

SEPTEMBER 30-OCTOBER 1, 1977

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MISSOURI HIGHWAY DEPARTMENT DISTRICT SIX

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# PREFACE

The Friday afternoon trip is to the Laclede Gas Underground Storage Facility in north St. Louis County. This particular operation is unique in at least two ways. For one thing, commercial oil production was encountered during exploration for the storage reservoir. Another unusual feature is the largest mined cavern in the country for the storage of liquid propane.

The purpose of the Saturday field trip is to study the geology in the area of the Eureka-House Springs Anticline. The papers in the guidebook place emphasis on the stratigraphy, paleontology and structural aspects of the area as well as geologic problems encountered during the construction of Highway 30.

The Saturday afternoon portion of the trip includes a visit to two quarries. Emphasis is placed on the economics associated with rock formations in the field trip area.

A geologic column, cross section route map with stops and a road log is included in the guidebook.

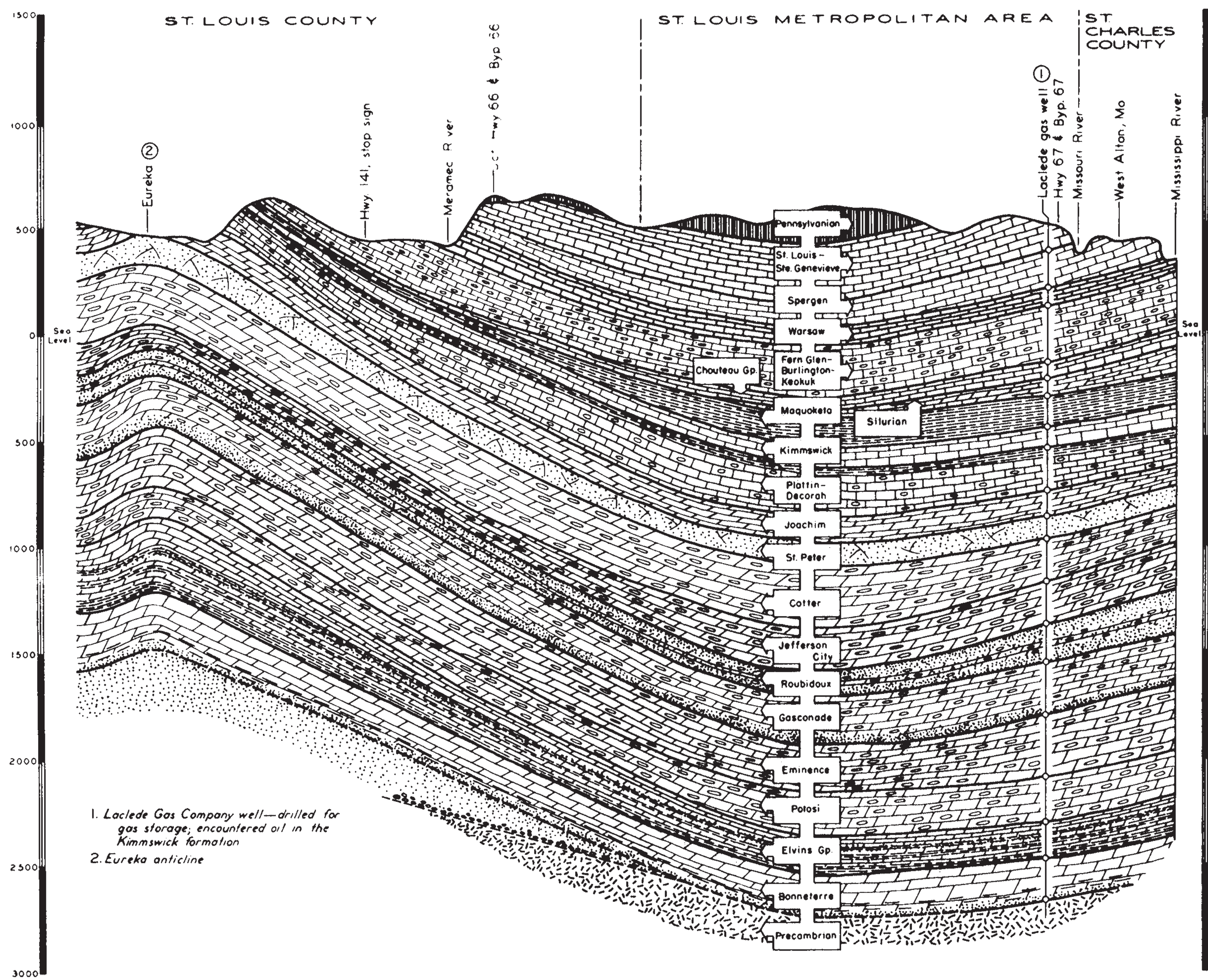
The Field Trip Committee wishes to acknowledge the help of James Martin and Waldemar Dressel who reviewed and edited the papers. Lois Phillips of Meramec typed, proofed and helped assemble the manuscripts. Sun Dunn of the Geological Survey drew the picture for the guidebook cover. Meramec Community College helped with the illustrations and printed the guidebook.

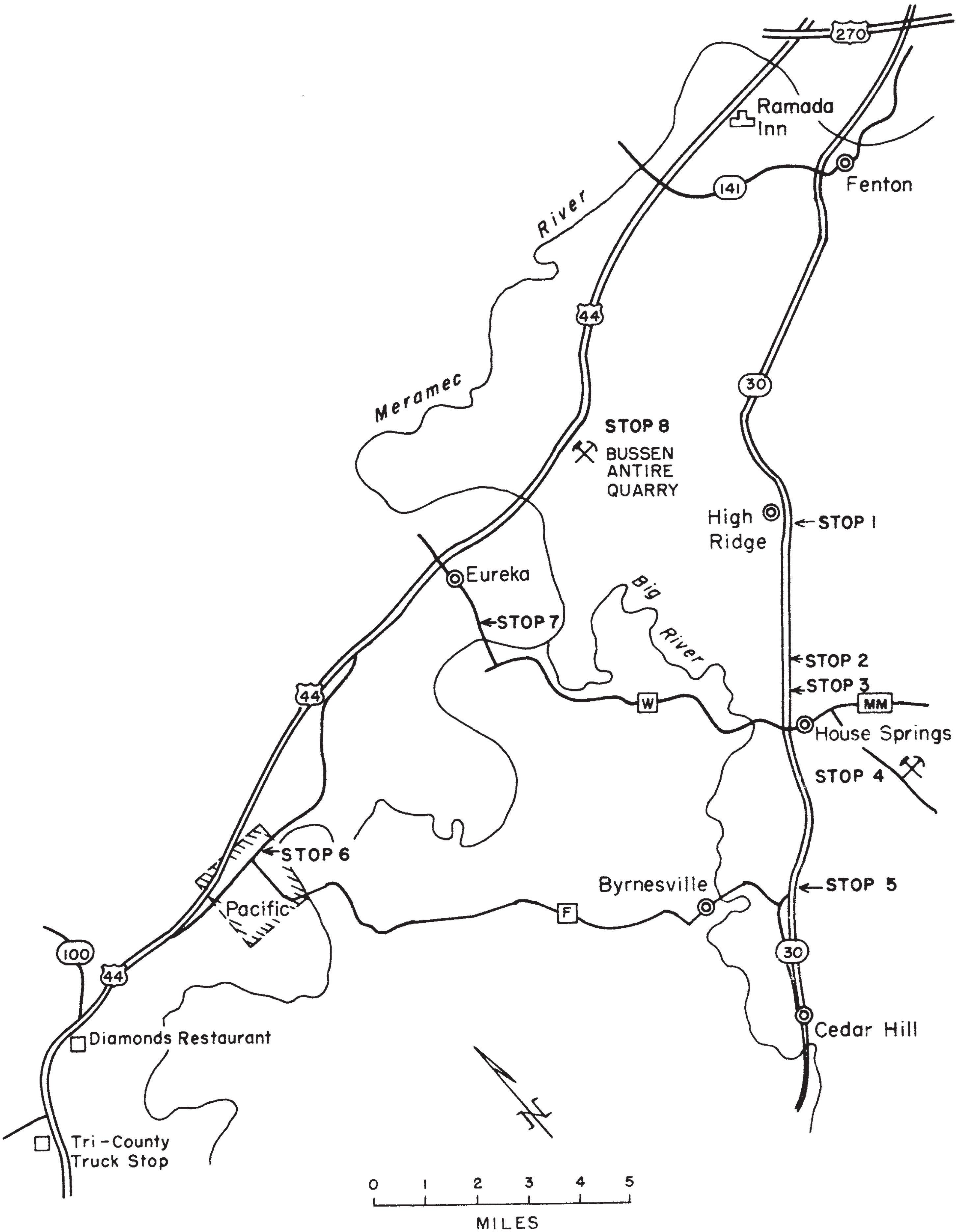
# GENERAL STRATIGRAPHIC COLUMN, ST. LOUIS COUNTY

QUATERNARY - PLEISTOCENE SERIES - Till, alluvium, & loess - 0-100'±
TERTIARY - PLIOCENE SERIES - "Layette" (Grover) gravels - 0-10'±

| System | Series | Formation or Group | Thickness | Dominant Lithology |
|---|---|---|---|---|
| PENNA. | MISSOURIAN | Pleasanton Group | 0-100± | Sandstone, shale |
| PENNA. | DESMOINESIAN | Marmaton Group | 0-75 | Limestone, shale, coal |
| PENNA. | DESMOINESIAN | Cherokee Group | 0-100 | |
| PENNA. | ATOKAN | Cheltenham | 0-30 | Clay (refractory) |
| MISSISSIPPIAN | MERAMECIAN | St. Genevieve | 0-50 | Limestone, sandy oolitic |
| MISSISSIPPIAN | MERAMECIAN | St. Louis | 200± | Limestone, lithographic |
| MISSISSIPPIAN | MERAMECIAN | Salem (Spergen) | 100-175 | Limestone, dolomite, cherty |
| MISSISSIPPIAN | MERAMECIAN | Warsaw | 70 | Shale, limestone, cherty |
| MISSISSIPPIAN | OSAGEAN | Keokuk | 200± | Limestone, cherty |
| MISSISSIPPIAN | OSAGEAN | Burlington | | Limestone, cherty |
| MISSISSIPPIAN | OSAGEAN | Fern Glen | 0-60± | Limestone, cherty, shaly |
| MISSISSIPPIAN | KINDERHOOKIAN | Chouteau | 0-25 | Limestone, dolomite, argillaceous |
| MISSISSIPPIAN | KINDERHOOKIAN | SULPHUR SPR. GROUP: Bachelor | 1+ | Sandstone, phosphatic nodules |
| DEVONIAN | UPPER | SULPHUR SPR. GROUP: Bushberg | 5-50± | Sandstone |
| DEVONIAN | UPPER | SULPHUR SPR. GROUP: Glen Park | 0-30 | Limestone, oolitic, (basal shale) |
| SILURIAN | | Subsurface St. Louis Co. | 0-150± | Dolomite |
| ORDOVICIAN | CINCINNATIAN | Maquoketa | 0-100+ | Shale |
| ORDOVICIAN | CHAMPLAINIAN | Kimmswick | 5-100 | Limestone, crystalline |
| ORDOVICIAN | CHAMPLAINIAN | Decorah | 25+ | Limestone, shaly, shale |
| ORDOVICIAN | CHAMPLAINIAN | Plattin | 80-150 | Limestone, fine, chert |
| ORDOVICIAN | CHAMPLAINIAN | Joachim-Rock Levee | 60-125 | Dolomite, argillaceous, shaly |
| ORDOVICIAN | CHAMPLAINIAN | St. Peter | 50-150+ | Sandstone |
| ORDOVICIAN | CANADIAN | Cotter-Powell | 100-300 | Dolomite, cherty |
| ORDOVICIAN | CANADIAN | Jefferson City | 150± | Dolomite, cherty |
| ORDOVICIAN | CANADIAN | SUBSURFACE ONLY | | |
| ORDOVICIAN | CANADIAN | Roubidoux | 100-200 | Sandstone, dolomite, cherty |
| ORDOVICIAN | CANADIAN | Gasconade | 250-300 | Dolomite, cherty |
| CAMBRIAN | UPPER | Eminence, Potosi | 200-450 | Dolomite, quartz druse |
| CAMBRIAN | UPPER | ELVINS GROUP: Derby-Doe Run | 150-400 | Dolomite |
| CAMBRIAN | UPPER | ELVINS GROUP: Davis | | Dolomite, shale |
| CAMBRIAN | UPPER | Bonneterre | 175-375 | Dolomite |
| CAMBRIAN | UPPER | Lamotte | 0-300 | Sandstone |

PRECAMBRIAN BASEMENT -- granite, red quartzite


ST. LOUIS COUNTY
ST. LOUIS METROPOLITAN AREA
ST. CHARLES COUNTY
Eureka ②
Hwy 141, stop sign
Meramec River
Hwy 66 & Byp 66
Laclede gas well ①
Hwy 67 & Byp. 67
Missouri River
West Alton, Mo
Mississippi River
Sea Level
1500
1000
500
0
500
1000
1500
2000
2500
3000
Pennsylvanian
St. Louis-Ste. Genevieve
Spergen
Warsaw
Fern Glen-Burlington-Keokuk
Chouteau Gp.
Maquoketa
Silurian
Kimmswick
Plattin-Decorah
Joachim
St. Peter
Cotter
Jefferson City
Roubidoux
Gasconade
Eminence
Potosi
Elvins Gp.
Bonneterre
Precambrian
1. Laclede Gas Company well—drilled for gas storage; encountered oil in the Kimmswick formation
2. Eureka anticline



270
Ramada Inn
141
Fenton
River
Meramec
44
30
STOP 8
BUSSEN ANTIRE QUARRY
High Ridge
STOP 1
Eureka
STOP 7
Big River
STOP 2
STOP 3
W
MM
House Springs
STOP 4
44
STOP 6
Byrnesville
STOP 5
Pacific
F
30
100
44
Cedar Hill
Diamonds Restaurant
N
Tri-County Truck Stop
0 1 2 3 4 5
MILES

## AREAL GEOLOGY OF THE EUREKA-HOUSE SPRINGS STRUCTURE

### ROAD LOG

| Mileage | Cum. | |
|---|---|---|
| 0.0 | 00.00 | Ramada Inn, Main Entrance. Turn east on outer road. |
| 0.9 | 0.9 | Eastbound on-ramp to I-44. |
| 0.5 | 1.4 | Monolithic concrete wall. |
| 0.66 | 1.56 | Take southbound connecting ramp to I-270. |
| 0.04 | 1.6 | Concrete crib-type wall high on right backslope. |
| 0.68 | 2.28 | I-270 cuts in Meramecian Series: Salem & Warsaw formations. |
| 1.02 | 3.3 | Broken backfill template 1:1 rock slope, 3:1 soil slope. |
| 0.09 | 3.39 | Take westbound connecting ramp to Route 30. |
| 0.41 | 3.8 | Traffic signal. |
| 0.22 | 4.02 | Meramecian backslopes. |
| 0.61 | 4.63 | Meramec River floodplain; road cuts through strath terrace. |
| 0.22 | 4.85 | Surcharged fill area. |
| 0.83 | 5.68 | Bridge over Meramec River. |
| 0.22 | 5.9 | West bridge approach fill failed. |
| 0.4 | 6.3 | Spring under fill. |
| 1.68 | 7.98 | Traffic signal. |
| 0.03 | 8.1 | Slope failure on right backslope. |
| 0.52 | 8.62 | Bridge over Saline Creek. |
| 0.63 | 9.25 | Traffic signal. |
| 3.1 | 12.35 | Traffic signal. |
| 0.15 | 12.5 | Backslopes on both sides are examples of deep residual mantle of cherty red clay typical in areas where the peneplain surface has survived over underlying Burlington-Keokuk formation. |
| 0.06 | 12.56 | Spring under fill. |

| | | |
|---|---|---|
| 0.56 | 13.12 | Traffic signal |
| 0.3 | 13.42 | STOP #1 - Road cuts expose unconformable contact between Bushberg sandstone and Kimmswick limestone. Sand filled solution cavities and basal brecciation are exposed along the service road to the left. |
| 0.38 | 13.8 | Large voids in cherty residuum. |
| 1.16 | 14.06 | Collapsed structure; folding on right. |
| 0.04 | 14.1 | Left backslope laid back. |
| 0.6 | 14.7 | Deep cuts expose Plattin formation overlying Joachim formation. |
| 0.16 | 14.86 | Divided highway ends; two-way traffic. |
| 0.94 | 15.8 | STOP #2 - Exposure of major fault on flank of Eureka-House Springs structure. |
| 0.5 | 16.3 | Archeological site of the "crescent quarry" type on the right. |
| 0.37 | 16.67 | STOP #3 - Backslope on the east side of highway exposes relationships of the Plattin, Decorah, Kimmswick, Bushberg (Sulphur Springs), and Fern Glen formations. |
| 0.38 | 17.05 | Junction with Route MM, turn left to House Springs. |
| 0.55 | 17.6 | Bear right at bridge to low water crossing. |
| 0.2 | 17.8 | Stop. Turn right on Route MM. |
| 0.03 | 17.83 | Straight ahead on county road. |
| 0.22 | 18.05 | Bridge over Heads Creek. |
| 1.08 | 19.13 | STOP #4 - House Springs Quarry. Material produced here was used in the construction of new Route 30. |
| 2.07 | 21.2 | Return to Route 30, turn left. |
| 2.8 | 24.0 | Cut through Crystal Escarpment. |
| 0.11 | 24.11 | Cave beneath roadway. |
| 0.04 | 24.15 | 120' high fill on left; $1\frac{1}{2}$:1 slope. |
| 0.04 | 24.19 | Turn left onto old Route 30. |

| | | |
|---|---|---|
| 0.32 | 24.51 | Turn left onto gravel road.<br>STOP #5 - Before grading for the new highway this was the crest of the crystal escarpment. View of Big River and Sandy Creek valleys to the south and west. |
| 0.32 | 24.83 | Return to Route 30, turn left. |
| 0.26 | 25.09 | Turn right on Byrnsville Road. Cut in Joachim. |
| 0.05 | 25.14 | Stop. Turn left. |
| 0.35 | 25.49 | Turn right on Byrnsville Road. |
| 1.41 | 26.9 | One lane bridge over Big River. Byrnes mill upstream. |
| 0.2 | 27.1 | Stop. Turn left on Lower Byrnsville Road. |
| 0.63 | 27.73 | Turn right on Lynch Road. |
| 1.7 | 29.43 | Top of Crystal escarpment. |
| 1.2 | 30.63 | St. Peter formation exposed on left. |
| 0.02 | 30.65 | Junction with Route F, bear to right. |
| 0.61 | 31.26 | Bridge over La Barque Creek, continue straight on Route F. |
| 3.41 | 34.67 | Stop. Junction with Route O, turn right on Route F. |
| 0.43 | 35.1 | Road cut exposes Joachim/St. Peter contact. |
| 0.68 | 35.78 | Bridge over Meramec River. |
| 0.1 | 35.88 | Pacific, Missouri. |
| 0.9 | 36.78 | Railroad crossing. |
| 0.23 | 37.01 | Junction with Route N, continue straight. |
| 0.08 | 37.09 | Stop. Continue straight. |
| 0.07 | 37.16 | Stop. Junction with Business 66, turn left. |
| 0.81 | 37.97 | Stop. Caution: on-ramp cross traffic does not stop.<br>Continue straight. |
| 0.16 | 38.13 | Stop. Continue straight. |
| 3.6 | 41.73 | Stop. Junction with Route 100, continue straight. |
| 0.02 | 41.75 | Diamonds Restaurant. |

| | | |
|---|---|---|
| 1.82 | 43.57 | Stop. Junction with Route AT, continue straight. |
| 0.28 | 43.85 | Tri-County Truck Stop Restaurant. |
| 0.28 | 44.13 | Return to Junction Route AT & 100, turn right. |
| 0.2 | 44.33 | Continue straight on eastbound on-ramp to I-44. |
| 3.28 | 47.61 | Take off-ramp to Pacific. |
| 0.1 | 47.71 | Stop. Turn left on Business 66. |
| 0.17 | 47.88 | Stop. Continue straight. |
| 1.88 | 49.76 | STOP #6 - Pennsylvania Glass Sand Co. |
| | | Continue east on Business 66 after stop. |
| 2.65 | 52.41 | Bridge over Fox Creek. Fox Creek has been beheaded by the Meramec River; Business 66 and the railroad go through the watergap to the right. |
| 1.3 | 53.71 | Merge left with I-44. |
| 1.96 | 55.67 | Take off-ramp to Eureka. |
| 0.19 | 55.86 | Stop. Turn right on Route W. |
| 0.24 | 56.1 | Railroad crossing. |
| 0.14 | 56.24 | Stop. Continue straight. |
| 0.14 | 56.38 | Bridge over Flat Creek. This was the valley of Fox Creek prior to the piracy of its headwaters. |
| 0.63 | 57.01 | STOP #7 - Roadcuts expose folding and faulting associated with Eureka-House Springs anticline. |
| 1.3 | 58.31 | Return to I-44, turn right on eastbound on-ramp. |
| 1.88 | 60.19 | Bridge over Meramec River. |
| 0.27 | 60.46 | Take off-ramp to Lewis Road & Times Beach. |
| 0.22 | 60.68 | Stop. Cross over I-44 to outer road. |
| 0.33 | 61.01 | Turn left on Beckwoods Drive, go under I-44. |
| 0.15 | 61.16 | Turn left on gravel road. Watch for truck traffic. |

| | | |
|---|---|---|
| 0.75 | 61.91 | Turn right into Bussen Antire Quarry.<br>STOP #8 - Section of Joachim through Kimmswick formations. |
| | | Turn right leaving quarry. |
| 1.1 | 63.01 | Junction with Beaumont-Antire Road. Caution: bear to left. |
| 1.05 | 64.06 | Merge left with I-44. |
| 4.59 | 68.65 | Take Bowles Avenue off-ramp. |
| 0.23 | 68.88 | Stop. Turn right, then left onto outer road. |
| 0.65 | 69.53 | Ramada Inn. |

# GEOMORPHIC HISTORY OF FIELD TRIP AREA
24th Annual Meeting, A.M.G.

Ray Linebach
Missouri State Highway Department - District Six

The area traversed by the field trip is one which has been influenced by many geologic processes, directly and indirectly, and bears their marks in a sometimes bewildering array of field data. Certainly the most prominent of these processes in terms of influencing landform are the two opposing forces of diatrophism and erosion, more specifically: the Ozark uplift and the humid fluvial cycle.

Being an asymmetrical uplift overlapped by sediments of various thickness and lithologies, subsequently truncated, each flank of the Ozark dome has its own morphologic peculiarities. This, the northeast flank, by virtue of relatively steeper dips, has exposed many formations in short lateral distances.

Ages of formations at the surface range from the Ordovician-Jefferson City group to the Pennsylvanian remnants in filled sink-structures, which in turn are post-dated by Pleistocene loess, and even younger alluvial deposits.

Geomorphic history of the field trip area is complex and only partially understood, although much discussed. The influence of time that we observe in the field here, as everywhere, attenuates as one looks back through geologic history. That is, the most recent processes are the most obvious. For example, it is fairly obvious that the streams here are incising their valleys; that gradient and load are not yet balanced at base level throughout their course. It is somewhat less obvious to the casual observer that at one time these same streams had not only reached base level but had reduced their entire drainage basins to near the ultimate end of the fluvial cycle: a peneplain. Furthermore, the fact that this cycle has run its course at least twice is not at all obvious. In fact, one must go far outside the field trip area to observe the strongest evidence of this concept.

Nevertheless, Ozark landforms are the result of a repeated cycle of uplift and erosion that has been going on at least since Cambrian times. The structural apex of the dome, the St. Francois mountains, has been above tide since the Pre-Cambrian, and the Paleozoic formations which onlap its flanks have been positive landforms since late Pennsylvanian time.

An extensive plain of erosion was buried by the transgressing Pennsylvanian sea, apparently a plain of karst topography. We see evidence of that in the innumerable roughly circular depressions which now contain virtually all that remains of basal Pennsylvanian sediment within the Ozark province. Considerable relative uplift was required to remove the great thickness of cyclic Pennsylvanian mud and sand. This erosional period is obscure, as are all periods of non-deposition, but apparently continued throughout the entirety of the Mesozoic Era and culminated in the widespread Springfield peneplain.

Renewed uplift in the early Tertiary terminated this cycle and initiated the next, or Ozark cycle. The Ozark surface did not have as much time to develop to the extent of the Springfield peneplain, for rejuvenation in fairly recent times has Ozark streams entrenching themselves again. The last uplift has been pulsatory, leaving strath terraces to record the hiatuses. The stages of Ozark streams today give no indication that this last orogeny is complete or that it is not ongoing.

The radially dipping formations overlying the dome have been beveled by each successive erosion cycle. The more resistant formations have formed a series of concentric infacing cuestas in the youthful stages of the cycles. Although the rivers of the Springfield peneplain successfully breached and eventually brought these cuestas down near base level, they still remained as low interfluves. Since the initiation of the Ozark cycle, two of these have been most prominent as topographic highs in Jefferson and St. Louis counties. They are the Crystal and Burlington scarps. The Crystal scarp is held up by the St. Peter and Joachim formations and the Burlington by the Burlington-Keokuk.

The relatively short-lived Ozark cycle did much less to wear down these divides, and our modern streams are undoubtedly very much the same as they were when renewed uplift forced them to cut down into their sinuous meanders on the Ozark peneplain. Today the summits of the two scarps are held high above the streams and still exhibit the low relief erosion surface of the Springfield peneplain. Both are dissected and crenulated by the recent erosion cycle to the degree that they are barely recognizable in the field. Still, these two scarps are the main reason that local interfluve summits here in the field trip area do not show the consistency of altitude that one normally associates with Ozark horizons to the west and south. In addition, the Ozark surface probably had relief of an order not commonly thought of as representing a peneplain, perhaps as much as 100'. It is also probable that the two old erosion plains intersect in this area, which would tend to further complicate interpretation of landforms.

A persistent dilemma associated with this area and others around the Ozark province is the presence of stream-rounded silicates, from sand to gravel size, on summit flats. The history of these intermittent thin deposits is obscure. If they were limited to a belt a mile or two wide, major stream could be envisioned carrying gravels with the competence imparted by rejuvenation somewhere closer to its headwaters. These coarse deposits could then be explained by alluviation of the lower drainage basin along the meander belt. The deposits are quite widespread however, and one loses confidence at the prospect of the stream dynamics that would be required to broadcast this material over what we have defined as a region at base level. Some students feel that these gravels are of different source areas, which seems to be the case. Much of the gravel deposits could easily be residual from Missouri's carbonate formations, but others are of a composition quite foreign to any rock in the Ozark area. At any rate, headwater rejuvenation of several major streams seems to be the least awkward explanation.

These gravels may be found on the summits of both the Burlington and Crystal scarps which makes them contemporary with the Springfield peneplain, or early Tertiary.

The peneplain trace is typically underlain by a thick mantle of cherty red clay, residual from the limestone weathered away during the long subaerial exposure of the Springfield cycle. The residuum ranges from 40' to as much as 50' on the interfluves that have retained it in its entirety. Generally this is capped with a few feet of Pleistocene loess.

Another phenomenon that is common where the Springfield surface is intact are the so-called filled sink-structures. One normally associates these with the north and northwestern slopes of the dome in central Missouri where they are an important source of fireclay but they seem to be much more numerous in the field trip area than is generally suspected. Almost every new highway with roadcuts in the peneplain surfaces encounters one of these collapse structures.

A fairly large sink-structure was encountered in excavation for the new Route 30 cut through the Crystal scarp. The roadway at its high point passes through the center of this structure. All of the Pennsylvanian material has been excavated. There was a good deal of stream-rounded pebbles and cobbles of quartzite, chert, and hematite in the residual clay. This filled sink-structure was particularly interesting because it was in close proximity to voids in the Joachim formation below it. This juxtaposition might lead one to believe that the two features are related but they are not, other than the fact that both are the result of carbonate solution. Ozark caves were formed during a period of quiescence, by phreatic water at a much lower elevation than this one. Filled sink-structures are products of uplift when meteoric waters percolating down from the surface dissolved the limestone under the filled sinks and the structures slowly subsided.

There were no surface indications of the presence of this collapse just as there were no signs of the major fault exposed by the roadcut three miles to the northeast.

This fault is almost certainly associated with the so-called Eureka-House Springs anticline. Vertical offset appears to be on the order of 70' but the intense brecciation leads one to speculate on lateral components. The geometrics of this fault should be quite interesting to those of us more familiar with the structures of Missouri. Exposures of this type cannot help but lead to greater insights to the history of the Ozarks.

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# GEOLOGICAL PROBLEMS ENCOUNTERED DURING THE DESIGN AND CONSTRUCTION OF HIGHWAY 30 ST. LOUIS - JEFFERSON COUNTIES

James G. Clemenson
Missouri State Highway Department

The use of geologic principles in the design and construction of highways is essential. For this purpose, the Missouri State Highway Department employs a staff of experienced geologists who conduct geologic reconnaissance for new highways. Extensive drilling programs, detailed soil studies, and foundation investigations comprise the major portion of this reconnaissance. In the pursuit of this information, the need to understand the geology of an area and to apply this knowledge to the solutions of potential problems is important. By understanding the geology of an area, many of the potential problems can be predicted and with further investigation, a solution or solutions may be formulated.

Anticipating and solving a given problem is not always easy. On occasion, a calculated risk must be taken in the design of modern highways. There have been times when it was not possible or practical, from an economic viewpoint, to remove all adverse conditions. The problems presented by these conditions can usually be resolved by specifying special construction procedures and controls. And, if these options appear impractical, there is always relocation.

With the advent of modern design criteria, deep cuts and high fills which were once avoided are now commonplace. As such, backslope, as well as foundation problems, must be anticipated during the initial stage of the geologic reconnaissance. Once the initial reconnaissance has been completed, every effort is made to investigate isolated problem areas. Soil samples and rock cores, from proposed cut sections, taken to a depth fifteen feet below proposed grade line by conventional methods, provide a good indication of what will occur when the cut is opened. All cores taken are logged and correlated with auger soundings prior to being left exposed to the elements, in order to weather naturally. Periodically, these cores are checked and the degree of weathering is noted for future reference. During the design of cut slopes, benches at predetermined elevations are recommended based upon the physical characteristics of the material to be exposed. Benches are designed a sufficient width to catch rock debris which would otherwise tend to accumulate in the ditchline, resulting in drainage and maintenance problems.

Many roadcuts, particularly those in the shaly Warsaw formation, which may have been smooth and clean when presplit, have disintegrated to ragged sections through the weathering process. As you will see, backslopes are only half of the problem. In areas where high fills are proposed, other problems arise.

Of primary importance is the question whether or not the subsoil will support the proposed fill without danger of foundation failure. This is, more often than not, a question which cannot be answered by conventional investigative methods. Sophisticated investigations and testing procedures must be employed.

Undisturbed soil samples are taken from foundation sites where settlement and stability problems are suspected. These samples, which are tested in our main laboratory in Jefferson City, are subjected to various tests, such as triaxial shear, direct shear, unconfined compression and consolidation. An analysis, based on these test data, is then made concerning foundation stability and the rate and amount of settlement calculated for the most critical condition possible. Pertinent recommendations, such as fill slope configuration, rate of fill placement, camber for box culverts, etc., are then incorporated in the plans.

Another problem which is common, is the tendency for landslides to develop adjacent to roadways in backslopes underlain by shales or on natural ground sloping toward the roadway. In areas where these conditions exist, it is only a matter of time before slides develop and encroach onto the roadway. Slides are especially abundant during the spring as a result of heavy rains which saturate the soil and result in the loss of internal friction and cohesion.

Examples of two types of retaining walls used to insure backslope stability can be observed at Mileage Points 1.40 and 1.60. Since this entire area has had a history of landslides, a special backslope investigation was conducted to formulate a design to prevent future slides. Considerable right-of-way would have been required to flatten the backslopes sufficiently to prevent the possibility of landslides. The decision to construct retaining walls was ultimately based upon economics, i.e., the cost of retaining wall, versus the cost of additional right-of-way.

The monolithic retaining wall at Mileage Point 1.40 is founded upon a solid limestone member of the Warsaw formation and constructed a sufficient height to allow for a 3:1 backslope behind the wall.

The "crib-type" retaining wall at Mileage Point 1.60 was constructed to prevent further sloughing of the soil mantle on top of a shale member of the Warsaw formation. Unlike the monolithic retaining wall, the "crib-type" wall can withstand greater movements without affecting its function.

Excellent examples of block jointing in the upper Warsaw formation are evident along Interstate Route 270 between Interstate Route 44 and Highway 30, and then again along Highway 30, between Interstate Route 270 and Highway 141. The major trend of the joint systems is in a northeast-southwest direction. Interstate Route 270 traverses these joints at nearly right angles, exposing large blocks and boulders to weathering. Since Highway 30, at least in the Fenton area, runs roughly parallel with the joint systems, the larger blocks are not as great a problem as on Interstate Route 270. Benches are constructed in the rock cuts to provide additional storage space for the accumulation of rock debris that may weather out.

A high fill is evident between Mileage Points 3.0 and 3.50. By utilizing a broken back template, the length of a box culvert was reduced by some 300 feet, which resulted in considerable savings in the construction cost of the culvert. The lower two-thirds of the fill was constructed on a 1:1 slope, using shot rock. The upper one-third of the slope was then constructed on a 3:1 slope, utilizing compacted soil. The outer roadway on the right serves as a berm, providing lateral support for the embankment.

The roadway embankment in the vicinity of Mileage Point 4.85 is constructed across an old meander of the Meramec River. An extremely high groundwater table and a silty, sandy soil were found to overlie a stiff clay to a depth of twenty feet. Under normal conditions, such poor foundation materials can be either removed or surcharged in such a manner as to eliminate long-term differential settlement.

In this instance, it was more economical to surcharge the fill than to remove the poorly consolidated soil. Consequently, the embankment was constructed at a controlled rate and surcharged to increase the consolidation rate of the foundation material. However, as was the case just ahead of Byrnsville Road (Mileage Point 25.09), the removal of the undesirable foundation material was not economically feasible.

A foundation investigation in the Sand Creek Bottom had revealed the existence of a twenty-three foot thick layer of soft, gray, silty clay, overlain by ten feet of sandy soil. Consolidation Test data indicated as much as 1.5 feet of settlement under thirty feet of fill. Time required for substantial completion of settlement was calculated to be on the order of sixteen years. Further calculations indicated that approximately six years would be required to safely construct the fill under standard pore pressure controls.

Because of the time element involved, surcharging was not feasible. The most practical solution was the installation of an elaborate system of vertical sand drains to accelerate settlement and to provide for adequate stability against failure. Approximately 3,200, sixteen inch diameter, vertical sand drains spaced on a seven foot triangular arrangement were installed. The spacing was gradually increased between the rows within the last twenty-seven feet of the western end of the sand drain field to provide a settlement transition. After the drains were installed, a two and one-half foot lift of clean shot rock was placed over a five-foot sand blanket. Five feet of clean, shot rock was placed in two lifts from the edge of the sand blanket out to the toe of the berms and/or slopes to provide an outlet for pore water and seepage. The rate of fill placement was governed by the use of pore pressure measuring devices.

The west approach fill to the Meramec River (Mileage Point 5.90) is situated at the base of a steep hill. The maximum fill height right of centerline is forty-eight feet. The first indication of a potential embankment failure was evident by the tilted rockers on the west abutment of the westbound lane. Fill distress was believed to have been caused by the spill fill being designed too steep for the height of fill. Also obvious was the fact that Fenton Creek had eroded the foundation area adjacent to the spill fill, decreasing what little lateral support there was. To make matters worse, seepage from the steep hill immediately ahead of the abutment was found to be infiltrating the fill. Remedial steps were taken to correct the situation by constructing a massive rock berm across the spill slope, which was then warped around the right side slope. The upper portion of the berm was constructed on a 5:1 slope with a 2:1 lower slope. The berm was keyed into the embankment by constructing a series of small benches in the existing fill.

It is not too uncommon to encounter active springs during the reconnaissance for a highway. However, unless the source of the spring can be pinpointed early during construction, the outflow could have a devastating effect on the roadway embankment and would ultimately lead to instability within the embankment itself. This, in turn, could result in an embankment failure. Fortunately, in both cases, the springs encountered at Mileage Points 6.3 and 12.56 were detected early and their sources located. Spring boxes were constructed to collect and centralize the flow. The outflow was then piped from beneath the fill and allowed to be discharged in special ditches. In areas where wet weather springs or seeps are evident, crushed stone is placed throughout the immediate foundation area and extended to the toe of the embankment slope.

A rather minor slope failure in the right backslope at Mileage Point 8.1 became significant, in that the slide was fast encroaching upon a twelve inch water main. The disturbed material was removed, the slippage plane destroyed and soil was recompacted over a eighteen inch thick crushed stone friction drain (a portion of which is visible in the backslope).

A yet unexplained phenomenon was revealed in the vicinity of the cut section at Mileage Point 13.8. Widely spaced and randomly oriented voids ranging in size from one to eight cubic yards were encountered in the cherty residuum. There were no apparent openings associated with these voids. They were fortunately situated well above grade and were cut out with no further evidence of the like at, or below, gradeline.

The collapsed structure exposed in the right backslope at Mileage Point 14.1 was also exposed in the left backslope. However, due to the inability of the loosely consolidated sandstone to stand on a ¼:1 slope, the left backslope was laid back on a 2:1 slope.

Cut classification soundings first indicated the existence of a collapsed structure at Mileage Point 24.1. Soundings revealed an area near the center of the hill where little or no rock was encountered. Cores showed that, at random locations around the perimeter of the structure, there was solid limestone. At other locations, there were alternating layers of clay and limestone. Several cores revealed the existence of fifteen-foot to twenty-foot clay seams beneath thirty-five to forty feet of solid limestone. A final analysis of all available boring data indicated the existence of an old sink structure which had been subsequently filled with Pennsylvanian clays and shales, pebbles and boulders. Additional borings showed that the roadway would be outside the perimeter of the sink area if it were shifted two hundred to three hundred feet to the right. A recommendation to this effect by geology personnel was not acted upon.

During the actual construction of the cut section, the contractor experienced great difficulty in establishing a presplit line to work from. It was no surprise to anyone, except perhaps the contractor, when several caverns were exposed at a slightly below gradeline elevation. These caverns were directly associated with the old sink structure and took the form of an enlarged joint system, converging on one central shaft some one hundred feet in depth. The caverns, for the most part, were collapsed and filled with shattered rock excavation prior to subgrade preparation.

The section of roadway on the left, ahead of Mileage Point 24.19, is situated on a steep hillside. Right-of-way was so restricted that the embankment could not be built normally. The fill was constructed on top of the St. Peter sandstone on a $1\frac{1}{2}:1$ slope using select shot Plattin limestone. Prior to placing the embankment, the soil was stripped from the side hill. A series of benches were then constructed on the exposed rock slope. Where possible, natural benches were utilized. The slight berm on the lower slope is the result of a construction error. Initially, the rock was brought up on a $1\frac{1}{4}:1$ slope to a height of twenty feet, before a template change was ordered.

## SUMMARY

The foregoing illustrates the importance of conducting a complete and thorough geologic reconnaissance for new highways. Only by obtaining the most reliable design information possible can the Missouri State Highway Department hope to insure the traveling public one of the best road systems in the nation.

# NOTES ON PALEONTOLOGY AND BIOSTRATIGRAPHY OF HIGHWAY 30 BETWEEN I-270 AND CEDAR HILL

B. L. Stinchcomb
St. Louis Community College at Florissant Valley

Extensive cuts exposed along Highway 30 as it crosses the northeastern escarpment of the Ozarks exhibit a wealth of fossiliferous limestones, shales and cherts which cover a major part of the Paleozoic era or some 250 million years of the geologic time scale. These exposures impressively lay out a section of marine sedimentary rocks which record a large part of the Paleozoic epicontinental sedimentation in the southern mid-continent. Strata representative of the middle Mississippian (Meramecian) to the lower Ordovician (Canadian) are exposed in a more or less continuous series of cuts.

## ST. LOUIS FORMATION

Lower beds of the St. Louis formation are exposed at the Highway 30 - I-270 interchange. At the northeastern part of the interchange are some silicified colonies of the tabulate coral Lithostrotionella, a marker for the St. Louis limestone (Fig. G, Pl. 3). Chert nodules and masses at the top of these cuts are also fossiliferous, yielding numerous fenestellate bryozoans and impressions of the coral Lithostrotion.

## SALEM FORMATION

The exposures between I-270 and the Meramec River are stratigraphically below the St. Louis formation. Fossils in the Salem formation are "spotty". Typical Paleozoic invertebrates such as Spirifers, Syringopora, and fenestellate bryozoa are common. A few horizons of the Salem formation carry somewhat abundant teeth of shell crushing, shark-like vertebrates (Bradyodonts) and occasional dorsal spines of shark-like vertebrates (Fig. G, Pl. 1). The lower part of the formation is calcareous, which if not oxidized is usually gray. These beds are generally barren of any fossils even though they look like they should contain them.

The pure beds of limestone, exposed just southwestward from I-270 is correlative with the well-known Indiana limestone, extensively used in the U. S. for construction and carving. These beds carry an extensive micro fossil fauna which is dominated by the foraminifera *Endothyra* sp.

## WARSAW FORMATION

Shaley beds exposed along the exit ramp where Highway 30 crosses Highway 141 are in shale and limestone beds of the lower Meramecian Warsaw formation. This formation is one of the more fossiliferous formations in the St. Louis area. Its fauna is an extensive one which was first studied in detail during the mid-19th century (Hall, 1858).

The spiral shaped bryozoan axis, *Archimedes worthini* Hall, is usually present as well as the brachiopod genera, *Reticularia*, *Schizopharia* and *Athyris*.

The echinoderm fauna of the Warsaw is diverse, however, as would be expected, complete specimens of Warsaw crinoids, blastoids, starfish and sea urchins are rare. The disarticulated fragments of these echinoderms are generally useless for any form of identification of the formation.

Since the days of Shumard, Meek and Worthin, Warsaw echinoderms have been sought after by professional and amateur collectors alike. Supposedly, Warsaw fossils, well cleaned from their matrix, provided extensive material for some "dime museums" located on South Broadway in the 1860's and 1870's. Modern day collectors in the St. Louis area still "wrestle" beautiful crinoids and other echinoderms from the formation.

The lower part of the Warsaw, or the upper Keokuk, is exposed along the

Meramec River at the old Highway 30 bridge, downstream from the new bridge. Here numerous brachiopods of the genus Marginirugus (Fig. F, Pl. 1), and many other fossils along with occasional crinoid calyces can be found. At this location the "contact" between the Warsaw and the underlying Keokuk formation is exposed. The more massive, white limestones of the Keokuk grading into the more slabby and shaley beds of the Warsaw. The Keokuk at this locality is quite fossiliferous. Specimens can be secured by prying slabs of the limestone than breaking to pop out the fossils.

## KEOKUK FORMATION

The upper beds of this formation, the youngest of the Osagian Series, are locally highly crinoidal. The Keokuk limestone along Highway 30 is very cherty, and is often composed of a characteristic mottled, flinty gray and white chert. Some of the bedding planes of the formation between Fenton and High Ridge apparently represented a "hard ground" on the Keokuk sea floor. On this lived large crinoids whose holdfasts were found in fair abundance in exposures during highway construction (Fig. I, Pl. 2). Unfortunately these beds are now poorly exposed.

## BURLINGTON FORMATION

The Burlington is a cherty, crinoidal limestone which is well exposed on the downthrown side of the Eureka fault. The most conspicuous fossils in the formation are the remains of crinoids. These weather from the limestone as fragments and as internal and external molds in the extensive residual chert of the formation. The spines or spikes of the distinctive crinoid Dorycrinus are often seen in the Burlington limestones southwest of the fault (Fig. A, Pl. 2). Large stems of what were probably garontic individuals are also locally common, many at the upper parts of the cuts. These might well be the remains of lucky individuals who escaped being devoured by the shell crushing bradyodonts whose worn crushing teeth (worn from crushing the calyces of perhaps thousands of crinoids) can also be found weathering from the limestones. The large brachiopod Spirifer grimesi is abundant in the Burlington in this area as it is in many places.

## FERN GLEN FORMATION

The Fern Glen formation is represented by bluish or greenish argillaceous limestone in cuts near the Eureka fault. To the east the Fern Glen becomes thicker and is more shaley. The shales often are fossiliferous. The peculiar star shaped bryozoan Evactinopora sexradiata is locally common in the Fern Glen of this area. The Fern Glen is often readily distinguished by its red color, a feature which is, however, entirely lacking in this area.

## BUSHBERG SANDSTONE

Probably uppermost Devonian in age, the Bushberg is a blanket sandstone of somewhat variable appearance. In the exposures south of the Eureka fault, the formation is distinctly cross bedded. The formation is sparsely fossiliferous, locally the elongate crushing or pavement teeth of Ptyctodus are common (Fig. H, Pl. 1). These were arranged in rows which produced an effective "crushing mill" for feeding. Occasionally parts of normal spines of this or some other shark-like vertebrate can be found associated with the teeth.

## KIMMSWICK FORMATION

This formation is a pure, massive white limestone which is usually made up of fragmented bryozoans, brachipods and trilobites cemented together by a sparry calcite matrix. In the area of Highway 30 the Kimmswick is considerably thinner than to the east, however, its lithology remains fairly constant. The peculiar sponge-like fossil Raceptaculites oweni is locally present and sections of the form are exposed in dipping strata near the top of the Eureka fault section on the east side of the highway. The smaller bowl shaped Ischadites is also present (Fig. D, Pl. 3) as are casts of large, straight nautaloids. Trilobites are fairly common in the formation, however, they are hard to collect. Some of these are large, the tails of Isotelus sp. being one of the common forms.

Large specimens of Bumastus milleri (Billings) have been found in the area, the specimen illustrated in Fig. E, Pl. 1, was collected at the Eureka fault south of Eureka, Missouri.

## DECORAH FORMATION

The Decorah is probably one of the most fossiliferous rock units in eastern Missouri. Consisting of alternating limestones, made up of brachiopod shells, and shale beds; the fossils of the limestone-shale interfaces are often real things of beauty. The Decorah is exposed on the upthrown side of the Eureka fault both at Highway 30 and at the Meramec River south of Eureka. Predominant on surfaces of the Decorah limestone slabs are the brachiopods Pionodema, Camarella, Zygospira, Sowerbyella and Rafinesquina. Branching bryozoans and the trilobite Eomonorachus (particularly heads) and fragmental Isotelus sp. are also present. The upper part of the formation exhibits the greatest amount of fauna diversity, the lower, more shaley beds are often a coquina of Pionodema sp. shells.

## PLATTIN FORMATION

One of the thicker limestones in eastern Missouri, the Plattin, crops out in many cuts on Highway 30. The formation is only moderately fossiliferous with fossiliferous zones concentrated in the upper beds of the formation. Exposure of the upper beds which have weathered under a cover of residual clay are the best places to find fossils in the Plattin. Fresh exposures make it almost impossible to spot the formation's "bugs".

Corals are some of the most obvious fossils other than the ubiquitous burrows, a trace fossil which weathers to give the holey or "spongy" appearance to the Plattin limestones. The coral fauna of the Plattin is one of the earliest in the world, at least one of the earliest fauna where corals are conspicuous. Columnaria or Favistella is a common colonial coral; the horn coral Lambeophyllum (Fig. C, Pl. 3), is common at the top of the formation on the west side of the Eureka fault and in a cut on the old highway west of Clearview Road where the form is silicified. Sponges are locally present in the formation, some of the Plattin sponges looking like and of the same size as a Frisbee (Fig. B, Pl. 3). The Plattin also locally carries colonies of the puzzling stromatoporoids and labachiids forms which do not fit into any living phylum. Echinoderms are locally found in the Plattin, they are often small and of unusual types (Shourd and Winter, 1976).

## JOACHIM FORMATION

Unlike the rock units above it, the Joachim formation is primarily a dolomite, and is usually barren of organic remains. The depositional environment of this formation may have been one of hypersalinity as what appears to be salt-hopper crystal impressions occur in the formation exposed by the Eureka fault south of Eureka. North of Scenic View Drive, in a ravine west of Highway 30 occur relatively large, low domal stromatolites in either the uppermost Joachim or the lower Plattin. They are a form of the genus Cryptozoon not too unlike Cryptozoon walcotti, a laterally linked hemispheroidal stromatolite which has been found in some of the oldest carbonate rock in North America. (Hofmann, H. J., 1971).

PLATE ONE

Figure

A. Brachiopod Athyris cf. lamellosa. Chert steinhern from chert nodule. Burlington Fm. Hy. 30 at Crystal escarpment. XI.2.

B. Tails of the trilobite Eomonorachus intermedius Middle Ordovician, Decorah Fm. XI.

C. Slab of Decorah brachiopods. Rafinesquina and Sowerbyella. XI.3.

D. Section through straight naulaloid, Actinoceras X½, Plattin Fm. Middle Ordovician. Hy. 30.

E. Trilobite Bumastus milleri Kimmswick Fm., Middle Ordovician. Eureka fault south of Eureka, Mo.

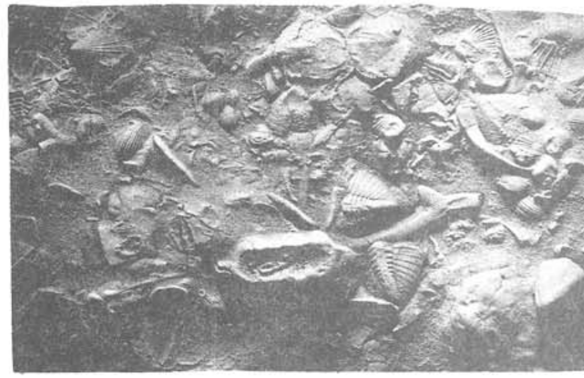
F. Brachiopod Marginirugus sp. Keokuk Fm., Middle Mississippian, Meramec River, Fenton, Mo.

G. Dorsal spine of shark-like form. Warsaw Frm. Fenton, Mo.

H. Crushing teeth of shark-like forms. Bushberg sandstone, Upper Devonian. Glen Park, Mo.

# PLATE ONE


A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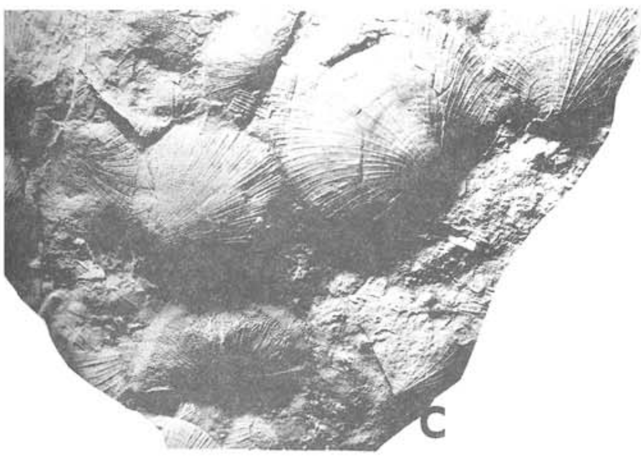
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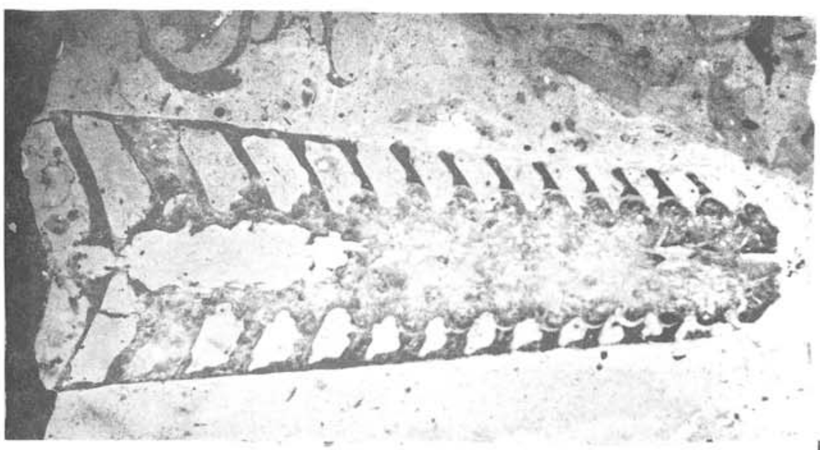

D


E


F


G


H

# PLATE TWO

Crinoids and Blastoids

A. Doryocrinus sp. Burlington Fm. Middle Mississippian. XI

B & C. Chert steinkerns of typical Burlington crinoids. XI

D. Blastoid. Globoblastus, sp. Burlington Fm. XI.3

E. Parichthyocrinus meek: Keokuk Fm. High Ridge, Mo. XI

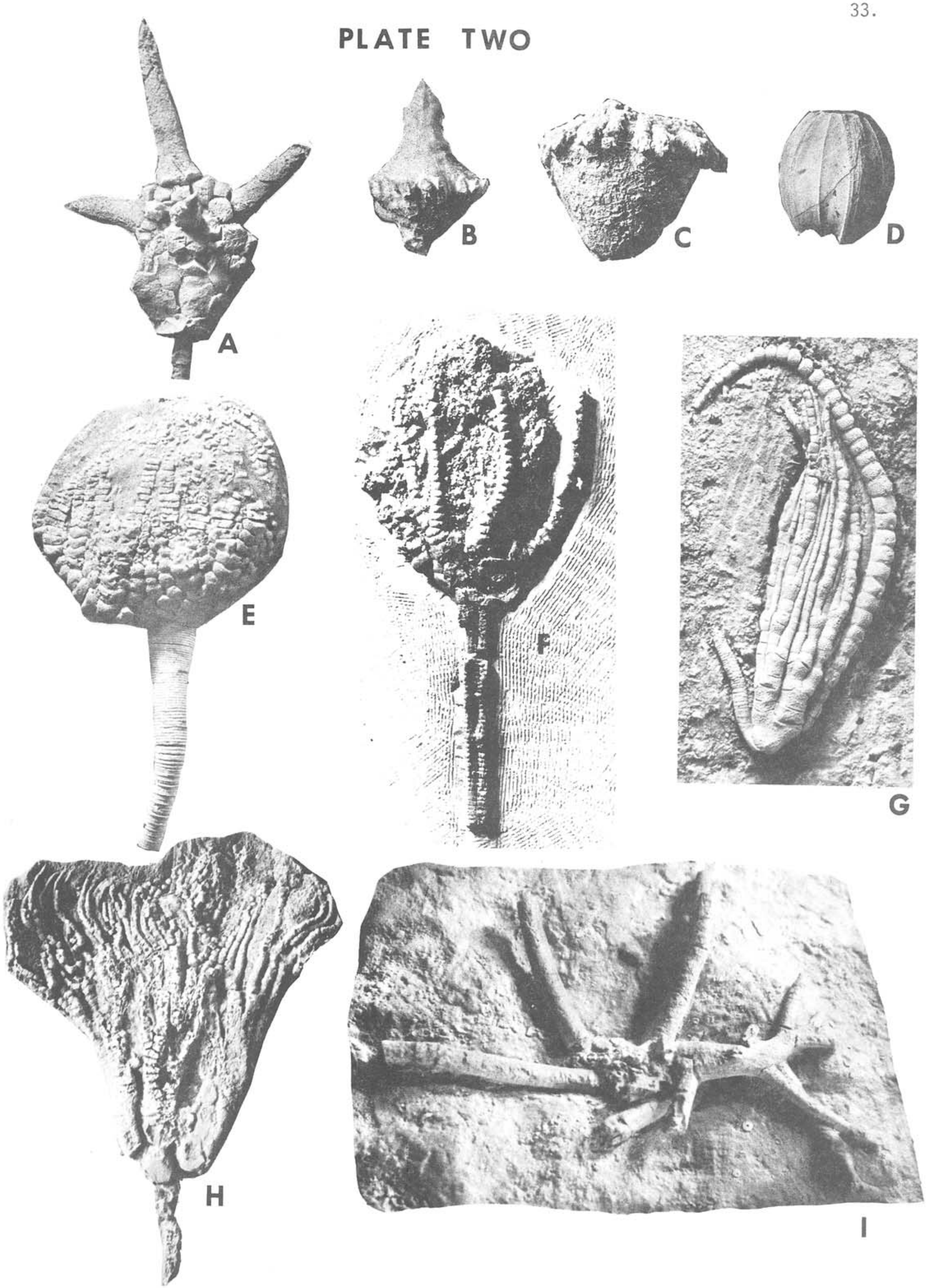
F. Barycrinus sp. Warsaw Fm. Fenton, Mo. X½

G. Cremacrinus sp. (Nodding crinoid) Decorah Fm. House Springs, Mo. XI.3

H. Cupulocrinus sp. Kimmswick Fm. Hy. 30 cut near Eureka fault.

I. Crinoid holdfast. Keokuk Fm. A zone of these in Keokuk Cuts was uncovered near High Ridge X½

# PLATE TWO



## PLATE THREE

Figure

A. Stromatolite. A zone of stromatolites very similar to this is exposed north of the Crystal escarpment. Specimen shown here from 2.5 billion year old Steeprock Series, Steeprock Lake, Ontario.

B. Sponge
Specimen not silicified, however many Plattin sponges are silicified. Plattin Fm. at Eureka Fault south of Eureka, Mo. X$\frac{3}{4}$

C. Coral *Triplophyllum spinulosum*. Warsaw Fm. Fenton, Mo.

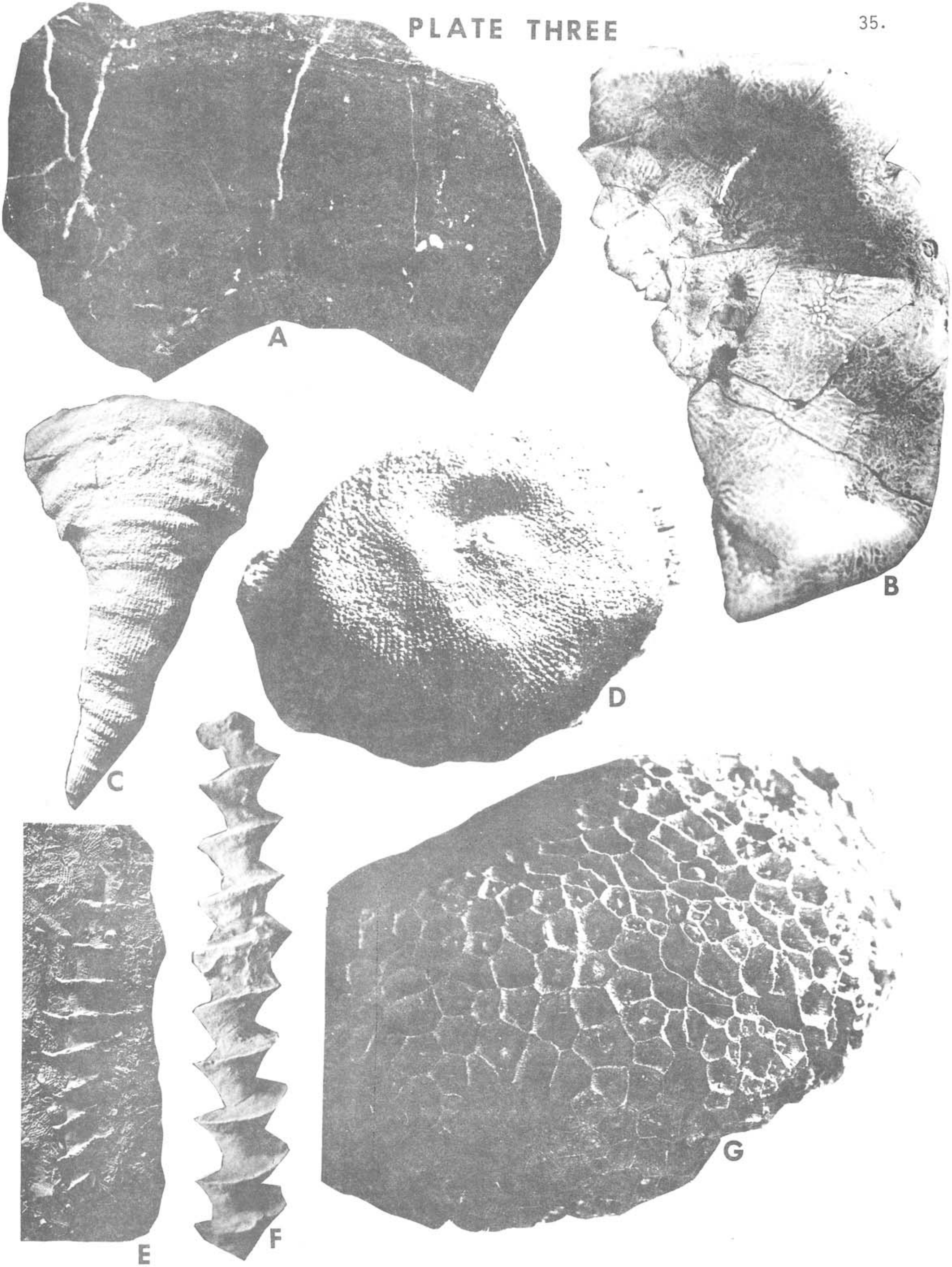
D. Red Algae? *Receptaculites oweni*. A common guide fossil to the Kimmswick X½. Bryozoan.

E. *Archimedes wortheni*. Probably younger growth which is not so robust. Warsaw Fm. XI.

F. *Archimedes wortheni*. Typical robust form. Warsaw Fm. Fenton, Mo. XI.

G. Coral *Lithostrotionella castelnaui*. A typical guide fossil to the St. Louis Fm. Arnold, Mo. X½.

# PLATE THREE



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## HOUSE SPRINGS QUARRY

| | |
|---|---|
| FORMATION: | Burlington, Fern Glen, Kimmswick, Decorah, Plattin |
| | <u>Quarry Floor - PLATTIN</u> |
| #1<br>7' | Gray, massive, fine grained limestone with brown mottling. Numerous shale laminae. |
| #2<br>10' | Gray, massive bedded, fine-grained limestone with chert nodules. Persistent chert band in lower half of ledge. Numerous shale laminae. |
| #3<br>9.5' | Gray, medium to massive bedded, lithographic limestone. Clay filled vugs common. |
| | __________ Bench |
| #4<br>10.5' | Light gray, massive bedded, fine-grained limestone. Differential weathering gives part of ledge a pitted surface. |
| #5<br>7.5' | Light gray, massive bedded, fine-grained limestone. Prominent bedding planes at top and bottom of ledge. |
| #6<br>10' | Light gray, massive bedded fine-grained limestone. Prominent bedding planes at top and bottom of ledge. |
| #7<br>7' | Light gray, medium bedded, fine-grained limestone. Contains numerous chert bands. Prominent ledge. |
| | __________ Bench |
| #8<br>9.5' | Gray, massive bedded fine-grained, dull limestone with brown and gray fucoidal structures. |

#9 Brown gray, massive bedded limestone with chert bands and dark mottling.

11'

#10 Gray, massive bedded, fine-grained limestone with dark mottling.

8'

#11 Gray, massive bedded, fine-grained limestone. Thin dark streaks parallel bedding planes. Quartz filled geodes common throughout ledge.

7'

Bench PLATTIN Formation
DECORAH Formation

#12 Prominent green shale with interbedded fossiliferous limestone.

12'

#13 Brown to gray, thin-bedded, argillaceous, fossiliferous limestone with interbedded shale.

9'

Bench DECORAH Formation
KIMMSWICK Formation

#14 Gray to dark gray, massive bedded, coarse limestone.

4.5'

KIMMSWICK Formation

BUSHBERG Formation
FERN GLEN Formation

1.5' Rusty brown friable sandstone

#15 Light tan to gray, coarse grained, massive bedded limestone. Fossiliferous limestone ledge.

5'

#16 Gray to dark gray, massive bedded, coarse grained, limestone. Bottom contact is a prominent bedding plane. Fossiliferous limestone ledge.

10'

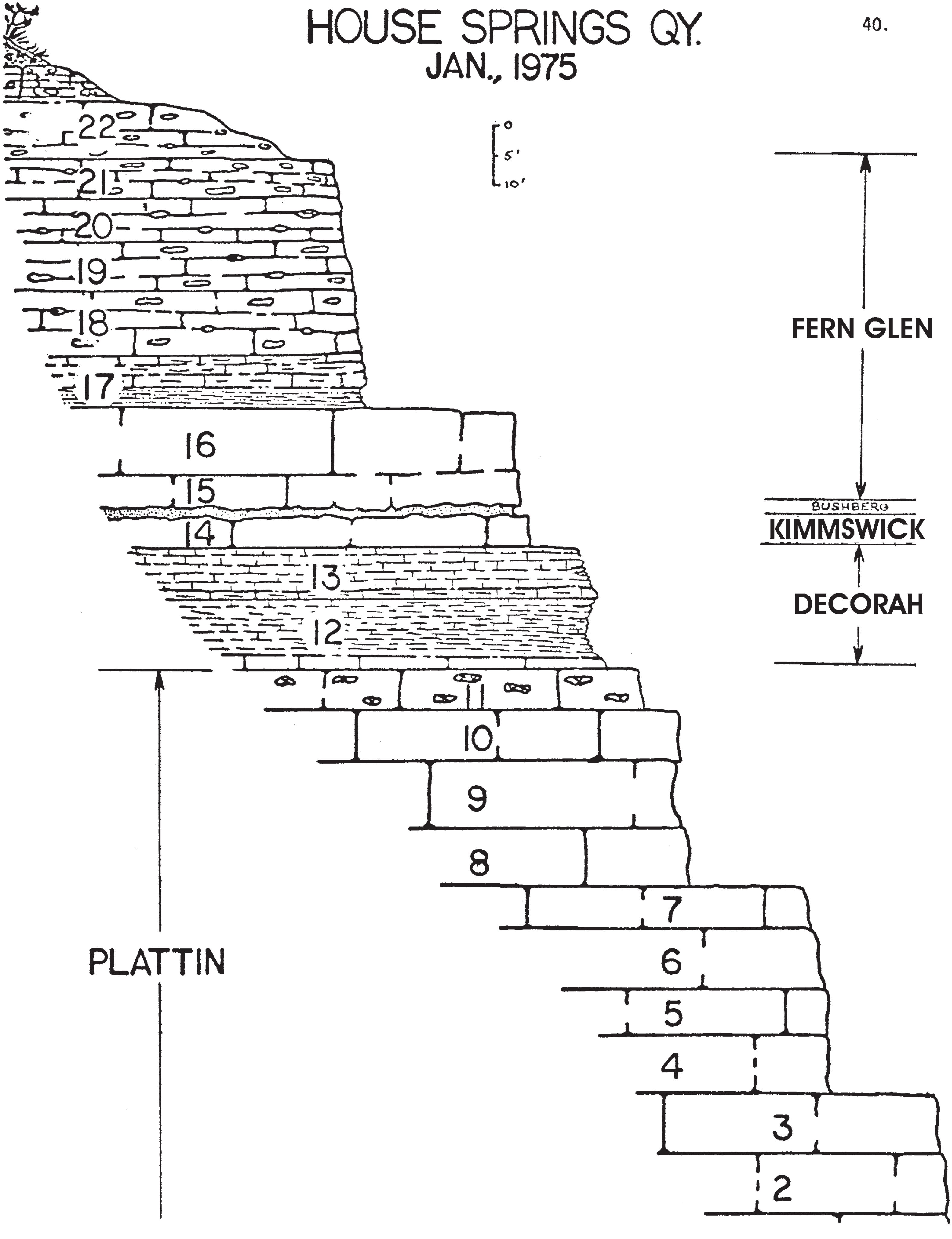
__________ Bench

| | |
|---|---|
| #17<br><br>9' | Dark blue-green, thin-bedded, shaley limestone. Interbedded with dark chert bands. |
| #18<br><br>10' | Light gray to tan, thin to medium bedded, crinoidal, coarse grained limestone.<br><br>Ledge contains many light chert bands. |
| #19<br><br>8' | Light gray to brown, medium bedded, coarsely crystalline, crinoidal, cherty limestone. |
| #20<br><br>7' | Tan, medium bedded, coarse limestone. Many thin shale beds throughout. Limestone is crinoidal and cherty. |
| #21<br><br>6' | Light gray to tan, medium bedded, coarse limestone, crinoidal; ledge contains chert bands. |

Bench FERN GLEN Formation
BURLINGTON Formation

| | |
|---|---|
| #22<br><br>10' | Brown, medium bedded, coarsely crystalline, fossiliferous limestone. |

# HOUSE SPRINGS QY.
JAN., 1975



BUSSEN ANTIRE QUARRY

FORMATION: Kimmswick, Decorah, Plattin, Joachim

_________ Present Floor

| | | |
|---|---|---|
| #1J<br>4.9' | A dark gray, fine-grained, thin bedded limestone. Ledge exhibits an absorptive appearance and irregular fracture. Ledge contains several thin shale seams. | |

JOACHIM Formation / PLATTIN Formation Contact

| | |
|---|---|
| #1<br>4.5' | A fine to very fine-grained, thin to medium bedded limestone with numerous thin shale seams. Ledge contains dark fucoidal structures and exhibits an irregular fracture. Bottom contact is a thin, black shale seam on a distinct, but irregular bedding plane. |
| #2<br>16.5' | A light gray to gray, massive bedded limestone. A few scattered stylolite seams are located throughout the ledge. Several brown colored areas are present. Ledge contains numerous dark fucoidal structures. |
| #3<br>12.5' | A gray, hard, medium to massive bedded limestone. Top contact is a distinct bedding plane. Ledge contains brown fucoidal structures. |
| #4<br>11.5' | A medium bedded, dark gray, hard limestone. Very fine to medium grained. 5.7' down from top contact is a 1' layer of light gray, very fine-grained limestone. Bottom 1.5' of ledge contains numerous thin bands of nodular chert. Entire ledge contains dark fucoidal structures. |
| #5<br>17.0' | A gray, massive bedded limestone with dark gray fucoidal structures. Bottom 2.0' of ledge is a hard, dark gray, sublithographic limestone at the top of which is a ½" black shale seam. |
| #6<br>18.0' | A light gray, massive bedded limestone containing dark gray fucoidal structures throughout. Bottom contact is the bottom of a 2' thick band of dark gray to brown, hard limestone. |

#7 A hard, massive bedded limestone containing dark brown fucoidal structures. Ledge contains intermittent chert bands throughout.
15.0' Color of ledge is gray to brown.

#8 A brown to gray, finely crystalline limestone with a laminated appearance. Chert nodules are present throughout.
2.0'

#9 A light gray, massive bedded, fine-grained limestone with irregular fracture. 1.3' below top contact is a stylolite
4.0' seam on a bedding plane.

#10 A light gray to brown, massive bedded limestone with dark brown fucoidal structures throughout. 1.5' above bottom
13.5' contact is a distinct bedding plane.

#11 A light gray to gray, massive bedded limestone with brown fucoidal structures throughout. A small, intermittent
8.5' band of gray and brown chert nodules is located 1 ft. down from top contact. Another thin band of brown, weathered chert is located 1 ft. up from bottom contact.

#12 A light gray, medium to massive bedded limestone with intermittent black chert bands 3 ft. above bottom contact. Numerous
10.0' brown fucoidal structures are found in the upper 2/3 of ledge. There are two prominent 4" to 6" bands of gray, very hard, coarsely crystalline limestone located 1½ ft. to 3 ft. below top contact.

#13 A dark gray, massive bedded, medium to finely crystalline Plattin limestone.
5.0'

PLATTIN / DECORAH Contact

#14 Multi-colored shale with thin beds of fossiliferous limestone.
15'

#15 A thin to medium bedded, fine-grained dark blue-gray limestone. Ledge contains several thin, fossiliferous shale partings.
11.0' Top contact is the formational contact which is a 2" to 3" thick layer of clay (metabentonite).

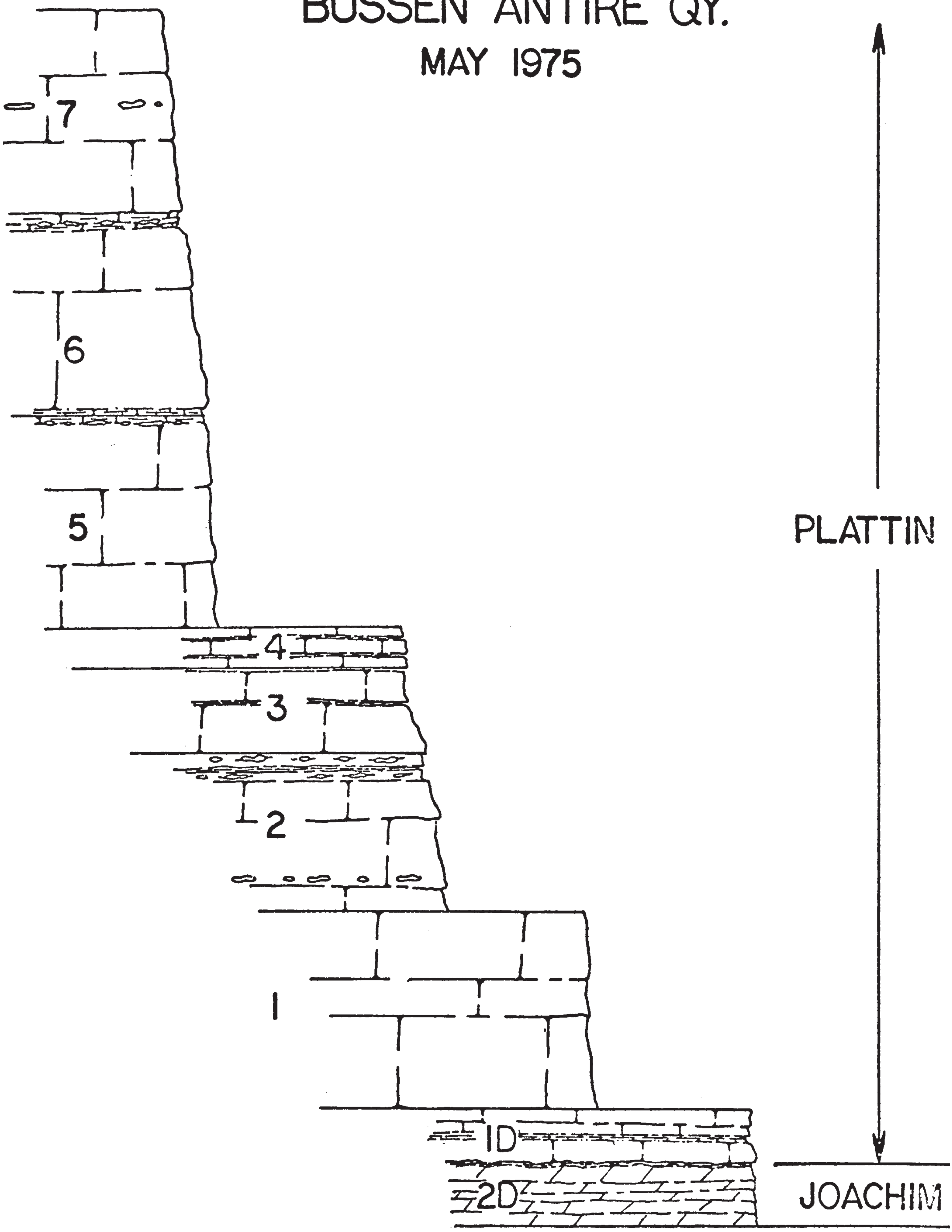
DECORAH / KIMMSWICK Contact

| | |
|---|---|
| #16<br>17.5' | A coarsely crystalline, hard, white to light gray limestone. Top 9' of ledge is characteristically pitted and exhibits a weathered appearance. |
| #17<br>17.0' | A coarsely crystalline, hard, massive bedded limestone. Top 5' to 7' of ledge is brown and contains nodular chert bands. Bottom 10'-12' of ledge is white to light gray. Bottom contact is a distinct bedding plane. |
| #18<br>12.0' | A white to light gray, hard, massive bedded limestone. Texture is coarsely crystalline. |

Overburden

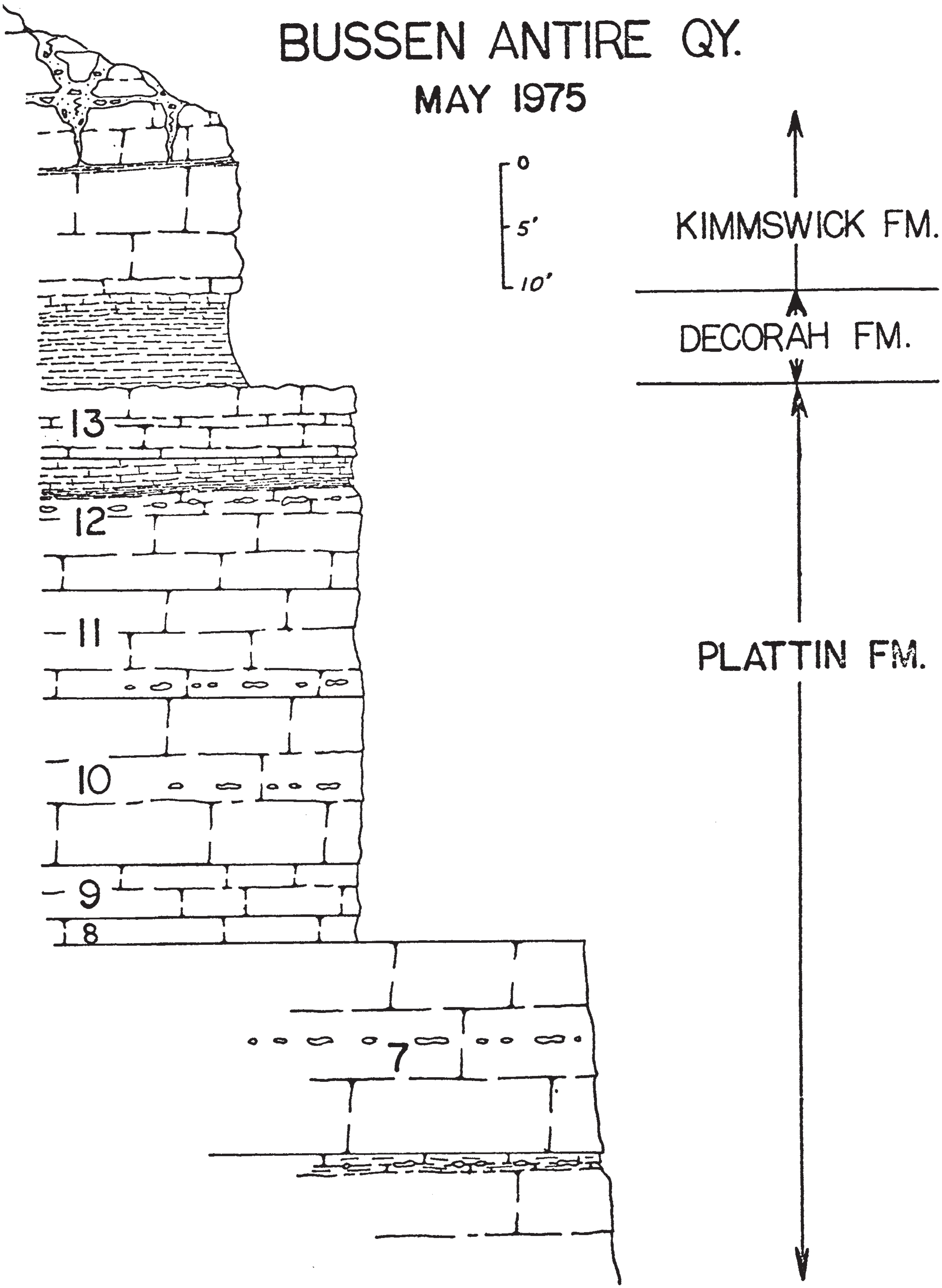
# BUSSEN ANTIRE QY.

## MAY 1975



# BUSSEN ANTIRE QY.

## MAY 1975



# FLORISSANT DOME UNDERGROUND STORAGE FIELD

Loren F. Vogel
Laclede Gas Company

## BACKGROUND ON UNDERGROUND STORAGE

Underground gas storage, by definition, means that gas is transferred from producing fields to other reservoirs, usually closer to market areas, where it is stored until needed to supplement other natural gas supplies in meeting market requirements. Its primary functions are to meet peak demands for gas during the heating season and to provide for off season depositories for pipeline gas. In this way, pipeline facilities are used more effectively and native gas field production rates can be stabilized.

There are basically two types of fields in use for underground storage; (1) abandoned or depleted oil and gas fields and (2) aquifer formations that had no previous hydrocarbon production. The Laclede storage is of the aquifer type and is one of the first aquifer fields to be developed.

The first recorded successful experiment in storing gas underground was accomplished in Ontario, Canada in 1915 by National Fuel Gas Company. This was in a partially depleted gas field. In 1916, Iroquois Gas Company started storing gas in the depleted Zoar field south of Buffalo, New York. This field is still in use. Experiments were initiated in 1931 and later expanded on by Louisville Gas & Electric in storing gas in an aquifer formation. That company's development of the Doe Run Field in Meade County, Kentucky in 1946 marked the first major use of an aquifer zone for gas storage. Now there are over 50 aquifer storage fields and over 380 storage fields of all types in the United States and Canada.

## LACLEDE GAS COMPANY BACKGROUND

Laclede Gas Company began operation in March of 1857 in the city of St. Louis. In 1948, Laclede purchased the St. Louis County Gas Company and in 1949 natural gas in sufficient quantity for widespread distribution became available by virtue of completion of a second pipeline into the St. Louis area. Laclede switched from the distribution of manufactured gas to straight natural and by the early 1950's, it was evident that the supply would soon lag behind the demand.

Laclede looked at three possible solutions to the problem of balancing supply and demand. They were: 1) build a pipeline of their own, 2) use additional propane to supplement the natural gas, or 3) develop an underground storage field.

A pipeline was ruled out as being economically prohibitive for the relatively small number of days it would be used. It would only be needed on the few days of the year when the existing pipeline capacity was exceeded.

Increased use of propane was a possibility, but continued expansion of propane facilities was near its practical and economic limits. Laclede blends propane vapor into the natural gas stream to increase the heating value of the total gas stream. Two limitations are imposed on this use of propane. First, the maximum amount of propane that can be blended into the natural gas without changing the burning characteristics of the mix is approximately 12% and second, the mix is sold at about or a little less than the cost of producing it. Propane can be used as a supplement to help supply gas for short periods but can not supply all the additional gas requirements.

The only viable solution was to attempt to develop an underground storage field. The problem then became the obvious one of finding a suitable geologic structure. There were no oil or gas fields in the St. Louis area that could be adapted for use as an underground storage field. The concept of storage in a water bearing formation (aquifer formation) was being developed in several small scale projects at this time and Laclede decided to attempt to find and develop a large storage area in an aquifer formation in the immediate St. Louis metropolitan area.

EXPLORATION AND DEVELOPMENT OF FLORISSANT DOME

Laclede obtained the services of a consulting geological firm to aid them in locating and developing a suitable storage field. The consultants and Laclede's staff obtained information from the Missouri Geological Survey in Rolla, Missouri relating to structure contour maps of various formations in the St. Louis area. Several possible structures were indicated by the contour maps and the decision was made to investigate further the structure located to the north of St. Louis near Florissant, Missouri.

An extensive surface geologic investigation of the Florissant structure area was performed. Outcrop samples were obtained from the Missouri River bluffs, stone quarries, road cuts and stream cuts in the area. The entire Missouri River bluff was sampled on a one foot vertical interval every 300 to 400 yards. All samples were microscopically studied and described as to their lithology and distinctive characteristics for correlating purposes.

After the microscopic sample study, the samples were pulverized and dissolved in acid and the insoluble residues measured. Insoluble residues were used to indicate marker beds and were one of the methods of mapping the structure. These residues could be correlated with similar work done by the Missouri Geological Survey on shallow water wells drilled in the area.

Four shallow structure test wells were drilled in 1952 and confirmed the possible structure. In 1953, a deep well was initiated to investigate possible gas storage zones. The well, known as the Lange #3, was cored with a 5" diameter core, from 830' to a TD of 3218' in the granite.

The Lange #3 found two possible gas storage sands, the St. Peter at 1500' and the Roubidoux at 2000' and something that had not been anticipated, oil in the Kimmswick or "Trenton" formation at 1000'. The existence of the oil in the Trenton confirmed the presence of a structural high that could be utilized for the storage of gas.

Since the initial discovery well, a total of approximately 50 wells have been drilled for oil, 50 wells for the injection and withdrawal of gas, 30 for observation of the gas storage zone and 130 shallow wells for structural exploration and definition, a total of approximately 260 wells. Of the 50 oil wells, 21 are still producing oil, 9 are being used for gas repressurization and sweeping of the oil zone and the rest were either dry when drilled or have been abandoned.

Gas volume in storage has been increased since the initial test injection in December, 1955, to a present volume of approximately 31 billion cubic feet. Of that volume, anywhere from 5 to 10 billion cubic feet will be utilized in a winter season. Daily rates will be as high as 400 million cubic feet per day with the underground storage providing 45% of the total system gas requirements.

## MINED PROPANE CAVERN

In addition to the structural geologic features of the Florissant Dome and their associated uses, Laclede has constructed one of the largest mined caverns in the country for the storage of liquid propane. This cavern is situated on the relatively flat western flank of the dome. It is mined out of the section just above and including the contact between the Warsaw shale and the Warsaw limestone that is just above the Keokuk-Burlington limestone. Physical dimensions of the cavern, mined in a room and pillar type operation are as follows:

| | |
|---|---|
| Capacity: | approximate 33,500,000 million gallons |
| Room size: | 20' high x 20' wide x 700' long |
| Pillar size: | 45' x 45' on 55' centers |
| Depth: | 400' to top of cavern |
| Configuration: | criss-crossing corridors |
| Area: | approximately 10 acres |
| Main shaft size: | 60" diameter |
| Ventilation shafts: | 4 - 16" & 1 - 5" |

Propane is used to supplement the natural gas for high load "peak shaving" conditions in colder weather or during extended periods of cold weather. Last winter over 25,000,000 gallons of propane were pumped from the cavern at rates of over 4,000,000 gallons per day.

The cavern was completed in July 1972 and storage was commenced at this time. Operations have been continuous since date of completion.

## GEOLOGY OF FLORISSANT DOME

The Florissant Dome is an asymmetrical dome draped over a bump in the granite basement rock. It has relatively steep sides to the north and east and flattens out to the south and west. A substructural high occurs in the flattened area to the west. Total closure on the St. Peter sandstone is about 200'. Associated with the Florissant Dome and most likely formed in a similar manner are structural highs to the northwest under Pelican Island and to the east near the town of West Alton, Missouri.

No basal sandstone exists near the top of the Florissant Dome. The only well to penetrate to the granite, the Lange #3, encountered approximately

190' of Bonneterre dolomite situated directly on the granite. The accompanying geologic columnar section depicts the formations as they appear in the Lange #3 well. The primary zones of interest to Laclede are the oil producing Trenton limestone and the gas storage zone, the St. Peter sandstone.

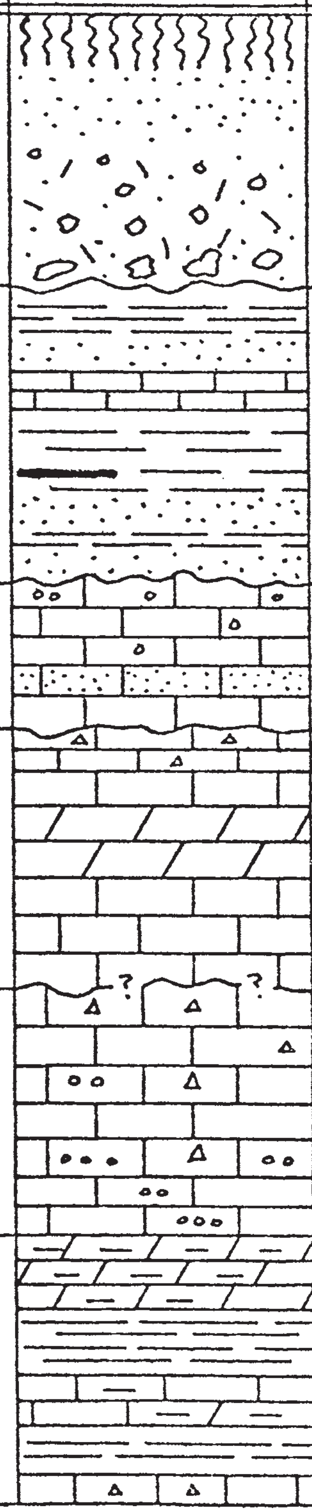
The Trenton limestone is tan colored, fine to coarsely crystalline, very fossiliferous with scattered calcareous deposits. Average thickness is about 90' with the upper 30'-35' being tighter and less porous than the lower sections. Oil production is from the lower section where the average permeability is 1 to 2 md. and average porosity is 5 to 6 percent. All production wells have been acid-fractured and generally have 15' to 20' open in the middle of the formation.

The St. Peter sandstone is a white sandstone with thickness varying from 90' near the top of the structure to over 150' on the flanks. Average permeability is approximately 450 md. and average porosity is about 18 percent. Near the top of the structure there are thin, non-continuous shale membranes about 35' below the top that tend to keep the storage gas in the top of the sandstone. These shale membranes are not found in some of the outer flank wells.

# COLUMNAR SECTION
# FLORISSANT DOME AREA
# ST. LOUIS AND ST. CHARLES COUNTIES, MISSOURI

THOMAS G. FARRELL
July, 1977

| SYSTEM | SERIES | FORMATION OR GROUP | LITHOLOGY | THICKNESS (FT.) | GENERAL DESCRIPTION |
|---|---|---|---|---|---|
| QUATERNARY | PLEISTOCENE | | | 5-130 | Soil, Loess, Silt, Clay, Sand, Gravel, and Glacial Till |
| PENNSYLVANIAN | DESMOINESIAN | CHEROKEE | | 0-185 | Shale, gray, brown, variegated, silty, Micaceous; Silt-stone; sandy Shale; Sandstone; Clay; thin Coal; thin Limestone |
| MISSISSIPPIAN | MERAMECIAN | STE. GENEVIEVE | | 0-80 | Limestone, white, sandy toward base |
| | | ST. LOUIS | | 0-185 | Limestone, light gray, Lithographic, small amount Chert; Dolomite gray, brown |
| | | SALEM | | 50-110 | Limestone, tan Oolitic and Calcarenitic; Chert in upper part |
| | | WARSAW | | 40-80 | Shale, gray, Dolomitic; Dolomite, gray, Argillaceous; Limestone, gray, Argillaceous, some Chert |



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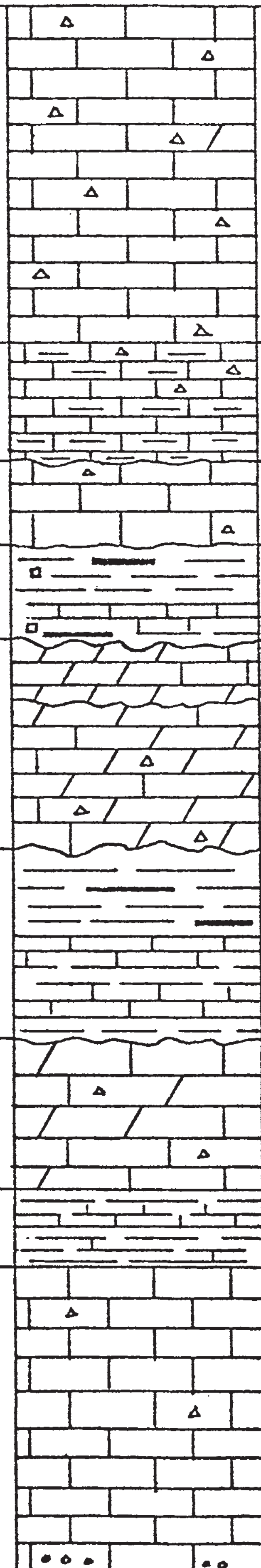
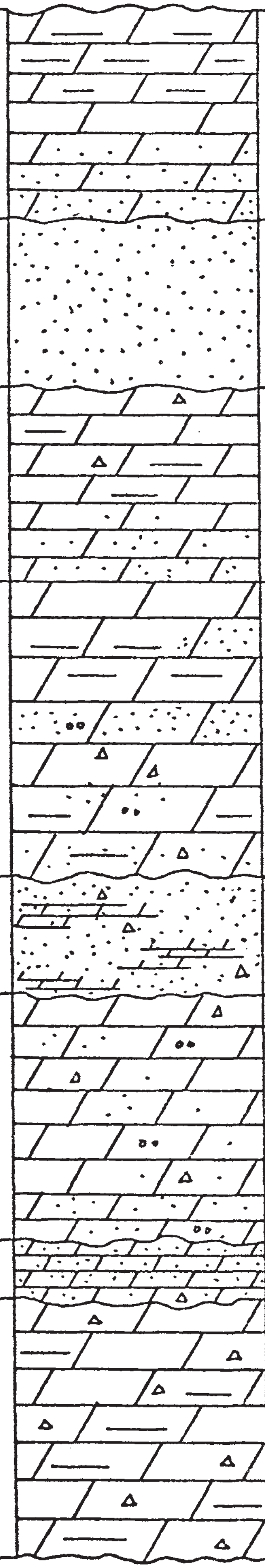
|---|---|---|---|---|
| MISSISSIPPIAN | OSAGEAN | BURLINGTON-KEOKUK | 180-260 | Limestone, gray-white, fine to coarsely Crystalline, cherty |
| | | FERN GLEN | 25-70 | Limestone , gray, green, red, cherty, Arg.; shale, red, green |
| | KINDER-HOOKIAN | CHOUTEAU | 30-50 | Limestone, gray, sub-lith.; some Chert |
| | | CHATTANOOGA | 20-60 | Shale, gray-black, Carbonaceous, Pyritic |
| DEVONIAN-SILURIAN | NIAGARAN-ALEXANDRIAN | ? <br> BAINBRIDGE SEXTON CREEK EDGEWOOD | 70-180 | Dolomite, buff, fine-med. Crystalline; Limestone, buff, some Chert |
| ORDOVICIAN | CINCIN-NATIAN | MAQUOKETA | 150-160 | Shale, greenish gray-black, Carbonaceous |
| | CHAMPLAINIAN | KIMMSWICK | 85-100 | Limestone, gray, fine-coarsely Crystalline |
| | | DECORAH | 20-30 | Limestone, shaley |
| | | PLATTIN | 160-200 | Limestone, gray, fine grained to dense; Oolitic pebble conglomerate at base |





| System | Series | Formation | Lithology | Thickness | Description |
| --- | --- | --- | --- | --- | --- |
| ORDOVICIAN | CHAMPLAINIAN | JOACHIM | | 115-150 | Dolomite, gray-tan, Argillaceous; sandy in basal 30-40 feet. |
| | | ST. PETER | | 80-140 | Sandstone white, well-sorted, Quartzose |
| | CANADIAN | POWELL-COTTER | | 175 | Dolomite, gray-buff, Argillaceous, sandy toward base |
| | | JEFFERSON CITY | | 230 | Dolomite, gray-buff, cherty, Argilla-ceous, sandy, Oolitic |
| | | ROUBIDOUX | | 30-50 | Sandstone; Dolomitic Sandstone; Chert |
| | | GASCONADE | | 230 | Dolomite, gray, finely Crystalline, Oolitic, sandy, some chert |
| | | GUNTER (MEMBER) | | 35 | Dolomite, sandy |
| CAMBRIAN | UPPER CAMBRIAN | EMINENCE | | 185 | Dolomite, light gray, fine-medium grained, cherty, light green shale partings |

| System | Series | Formation | Lithology | Thickness | Description |
|---|---|---|---|---|---|
| CAMBRIAN | UPPER CAMBRIAN | POTOSI | | 325 | Dolomite, gray to buff, fine to medium Crystalline, cherty, vugular, drusy Quartz |
| | | DERBY-DOERUN | | 120 | Dolomite, dark gray |
| | | DAVIS | | 95 | Dolomite, sandy, Argillaceous, some bluish shale |
| | | BONNETERRE | | 190 | Dolomite, light gray, Crystalline; contains granite pebbles at base |
| PRECAMBRIAN | | IGNEOUS ROCK | | | Granite, coarse grained, pink to reddish Feldspar, colorless to light gray Quartz |