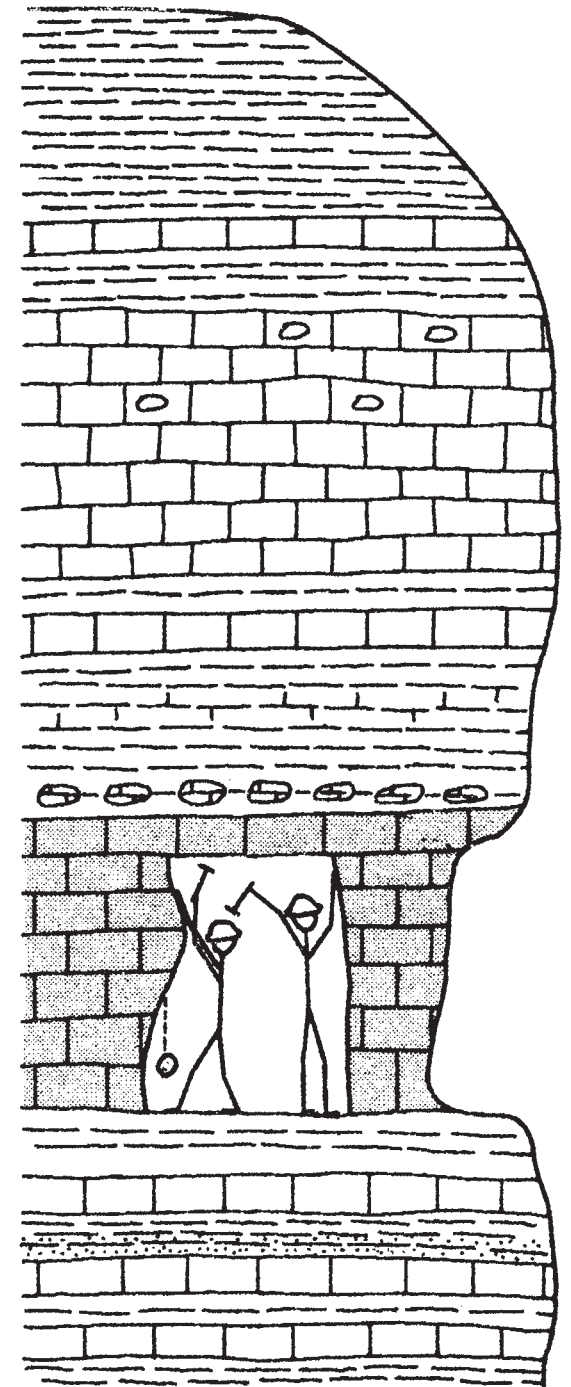


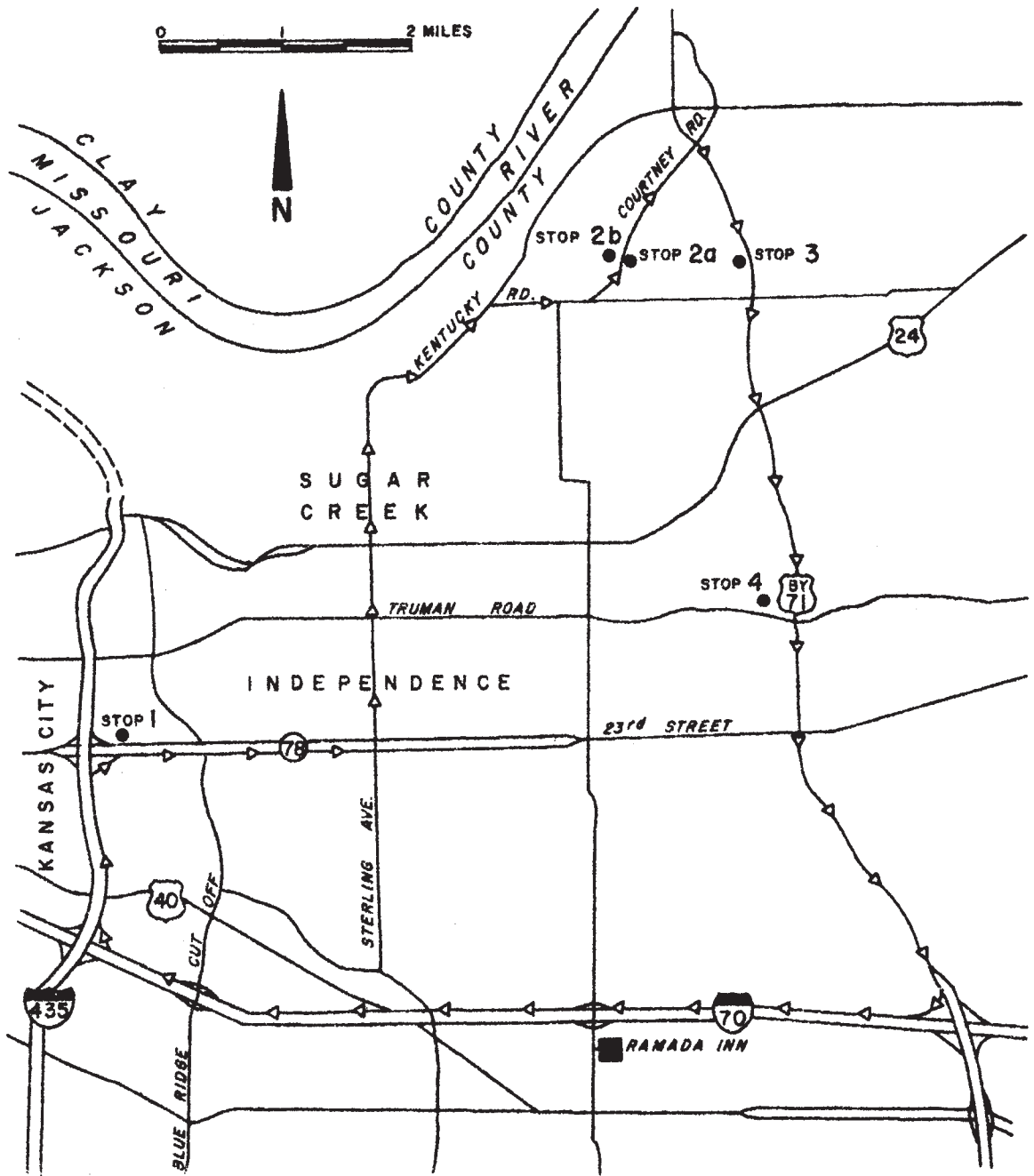
GUIDEBOOK
TO THE GEOLOGY AND UTILIZATION
OF UNDERGROUND SPACE
IN THE KANSAS CITY AREA, MISSOURI



PREPARED FOR THE ASSOCIATION OF MISSOURI GEOLOGISTS, 18TH ANNUAL FIELD TRIP
AND MEETING, SEPTEMBER 24 & 25, 1971 BY RICHARD J. GENTILE AND GOMER JENKINS

ROUTE MAP

- STOP 1 BRUNSON INSTUMENT CO.
- STOP 2a COURTNEY ROAD EXCAVATION
- STOP 2b MISSOURI PORTLAND CEMENT CO. QUARRY
- STOP 3 NORTH INDEPENDENCE INDUSTRIAL PARK
- STOP 4 OVERLAND INDUSTRIES INC.



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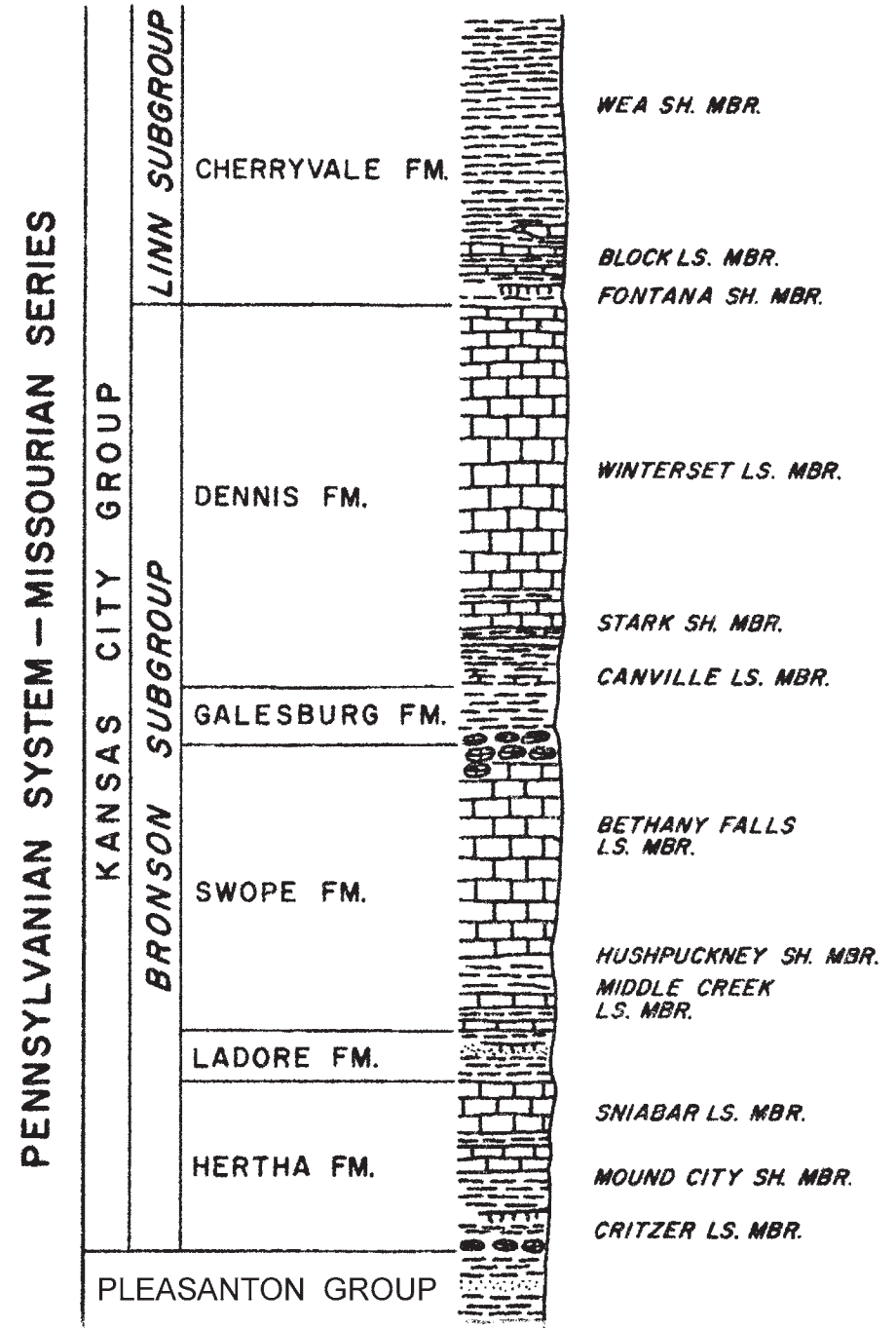
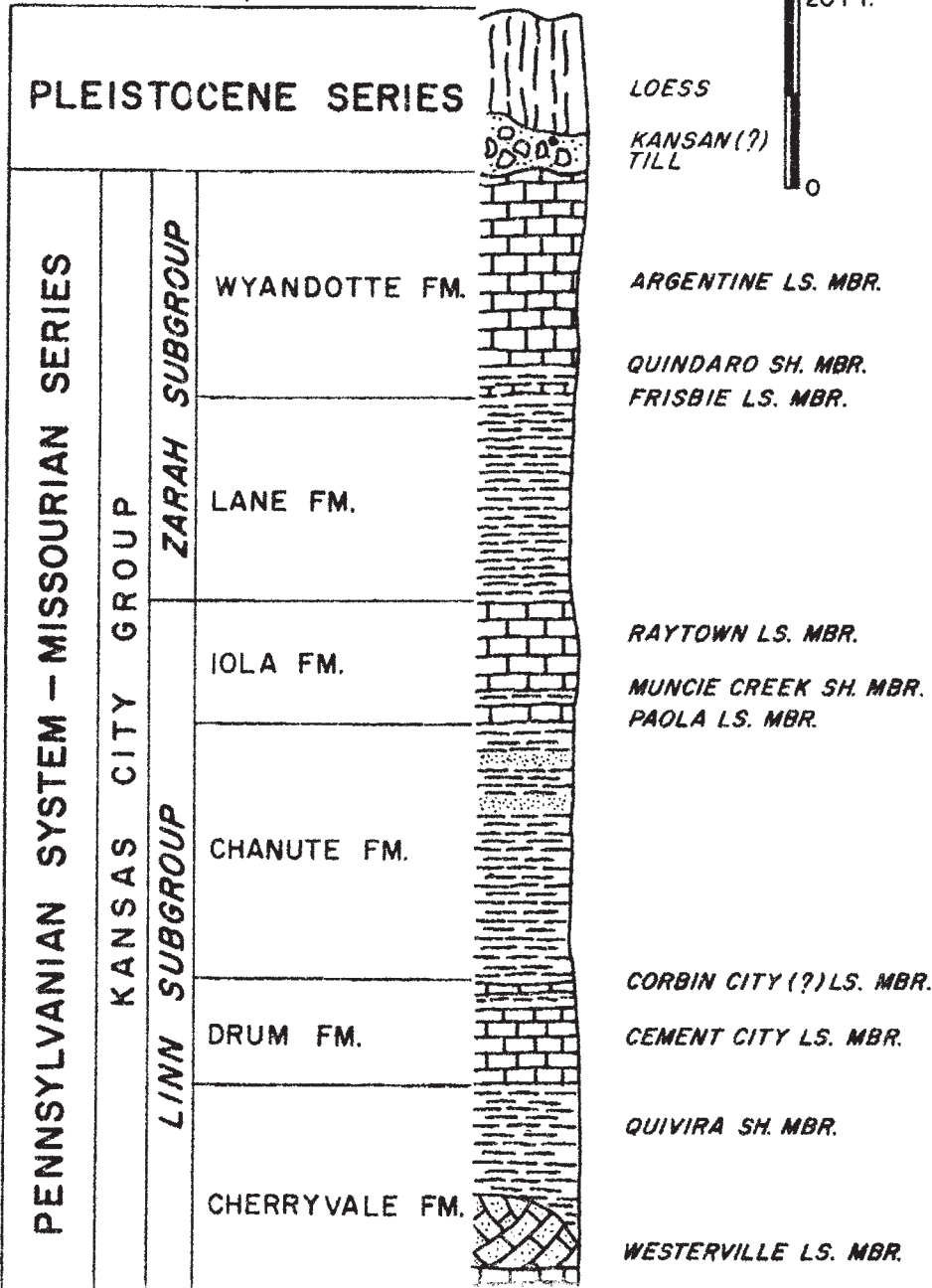
Richard J. Gentile, University of Missouri, Kansas City - Chairman

Gomer Jenkins, Missouri State Highway Department, Kansas City

FRANK COOK GREENE
1886 -

This guidebook is dedicated to Frank C. Greene who began field investigations in the Kansas City area over 60 years ago. Frank was an early believer in the use of underground areas for industrial purposes. In the early 1950's he applied his knowledge of the rock strata in the mining operations which created the underground space occupied by the Brunson Instrument Company. This is considered to be the first facility in America in which underground area was excavated specifically for industrial use. Officially retired from the staff of the Missouri Geological Survey in 1958, Frank is active in the Kansas City area as a consultant and enthusiastically supports numerous projects for the continued and expanded usage of underground space.

Generalized stratigraphic column exposed along field trip route -- Independence-Kansas City area.



INTRODUCTION

In the years following World War II it was realized that the many acres of underground space which remained after mining operations in the Kansas City and surrounding areas could be utilized commercially for storage, manufacturing and offices. This year's field trip will take us to three underground facilities where we will observe the utilization of the underground or "inner" space as it is commonly called. A fourth stop is included to acquaint the participant with the geology of the rock units that are involved in mining operations to produce the underground space.

The unit most commonly mined is the Bethany Falls Limestone Member of the Kansas City Group (page 4). The Bethany Falls ranges between 20 and 25 feet in thickness and underlies metropolitan Kansas City and surrounding areas except in the larger stream valleys where it has been removed by erosion. The Bethany Falls is particularly well adapted to underground mining by the room and pillar plan. Numerous mined out areas with a total combined area of many square miles underlie the greater metropolitan area of Kansas City and more is being produced every day. There are over a dozen underground mines. The larger ones mine about 10 acres per year. At one time, underground space was considered of little or no value but in the past few years the space left after mining operations is frequently many times more valuable than the limestone product produced.

Although most underground space now in use is used for warehousing, other activities include: printing, drapery processing, film processing, computerized data processing, boat and toy manufacturing. Underground space is occupied by artists, soils foundation engineering specialists, food stores, petroleum companies, breweries, and the U.S. Government. One underground facility consists of 23 businesses and employs nearly 800 people. Because of the large scale and increased usage of underground space, Kansas City is becoming known as "The City That Moved Underground".

There are many advantages to moving underground:

- 1) The surface area above the underground facility can be rented or leased.

- 2) Most of the facilities are near major highways and have access to railroads. Future uses suggested for underground space include freeways and freight and passenger terminals for airways and trains.
- 3) Underground areas are relatively free of noise, vibration and dust. The absence of vibration and dust allows for the manufacture of instruments of incredible accuracy.
- 4) The temperature in underground workings varies from 50°F in the winter to 65°F in the summer, thus the relatively uniform temperature results in reduced heating and air conditioning costs.
- 5) There are many factors which cause a variation in the ready-for-use cost, but \$3.00 per square foot is average, for development of warehouse facilities. Variation depends on mining procedure and, to some extent, the quality of the limestone. Savings of from 30 to 40 percent can be expected in rental and maintenance costs over comparable surface warehouse space.
- 6) Underground facilities are virtually burglar proof. As a result, insurance rates are generally lower.
- 7) Underground areas are free of such surface hazards as tornados, lightning, high winds, etc.

The disadvantages of moving underground must also be considered. Included among them are such deleterious factors as:

- 1) Possibility of cave-in or roof collapse - the likelihood of this happening, however, in properly constructed underground areas is negligible.
- 2) Cost of ventilation to remove toxic and irritating gases created by various industrial processes such as spray painting, etc.
- 3) Water seepage sometimes occurs in the best planned and constructed underground area and costly preventive measures must be taken to eliminate it.

- 4) Swelling of portions of the floors caused by growth of gypsum crystals in the underlying black shale of the Hushpuckney Member has become a problem of major concern in some underground areas.
- 5) Certainly of major importance is the psychological fear that some people have of going underground.

Because of time limitations, only three of the many underground facilities could be included on this trip, nevertheless, it is hoped that the selection of underground facilities will be sufficient to acquaint the participant with the extent and variety of usages of underground space.

For a detailed discussion of underground mining in the Kansas City area see the excellent article by Dean, Jenkins and Williams (1969)(appended to this guidebook).

Acknowledgments

The Association of Missouri Geologists wishes to acknowledge and thank the following for their cooperation in assisting the Field Trip and Arrangements Committee: Mr. A. N. Brunson, President of the Brunson Instrument Company; Mr. Harry Gerleman, Plant Superintendent, Missouri Portland Cement Company; Mr. Paul R. Roberts, Secretary-Treasurer, Andes & Roberts Construction Company; Mr. Glen E. Bowerman, Anrok Materials Company; Mr. Grady Truitt, Price Williford Company; Dr. Arthur B. Rhoades, President, and Mr. Gene L. Kingsley, Vice President of Overland Distribution Center.

Mr. Jerry D. Vineyard, Chief, Publications and Information, and Mr. Douglas Stark, Chief Draftsman, Missouri Geological Survey, assisted in preparation of the guidebook. Other members of the Missouri Survey staff, in particular, James Williams and Thomas J. Dean are acknowledged for critically reading the guidebook.

GEOLOGY AND UTILIZATION OF UNDERGROUND SPACE
IN THE KANSAS CITY AREA

Saturday, September 25, 1971

Chartered busses will depart at 8:00 A.M. from the Ramada Inn parking lot, Jct. Noland Road and I-70, Independence, Mo.

<u>Cum.</u>	<u>Mileage</u>	<u>Diff.</u>	
0.0			Ramada Inn. Proceed west on U.S. Interstate Highway 70.
2.8	2.8		Raytown limestone, Lane shale and Argentine limestone exposed in road cut.
3.5	0.7		Harry S. Truman Sports Complex on the left, a \$43,000,000 Jackson County Bond Project.
3.9	0.4		Excellent section extending from the Westerville limestone up to the Argentine limestone. The Chanute shale can be readily distinguished by the red color. The Leeds Road overpass is built on the Argentine limestone, Jct. I-70 and I-435. Proceed north on I-435.
4.5	0.6		Top of Wea shale and overlying Westerville limestone exposed under Hwy. 40 overpass and for several hundred feet northward along I-435.
5.2	0.7		The three thick limestones of the lower part of the Kansas City Group, Sniabar, Bethany Falls and Winterset, are exposed on both sides of the highway.

Underground mining of the Bethany Falls limestone has been extensive in this area. On cold days motorists have been startled by what appears to be plumes of white smoke rising from out of the ground. The white plumes are, in fact,

condensation of moisture as warm air escapes through air vents and other openings to the underground workings.

5.8 0.6 Jct. I-435 and 23rd Street (Missouri Highway 78)
Proceed east (right) on 23rd street.

6.0 0.2 Stop 1: Brunson Instrument Co., 8000 East 23rd St.
The stratigraphic section from the Middle Creek limestone up to the Winterset limestone is exposed at the plant entrance.

Brunson Instrument Company is a manufacturer of precision instruments used extensively by the armed services and by missile and space industry and construction. These instruments require a highly stable, vibration-free factory with fully controlled humidity and temperature. It was to obtain these factors that this underground facility was planned. The previous location was subject to a great deal of vibration, dust and noise which is virtually absent at the present site.

This site was chosen after consideration of a number of abandoned mines and quarries. None of them were suitable so Mr. A. N. Brunson, President of the Brunson Instrument Company dug his own underground area. It took six years. The work was completed in the early 1960's. The limestone was sold as it was mined.

Owners and operators of "inner space" in the Kansas City area are unanimous in the opinion that Mr. Brunson is "The Father of Underground Space Use". He was the first in America to excavate an area specifically for industrial use. When he began development of his facility it was dubbed by many as "Brunson's Folly". However, time has proven the wisdom of his decision. Now numerous corporations are mining for the specific purpose of using the space for storage, offices and many other uses.

The plant consists of 140,000 square feet. There are six east and west tunnels and seven north and south tunnels with pillars

15 by 65 feet between tunnels. Ceilings are about 12 feet high. It is interesting to note that not a single roof bolt was required in plant construction. A 50 ton air conditioning unit provides all the cooling for the entire plant. A 300,000 BTU heater provides all the necessary heat for the factory with a 150,000 BTU heater for the office area.

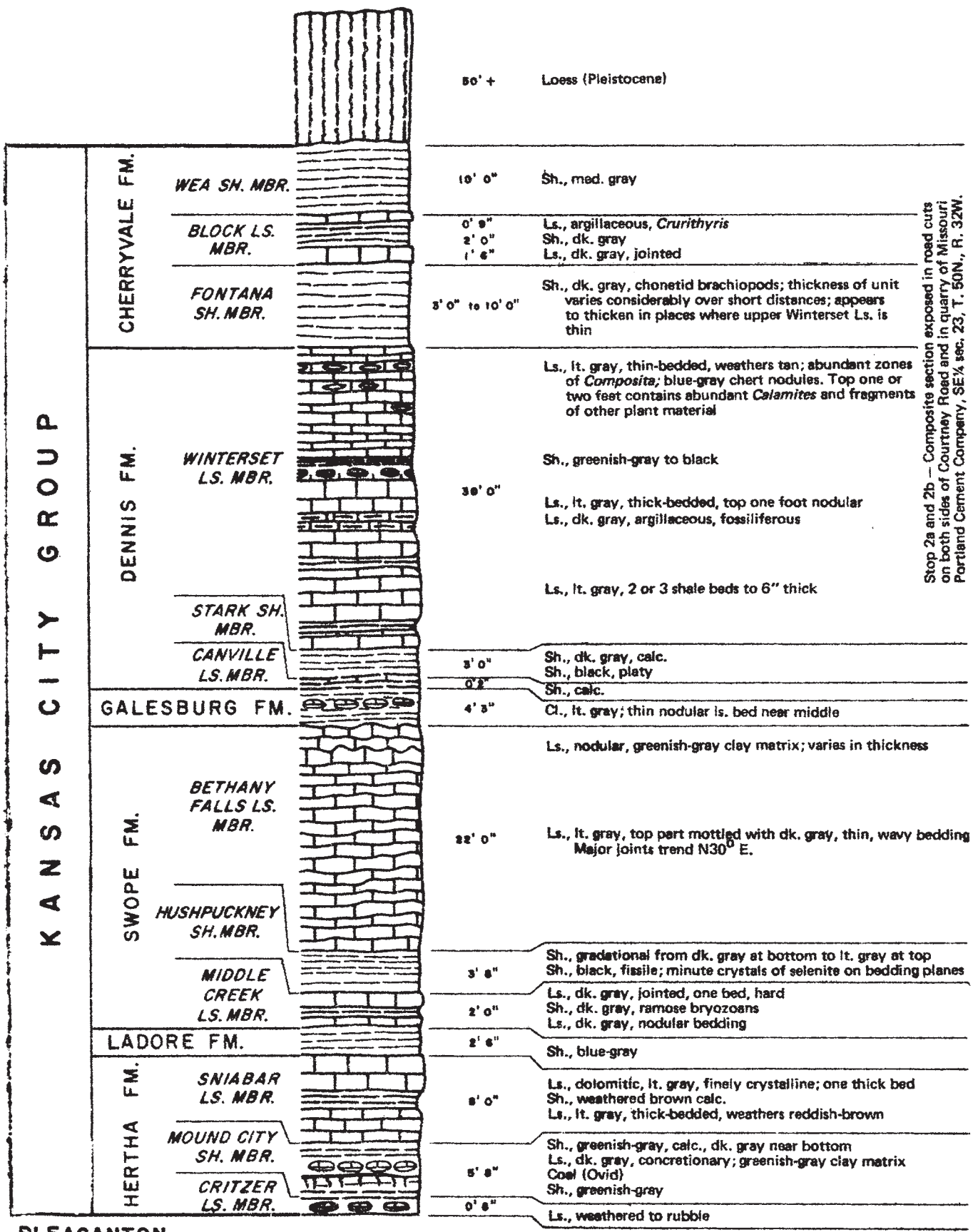
The factory concrete floor is sealed with a concrete sealer to prevent dust. The limestone ceilings and walls are sealed with latex. Where it was necessary to have a straight wall concrete blocks were installed.

In the office, which consists of 7,750 square feet plus 1,000 square feet of equipment area, the floors are concrete with asphalt tile. Three feet of air space exists between the acoustical ceiling and the roof rock.

The sewers are connected directly to the city sewers and the water supply is furnished by the city. All sewer pipes are graded for drainage and are in the Hushpuckney shale under the plant floor. Water pipes are also buried in the rock beneath the concrete floor.

Proceed east on 23rd street.

- 6.1 0.1 The stratigraphic section from the Hertha limestone to the top of the Winterset limestone is exposed in deep road cut on 23rd street. The Bethany Falls is the lowermost of the two thick limestones exposed near the middle of the hill. The gray mottled appearance which distinguishes the Bethany Falls can be seen from the bus window. The dark gray mottled appearance of the Bethany Falls limestone has been attributed to algae.
- 6.5 0.4 Stark Road and 23rd Street - Upper part of Winterset limestone. Characteristically the upper Winterset is thin bedded and weathers tan.



Stop 2a and 2b - Composite section exposed in road cuts on both sides of Courtney Road and in quarry of Missouri Portland Cement Company, SE 1/4 sec. 23, T. 50N., R. 32W.

PLEASANTON GROUP

- 8.3 1.8 Jct. 23rd Street and Sterling Road; north on Sterling.
- 10.9 2.6 Sugar Creek Refinery of the American Oil Company. This facility converts crude oil into gasoline and other petroleum products.
- 11.0 0.1 Sterling Road makes sharp turn to right and becomes Kentucky Road.
- 12.3 1.3 Entrance to Missouri Portland Cement Company on left. Continue on Kentucky Road.
- 13.3 1.0 Veer left onto Courtney Road.
- 13.8 0.5 Stop 2a - Road cuts, both sides of Courtney Road. The lower part of the Kansas City Group from the Sniabar Limestone Member is well exposed at this stop. Southward along the road cut, thick deposits of loess can be seen resting unconformably on successively younger beds of the Kansas City Group, including units from the Bethany Falls to the Winterset Limestone Members. The Sniabar Member is exposed as two relatively thick beds of limestone separated by a thin shale parting. The limestone beds of the Sniabar member are slightly dolomitic. Weathered surfaces are reddish-brown, particularly the upper part. The Middle Creek Member occurs in the shale interval between the top of the Sniabar limestone and the base of the Bethany Falls limestone and consists of two limestone beds, each less than a foot thick separated by an equal thickness of shale. The black fissile shale of the Hushpuckney Member overlies the Middle Creek limestone. Minute crystals of selenite gypsum occur along the bedding planes of the black fissile shale.

Warping and buckling of floors in some underground areas is attributable to crystal growths of selenite gypsum. A proposed solution to this problem is to remove the shale of the Hushpuckney Member. The floor of the underground area then rests on the

upper limestone bed of the Middle Creek Member which is a hard uniform bed with an even upper surface. However, this unit is thin and joints are closely spaced.

The Bethany Falls limestone is a light gray, wavy-bedded limestone which ranges from 20 to 25 feet in thickness. The upper 2 or 3 feet is a nodular limestone that may increase considerably in thickness over lateral distances of several feet. When penetrated in underground mining operations, it has a tendency to cave. This facies of the Bethany Falls lacks the structural strength of a limestone bed. Thus in mines where this factor has not been recognized, or occasionally ignored to rob some additional stone, caving of the roof can occur and collapse may extend to the surface.

The Bethany Falls is jointed into large blocks. The placing of pillars at joint intersections for additional support is recommended in underground mining activities. Pillars spaced on approximately 40 foot centers will randomly fall along joints or joint intersections since that is the approximate spacing of joints in the Bethany Falls.

Stop 2b - Time permitting, we will walk about 300 yards cross country to the quarry of the Missouri Portland Cement Company. At the quarry the Bethany Falls and overlying strata consisting of the Galesburg Formation, Stark Shale Member and Winterset Limestone Member are well exposed.

The Galesburg consists of 4 or 5 feet of light gray clay with sparse limestone nodules in the bottom part. The Canville Member is represented by 2 or 3 inches of calcareous shale at the base of the Stark Shale Member. The Stark is similar lithologically to the Hushpuckney Shale Member.

The Galesburg forms an impervious seal which inhibits water seepage into underground areas. This advantage is partially

negated by the relatively permeable Stark Shale where water movement occurs along parting planes and joints in the shale.

The Winterset Limestone Member is approximately 30 feet thick. The limestone is closely jointed and thin-bedded. Several persistent beds of shale occur throughout the unit. The Winterset will not support its own weight and has a tendency to cave in unless supported by a Bethany Falls roof of adequate thickness.

Return to Courtney Road.

14.0 0.2 Hertha Limestone to base of Bethany Falls Limestone exposed on left side of Courtney Road.

14.3 0.3 Harris Crushed Rock Quarry on the left.

15.8 1.5 Jct. Courtney Road and By-pass 71 highway.
Proceed south on By-pass 71.

15.9 0.1 Bridge over Mill Creek

16.5 0.6 Entrance to North Independence Industrial Park. Some of the tenants located at the entrance are: Fordyce Concrete, City Wide Asphalt, as well as heavy truck companies.

Proceed through the Industrial Park to the entrance tunnels.

16.6 0.1 Stop 3 - This is also a lunch stop. The stratigraphic section overlying the Bethany Falls Limestone which consists of the Galesburg Formation, Stark shale and Winterset limestone are well exposed above the entrance tunnels. At this stop we will have the opportunity to follow the development of "inner space" from the mining of the Bethany Falls limestone to the utilization of the space for warehouses and offices. In the late

1950's, Mr. Paul L. Roberts envisioned that land owned by Andes and Roberts Bros. Construction Company might be utilized economically as mined storage area. Preliminary test borings were made and mining operations began in the fall of 1963. The Industrial Park covers 320 acres. Presently there are 17 entrance tunnels -- each 30 feet wide. The tunnels in the mine area also are 30 feet wide. The pillars are 20 by 20 feet and are centered every 50 feet apart. The length of each tunnel varies and has concrete floors throughout.

Tunnel No. 3 is occupied by Andes and Roberts Construction Company offices and covers approximately 6,200 square feet. Mr. Roberts' office is unique in that the ceiling is limestone. Tunnel No. 4 is occupied by Home Utilities Company and Home Material Company and covers approximately 20,625 square feet. Tunnel No. 5 is occupied by a sheet metal shop, plumbing shop and a warehouse and covers 6,250 square feet. Tunnel No. 6 covers 22,875 square feet and is a heavy equipment maintenance shop.

Allis-Chalmers Combine Division leases 250,000 square feet and Bailey Publications leases 9,200 square feet. The R.L.S.D. Church has a complete book storage and record center.

An additional 7,000 square feet has been donated to Civil Defense for emergency food supplies and hospital equipment. Heating, lighting and air conditioning exists in most offices and work areas. The unoccupied areas remain about 56 degrees throughout the year.

Mined out area is being added continuously by the Anrock Materials Company. Approximately 2,000 tons per shift of limestone is being produced at the present time. Masonry concrete aggregate, asphaltic concrete aggregate, agricultural lime, screened stone, crusher run and rip rap are the products of the Anrock Materials Company.

The land above the area being mined is used for a drive-in theatre and farming.

Return to 71 by-pass and proceed south.

20.1 3.5 Stop 4 - Overland Distribution Center Inc., 16500 East Truman Road. Entrance at U.S. 71 By-pass and Peck Rd.

This is one of the largest underground warehouse facilities in the Kansas City area. The warehouse consists of 505,000 square feet of -5° freezer area for storing frozen foods and 330,000 square feet of humidity and temperature controlled area. The ceilings are 16 feet high and there is ample space for 70 trucks at the truck dock and for 40 rail cars at the rail dock. Rail service is by the Missouri Pacific Railroad. Both the rail and truck docks are conveniently located underground and are covered by closed circuit television. The television setup permits central control for easy flow of rail and truck traffic and also minimizes chances of theft.

Fire protection is by sprinkler system but fire trucks of the City of Independence can drive directly into the warehouse to use the strategically located fire hydrants. Adequate fire protection and other safety features which were incorporated in the planning stages have allowed this facility to have the lowest insurance rates of any warehouse in the Kansas City area.

The venture was incorporated in June 1969, and was recently completed at a cost of 5 1/2 million dollars. The underground area which extends under U.S. 71 By-pass covers 115 acres and was formerly a limestone mine.

Dr. Arthur B. Rhoades, the company's president estimates that there will be in operation by the end of this year 18 million cubic feet of freezer space.

Return to 71 By-pass and proceed south.

- | | | |
|------|-----|---|
| 20.4 | 0.3 | Bethany Falls limestone exposures both sides of By-pass 71 Highway. |
| 22.6 | 2.2 | Bethany Falls limestone and Winterset limestone. |
| 23.6 | 1.0 | Jct. By-pass 71 Highway and I-70. Excellent exposure of Bethany Falls limestone along access road to I-70.

Proceed west on I-70. |
| 24.5 | 0.9 | Upper part of Winterset limestone exposed along highway for distance of one-half mile. |
| 25.1 | 0.6 | Fontana shale and Block limestone exposed in road cuts along I-70 just west of Phelps Road overpass. |
| 25.7 | 0.6 | Westerville limestone south side of highway. Good exposure of cross-bedded oolitic limestone. |
| 26.5 | 0.8 | Jct. I-70 and Noland Road.
Proceed south on Noland Road. |
| 26.7 | 0.2 | Ramada Inn -- End of Trip. |

Selected References

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UNDERGROUND MINING In The Kansas City Area

The basic paper was presented at the annual meeting of the Kansas City Section of the Assoc. of Engineering Geologists on Sept. 13, 1968. Photography and captions, except where noted, are by Jerry D. Vineyard.

By Thomas J. Dean
Gomer Jenkins
James H. Williams

Commercial mining in the greater Kansas City area started prior to 1900 in surface strip pits on outcrop lines, where the overburden was thin enough to permit removal by horse-drawn, hand-operated scoops or scrapers. The Bethany Falls Limestone was extensively quarried and descriptions of the working faces of some of the quarries described in 1902 were "several thousand feet long and thirty feet in height." Only the upper few feet of soil were removed as overburden and the remainder including shale sections, was used as macadam and what was called "rubble". The Hushpuckney Shale Member of the Swope Formation was apparently the working base in these open pit quarries as it is today in the underground quarries in the Kansas City area. All drilling and loading of the blasted material was done by hand or hand tools. Horses and/or mules pulling sleds were the chief transportation between the quarry, crusher, and stockpiles.

Except for the manufacture of cement and for use as fill material, the upper strata of the Bethany Falls Member, the Galesburg Formation and the Dennis Formation were not used, although they had to be removed in quarrying. To avoid stripping tens of feet of silt and loess material and the underlying clays, shales, and limestone from the Bethany Falls, underground mining began. In this method of mining, inclement weather, dump areas to dispose of waste material, and the total destruction of the surface were eliminated. In a well-run underground mine, the miners could work every

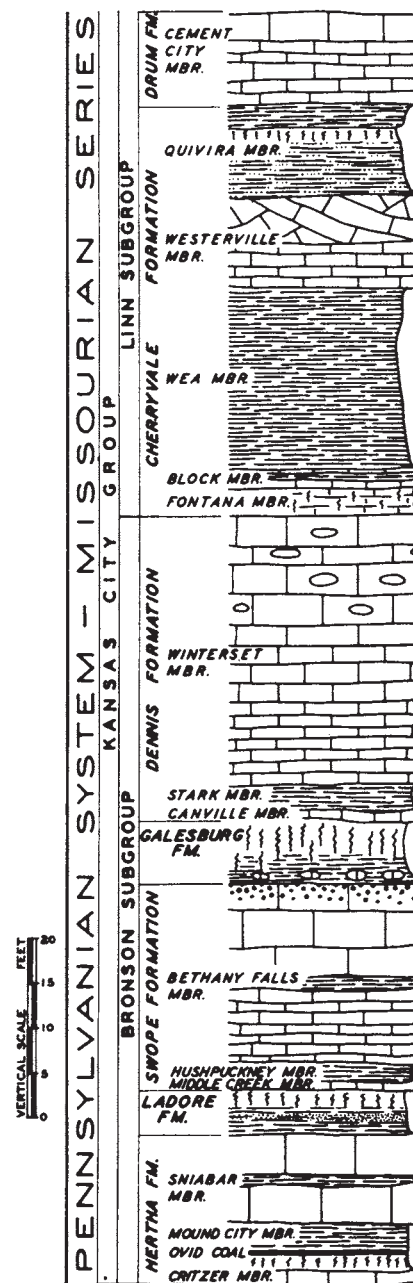
Important Formations In Kansas City Mining

Geologists use a diagrammatic rock column to indicate the type and relative positions of the various rock formations in an area. Rock types are shown by symbol; the brick-like pattern indicates limestone; short horizontal lines depict shale; and a stippled pattern is sandstone.

The column at left is a composite showing the Pennsylvanian rock formations important in Kansas City mining activities. Not all these formations are found in any one section, but the column shows relative ages of the rocks (oldest rocks are at the bottom, and become progressively younger toward the top).

The Bethany Falls Limestone Member of the Swope Formation is the only stone currently mined in the Kansas City area, and the column shows one reason why. The upper beds of the Bethany Falls are massive and strong, and they make fine roofs for underground mines. The Winterset Limestone Member of the Dennis Formation is thicker, but it is much more highly jointed (joints are not shown in column).

The Bethany Falls is only 20-25 feet thick, but it is exposed over a wide area in a favorable position for mining, and the stone meets the Missouri State Highway Department's specifications for concrete aggregate. It is desirable in underground mines to have the Winterset Limestone in place over the Bethany Falls to provide a better mine roof. Where most of the Winterset is absent, roof stability problems are encountered in Bethany Falls mines. Where necessary, roof bolts can be set into the Winterset from mines in the Bethany Falls.



UNDERGROUND MINING. . . (Continued)

day of the year. After World War I, many of the limestone quarries were mining into the Bethany Falls and it soon became apparent that the underground workings were the wave of the future. Since that time it has been estimated that quarrying operations now actively engaged in mining, abandoned mined-out areas, and ownership of areas by mining companies that are to be mined, would total approximately 30 square miles in and near Kansas City.

The Bethany Falls Limestone Member of the Swope Formation is perhaps one of the most easily recognized rock units in the greater Kansas City area. The total thickness of the limestone ranges from 20 to 25 feet. It consists of massively bedded limestone that forms bluffs along valley walls. At many localities the uppermost 2 to 4 feet of the Bethany Falls weathers to a nodular limestone rubble. Pronounced jointing in the formation forms large slump blocks ranging from 10 to 20 feet in length and width. The Bethany Falls Member is underlain by the Hushpuckney Shale Member of the Swope Formation which ranges from 3 to 4 feet in thickness. The important formations that are considered here are the Swope Formation which includes the platy Hushpuckney shale and the massive Bethany Falls Member. The Swope is overlain by the Galesburg Formation, a massive shale approximately 4½ feet thick. Above the Galesburg is the

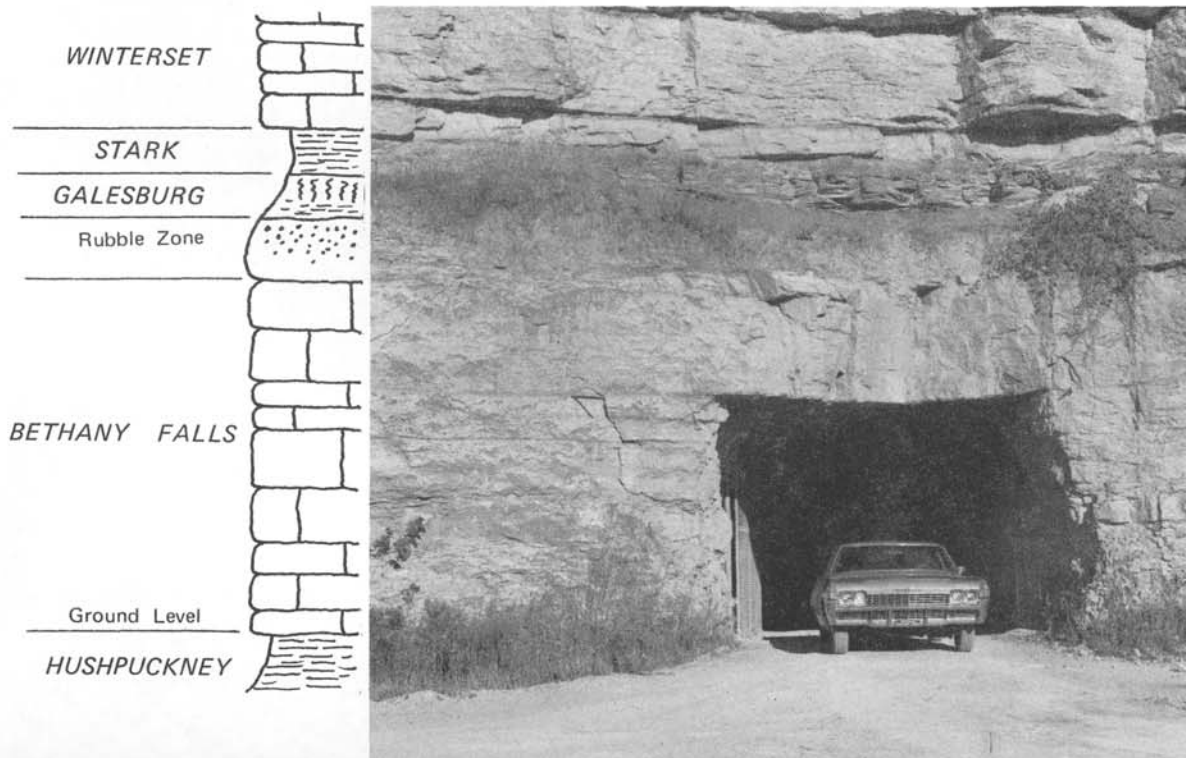
Dennis Formation, which includes the Stark Member, a 2 to 3 foot thick platy shale, overlain by the Winterset Member. The Winterset is 30 to 40 feet thick and is composed of thin- to medium-bedded cherty limestone interlayered with thin clay or shale. The Winterset beds do not support their own weight when undermined because of persistent joints and thin bedding.

The Bethany Falls Limestone is by far the most commonly quarried stone in the Kansas City area because it is the only limestone of sufficient thickness and quality to fill all construction needs.

Where underground limestone mines are operated with the primary intent of extracting the maximum tonnage of stone available, construction problems in the mined-out areas are sometimes insurmountable. Many of the earlier mines, and some newer ones, operate without consideration for use of the mine after the stone has been removed. Location of the mine openings and room, roof, and pillar dimensions have been planned with the only concern being the extraction of a maximum amount of stone products. Once an area has been mined-out and roof failure and collapse have begun, the underground portion of the mine and the surface real estate are of little value. In a collapsing mine some areas will remain stable for long periods of time but no long term studies have been made that could differentiate safe areas from collapsing areas.

One mine in southwestern Kansas City is in such precarious condition that it is generally forbidden to enter. The old practice of robbing pillars and roof contrasts sharply to modern mining practice. The shallow overburden coupled with widely spaced pillars allows collapse in the mine, with total destruction of the surface.

THIS MINE PORTAL clearly shows the massively bedded Bethany Falls Formation, the rubble zone at the top of the Bethany, the Galesburg Shale, Stark Shale and Winterset Limestone. Note that the mine roof coincides with a prominent bedding plane in the Bethany Falls, and that a thick, massive bed of limestone supports the roof of the mine. This is ideal mining practice, and if all operators followed good design practices, problems of limestone mining in Kansas City would be very few indeed.

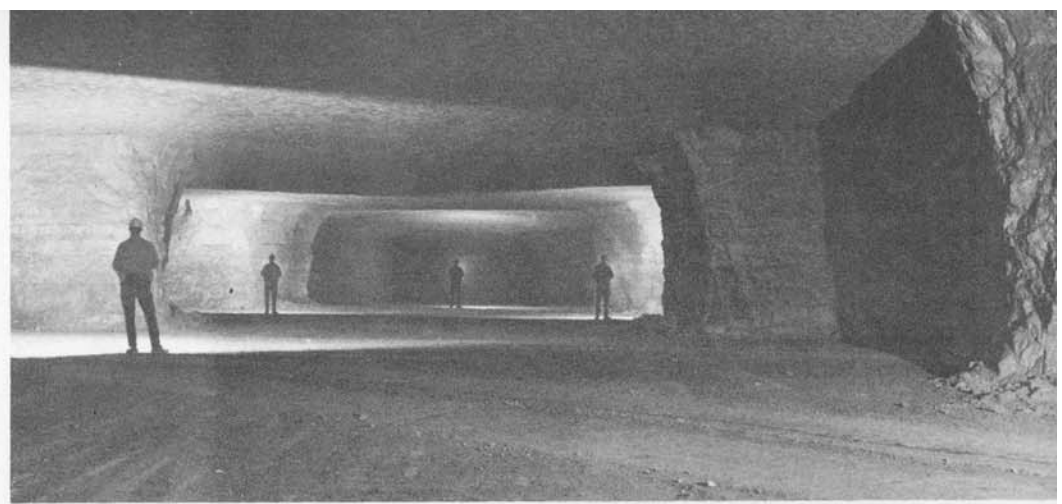


UNDERGROUND MINING. . . (Continued)

The importance of planning in this type of operation is more apparent when we consider that there is more than 4½ square miles of mined space beneath Jackson and adjoining counties in Missouri and Kansas. Figures released by the Independence Chamber of Commerce show that there is about 51 million square feet of warehousing and manufacturing space in 21 different mining areas around Kansas City. These figures indicate usable underground floor space. If one adds the 25 percent pillar space this would amount to about 2½ square miles of mined-out area. Thus, more than half of the mines that could have been used for offices, storage, etc. are unsafe due to collapse, poor design, and various other hazardous conditions.

The tremendous volume of safely mined-out space has barely been tapped as office, manufacturing or storage use, but the rate of development is rapidly increasing as area businessmen observe the success of including such installations as Brunson Instrument, J. C. Nichols, Hallmark, Inland Underground Storage, Anrock, etc. S. J. Callahan (1965) estimates that there is approximately 5,800,000 square feet of underground warehousing and manufacturing facilities that have been constructed or are in the process of being constructed in the Kansas City area.

Unfortunately, many mined space developers find the prefabricated rooms and pillars of stone left by the quarrymen poorly arranged and sometimes hazardous and difficult to improve. Many of these problems could have been avoided with a planned approach of engineering geology and economic studies before mining began. In anticipation of a planned study for a proposed mine and subsequent industrial site, one should consider some of the more common problems that beset the opening and utilization of an underground limestone mine. These problems will not necessarily be



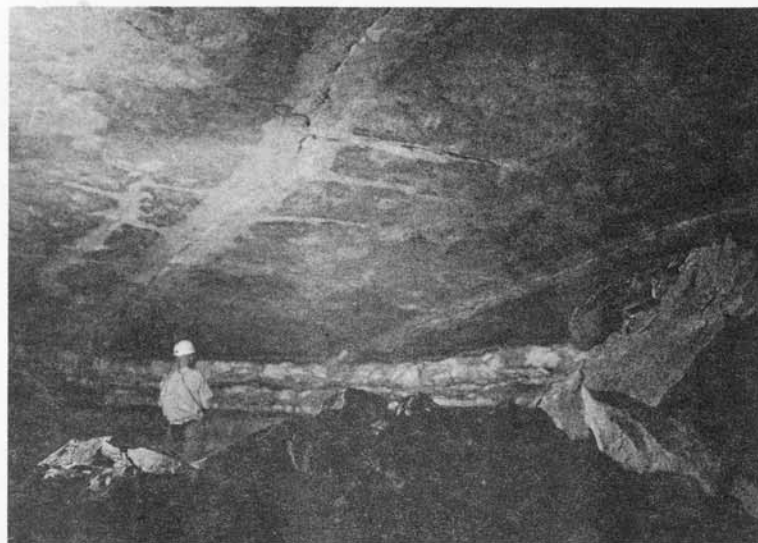
(Top Right) — GOOD MINING PRACTICES in the Kansas City area provide mined space with carefully dressed pillars; smooth, bedding plane roof; and long spacious bays ideal for development. Careful attention to rock structure results in a dry mine. (Center Right) — TRUCK AND/ OR TRAIN LOADING FACILITIES can be provided in Bethany Falls mined areas by excavating the Hushpuckney Shale which underlies the Bethany Falls Limestone. The Hushpuckney Shale is subject to swelling when exposed to water, so it is commonly protected by a concrete apron to prevent wetting and swelling of the shale. (Bottom Right) — POOR MINE DESIGN, with drainage only an after-thought, can result in water problems that make the difference between successful operation and a losing venture. The time to consider drainage is in the initial planning stages, before the first portal is opened. Wet mines such as this one have a short life expectancy because wet shale on the floor of the mine swells, causing pillars to fail and floors to buckle. When pillars fail, roof collapse cannot be far behind.

UNDERGROUND MINING. . . (Continued)

discussed in order of importance because various plans for mining and space utilization will alter the merits of each of these major problems.

1. Type and thickness of overburden.

The entrance area or mine drifts which are under a thin cover of bedrock and soil are generally hazardous. The mine entrance(s) should be located so that the bedrock and soil overburden is of adequate thickness for stability as well as reducing the amount of seepage resulting from seasonal rainfall. If the mine entrance in the Bethany Falls Limestone is not immediately overlain by the Galesburg and Stark Shales and at least the lower part of the Winterset Limestone (preferably all of the Winterset), then roof fall and surface caving can occur within a short period of time unless some sort of a mine support system is used. This is evidently caused by the weathered condition of the bedrock under a thin soil cover. If mine passageways are extended under a thin cover of surface soil and bedrock such as beneath a small valley, collapse can occur. For minimum safe roof conditions, a full thickness of Winterset over the mine is highly desirable. Soil cover, thickness and surface elevation alone may be misleading due to irregular bedrock topography. Surface exploration drilling and detailed survey is another early step needed in mine development. Thin rock



HIGHLY DANGEROUS MINE SUBSIDENCE is progressing upward toward complete collapse. The man is standing on rubble from the Stark and Galesburg shales, which have collapsed and filled the opening in the Bethany Falls Limestone. Stopping is progressing upward into the Winterset Limestone, which will eventually collapse and a sinkhole will appear on the surface. Breakdown such as this occurs where the overburden is too thin or where the Bethany Falls ceiling has been scalped too near the rubble zone.

THIS ACTIVELY COLLAPSING MINE shows joint systems in the Winterset Limestone. Ceiling breakdown in a Bethany Falls Limestone mine has already progressed through the shale formations above the Bethany Falls and is encroaching upon the overlying Winterset Limestone. Groundwater moving downward through the joint systems has weathered and discolored a zone adjacent to the joint, causing the contrasting light streaks on the mine roof. Areas such as this are highly dangerous and should be avoided even by cameramen.

cover over a ceiling in an underground mine even with thick soil cover will probably be a site for roof fall and possible collapse extending to the surface.

2. Groundwater. Groundwater volume in the Kansas City area seldom exceeds a few gallons per minute. The groundwater is primarily in two shale members, both of which are black, fissile and jointed. Water in the lower shale, the Hushpuckney, will pond in mines if the bedrock slopes toward the working face. The Hushpuckney is a hard, slaty shale and trenching for drains is rather costly, but if water stands on the shale it quickly becomes soft, causing heaving floors and sagging pillars.

Water in the overlying Stark shale is in the same general geologic setting as the water in the Hushpuckney. Water problems in the Stark may contribute to roof falls when the Bethany Falls is mined so that on roof sags water entry into enlarged parting planes will further weaken the roof. If holes or shafts are drilled or excavated through the Stark they usually have to be grouted. Both the upper and lower shales will swell when exposed to air for a period of time. If shale is exposed by undercutting the mine floor

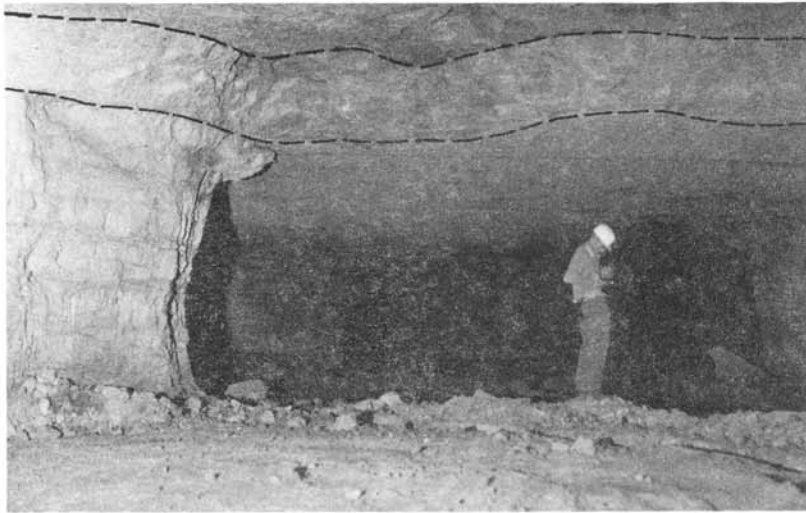
such as for railway car clearance, water should be kept away from the shale preferably by sealing the shale section with a concrete apron or other means.

3. **Mine design and development.** Very little can be done to change a mined out area, especially if it has been left in a hazardous and unsafe condition. Once the random arrangement of rooms has been established, the pillars have been robbed, or the roof scalped during removal of limestone, remedial measures such as artificial roof support are expensive, hazardous and probably short-lived. If the mine floor slopes in the wrong direction, water problems will be an expensive and continuous maintenance item.

A good topographic survey should be one of the earliest planning phases of a new mine. The general mine outline can be planned before the first face is drilled and shot. The topographic map is invaluable in planning entrances that are most easily served by utilities, roads and railroad facilities.

Bedrock inclination or dip should be considered so that drainage by gravity can be utilized where possible. Commercial use of the mined space after mining demands planning for unusual features such as fumes, vibration, heat, air conditioning, dark-rooms, refrigeration, etc. If firewalls will be needed, longwalls rather than individual pillars may be desirable. Highway and railroad grade levels may require excavation into shale foundations. Railroad spurs into underground quarries generally require from 17 to 18 feet of clearance above the rail. This necessitates removal of the Hushpuckney shale down into the Middle Creek Member because an adequate roof must be left in place. Water causes these shales to swell, resulting in buckling of the mine floor or base of the pillars. Some mine operators have introduced a moisture barrier between the shale floor and the asphalt or concrete that is used as a road surface or in the retaining walls (aprons) around the base of pillars where shale is exposed.

The follow-up engineering geology and topographic surveying of the mine during the active quarrying phase is equally important. Room and pillar spacing, for instance, can be maintained as planned or altered if underground conditions change. Continuous survey of this kind can assist in avoiding unsafe areas. Dangerous roof conditions resulting from bedrock changes can be located and remedied. A complete mine survey, including



(Top) **ROBBING THE ROOF, OR SCALPING**, is a common practice where stone removal is the primary concern. However, such practices can only be considered short-sighted, because the removal of a scant two feet of roof rock can mean the difference between a collapsing mine with the mine owner subject to litigation from surface landowners, and a highly profitable operation utilizing mine space with a safe roof. Dotted lines show scalping of about 2 feet of stone. Roof failure occurred within 50 feet of this area (see photo on p. 44) (Bottom) **ROOF FAILURE** has occurred as a result of scalping. Removal of only two feet of stone brought the mine roof dangerously close to the rubble zone at the top of the Bethany Falls, and resulted in collapse of the mine all the way to the surface, creating a large sinkhole and ruining the land for surface development.



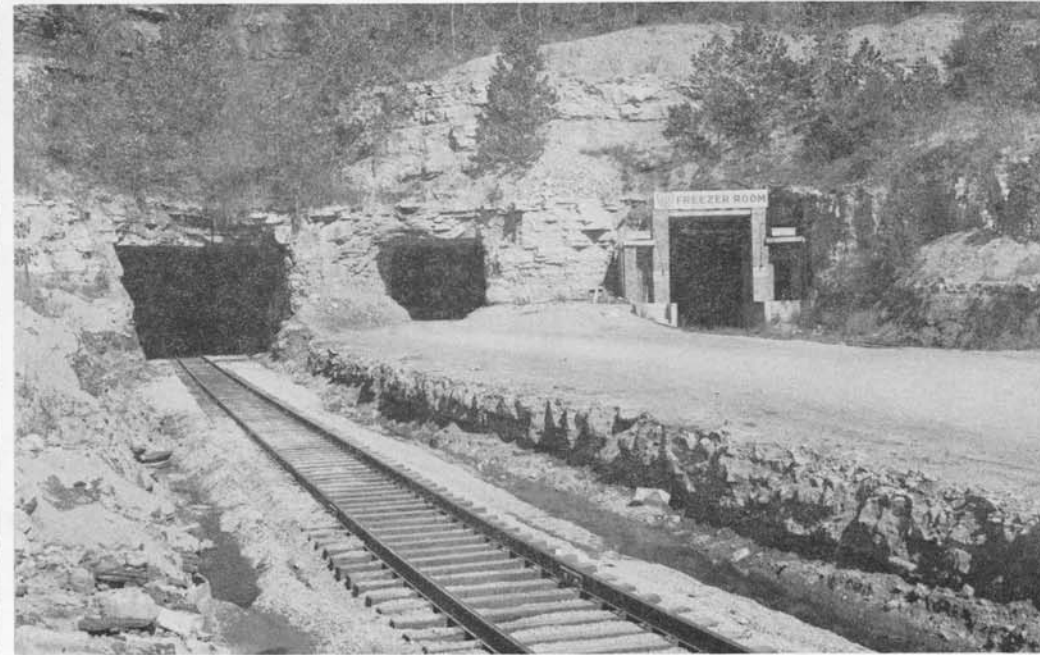
UNDERGROUND MINING. . . (Continued)

pillars, room dimensions, rock falls and groundwater seeps, is perhaps the most important single item needed for industrial development. One recent illustration for the need for accurate and reliable survey data is a discrepancy of about 250 acres between estimates of the acreage in a Kansas City mine. As recently as 1965 city and county ordinances have been proposed that would require yearly or semi-yearly surveys of mines by competent personnel. Specific codes for mine safety were also considered but these ordinances were never passed. Local ordinances exist but apparently are not well known.

There are about 15 active underground limestone mines in the Kansas City area. The larger ones mine from 10 to 12 acres per year. For the most part there is no public record of this activity, so if the figures are ever completed we might find more usable warehousing or manufacturing space or conversely more unsafe mining conditions with the future of the surface area in doubt.

4. **Stability.** Mine stability is a direct consequence of techniques used in mining. Less is known about this extremely important item than about many minor problems. So far there has been only imperical consideration of room dimensions, pillar shape and diameter, roof thickness and overburden. Several programs have been proposed in the past through various universities in Missouri to conduct rock mechanics studies in various limestone mines to determine safe and economical mining practices. None of the studies have been carried out.

(Left) SAFELY MINED AREAS provide unbeatable space for development of underground storage facilities, manufacturing companies, office spaces and many other potential uses. Lighting and utilities are anchored to mine roofs, the gray limestone walls and ceilings are sprayed white, and a thin concrete floor is poured over the shale mine floor to provide stable and level base. Heating and air conditioning problems are minimal because of the relatively constant temperatures underground, which are unaffected by surface weather conditions. (Below) MINING AND MINED-SPACE USAGE is infinitely easier in the Kansas City region because the outcrop line of the Bethany Falls conveniently coincides with the lower part of bluffs and hills. Mine entries are easily constructed and access by rail, truck and even barge (where mines are near the Missouri River) is no problem. Underground cold storage is economical in mined space because the low thermal conductivity of rock cuts cooling costs.





ONLY THE BUILDER KNOWS. The offices of Woodward, Clyde and Sherrard, a consulting engineering firm in Kansas City, are in a converted mine. Modern materials conceal any clue that the offices are far underground, and the rock insulates against traffic noises, sonic blooms, and severe weather. (Photo courtesy Woodward, Clyde & Sherrard.)

UNDERGROUND MINING . . . (Continued)

It is general knowledge among mining people that spans between pillars greater than 35 to 40 feet and center-to-center dimensions greater than 65 feet result in eventual collapse of the roof with possible surface subsidence. Some mines use a random pillar arrangement with no thought given to spacing or direction of joints and possible uses of the area after mining.

Mines with "safe" room dimensions can still be subject to roof falls if the limestone roof is too thin. A local thickening of the rubble zone at the top of the Bethany Falls weakens the roof and collapse can occur. What is considered a safe roof thickness is based more on past successes and failures than on technical engineering or geological studies. Thus if up to 8 feet of limestone including the rubble zone is left as a roof, the mine will not be plagued by collapse if room and pillar designs are adequate. However, some operators leave a total roof thickness of only 5 to 6 feet. Therefore when the rubble zone increases in thickness from 2 to perhaps 4 feet only 1 to 2 feet of sound limestone remains in the roof. This is followed by roof falls and perhaps total collapse to the surface. Since there is no definite way to predict where the rubble zone will increase in thickness unless the roof is perforated with core holes, the underground quarry operations that have left at least two thick beds (5 to 7 feet) of Bethany Falls plus the upper 2 to 4 feet thick rubble zone have stable roofs.

There is precedent for rock bolting in the Kansas City underground mines. Some roofs have been bolted without apparent need and others bolted only when trouble developed. Rock bolting practice has been on 4 to 6 foot centers, especially over areas where machinery is to be stored. If the roof of Bethany Falls is of sufficient thickness, the rock bolts can be set into the Bethany Falls. However, if the Bethany is sufficiently thick to bolt, bolting may not have been necessary if room dimensions were properly designed. In some instances it is necessary to set long roof bolts that go up into the overlying Winterset. The practice of putting rock bolts only into the Bethany Falls would normally be cheaper and it reduces the leakage problems in the roof that are often prevalent after the Stark and Galesburg shales have been penetrated. Perhaps more stone could be quarried if the roof were bolted, but then again perhaps it would be cheaper to quarry less stone and use no rock bolts except in isolated areas. The practice of rock bolting is governed by economics and the future plans for the mined space. There is also inadequate information to predict the long-term success of

roof bolting where the Bethany Falls roof is thin and the room and pillar spacing have been overextended.

Stability is also a problem at mine entries. Longwalls may be preferred to pillars around entries. This may be especially true if it is necessary to undercut the floor of the mine so that sufficient room height is available for trucks and rail spurs. It may be necessary to excavate the Hushpuckney shale and deepen the floor into the Ladore shale, possibly to the Middle Creek Limestone. The base of the pillar or longwall will then rest on shale with no lateral strength. Exposed shale is subject to gypsum crystal growth, swelling, air slaking and the like.

Floor problems usually are not serious, but unusual storage or industrial requirements may increase the problems resulting from movement in the shale floor. This problem needs thorough investigation in each mine if a floor grade is to be undercut into the Ladore shale.

Joints most apparent in the Bethany Falls are vertical fractures that are regularly spaced and fairly regularly oriented with the general pattern of northwest-southeast and northeast-southwest. Joints measured in several of the mines in the Bethany Falls have an alignment of N 30° E to N 60° W. We have noticed variations in joint trends so that minor joint sets exist. However, the general pattern still is a northwest-southeast northeast-southwest direction. Some mine operators do not take into consideration their pillar pattern with respect to these joints. They indicate that they put a pillar wherever they feel it is needed but not necessarily at the intersection of fractures. Obviously, joints should not be allowed to continue down a passageway uninterrupted without some support. If a general cave-in does not occur, slabbing of the roof sometimes does. The pillar pattern should be such that these vertical fractures are intercepted by the pillars if at all possible. Locally this may interrupt the pre-planned pillar spacing and disrupt a long horizontal passage. Joints are sometimes enlarged to a greater degree near the mine entrances and where mine passageways pass beneath areas of thin overburden. Joints generally are not obvious where the overburden of soil and bedrock is relatively thick. Therefore the need to plan a pillar in the midst of an aligned passageway is not necessary if there is adequate overburden, sufficient Bethany Falls roof thickness, and proper room dimensions.

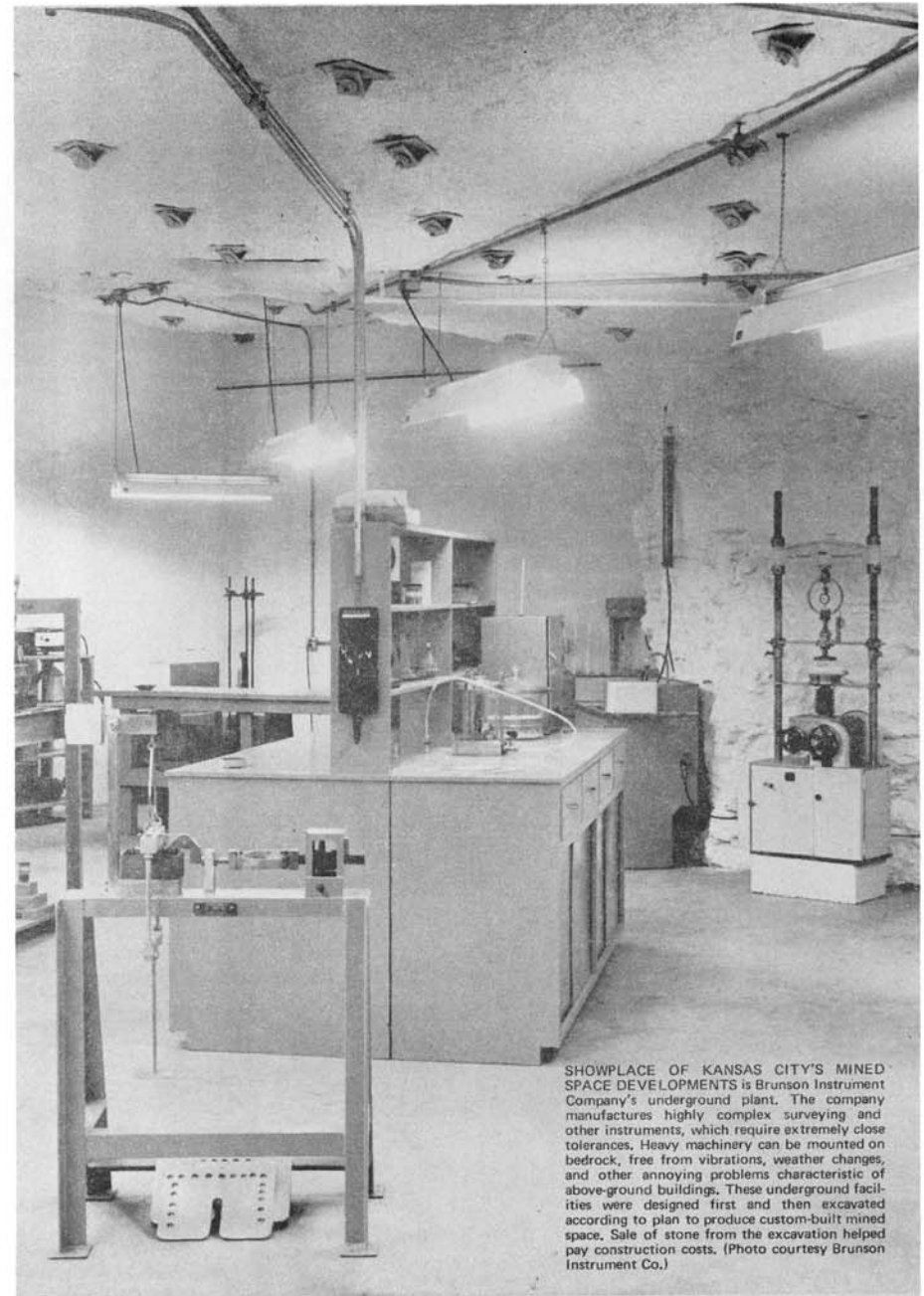
5. **Mine life expectancy.** Mine life expectancy depends upon the roof thickness, spacing of the pillars, room span, pillar diameter, joints,

UNDERGROUND MINING... (Continued)

groundwater, etc. If these various items have been properly considered - and we do not know what "properly" is in all aspects of Kansas City mining as yet - the life expectancy will be decades and probably centuries. We know of stable mines that are 20 to 30 years old. In reference to areas that have already been mined and have experienced some roof fall and possibly some surface subsidence, the most obvious factor that can be considered in projecting the life expectancy from immediate adjoining areas that have not suffered collapse is the present mine arrangement. Pillar and room spacing, pillar diameter, roof thickness, overburden and joint patterns are features that should be closely studied. If these are such that the anticipation of roof fall or cave-ins is not obvious, and remedial and monitoring measures can be practical, the surface or subsurface owner may be able to proceed with industrial or real estate development. However, this is only an educated guess at times and can probably be of little merit to an individual considering a major investment.

There is a definite need for professional guidance in underground mining, but it seems to be an obvious need that is most neglected. Several groups of experienced people can assist in the planning and excavation of an underground quarry. These include the engineer who is familiar with rock mechanics, the geologist, surveyors and experienced quarry operators. For the most part, in the Kansas City area, it seems that the engineering geologist has neglected this area of his profession. I can think of no group who could be more qualified to study the geologic problems and make recommendations to the engineers, the quarry operator and the potential users of the mine before and after the quarry operator has completed the excavation.

6. **Mining economics.** Crushed aggregate sells at the mine for approximately \$1.80 per ton yielding a gross income of about \$2.00 per square foot of mine, with a 16 foot working face. By taking 2 more feet from the roof, about 35 cents in additional gross income would be yielded but it may leave an unsound roof and surface condition. Warehouse lease space sells for anywhere from 50 cents to \$1 per square foot per year and the fully developed spaces may double or even triple these values. In the long run, the value of the mine as a commercial development for warehousing, manufacturing and so forth can far outstretch the value of the rock that was quarried from the mine. In addition large surface acreage tracts may sell for \$3,000 to \$5,000 an acre. With these figures in mind, it might sometimes pay to quarry the



SHOWPLACE OF KANSAS CITY'S MINED SPACE DEVELOPMENTS is Brunson Instrument Company's underground plant. The company manufactures highly complex surveying and other instruments, which require extremely close tolerances. Heavy machinery can be mounted on bedrock, free from vibrations, weather changes, and other annoying problems characteristic of above-ground buildings. These underground facilities were designed first and then excavated according to plan to produce custom-built mined space. Sale of stone from the excavation helped pay construction costs. (Photo courtesy Brunson Instrument Co.)

UNDERGROUND MINING. . . (Continued)

rock and throw it in the river, if necessary, to make the mine safe for the future, because the value of the rock mined is but a small portion of the extended value of the space.

Many of the unanswered problems that occur in the underground workings are problems that have not been studied in detail. Herein lies the potential for vast amounts of work to be done by geologists and engineers. There are some 30 active and inactive quarrying operations in greater Kansas City, and many of these can be studied with the cooperation of the owners. Sound evaluations and recommendations can come from these studies.

In summary, problems of mined-out areas can partially be solved subsequent to cave-in and collapse but the time to start is while the mine is in the planning stage. When this is not possible, our present state of knowledge is such that we must judge whether areas near collapse are safe only by comparison with similar conditions in other mines. If all minimum dimensions and imperial equations fit and if remedial measures, such as pillar installation, roof bolting and monitoring can be installed, commercial development may proceed.

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