

Association of Missouri Geologists

46th Annual Meeting and Field Trip
Hannibal, Missouri

September 24-25, 1999

Economic Geology, Utilization, and Waste Recycling
in Northeast Missouri

Central Stone Co. Quarry #1,
Continental Cement Co. and MFR, Inc.,
Scheffler's Geode Mine



ACKNOWLEDGEMENTS

We gratefully acknowledge the following businesses and individuals who have provided information, access, and resources for the Association of Missouri Geologist annual field trip in the Hannibal, MO area: Larry Monroe and Richard Klimstra, Central Stone Company, Frank Salter and Alan Ruble, Continental Cement Company Inc. and MFR Inc., Dennis Lambert, Missouri Department of Transportation, Hannibal Tourist Bureau, George Lee.

1999 AMG Field Trip
Economic Geology, Utilization, and Waste Recycling in Northeast Missouri

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Friday, September 24

12:00 Noon Leave Hannibal Inn-East on Highway 61

0.3-1.8 mi. The strata exposed along this stretch of road is the Burlington Limestone. The Burlington Limestone is the main cap rock for the hills in Hannibal. Glacial drift is exposed above the rock behind businesses along this stretch of Highway 61.

3 mi. North on Highway 61 along the western edge of the Illinois Basin. As we proceed north the bluffs to the west are Mississippian strata. The low-lying land to the east is Mississippi River flood plain.

23.4 mi. just past the Taylor turnoff is a Missouri Department of Transportation (MoDOT) sand operation west of Highway 61. Sand is separated from the Pleistocene-age sand-gravel deposit.

28.7 mi. Wakonda State Park, This is the site of a former sand-gravel operation in Pleistocene gravels owned by MoDOT and operated by Missouri Gravel Company until sold to the Missouri Department of Natural Resources. It was reclaimed by the Department of Natural Resources to add land to the park, which has a 75 acre fishing lake and the largest natural sand beach in the Missouri Park System (Earngey, 1995).

54.6 mi. STOP and pay fees at Scheffler's Rock Shop and Geode Mine

4:00 PM Board bus for return trip

Saturday, September 25

8:00 Leave Hannibal Inn

8:30 **STOP 1:** Central Stone Company #1 Quarry at Huntington, Tour and fossil hunt

10:15 Leave Central Stone Quarry, proceed east on Hwy 36, south on Hwy 79

10:35 14.6 mi. turn east then 1st right

STOP 2: Base of Lover's Leap -Louisiana Limestone, type section of the Hannibal Shale, Burlington Limestone

10:55 Board buses and continue south on Hwy 79. Notice the Hannibal Shale in the roadcut on both sides of the entrance to Lover's Leap on the east side of the highway. The Burlington limestone is exposed in a long cut to the entrance to Mark Twain Cave.

11:00 Enter Mark Twain Cave Park. To the north (right) on the hill is a green building which marks the entrance to Cameron Cave. The entrance to Mark Twain Cave is south of the entry road near the pavillion

STOP 3: Lunch and necessity break

Mark Twain Cave and Cameron Cave are located 1 mile south of Hannibal on Highway 79. The cave entrances are on either side of the Mark Twain Cave Park road approximately 1/2 mile apart. Both caves are in the Louisiana Limestone and are maze-type caves. Mark Twain Cave became the first show cave in the state of Missouri in 1886. It grew famous through stories by Mark Twain and is now a national landmark. Large passageways such as Grand Avenue and formations such as the alligator, submarine, and the grand piano characterize the cave. Cameron Cave contains over two miles of narrow passageways that are open to the public (Earngey, 1995; Mark Twain Cave, brochure; Cameron Cave, brochure).

11:50 Leave Mark Twain Cave Park

12:00 Noon **STOP 4:** Continental Cement Company and Missouri Fuel Recycler (MFR Inc.) Tour and fossil hunt

3:00 Leave Continental Cement Co. and MFR

3:15 **STOP 5,** Brief stop to view Pleistocene gravel deposit. The deposit forms a hill that extends 0.5 miles in an east-west direction and extends 1-2 miles in a north south direction bounded by Market Street and Minnow Creek.

3:30 Return to Hannibal Inn.

The Structural and Physiographic setting of the Hannibal area

The physiographic setting of Hannibal, Missouri is controlled by its regional position on the Mississippi Arch and the eastern slope of the Lincoln fold. In addition part of the area is topped with thick layers of till and loess. The Lincoln Hills are well developed between Highways 61 and 79 from Hannibal south to the Troy-Winfield area, where the Lincoln fold is eroded and exposed in outcrops and bluffs (Beveridge, 1990).

The Mississippi River Arch extends south-southwest from southern Wisconsin to northeastern Missouri parallel to the Mississippi River. The Mississippi Arch is a broad corrugated fold that separates the Forest City Basin from the Illinois Basin. It originated in the late Paleozoic and is at least as old as Pennsylvanian age (McCracken, 1971).

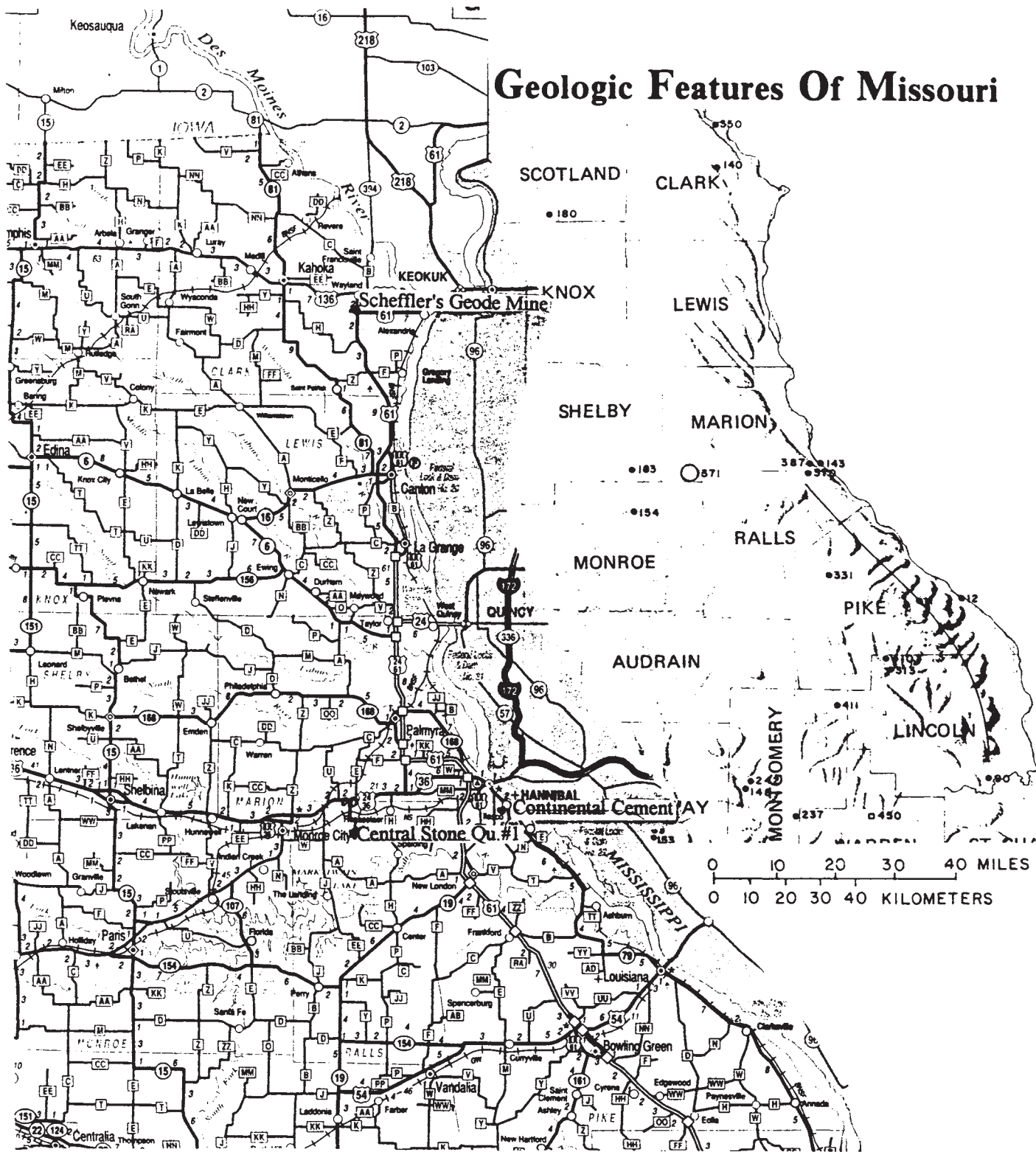
The Lincoln fold, a regional uplift, extends from the Cap au Gres fault northwest through Lincoln County, Pike, Ralls, Marion, Shelby, Knox and Scotland Counties in Missouri. It is an asymmetrical anticline with general regional axis striking N 45° W, and may continue en echelon as the Kirksville-Mendota anticline in Putnam County. The steeply-dipping southwest side of the fold is faulted in some locations, whereas the northeast flank of the fold dips gently and is apparently unfaulted. Rock exposures include Ordovician at the axis surrounded by Silurian, Devonian, and Mississippian outcrops. The total length in Missouri is 165 miles, width varies as much as 15 miles, and structural relief is up to 1000 feet (McCracken, 1971; Unklesbay and Vineyard, 1992).

Glacial Gravels

One of many Pleistocene deposits of glacial gravel in the area is exposed along the 2500-2900 block of Market Street in Hannibal, Marion County in E1/2, sec. 31, T. 57 N. R. 4 W on the south side of a hill bounded by Market Street and Minnow Creek. The Pre-Illinoian age gravels, dropped by glaciers during melt back or carried by meltwater include deposits as thick as 75 feet locally. The glacial drift is predominately sand stained red by iron oxides and assorted pebbles, including Lake Superior agates from a variety of source areas. (Beveridge, 1990; Thompson, 1995; Unklesbay and Vineyard, 1992).

Locally glacial gravels are used for fill or as a source for sand. A MoDOT gravel pit located 1.2 miles north of Hannibal on Highway 61 is worked for the sand. Another prominent deposit on Highway 61 is at Wakonda State Park south of LaGrange. The land was formerly used as a gravel operation and was reclaimed by the Department of Natural Resources. It has the largest natural sand beach in the Missouri Park System on a 75 acre fishing lake. (Earngy, 1995; Dennis Lambert, personal communication, 1999).

Geologic Features Of Missouri



Location Map

Scheffler's Geode Mine

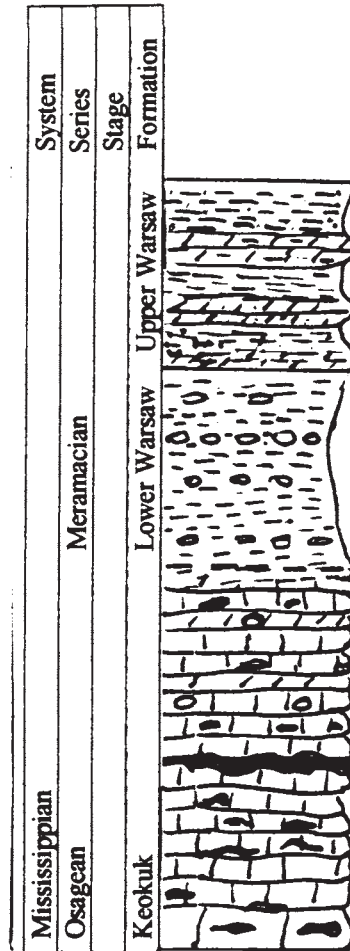
Scheffler's Geode Mine is located 60 miles north of Hannibal at the junction of US 61 and US 136. The outer walls of the Scheffler's Rock Shop are embedded with mineral samples 0.5 meter x by 0.5 meter and larger. The rock shop contains an assortment of Keokuk or Warsaw geodes and fossils from the property as well as specimens from other parts of the world.

Geodes occur in northeastern Missouri, Southeastern Iowa, and the Nauvoo to Hamilton, Illinois region in stream beds or exposures of the lower Warsaw Formation and sparsely in the upper Keokuk Formation. The Warsaw Formation, Meramecian Series, Mississippian System in northeastern Missouri is argillaceous, highly fossiliferous, and about 40 feet thick in the area (Thompson, 1986 Spreng, 1961). Geodiferous beds in the Warsaw Fm. are (1) argillaceous dolomite, composed of silt-sized dolomite rhombs mixed with clay and silt-size detrital silicates (2) poorly-laminated dolomitic mudstone and indurated, poorly sorted, detrital silicate sand, silt, and clay with some dolomite rhombs.

Scheffler's mine is a surface exposure produced by bulldozing the overburden from the geode layer. Geodes occur in the walls or in the softer argillite at the bottom of the shallow pit. Quartz geodes with chalcedony shells are predominant at the mine, but other minerals in the geodes include calcite, pyrite, chalcopryrite, sphalerite, kaolinite, millerite, dolomite, hematite, limonite, malachite, goethite, selenite, smithsonite. Pyrite cubes from 1 mm in size to over 2 cm are also common in the argillite.

In addition to geodes the mine is a good source for Mississippian fossils. A recent find of a primitive form of jelly fish was confirmed by the Chicago Museum of Natural History (Betty Scheffler, personal communication).

Hayes, 1964 suggested that the Warsaw geodes near Keokuk, Iowa were formed from calcite concretions by a complex process including recrystallization of calcite, replacement of calcite by silica, solution of calcite to form cavities, precipitation of minerals in the cavities. Silica is in the form of chalcedony spherulites as a replacement rim, a mixture of chalcedony spherulites, euhedral and anhedral quartz grains as residue after solution of the concretion core, and as a layer of larger euhedral quartz crystal deposited from solutions in the geode cavity.



HISTORY OF CENTRAL STONE COMPANY

Richard Klimstra

Our company was started in 1892 by James P. Pearson, Emil Carlson and Will Robinson. They were in the natural ice business, harvesting ice from the Mississippi River and storing it in warehouses at the Moline Yard's present location. It was named the Moline Channel Ice Co. The State of Illinois issued a charter on December 23, 1898, to the Moline Channel Ice Co.

Apparently, because the ice business was seasonal, Mr. Pearson purchased a stand of timber located at the present Moline Memorial Park Cemetery and cut it for cord wood which started the company in the fuel business later developing into the coal business.

In the late 1890's the first steam boat with the name James P. Pearson was put into service. The steam boat was evidently purchased to start the company in the sand business, and on July 17, 1903 a charter was issued by the State of Illinois to the Moline Sand Co. The officers were James Pearson, Edward Wiese and Emil Carlson.

The company added to its river fleet with the purchase of the steamboat Marquette, and several wooden barges in 1912.

Charles Loptien, a former leader of the company, is first shown on past records as joining the firm as bookkeeper, in 1908. In 1911, O. W. Ellis, another builder of the company was shown as an addition to the company.

During this period the river boats were being used on the river for excursion trips. This was a very colorful part of company life and will be remembered by the older residents of the area for the good times and numerous stories will be passed along by them for years.

The Moline Sand Company then expanded to include the handling of lime, cement, and a variety of other building products. Also at this time, a concrete block and silo stave manufacturing operation was started. This must not have proved very successful, although the walls of the present Ready Mix Office at Moline is built of blocks manufactured by them.

In the year 1917, the Moline Channel Ice Co. and the Moline Sand Co. merged, and were incorporated under the name of Moline Consumers Co. The first record of a stockholders meeting was March 31, 1917. Stockholders of record were James P. Pearson, Charles C. Loptien, Ed Wiese, J. Oscar Johnson, W. E. Loptien, Nelson Greene, O. W. Ellis, R. C. Shallberg, and Gus a Shallberg.

From then on, with the guidance and hard work of O. W. Ellis, C. C. Loptien and James P. Pearson the company grew in leaps and bounds.

By 1919, a sand and gravel plant was started in Ottawa, Illinois.

In December 1920, a competitive ice company, namely The Union Ice Co. which adjoined the Moline yard was taken over. Contracts were made to supply river needs of cement to the U. S. Government. Much material was furnished to the Government during the First World War.

In 1925, the steamboat Pearson was taken to La Grange, MO to prospect for sand and gravel. Evidently, the material they were able to produce was good and they returned later to dredge on the river just south of the city limits along the Mississippi River shore line.

At this same time, there was a small abandoned sand and gravel pit along Rt. 61 owned by MoDOT. It was natural that the company was interested in such a location. The company obtained a lease on the property and a plant was built in 1926. This location was the start of a business called Missouri Gravel Company. Our company had a continuous operation near La Grange until 1990. MoDOT decided that it wanted to sell the property to the MoDNR and expand Wyconda State Park.

We were able to locate another deposit just south of La Grange at Taylor, MO on the Norman Haerr property, where we are presently producing all types of sand and gravel products.

At or around the same time we started at La Grange, 1926, we started five small sand and gravel pits in Adams County, Illinois and in Ralls and Pike County, Missouri.

As World War II was coming to a close, the company decided to start in the rock crushing business. There were several very small operations started in Adams, Brown and Schuyler County, Illinois in old WPA quarries and the name Western Illinois Stone Company came into existence.

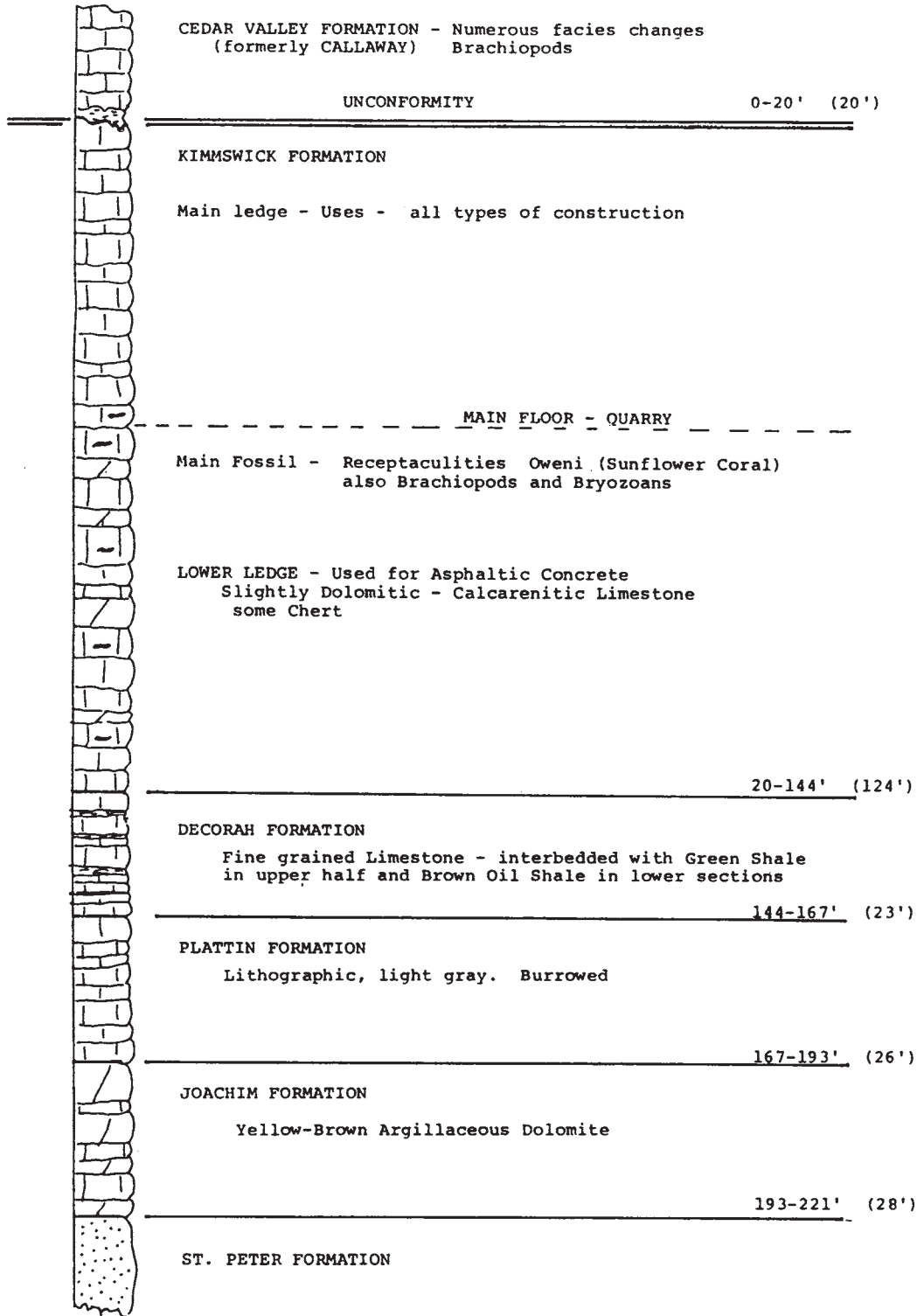
Central Stone Company was started in 1947 with our operations at Huntington, Missouri. It remains our main operation today producing and selling over one million tons per year.

At one time, all three companies had 48 separate operations, however, at the present time only 21 are still active.

We kept the three names, Western Illinois Stone Company, Missouri Gravel Company, and Central Stone Company until approximately 13 years ago and it was changed to Central Stone Company.

Our company prides itself in producing construction aggregates of the highest quality for all types of needs. At Huntington, over 300,000 tons of material per year is shipped to two power plants for their pollution scrubbers.

COLUMNAR SECTION - CENTRAL STONE COMPANY - HUNTINGTON
 RALLS COUNTY, MISSOURI



PLANT SET-UP

MAIN PLANT

Shot rock is dumped into a 50" x 20' feeder feeding our Primary 4650 Impact Crusher. The output material (6" x 0") is belted to a surge pile. The surge pile was put in to give the plant an hour or so of rock to run if there was a problem in the quarry.

The crushed material is run across a scalping screen. The 1" minus is screened out and by-passes the crusher. The plus 1" material is fed into a 5½' STD cone crusher. The output material consists of 3" minus and is fed across 4 triple deck 5 x 16" screens. The plus inch material is fed into two cone crushers (5¼' SH cone and 4-¼' STD) for further reduction. The 1" minus material is fed back over the 4 sizing screens.

This is the "dry" section of the plant. Any lime produced during the process is taken out of the flow and stockpiled.

The rest of the material is fed into two 4430 log washers to eliminate any dust or deleterious material that might be carried over during the crushing process.

This washed material is then fed across 4 5 x 16" 3D screens where spray bars wash the material again.

The crushed stone is separated into five separate blending bins. These bins each have a different size material that can be blended back together to any type of a gradation that is needed.

The wash out material is de-watered by a sand screen and is belted to a loading bin, making manufactured sand.

The wash water is taken back down into the quarry and the material is settled out in ponds and the clear water is returned to the wash plant.

The plant has a production rate of 1,000 TPH, but will average 850 TPH over a years production.

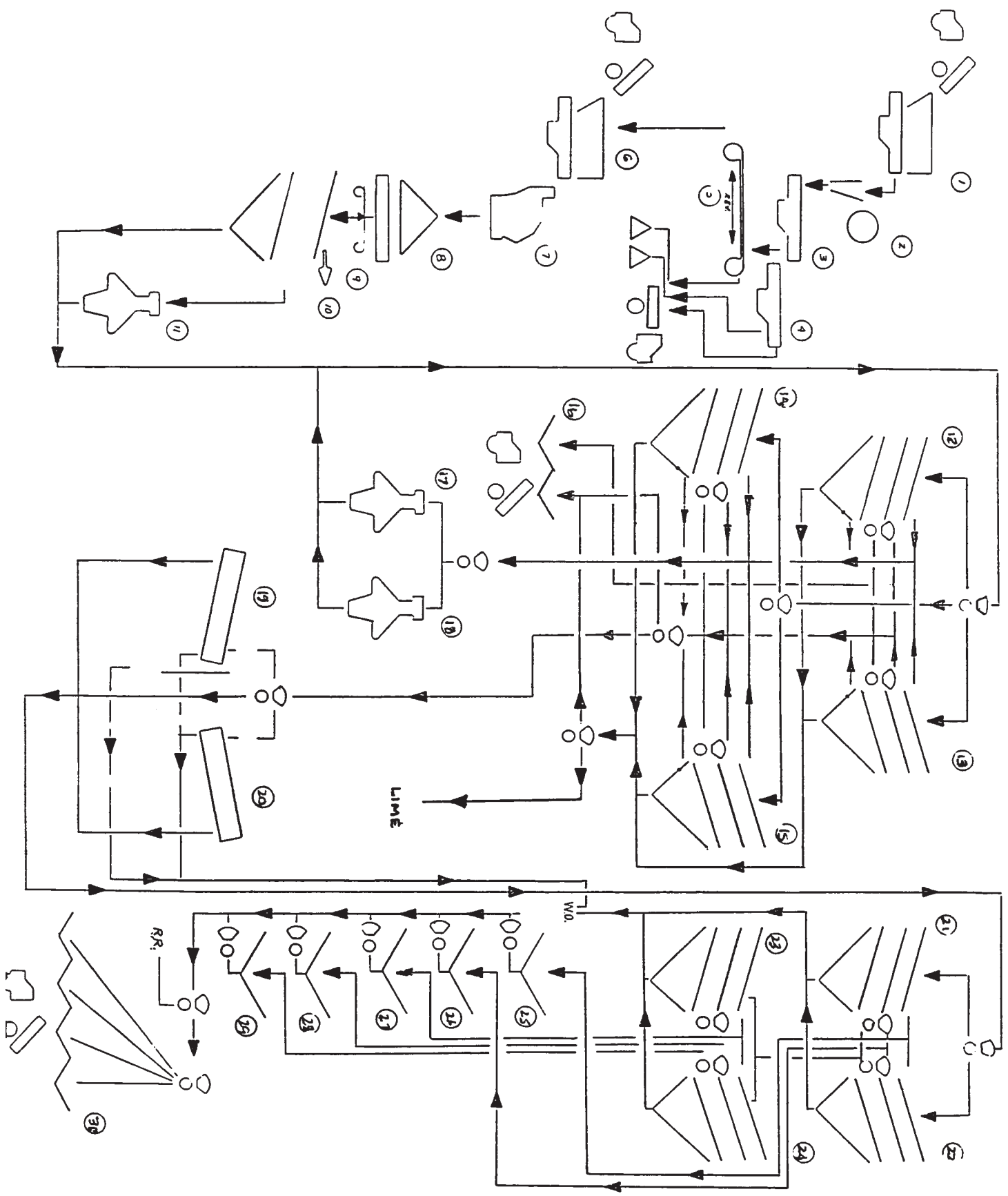
We also have a rip rap plant that is hooked into the system and is run periodically during the year. The plant was built in 1966 to meet a growing need for a quality, tightly controlled gradation for rip rap products.

Shot rock is dumped into a 44" x 20' feeder and the material is fed into a 33' x 46" Jaw Crusher with a maximum opening of 26". The fines, 6" down are belted over to our primary impact crusher and into our crushed stone system.

The larger material is fed across a stair-step set of grizzly bars and then across a second grizzly bar set up. We can actually make two sizes of rip rap material with this set up.

At one time, we produced six different sizes of rip rap for all construction needs. Recently, we have been keeping 100# and 400# rip rap sizes in stockpile. We were lucky enough to produce the rip rap and crushed stone for the Cannon Dam project.

Our 50' face of rock is normally drilled on a 9' x 18' pattern using 4" holes. When shooting for rip rap, we spread the pattern out to 11' by 21'. We normally get about 20% yield of rip rap material.



CENTRAL STONE COMPANY NO. 1
HUNTINGTON, MO

4/14/99

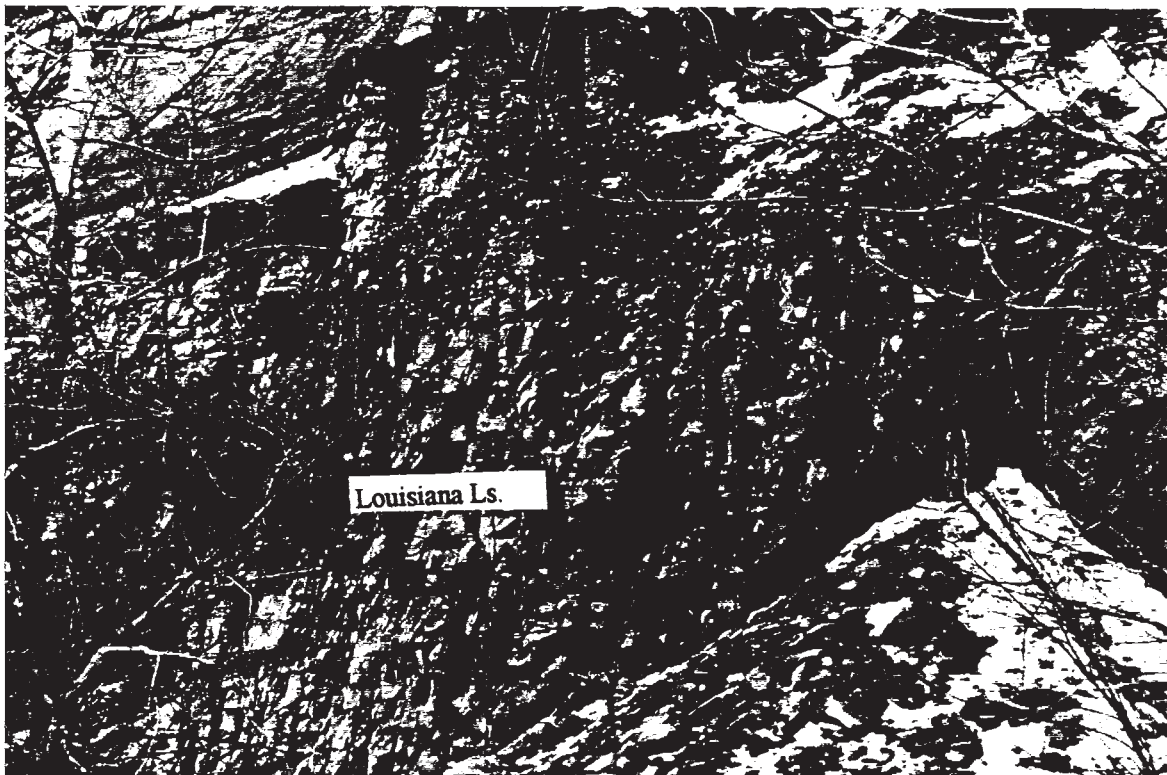
ITEM NO.	DESCRIPTION	MANUFACTURER	M/N	S/N	YEAR
1	Crude Rock Feeder	Pioneer	50"x 20' SRL-14	JOVF101	1968
2	Jaw Crusher	Pioneer	3546	C1120	1960
3	Grizzly Feeder	Simplicity	Stepped 74" x 24'		1966
4	Grizzly Feeder	Simplicity	74" x 14'		1970
5	Reversible Apron Feeder	Pioneer	48" x 13' 9"		
6	Crude Rock Feeder	Simplicity			
7	Impact Crusher	Universal	4650		
8	Surge Pile & Feeder	Homemade - Pan			
9	Belt Scale				
10	Scalping Screen	Simplicity	2D 5 x 14		1962
11	Cone Crusher	Nordberg	5-1/2' STD		1963
12	Sizing Screen	Simplicity	3D 5 x 16		1970
13	Sizing Screen	Simplicity	3D 5 x 16		1970
14	Sizing Screen	Simplicity	3D 5 x 16		1970
15	Sizing Screen	Simplicity	3D 5 x 16		1970
16	Material Load Out Bins	Homemade			
17	Cone Crusher	Nordberg	5-1/2' SH		1972
18	Cone Crusher	Nordberg	4' SH		
19	Log Washer	McLanahan	4430		1973
20	Log Washer	McLanahan	4430		1973
21	Wash Screen	Simplicity	3D 5 x 16		1974
22	Wash Screen	Simplicity	3D 5 x 16		1970
23	Wash Sceen	Simplicity	3D 5 x 16		1974
24	Wash Screen	Simplicity	3D 5 x 16		1974
25	Blending Bin	Homemade			
26	Blending Bin	Homemade			
27	Blending Bin	Homemade			
28	Blending Bin	Homemade			
29	Blending Bin	Homemade			
30	Material Load Out Bins	Homemade			

Lover's Leap

Located on the Mississippi River Bluff in Marion County at adjacent south corners of secs. 27 and 28, T.57 N., R.4 W, Lover's Leap rises 250 feet from the flood plain. A quarter mile drive up a winding blacktop road from Highway 79 to the Leap provides a panoramic view of Hannibal and the Mississippi River. Shuck Island and Pearl Island are on the Illinois side of the Mississippi River at this location. The Memorial Lighthouse first installed in 1935 and rebuilt in 1963 on Cardiff Hill is on the north side of Hannibal.

There are several versions of the legend of Lover's leap, but the view of the river and valley and exposed rock are the real attraction of Lover's Leap. The exposure of strata seen from the base of the bluff shows the Devonian System Louisiana Limestone, and the Mississippian System type-section of the Hannibal Shale, the Dolbee Creek Limestone, a local division of the Burlington Limestone, and Burlington Limestone. The famous promontory is Burlington Limestone topped with Wisconsinan age loess. (Beveridge, 1990; Thompson, 1995). The stratigraphic sequence and a detailed description of the section by Thompson, 1995 is on the next page.





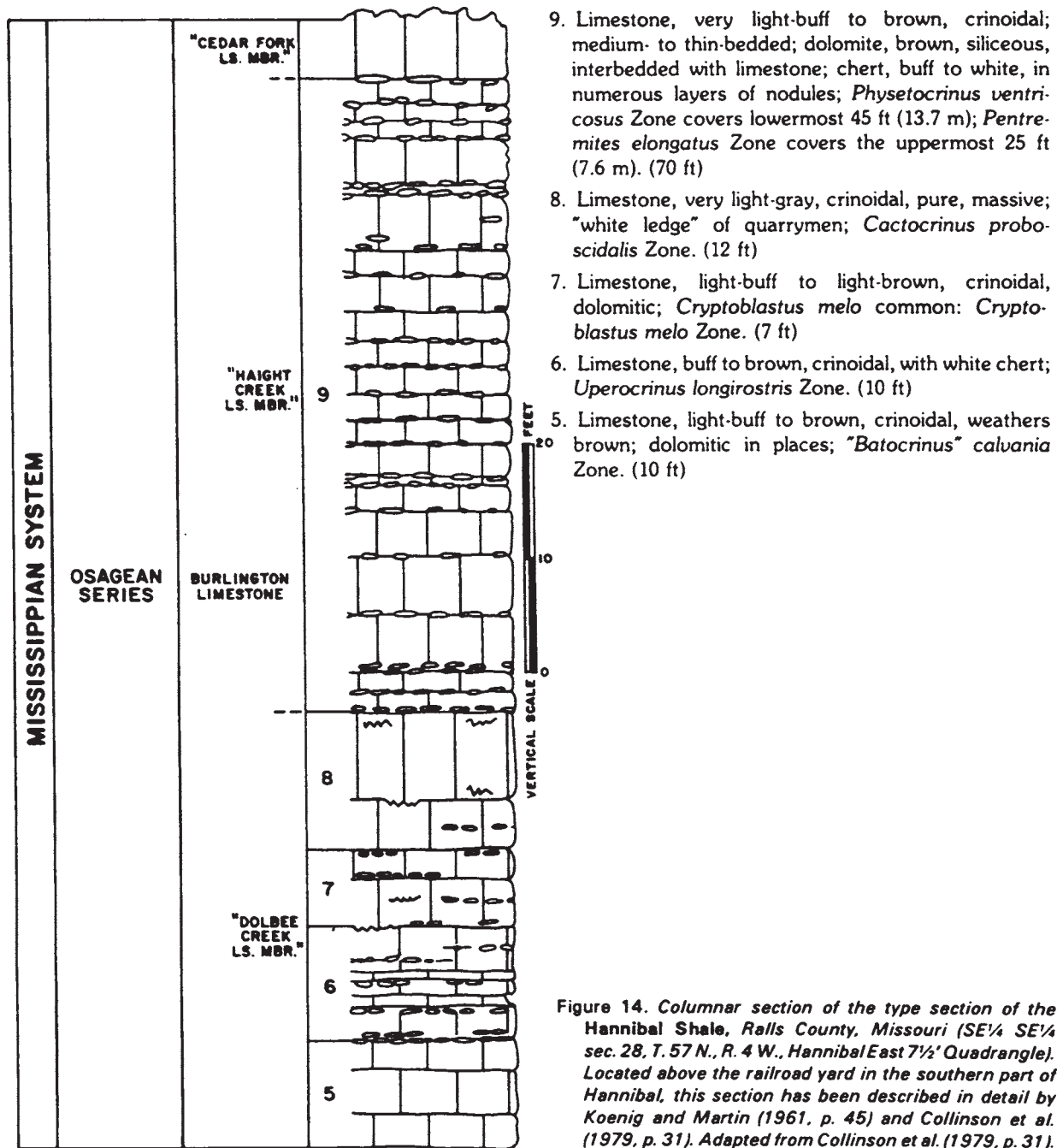


Figure 14. Columnar section of the type section of the Hannibal Shale, Ralls County, Missouri (SE¼ SE¼ sec. 28, T. 57 N., R. 4 W., Hannibal East 7½' Quadrangle). Located above the railroad yard in the southern part of Hannibal, this section has been described in detail by Koenig and Martin (1961, p. 45) and Collinson et al. (1979, p. 31). Adapted from Collinson et al. (1979, p. 31).

History of nomenclature —

(not) 1852	Owen	Encrinital Group of Hannibal (= Burlington Limestone)
1855	Swallow	Vermicular sandstones and shales
1891	Williams	Vermicular shale and sandstone
1892	Keyes	Hannibal shales
1897	Keyes	Hannibal shale ("Devonian in age")
1900	Keyes	Hannibal shales of Kinderhook formation
1946	Reed	Hannibal shale ("= Boice shale of Nebraska")

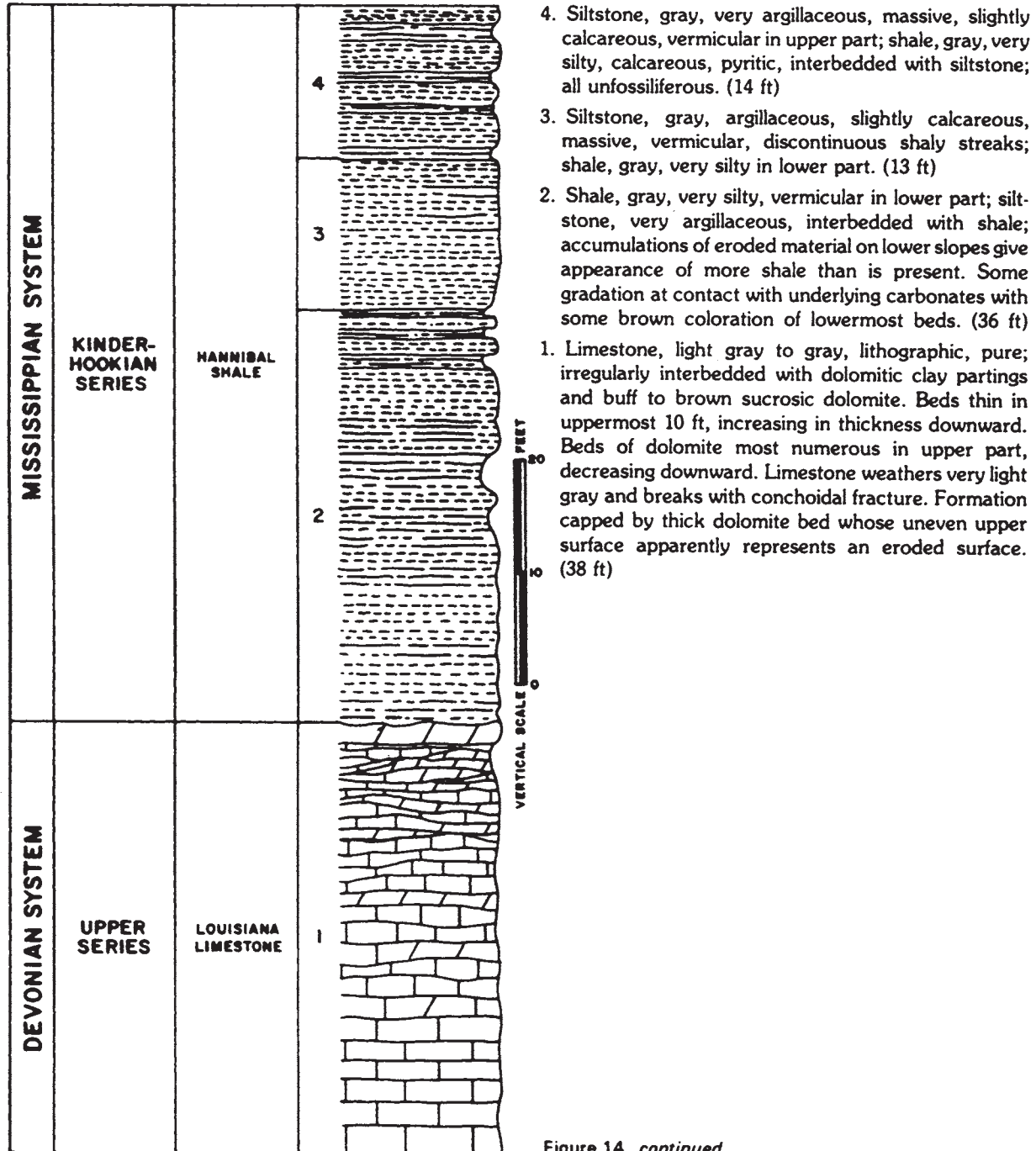


Figure 14. *continued*

1948	Weller et al.	Maple Mill shale (Hannibal shale)
1960	Mehl	Cuivre shale (= basal part of Hannibal)
1961	Spreng	Hannibal formation
1963	Carlson	Boice Shale (Forest City basin of northwestern Missouri and subsurface of Nebraska)
1973	Conkin and Conkin	Hannibal Formation Cuivre Member of Hannibal Formation
1984	Thompson	Hannibal Shale

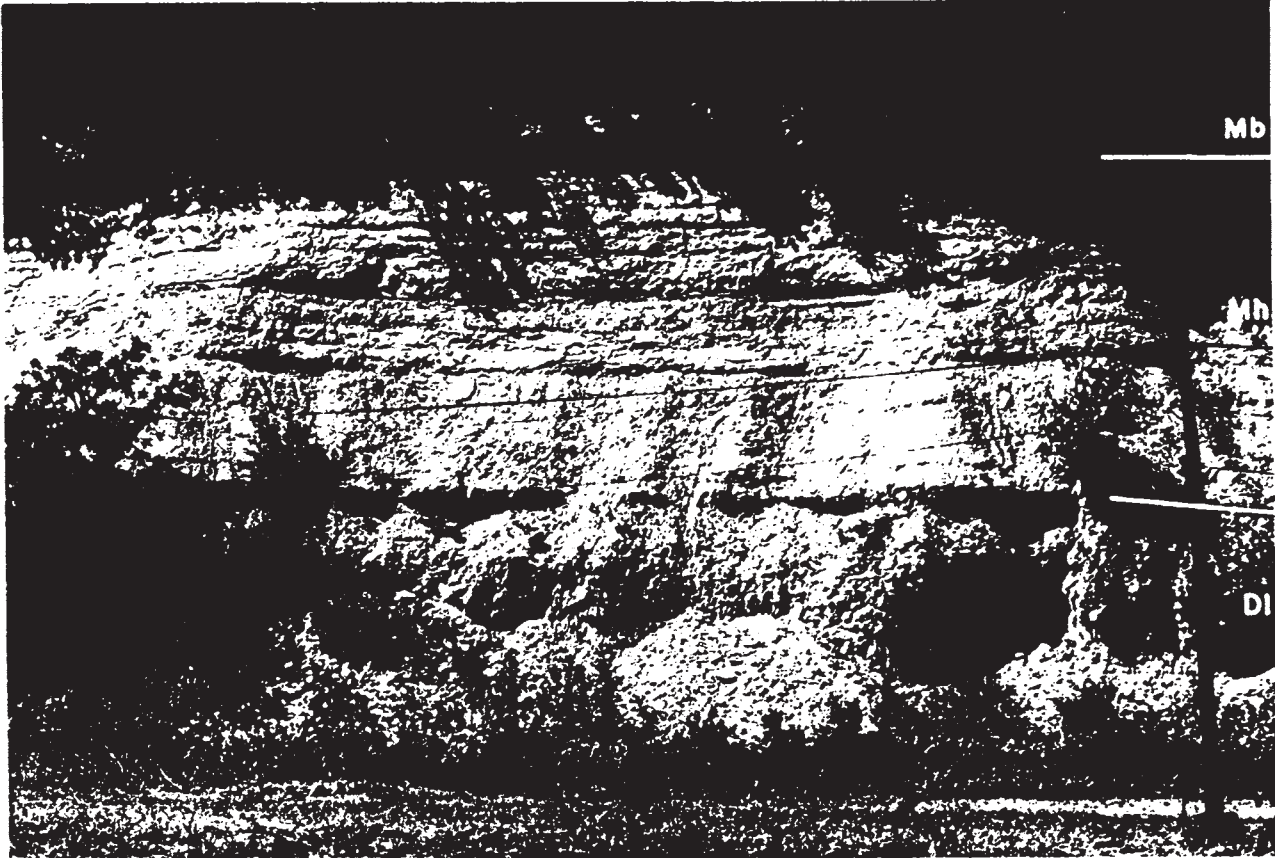


Figure 15. Type section of the Hannibal Shale at Lover's Leap, southeastern edge of Hannibal, Ralls County, northeastern Missouri (see fig. 14). DI = Louisiana Limestone; Mh = Hannibal Shale; Mb = Burlington Limestone. Photograph by T.L. Thompson.

Remarks — In northeastern Missouri, particularly in the vicinity of the type section at Hannibal, Kinderhookian strata are often represented solely by the Hannibal Shale, a sequence of up to 100 ft of gray to bluish-green shale, siltstone, and argillaceous sandstone. It weathers to pale bluish-green or light brown, and forms gentle slopes. Wherever it is composed of alternating layers of coarse- and fine-grained siltstone it has a characteristic banded appearance.

The base of the Hannibal Shale is early Kinderhookian; it is regarded as transitional with the underlying Late Devonian Louisiana Limestone (Scott and Collinson, 1961). In the region of the type section, the Hannibal is directly overlain by the early Osagean Burlington Limestone. Westward and southwestward, however, upper Hannibal strata are replaced by limestone of the Chouteau Group. Farther southward and westward, the Chouteau continues to thicken at the expense of the Hannibal, but the oldest Chouteau is probably never much older than middle Hannibal (middle Kinderhookian). The Hannibal, Horton Creek Limestone, and Bushberg Sandstone represent the only lower Kinderhookian Mississippian rocks identified in the state (table 1).

Present throughout the Mississippian outcrop region of northeastern Missouri, Hannibal shales and siltstones thin westward and southward, but can be traced westward in the subsurface until they become difficult to distinguish from shales of the "Kinderhook shale." Composed in places of both Hannibal and Chattanooga (or Grassy Creek) shales, the "Kinderhook shale" can be traced eastward in the subsurface of northwestern Missouri. Where the intervening Louisiana Limestone is absent, the greenish-gray Hannibal shales can be difficult to distinguish from the Upper Devonian Saverton and/or Grassy Creek shales. Where Hannibal Shale rests directly on the Upper Ordovician Maquoketa Shale, recognition of definite boundaries can also be difficult.

Where present, the Horton Creek Limestone intervenes between the Louisiana Limestone (or the uppermost Devonian unit present) and the Hannibal Shale. In some regions of northeastern Missouri, Mehl (1960) identifies a dark-gray to blue-black fissile shale in the lower part of the Hannibal as the **Cuivre Shale** (pronounced "quiver"), and he recovered a large conodont fauna from it. Future work may determine that the Cuivre shale should be recognized as a formal member of the Hannibal Shale. Mehl (1960, p. 98) identified the type locality for the Cuivre shale as

"the SE NE SE sec. 35, T. 54 N., R. 4 W., Pike County, Missouri, about 4.5 miles north of Bowling Green, exposed in one of the head branches of Grassy Creek."

In Illinois, immediately across the Mississippi River Valley from northeastern Missouri, at least two other units have been identified in the Hannibal (Collinson et al., 1979): the **Nutwood Member**, and a "Brown silt facies" (fig. 16). One or both may be equivalent to the Cuivre Shale of northeastern Missouri.

In the Hannibal Shale, fossils are generally sparse and pyritized. Brachiopods and pelecypods are major constituents of the fauna; conodonts and foraminifers are abundant in some beds. Common features of the formation are "*Taonurus caudagalli*" ("rooster-tail" markings) and *Scalarituba missouriensis* (irregular tubular structures or worm borings), the latter having led to the Hannibal Shale originally being named the "Vermicular shale and sandstone," and to initial correlation of the Hannibal with the "Vermicular Sandstone and Shales" (now identified as the Northview Formation of southwestern Missouri (Swallow, 1855).

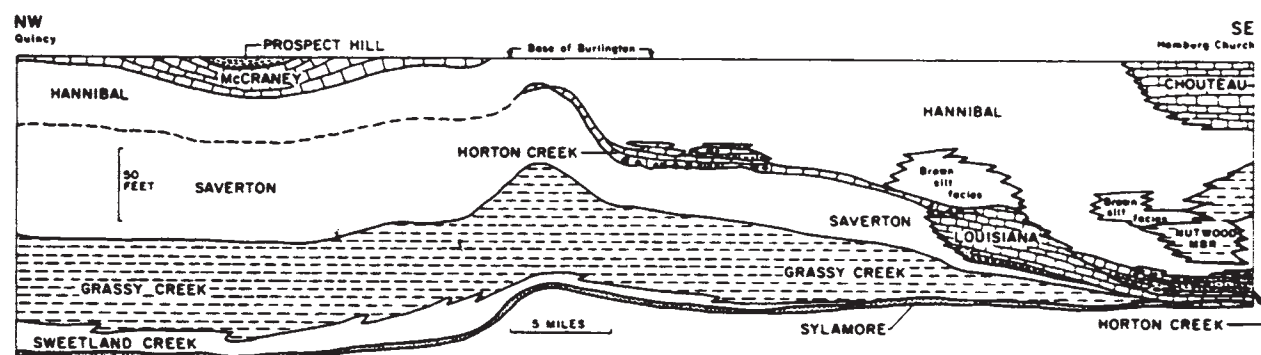


Figure 16. Cross section along east bluff of Mississippi River Valley between Quincy and Hamburg, Illinois, showing relationship of Late Devonian and Early Mississippian formations and members (from Collinson et al., 1979, p. 29-30).

Secrets of McDougal's Cave

Probably the most famous Missouri cave for anyone who was ever a child is the infamous McDougal's Cave, more properly called McDowell's Cave, or, today, Mark Twain Cave. This approximately 2 mile long cave, a maze of crisscrossed passages, first gained worldwide fame in 1876, with the publication of *The Adventures of Tom Sawyer* by Samuel L. Clemens, better known as Mark Twain.

The story of Tom Sawyer & Becky Thatcher's adventure underground has probably been responsible for more candles and string being taken into the dark than can ever be counted. What is less well known is the story of the cave itself. Discovered in the winter of 1819 or 1820 by Jack Simms, the cave became notorious during the 1840's, after its purchase by Dr. Joseph Nash McDowell. In 1849, McDowell put a wooden door on the cave, and locked it. This behavior aroused local curiosity, and it soon came to light that the doctor, in addition to his apparent ability as a surgeon, was quite interested in experiments and research on cadavers. This extended to methods of preservation, and one of his most macabre experiments involved suspending a copper and glass flask containing the body of his 14 year old daughter in the cave.

Once the locals found out, such a commotion was raised that the body was removed a year or so later. McDowell aligned himself with the Southern cause during the Civil War, and stockpiled guns and ammunition at his medical college in St. Louis. This gave rise to rumors of a munitions "stash" in his cave, although this was never proven. McDowell died in 1868, and the cave was purchased by the Fielder and Stilwell families. After the publication of *Tom Sawyer*, the cave became a full fledged tourist attraction, with the press of visitors causing John East to start a cave guide service in 1886. This made Mark Twain Cave the first commercial cave in Missouri, and it has been shown continuously ever since, by lantern until 1939, and with electric lighting since.

The cave was purchased in 1923 by Judge E.T. Cameron who had guided there in his youth. His son, Arch Cameron, discovered Cameron Cave, twice as large and never before entered, in 1925. Both caves are now shown to the public, although Cameron is shown by lantern only. In all, 6.5 miles of cave passage remain in what was originally one huge system, now intersected by Cave Hollow.

Both Mark Twain and Cameron Caves are unusual for Missouri in that they are maze caves--formed along intersecting joints in the extremely fine grained Louisiana limestone. At one point in Mark Twain five passages intersect, and in Cameron six do. This creates caves of an entirely different nature than most Missouri caves--high, narrow, dry passage crosshatching the rock under the hills, which end in dirt fill, when intersecting the valley sides, or when they become too narrow for people to fit through. This is in contrast to the low, wet, and muddy nature of many Missouri caves, whose shape more resembles a tree--a large trunk with smaller passages branching off. The most probable means of cave creation at Mark Twain and Cameron is that limestone joints were created during a period of uplift, while the limestone was still below the level of the water table. Water flowing through these joints then eroded the passage. Continued uplift of the region eventually drained the cave, and some additional solutioning came later, from surface sources. Because these caves are overlain with a layer of shale, preventing most water from entering, few speleothems occur in them.

Continental Cement Company*

History

Cement was first manufactured in the original plant in 1903 by Atlas Cement and has been produced continuously until present. Several thousand men, including many immigrants from eastern European countries and Italy carried out the construction and production of the cement plant. In order to accommodate these workers and their families, the town of Iasco was established on company land. Iasco, located east of present Continental Cement, was featured in Jim Fisher's Mid-America column, "Dust, cement part of the history that aids in Iasco's survival," Kansas City Star, May 23, 1999. Fisher refers to the book *City of Dust, A Cement Company Town in the Land of Tom Sawyer*, by Gregg Andrews, a former resident and historian, that describes the establishment of the town in 1901. The company chemist suggested the name Iasco, an acronym for the elements that make cement, iron, lime, aluminum, silicon, calcium, and oxygen.

The original facility was continuously modernized. The consistently high quality cement was used in the construction of famous structures, such as the Empire State Building and the Panama Canal. As local proof of the strength of the cement some of the original plant buildings are still standing on the property, in spite of efforts to tear them down (Frank Salter, personal communication, 1999).

In 1966 the original plant was rebuilt and a coal-fueled, 622 x16 ft kiln was installed which doubled the production. The present kiln is the second longest in the world and produces 600,000 tons of clinker. Distribution is from the production facility, St. Louis, Chicago, and the quad cities Iowa.

With rising fuel costs Continental began using supplemental waste fuels in 1986. In 1992 formed Missouri Fuel Recycler (MFR), Inc. after obtaining the assets of an on-site fuel recycler. MFR added two patented processes for handling solid waste. The combined operation is cost effective, preserves a natural resource, converts solid waste to energy and produces clean stack emissions.

Operation

Over 630,000 tons of Portland Cement per year are produced from the principle raw materials in proportions of 80% limestone 8% fire clay and minor amounts of silica and iron ore. The limestone is mined from the 3,500 acre Hannibal facility, and clay is trucked in from Owensville, MO.

Limestone boulders are crushed to gravel-sized particles in the primary crusher. Clay is also added and the mixture is conveyed to one of five 2000 ton storage silos. 3200 tons are fed into the kiln per day. Raw materials are then removed from the storage silos, fed into a secondary crushing system, and sent into a 3000 HP raw mill. After 175 tons of steel balls reduce the crushed rock to fine powder, water is added to create a slurry. The

slurry is pumped into one of seven blending and storage tanks and agitated to keep the particles suspended.

Chemical composition is continuously determined by x-ray diffraction and spectrophotometric analysis to assure a consistent quality of cement. The precisely formulated feed is introduced to the kiln through a system of pipelines, pumps, and mass flow meters. The 622' x 16' kiln is a cylindrically shaped industrial furnace, lined with heat resistant fire brick. It rotates approximately 68 revolutions an hour and produces 1900 tons per day. The process that takes raw feed from cold end of the inclined kiln to the burning zone takes 2 1/2 hours. Temperature rises to 2800 °F and creates physical and chemical changes that forms clinker.

Land Reclamation

Continental reclaims inactive quarries in several ways. 3500 acres of reclaimed land are planted either with native grasses or grain. The grain is not harvested but serves as food for turkey, quail, and white-tailed deer. An 18-acre lake stocked with blue gill and bass fills a former shale pit.

MFR, Inc. (Missouri Fuel Recycler)*

Continental Cement has augmented coal as a fuel with high-energy waste materials since 1986. The wastes are permanently destroyed without dangerous emissions. MFR, formed in 1992, is the wholly owned subsidiary that operates the RCRA-permitted resource recovery facility. The full-service fuel blender pre-qualifies, unloads, and processes RCRA hazardous and non-hazardous solids and liquids such as high-energy organic solids. Wastes such as still bottoms, paint solids, tars, dry powders, and debris are processed in a totally enclosed storage, blending, and processing building that vents organic vapors to the burning zone of the kiln. There are separate systems to handle dry materials and debris and wet tacky materials.

Liquid waste, such as solvents, paint and ink sludges, oily separator sludges, dry cleaning fluids, organic chemicals, and waste oils, is off-loaded from bulk tankers inside a contaminant area adjacent to the blending/storage facilities. Handling facilities include simultaneous multiple truck sampling, analysis, and unloading capabilities.

Materials that are not accepted by the facility are pesticides, dioxins, PCBs, or radioactive wastes.

Regulatory Compliance/Safety

In order to ensure safety, security, and compliance with government regulations regular monitoring of all phases of the operation are necessary. Certified stack test results indicate a destruction and removal (DRE of 99.99%). Continuous emission monitors (CEMs) continuously record stack gas data to verify compliance with facility

burn specifications. If any parameter should be exceeded, automatic shutoffs interrupt the flow of waste fuel to the kiln.

Operating and technical employees receive all training required by RCRA and MSHA, as well as intensive emergency response training. Vapor recovery systems prevent fugitive emissions. Laboratory samples, liners from shipments, filter basket cleanings and used personal protective equipment are injected into the burning zone of the kiln for on-site disposal.

Security is provided by the 24-hour operation of Continental Cement/MFR, video surveillance, fences, gates, and a guarded facility entrance.

Continental operates a fully-equipped on-site fuels laboratory with a staff of chemists and technicians. Stringent pre-qualification analysis ensures that a potential waste stream is compatible with the cement-manufacturing process and meets acceptance criteria for chlorine, BTU, organic compounds, and metals. Incoming shipments are again tested upon arrival prior to off-loading to ensure conformance with established waste profiles and permit specifications. A final lab test must confirm that all blended wastes conform with cement manufacturing requirements and government standards for burning hazardous wastes before the material is fed to the kiln. In addition all kiln inputs including coal, raw material feed and waste fuel are sampled and analyzed prior to burning.

Lab approval forms are provided to the control room operator before any material is released for use in the kiln. The metal and chlorine concentrations are entered into a computer network that calculates a percentage of permitted limits of all kiln input sources.

All kiln outputs (cement and kiln dust) are sampled and tested to confirm that no metals will leach into the groundwater. After passing TCLP tests the dust is put into an onsite landfill.

Environmental Benefits

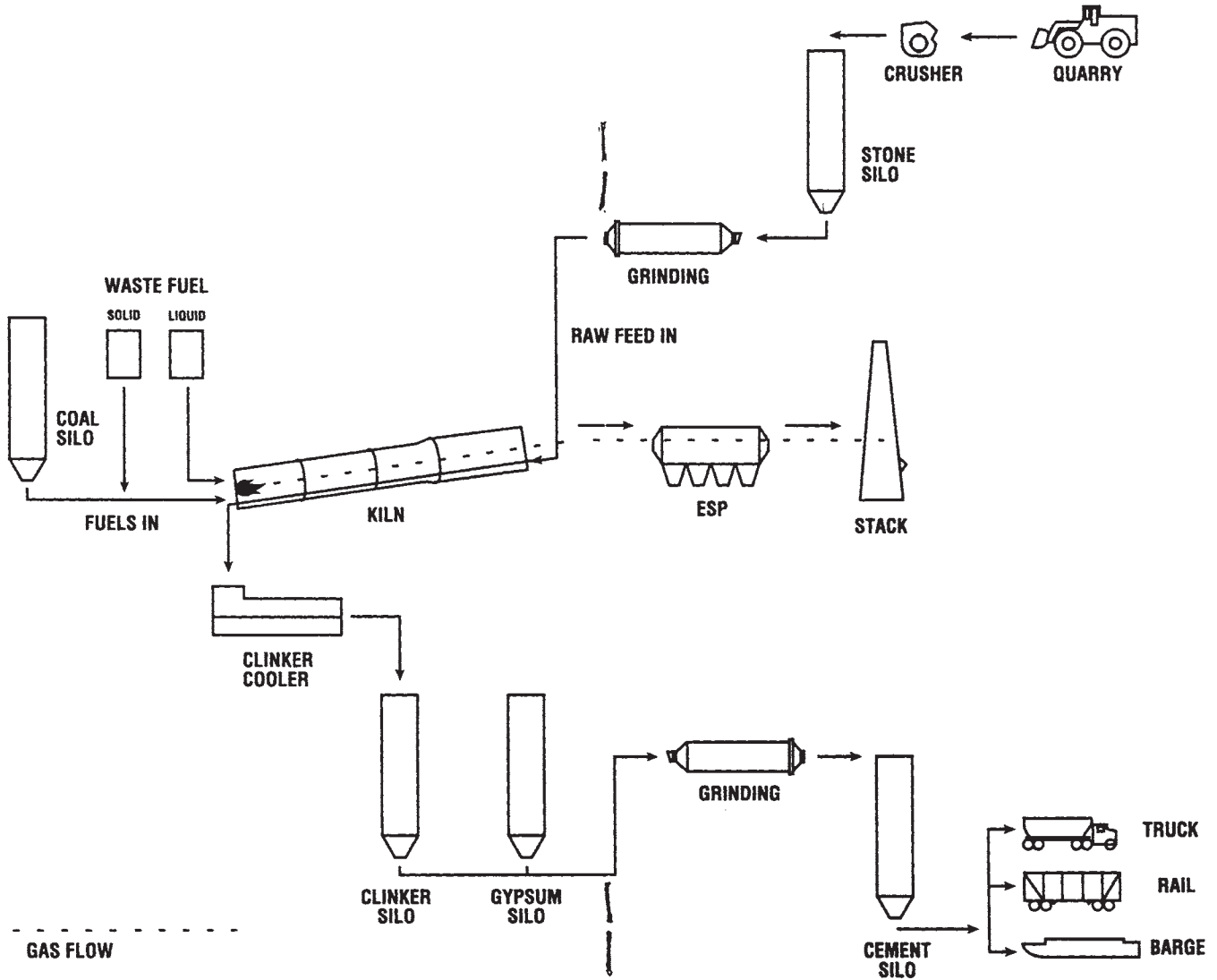
Burning flammable wastes in a cement kiln:

- provides safe and permanent destruction
- utilizes the energy value of wastes as fuel
- prevents these recyclable materials from filling landfills, being incinerated, or injected into wells
- reduces the need for coal and conserves non-renewable fossil fuels
- reduces stack emissions by replacing coal with cleaner burning waste fuels
- allows cement manufacturers to reduce operating costs

* The information for Continental Cement Co. and MFR, Inc. is from the brochures, "Taking the Resources of Nature and giving them back" and "Continental Cement Company" prepared by Continental Cement Company except where otherwise cited.

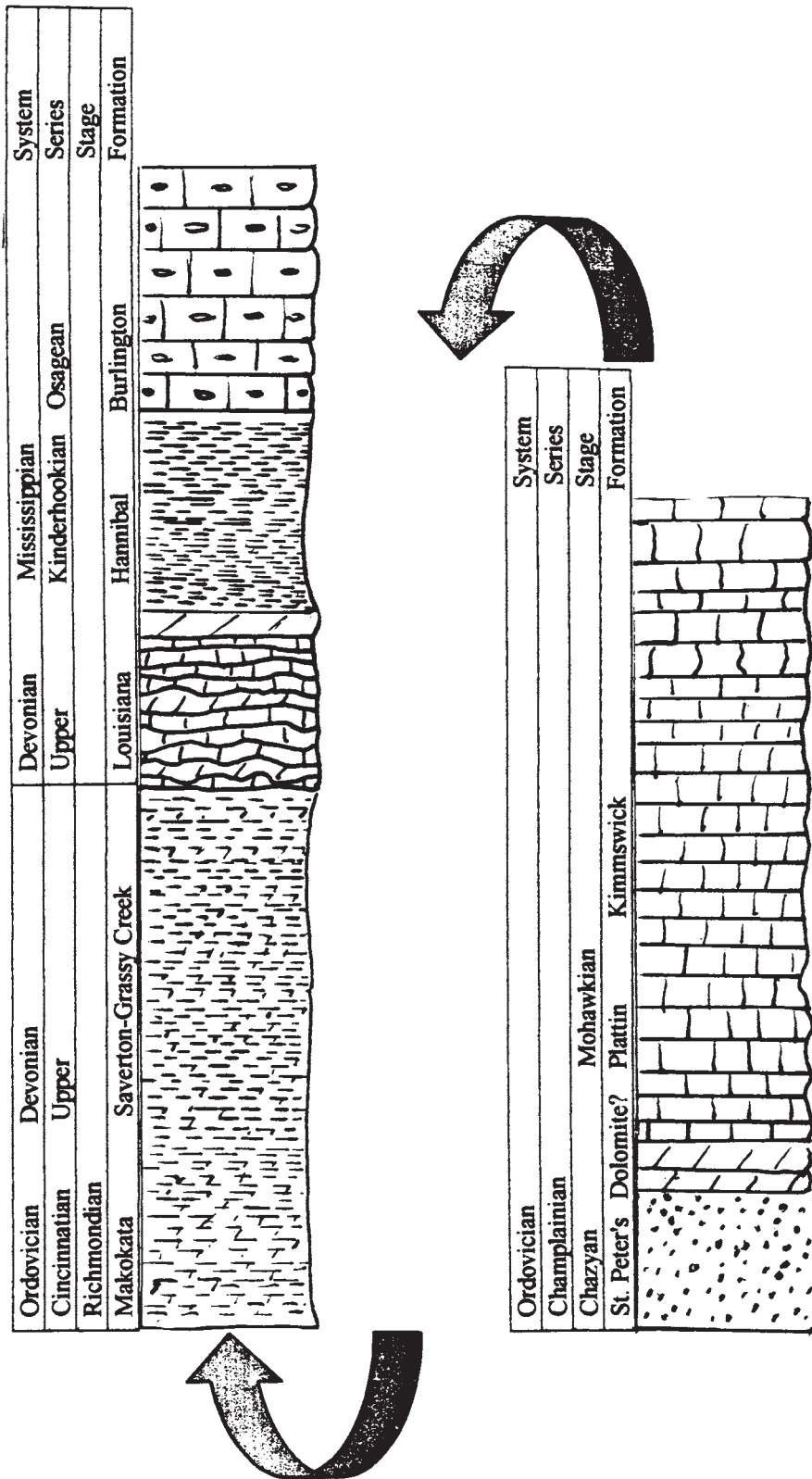
THE PROCESS

Brochure: Taking the Resources and Giving Them Back,
Continental Cement Company



A cement kiln is a perfect environment for safely processing waste and recovering its energy value. The chart shows the flow of material and gases through the kiln. The intense heat, long residence time, and high degree of turbulence ensure complete destruction of the waste.

Stratigraphic Section including exposed and subsurface strata at Continental Cement Company



Crushed stone:

Missouri's building blocks

by Dwight Weaver

The next time the stress of everyday living or too much of

a good meal sends you hurrying to the medicine cabinet for Mylanta or Roloids, you can thank the crushed stone industry, and especially the limestone industry, for some of the relief those antacids provide.

Crushed limestone (which contains calcium carbonate) and crushed dolomite (which contains magnesium carbonate) are used to make the lime from which these products are manufactured. They can settle your stomach because the carbonates neutralize acidity.

As you leave for work you might pause to consider that the concrete foundation of your house, basement floor, patio, retaining wall, walkway and driveway all contain crushed stone. In fact, it takes 100 tons to 300 tons of aggregate, which may contain gravel and sand as well as crushed limestone and dolomite, to construct the average house. The aggregate probably came from a source that is no more than 20 miles away.

Aggregate is a basic ingredient in construction, asphalt, and Portland cement concrete. A major highway cannot be built without large amounts of fine and coarse aggregate. Neither can a shopping center, an airport or a dam. Aggregate also is needed for erosion control, concrete blocks



DNR photo by Nick Decker

and railroad ballast. Crushed stone is widely used as a filter in public drinking water plants and sewage treatment facilities; in the manufacture of steel and paper; as agricultural lime for farm fields, lawns and golf courses; and in manufacturing chemicals, caulking and glass. Finely ground limestone is even used in many cosmetics and medications.

“Stone has been an important mineral commodity in Missouri since the very earliest settlements in the state began using it

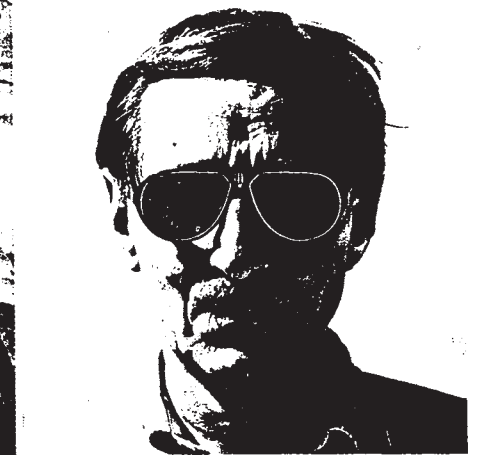
U.S. Highway 63 gets a foundation of crushed limestone for a new lane north of Jefferson City.

for foundations, buildings and quicklime,” says Ardel Rueff, a geologist with the Missouri Department of Natural Resources’ Division of Geology and Land Survey.

“In 1993, stone production in Missouri exceeded 53 million tons valued at more than \$177 million. When you add the \$320 million that cement and lime products generate to this figure, it represents nearly 60 percent of the state’s mineral industry.”

duced heating and cooling costs, and improved security. Mined-out underground chambers also offer uniform humidity and protection from storm and wind damage.

Because so much crushed limestone comes from surface mines, quarry operations are common landscape features in Missouri. They can generally be seen as one approaches any major town or city. In general, the larger the market area, the larger the quarry operation. This proximity of city and quarry is not happenstance. Nearly 85 percent of all crushed stone is moved by dump truck and used within 20 to



DNR photos by Nick Decker

30 miles of its point of origin.

“The biggest

cost factor for a stone operation is transportation,” says Rudloff. “You don’t have to go very far at all before the trucking costs far outweigh the cost of the materials. Moving a quarry just 10 miles away from a major population center increases that community’s building costs tremendously from added delivery costs alone.”

According to the Missouri Limestone News, which is published by the Missouri Limestone Producers Association, the presence of a nearby quarry stimulates economic growth simply because it makes available the most essential building material at lower costs. Most revenue from the sale of stone is returned to the community

A quarry in Jefferson City, owned by Beck Materials, mines for limestone. Larry Beck (inset), who owns several quarries in central Missouri, says that his company will spend over \$200,000 to stay in compliance with newly mandated regulations.

Missouri limestone resources are mined by both surface and underground methods. But surface mining accounts for 75 percent of the limestone mined in Missouri because it is more cost-efficient.

“We do have some significant underground mines in the St. Louis, Kansas City, Springfield and Carthage areas,” points out Steve Rudloff, who is the executive manager of the Missouri Limestone Producers Association.

The development of mined-out space beneath the surface for use as storage has become a thriving industry in some of these locations. Such use offers important advantages in low maintenance costs, re-

in the form of purchases, payroll and taxes.

The average production life of a stone quarry operation is 40 to 50 years. Quarries may cease operation for any number of reasons, but, being unable to acquire additional land for expansion or depletion of the supply of high quality limestone are two of the leading causes. In 1991, there were 184 quarries active in all but 22 of Missouri's 114 counties.

"In Missouri, stone is almost an unlimited resource but it is not available everywhere," says Rueff.

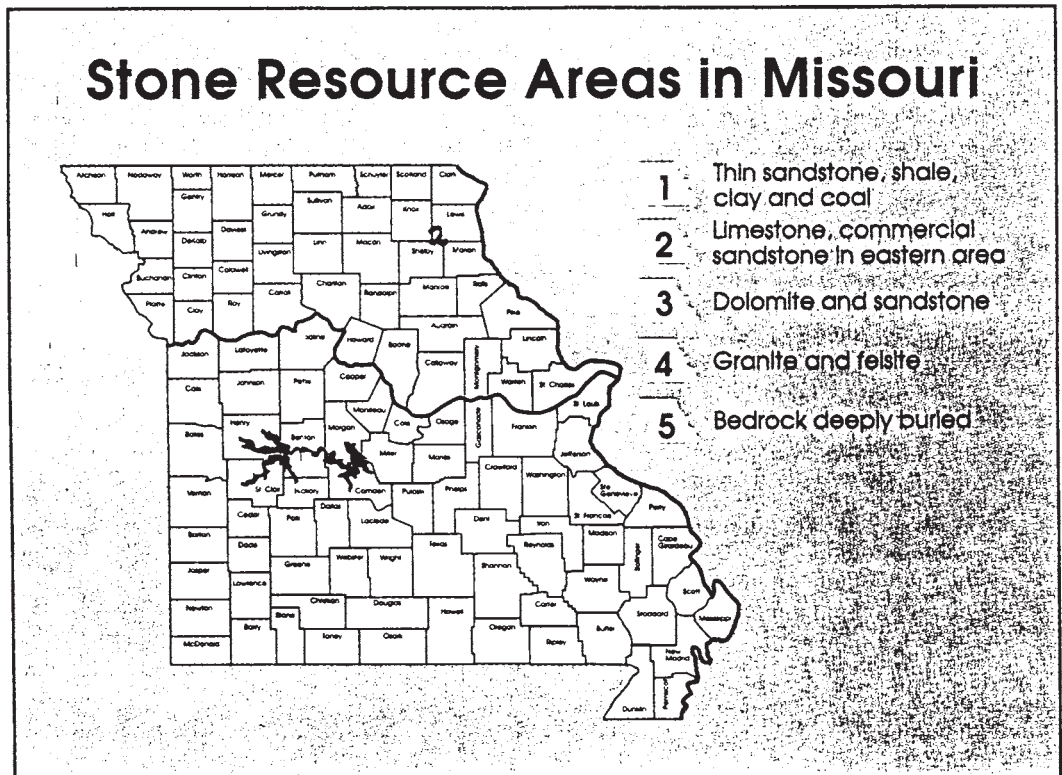
Missouri is divided into five major rock type areas.

In most of western and northern Missouri (Region 1), where much of the surface area is covered by deep deposits of rocks and soils left behind by ice age glaciers, there is very little limestone close to the surface. When a lot of crushed stone is needed it has to be hauled in from a considerable distance. The exception is in northwestern Missouri around Kansas City where good limestone deposits are exposed at the surface.

"Kansas City limestone mines are among the largest in the Midwest," says James H. Williams, acting director of the department's Division of Geology and Land Survey. "They offer many secondary uses for storage and office space."

A similar situation with regard to scarcity of stone exists in the Bootheel of southeast Missouri (Region 5) because of alluvial materials (deposits left by moving water, in this case, the Mississippi River). In this region, clay, silt, sand and gravel deeply cover all the bedrock.

Some of Missouri's best crushed stone resources come from the southern third of the state (Region 3). In this Ozark Plateau area, there are massive units of dolomite, and some limestone, dolomitic limestone and sandstone. These are sedimentary rocks that were formed largely by chemical reactions and the precipitation of calcium carbonate when shallow marine waters covered the land millions of years ago. Dolomite is a magnesium carbonate formed by the chemical alteration of limestone.



DNR graphic by Luci Branyan

In the St. Francois Mountains area of southeast Missouri (Region 4) there are mostly igneous granites and rhyolites, which formed more than a billion years ago when volcanoes produced lava flows and clouds of volcanic ash. When crushed, granite rocks produce stone useful as railroad ballast and roofing granules.

The best high-calcium limestone, which is so important for manufacturing cement and lime, comes from the southwest, southeast, and northeast sections of the state (Region 2).

One common use of crushed stone is for agricultural limestone, which also is called aglime. According to the U.S. Bureau of Mines, Missouri is one of the leading states in the production and use of aglime. Quarries producing aglime are located in 80 of Missouri's 114 counties.

Agricultural lime is finely ground limestone or dolomite. It is used to neutralize or "sweeten" soil acidity, to add calcium and magnesium to the soil, and to improve the soil's fertility.

Selecting a quarry site and developing a successful stone operation is a long and complicated process. In addition to siting,

“Kansas City limestone mines are among the largest in the Midwest. They offer many secondary uses for storage and office space.”

— James H. Williams



DNR photo by Kevin Runge

After Nelson Stone Co. finished mining for limestone at this quarry in Jasper, the area looked like a wasteland (above). But after regrading, reseeding and filling the pit with water, the land was restored to use as a pasture (opposite page).

engineering, equipment, staffing and financial challenges, there are zoning and permitting requirements to be met.

At least three permits are normally needed from the Department of Natural Resources – an air quality permit, a water quality permit and a land reclamation permit. Most permits require an application document, supporting documentation and a filing fee as well as an opportunity for a public hearing. For some permits, a performance bond also is required.

“This year we’re going to spend over \$200,000 on mandated regulatory compliance changes,” says Larry Beck, owner of Beck Materials in central Missouri. Beck’s quarries can be seen south of Jefferson City along U.S. Highway 54 West, and along U.S. Highway 63, north of the city.

Quarry operations can create a lot of airborne dust. Under current air quality regulations, quarry operations must obtain permits to construct and to operate. Additionally, when a crusher is added, new sifting screens are installed, or a new facility is built, the quarry’s air quality permits must be updated.

“A new source performance standard for nonmetallic mineral processing also is in effect now,” says Mike Stansfield, of the department’s Air Pollution Control permit-

ting section. This standard regulates the amount of pollutants that result from the operation of rock crushers and related equipment at quarries.

To meet compliance requirements, water trucks routinely wet down quarry roads to suppress dust.

A poorly managed quarry operation can damage the environment if it pumps out rain or groundwater that seeps in, discharges rock-washing waters, or discharges storm waters that carry sediments to streams or lakes.

The Clean Water Act of 1972 controls the discharge of process (wash or pumping) wastewater. Recent amendments to the act now require permits to control the discharge of storm water.

“The department’s primary focus is on storm-water runoff as it leaves the site carrying sediments to the streams,” says Dan Schuette, permit section chief for the department’s Water Pollution Control Program. “Sedimentation and the effects of suspended solids and settleable solids on the receiving streams and aquatic species are our biggest concerns.”

“Before the Land Reclamation Act of 1972, quarries were not required to stabilize high rock walls and slopes left from excavations, and they weren’t required to revegetate the site after mining ceased,”



DNR photo by Mike Larson

says Phil Schroeder, who works in the permit section of the department's Land Reclamation Program.

"The 1972 law and subsequent amendments require the quarry operators to reclaim the site including salvaging the top 12 inches of root growth material (topsoil) and storing it so it can be used to revegetate the quarry site after the mining operation ends."

How does the quarry industry feel about regulations it must comply with?

"You always have the questions of how stringently regulations are applied, or parts that might affect an individual operator," says Rudloff. "But just having regulations industry-wide is not a problem. It's an individual factor."

There is a question of how different values like the amount of emissions, control efficiencies or dust from a mining operation are applied to a particular location.

"When our people understand exactly what's expected of them, you can generally count on them to meet all the compliance requirements to the best of their ability," Rudloff says.

"I do think, though, that the 1990 Clean Air Act is going to have an impact upon the industry. It will probably accelerate the trend toward fewer but larger stone operations. There will be small operations that,

with all the new regulations, won't have the money to hire environmental consultants to process their permits."

Like all things dynamic, the stone industry grows and changes to meet the needs of its customers. The industry has its problems but, as the National Stone Association maintains, the smart, aggressive producers see such problems as opportunities.

"A hundred years ago the industry was labor intensive because so much had to be done by pick and shovel," says Rudloff. "Today, the industry is capital intensive and the trend is toward more efficient, computer-controlled processing plants."

"Most of the producers of crushed stone understand that they must operate in a manner that is compatible with sound environmental practices," says Ira Satterfield, director of the department's Geological Survey Program. "They are investing in the basic infrastructure that holds the fabric of our everyday life together. The quarry operators and their staff are as much a part of the community as their customers are. They are, quite literally, building the foundations of every community." 🌅

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