

Crushed Stone Aggregate Resources of Indiana

BULLETIN 42-H



STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY

SCIENTIFIC AND TECHNICAL STAFF OF THE GEOLOGICAL SURVEY

JOHN B. PATTON, State Geologist
MAURICE E. BIGGS, Assistant State Geologist
MARY BETH FOX, Mineral Statistician

COAL SECTION

CHARLES E. WIER, Geologist and Head
HAROLD C. HUTCHISON, Geologist
RICHARD L. POWELL, Geologist
MARVIN T. IVERSON, Geological Assistant

DRAFTING AND PHOTOGRAPHY SECTION

WILLIAM H. MORAN, Chief Draftsman and Head
ROBERT E. JUDAH, Geological Artist-Draftsman
MURIEL M. MALONE, Geological Draftsman
JOHN E. PEACE, Senior Geological Draftsman
ROGER L. PURCELL, Senior Geological Draftsman
JAMES R. TOLEN, Senior Geological Draftsman
GEORGE R. RINGER, Photographer

EDUCATIONAL SERVICES SECTION

R. DEE RARICK, Geologist and Head

GEOCHEMISTRY SECTION

R. K. LEININGER, Geochemist and Head
MAYNARD E. COLLIER, Chemist
LOUIS V. MILLER, Coal Chemist
E. M. CRAIG, Geochemical Assistant
MARGARET V. GOLDE, Instrumental Analyst
ALFRED E. WHITE, Geochemical Assistant

GEOLOGY SECTION

ROBERT H. SHAVER, Paleontologist and Head
HENRY H. GRAY, Head Stratigrapher
N. K. BLEUER, Glacial Geologist
EDWIN J. HARTKE, Environmental Geologist
JOHN R. HILL, Glacial Geologist
CARL B. REXROAD, Paleontologist

GEOPHYSICS SECTION

MAURICE E. BIGGS, Geophysicist and Head
ROBERT F. BLAKELY, Geophysicist
CHARLES S. MILLER, Instrument Maker
JOSEPH F. WHALEY, Geophysicist
CLARENCE C. HASKINS, Driller
GALEN L. CRAMER, Assistant Driller
JOHN R. HELMS, Geophysical Assistant

INDUSTRIAL MINERALS SECTION

DONALD D. CARR, Geologist and Head
CURTIS H. AULT, Geologist
GEORGE S. AUSTIN, Geologist
MICHAEL C. MOORE, Geologist

PETROLEUM SECTION

T. A. DAWSON, Geologist and Head
LEROY E. BECKER, Geologist
G. L. CARPENTER, Geologist
ANDREW J. HREHA, Geologist
STANLEY J. KELLER, Geologist
DAN M. SULLIVAN, Geologist
JAMES T. CAZEE, Geological Assistant
TIMOTHY LAWRENCE, Geological Assistant
JAMES F. THRASHER, Geological Assistant

PUBLICATIONS SECTION

GERALD S. WOODARD, Editor and Head
DONNA C. SCHULTZ, Sales and Records Clerk

Crushed Stone Aggregate Resources of Indiana

By DONALD D. CARR, ROBERT R. FRENCH, and CURTIS H. AULT

DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY BULLETIN 42-H



STATE OF INDIANA
Edgar D. Whitcomb, Governor
DEPARTMENT OF NATURAL RESOURCES
John R. Lloyd, Director
GEOLOGICAL SURVEY
John B. Patton, State Geologist

For sale by Geological Survey, Bloomington, Ind. 47401

Price 75 cents

Contents

Introduction / 1

History of crushed stone use / 2

Roadways / 2

Cement and lime / 9

Other uses / 10

Crushed stone uses and specifications / 10

Aggregate / 10

Agricultural limestone / 11

Filter stone / 13

Railroad ballast / 13

Riprap / 14

Other uses / 14

Sources of crushed stone / 14

Pennsylvanian crushed stone sources / 17

West Franklin Limestone Member / 17

Providence Limestone Member / 17

Mississippian crushed stone sources / 18

Glen Dean Limestone / 18

Golconda Limestone / 18

Beaver Bend Limestone / 19

Paoli Limestone / 19

Ste. Genevieve Limestone / 19

St. Louis Limestone / 20

Salem Limestone / 21

Harrodsburg Limestone / 22

Devonian crushed stone sources (northern Indiana) / 22

Traverse Formation / 22

Detroit River Formation / 23

Devonian crushed stone sources (central and southern Indiana) / 24

North Vernon Limestone / 24

Jeffersonville Limestone / 24

Geneva Dolomite / 25

Contents

Sources of crushed stone-Continued

 Silurian crushed stone sources / 25

 Salina Formation / 25

 Wabash Formation / 25

 Louisville Limestone / 26

 Waldron Shale / 27

 Salamonie Dolomite / 27

 Brassfield Limestone / 28

 Ordovician crushed stone sources / 28

Transportation / 28

Problems and programs for future development / 30

Literature cited / 31

Appendix: Producers of crushed stone in Indiana / 35

Illustrations

- Plate 1 Generalized columnar sections showing rock units, except Ordovician, quarried for crushed stone in Indiana in 1970 / Facing 2
- 2 Map of Indiana showing bedrock geology and locations of active crushed stone operations / Facing 14
- Figure 1 Abandoned railroad quarry exposing the Paoli and Ste. Genevieve Limestones in Orange County / 6
- 2 Abandoned railroad quarry exposing the Jeffersonville Limestone in Jennings County / 6
- 3 Production and value of crushed limestone and dolomite in Indiana, 1953-69 / 8
- 4 Inactive part of the Sellersburg Stone Co. quarry near Sellersburg, Clark County / 9
- 5 Underground mining of limestone at Hy-Rock Products Co., Marengo / 15
- 6 Sand and gravel pit and crushed stone quarry of the May Stone and Sand Co. near Fort Wayne / 16
- 7 Percentage of crushed stone shipped by truck, rail, and water in the United States, 1953-68 / 29

Tables

- Table 1 Indiana State Highway Commission specifications for coarse crushed aggregates / 11
- 2 Typical range of physical properties of some crushed stone aggregate from Indiana / 12
- 3 Physical specifications for railroad ballast 14

Crushed Stone Aggregate Resources of Indiana

By DONALD D. CARR, ROBERT R. FRENCH, *and* CURTIS H. AULT

Introduction

Mineral aggregate is an aggregation of mineral material, such as crushed rock, expanded shale, perlite, sand and gravel, shells, or slag. It is sometimes bound with such material as cement or asphalt or is sometimes not bound for use as filter stone, flux stone, railroad ballast, riprap, or road metal. Crushed limestone and dolomite, sand and gravel, slag, perlite, and expanded shale are the main natural and fabricated aggregates currently used in Indiana. Some aggregate, such as sand and gravel, requires little or no processing and can be used almost as it is mined, but rock must be crushed and sorted into various desired sizes before it can be used. Many types of rocks can be used for crushed stone aggregate, but limestone and dolomite are used exclusively in Indiana (pl. 1). In this report crushed stone is synonymous with crushed limestone and dolomite.

Each type of aggregate has a distinct advantage with respect to cost and availability or to a specific use for which one type is more suited than another. The advantages of crushed limestone and dolomite are that they can be crushed and sized to meet most specifications, the materials are clean and angular and bind well with cementing mixtures, a uniform lithologic composition can be maintained with little or no selective quarrying in many areas, and they are available at low cost in most counties in Indiana. Crushed stone is one of Indiana's most important mineral commodities, ranking third in annual value behind coal and cement. During 1969 crushed stone production in Indiana totaled 25, 516,000 tons and was valued at \$34,418,000.

History of Crushed Stone Use

The history of crushed stone use in Indiana illustrates the close relationship between the growth of our culture and the accompanying need for more and more basic raw materials. Crushed stone has been used for such varied products as cement, flux stone, agricultural limestone, railroad ballast, chemical stone, lime, rock wool, and concrete for buildings, but most crushed stone has been used in constructing and repairing Indiana's road and highway system. Tremendous tonnages of aggregate have been produced for roadstone and for aggregate in concrete and bituminous surfaces.

ROADWAYS

Modern man tends to think that all technology evolved from simpler beginnings and that the ancients could have profited much if they had only known as much as we do. The fallacy of this premise is evident to those who consider the history of crushed stone use in road building.

The Romans built roads for their armies and war equipment that lasted more than 15 centuries. The roads were massive, many 3 feet thick or more, with base layers of heavy stone overlain by layers of sand and gravel in many places, and were topped with crushed stone mixed with mortar or with a layer of flat stones set in cement. The need to transport war supplies spurred Napoleon to make major road improvements in France and Switzerland in the late 18th century, but the first extensive use of crushed stone for commercial roads was probably not until the early 19th century in Great Britain. It was here that John L. Macadam, a Scottish engineer, perfected an inexpensive road-building process which is still widely used today. Macadamized roads are those that are constructed from compacted crushed stone without a paved foundation. The addition of tar or other bituminous material as a binding agent was a later improvement that began about 1876 in England (Valton, 1947, p. 52).

Macadamized road construction without bituminous binding was extensively adopted in the United States in the mid 1800's and was specified by the State of Indiana for a road from New Albany to

Vincennes in 1836. Prior to this, Indiana roads were mostly fair-weather roads. Planks or log-corduroy surfacings were used in swampy or marshy areas. One section of corduroy road in Carroll County is memorialized by rows of sycamore trees lining State Road 29 just south of the town of Deer Creek. The trees sprouted from freshly cut logs laid in a swampy area during the building of the Michigan Road in the 1830's. The few plank roads served well for the light traffic, but after about 10 years the wood rotted and the roads reverted to their normal condition of near impassability in wet weather. A dramatic description of the condition of the roads in central Indiana during the early 1800's is quoted by Cottman (1906, p. 48) from a book called "The New Purchase," by Baynard Rush Hall:

In the early spring, he [Hall] says, the streams were brim full, 'creeks turned to rivers, rivers to lakes, and lakes to bigger ones, and traveling by land becomes traveling by mud and water.' As one proceeded he must tack to right and left, not to find the road, but to get out of it and find places where the mud was 'thick enough to bear.'...The lumbering wagon plunged over a succession of ruts and roots, describing an 'exhilarating seesaw with the most astonishing alternation of plunge, creak and splash.'

The building of the New Albany-Vincennes road marked the beginning of the extensive use of crushed stone for all-weather road construction in Indiana. Blatchley (1906, p. 3 1-34) gave some detail on the construction and cost of the road. Construction started shortly after the state legislature authorized funds for the road in 1836. The portion of the road from New Albany to Paoli was completed by 1839. The cost of surfacing this section with crushed stone averaged more than \$5,000 per mile, about 40 percent of the total cost of the road, which included grading and bridging. The road was opened as a toll road in 1840.

The transportation costs for the crushed stone during construction of the road were a matter of much concern to its builders, just as such costs plague road builders today. Mr. Stansbury, the chief engineer in charge of the survey for the section between Vincennes and Washington, Ind., explained the high cost of one section of the road in words that are as economically sound for long-haul transportation

costs today as they were then: “The nearest point at which it (the stone) occurs in sufficient quantity is at such a distance that the cost of its transportation is the principal item of its expense” (Blatchley, 1906, p. 32).

Only granite, flint, or limestone was authorized for the surfacing. Only limestone was actually used, however, for constructing the New Albany-Paoli section; granite is not exposed at the surface in Indiana, and flint (chert) is normally present only in small percentages associated with the limestone. The stone was loaded by hand at the quarries, transported by wagon, and broken by hand at the roadside.

Although crushed stone later proved to be more expensive (but more durable) than gravel for surfacing in Indiana, the use of gravel in any amount before 1850 was not recorded. Cottman (1906, p. 51) suggested that gravel bars in streams were not used much before this because the dense vegetation had not yet been cleared from streams where gravel could be found.

The National Road and the Michigan Road were two of the most famous and well-used roads in early Indiana, but initial surface improvements on these roads in central and northern Indiana were mostly made with gravel. Portions of the National Road were graveled in the 1850's by the counties through which the road passed and by private corporations which operated parts of it as toll roads.

The typical crushed stone quarry in southern Indiana before 1900 was small and shallow and was worked by hand. In addition to crushed stone, many quarries in southeastern Indiana, especially those near the towns and cities, produced flagging for homes, curb-stone, and fencing. Wall stone, foundation stone, jail stone, and a seemingly endless variety of dimension stone products were produced in some larger quarries from rocks mostly of Silurian age. Most dimension stone in Indiana, however, was produced from the Salem Limestone (Indiana Limestone) in the south-central part of the state, where crushed stone production was of secondary importance. Indeed, Mance (1915, p. 308) reported that some dimension stone quarry operators gave waste stone to the railroads, loading the stone

free of charge just to get rid of it. The quantity of stone used as crushed stone was not recorded.

That railroads used large quantities of crushed stone in the early 1900's is reflected in the values of ballast reported by Mance (1915, p. 303) for 1913. The value of Indiana's production of railroad ballast that year was about \$200,000 (approximately 375,000 tons), a little less than a fourth of the value of crushed stone used in road construction. The amount of crushed stone used for railroad ballast before 1900 is difficult to determine, but the extensive early use of crushed stone for this purpose is recorded by the many abandoned quarries alongside the railroads in those areas where limestone and dolomite are exposed at the surface (fig. 1).

A second phase of road building and an upsurge in the use of crushed stone began about 1900 in Indiana when land assessment taxes and later gasoline taxes were used in constructing many township and secondary roads. The U.S. Postal Department played an unplanned role in road building in many areas about 1900. Rural mail delivery was refused to those communities with inadequate roads, and thus the desire for mail delivery helped speed road improvement and increased the use of crushed stone.

Crushed limestone and dolomite for short distances of road were obtained from many small roadside quarries in southeastern Indiana from about 1900 to about 1930 (fig. 2). In Decatur County, for example, many of the more than a hundred abandoned quarries that have been examined by the Indiana Geological Survey were active during this period. Available records show that more than 130 quarries, including some that have been worked only for dimension stone, have been operated in the county. Most of the crushed stone quarries were active for only a short time and generally yielded less than 10,000 tons.

Most of the small quarries in southeastern Indiana were near streams or in a valley where the bedrock was found exposed immediately beside the road. Exploration for a new quarry site was as simple or as difficult as finding a new exposure of limestone or



Figure 1. Abandoned railroad quarry exposing the Paoli and Ste. Genevieve Limestones in Orange County. This quarry is typical of many Indiana quarries that supplied ballast for building railroads about 1900. Although the life of these quarries was short, large quantities of stone were removed.



Figure 2. Abandoned roadside quarry exposing the Jeffersonville Limestone in Jennings County. Many quarries such as this were opened in the early 1900's to supply stone for roads that were being built nearby. Most of the quarries were abandoned after the roads were completed.

dolomite near the road to be surfaced. A tramp over the hills and through the valleys sufficed to locate usable rock in much of southeastern and eastern Indiana. Road contracts were let by county officials or the township assessor (as in Decatur County) for distances as short as half a mile in the 1920's and 1930's. In Decatur County many short roads were paid for from gas-tax revenues and were called "gasoline roads." Labor and quarrying equipment were inexpensive, and many small operators vied for the contracts.

Road construction and repair by contract replaced an earlier method which directly involved many male county residents. In the 1800's and early 1900's these men were required by law to work out road taxes by laboring on the roads within the county for a minimum number of days each year. Because of discontent among the conscripted workers and the lack of efficient supervision, the system produced poor roads and inadequate repairs and was eventually abandoned.

The early crushed stone producers were not hampered by rigid specifications. In Jennings County, for example, in the early 1900's, roadstone was crushed into pieces about the "size of your head" and smaller. If the size of stone was too large, the county representative complained and the contractor grudgingly crushed the stone to smaller sizes. Few records were kept, and today many small quarries are full of water or filled in and completely overgrown and even lost to the memory of oldtime landowners.

In the 1930's many operators went out of business when they could not compete with a few operators who purchased larger and more efficient quarrying equipment. Later, labor costs began to rise and local markets for road aggregate became fewer. By 1940 transportation had become less costly and a wider market area was served by high-capacity centralized quarries. From 1935 to 1947 the number of operating crushed stone quarries in Indiana decreased from 276 to 89. Production records are sparse, but the total amount of crushed stone taken from the quarries probably increased during this period (U.S. production tripled). In 1970 Indiana had 84 quarries producing crushed stone (appendix).

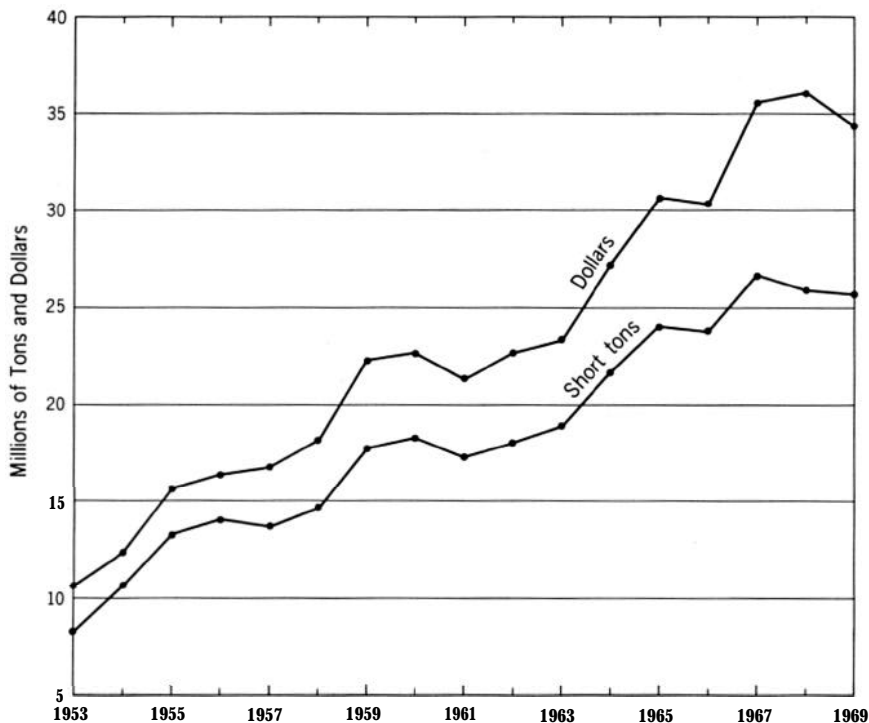


Figure 3. Production and value of crushed limestone and dolomite in Indiana, 1953-69. Information from U.S. Bureau of Mines Yearbooks and Preprints.

Highway construction and repair continued to account for a large share of the crushed stone used in Indiana from 1947 to 1967, when the production of stone increased more than fivefold from about 5 million to more than 28 million tons, even though the number of quarries remained relatively constant. The rapid rise in value and tonnage from 1953 to 1969 is shown in figure 3. French (1967a) discussed the geologic and economic factors affecting the industry from 1947 to 1967 and pointed out that highway construction programs would play a significant part in the industry's future.

Because past trends indicate future needs, the history of crushed stone use for roadways in Indiana is revealing. For example, the only active quarry in Jennings County (producing only moderate amounts of crushed stone by today's standards) has produced more stone from 1967 through 1969 than was probably produced altogether

from the more than 70 recorded quarries that were worked in the county in the past. The same trend of continuing expansion and increased production is evident in other counties where crushed stone is produced.



Figure 4. Inactive part of the Sellersburg Stone Co. quarry near Sellersburg, Clark County. Abandoned underground entries shown in the upper right of the photograph are in hydraulic limestones of the Speed Member of the North Vernon Limestone. Limestones of the Speed were used in many places in Clark, Floyd, and Jefferson Counties to manufacture natural cement until about 1900. Crushed stone was mined later from the mine shown in the lower left of the photograph after the upper mine had been abandoned and the quarry deepened.

CEMENT AND LIME

Natural cement was first produced in Clark County before 1850. An abundance of natural cement rock in Clark, Floyd, and Jefferson Counties allowed the natural cement industry to prosper until portland cement came into common use in the 1910's and 1920's (fig. 4). The production of portland cement then increased gradually and in recent years has accounted for more than 10 percent of the crushed stone used in Indiana.

Early settlers in Indiana produced lime from crushed stone for plaster and mortar. The market for lime expanded after about 1870, and larger kilns came into use. About 1930, however, the use of cement in mortar and gypsum in plaster increased, and the lime industry in Indiana declined. The last commercial production of lime from Indiana stone ceased in 1953.

OTHER USES

Lime, marl, blast furnace slag, water-softening refuse lime, and finely ground limestone and dolomite have been used as soil conditioners. Ground limestone and dolomite are now the principal agricultural liming materials in Indiana because they are low in cost and are readily available.

Rock wool, an insulating material made of filaments from blown molten rock, was produced in the 1930's and 1940's from shaly limestone in northern Indiana and from various raw materials, mostly limestone and shale, in southern Indiana. Slag then replaced shaly limestone as a raw material, and the consumption of crushed stone for rock wool declined sharply by 1950.

Records indicating the amount of crushed limestone and dolomite used as refractories, for such chemical purposes as whitening and filler, and as fluxes in steel and glass manufacture are not available. In recent years statistics of the U.S. Bureau of Mines have shown that more than 200,000 tons and even more than 300,000 tons of such miscellaneous products have been sold or used in Indiana each year.

Crushed Stone Uses and Specifications

AGGREGATE

Nearly 80 percent of the crushed stone aggregate produced in Indiana is used in concrete and highway construction. Most of this aggregate is contracted by federal or state government agencies and is subject to physical tests. Aggregate used by the Indiana State Highway Commission must conform to a specified particle size distribution and meet other specifications to qualify as a premium class of stone (table 1). Specifications and testing procedures pertinent to the

Table 1. Indiana State Highway Commission specifications
for coarse crushed aggregates
[From Indiana State Highway Commission, 1969, p. 416-417]

Class	Minimum specific gravity	Maximum deleterious materials (pct)	Maximum abrasion loss (pct)	Maximum soundness loss (pct)	Maximum absorption (Pct)
A	2.45	5	40.0	12	3
B	2.45	6	45.0	16	
C	2.45	10	50.0	20	

Indiana State Highway Commission can be found in “Indiana State Highway Commission Standard Specifications,” which can be obtained from the Engineer of Specifications, Indiana State Highway Commission, State Office Building, Indianapolis, Ind. 46204.

The physical properties of the rock formations in Indiana used for crushed stone aggregate have considerable range (table 2). The range in physical properties results largely from the compositional inhomogeneity of the rocks, especially the amount of clay and chert constituents, but textural inhomogeneity, such as grain size and grain to grain relationships, and the amount of porosity also affect the performance of carbonate aggregate (West and Johnson, 1965, p. 157-160). In some limestone rock sequences lithologic changes can occur abruptly both vertically and horizontally. Conversely, however, some dolomites of northern Indiana are remarkably homogeneous throughout wide areas.

AGRICULTURAL LIMESTONE

Agricultural limestone accounts for about 10 percent of Indiana’s total aggregate production. Only one company in Indiana quarries limestone mainly for agricultural limestone; the other companies produce agricultural limestone from the fines left over from the crushing operation that produces aggregate.

Specifications for agricultural limestone are based on its ability to correct soil acidity. Although there are no laws in Indiana to control the quality of agricultural liming materials, certain specifications

Table 2. Typical range of physical properties of some crushed stone aggregate from Indiana
 [Data compiled from Indiana State Highway Commission records]

Unit	Number of samples	Number of locations	Specific gravity	Abrasion loss (pct)	Soundness loss (pct)	Absorption (pct)
Pennsylvanian rocks:						
West Franklin Ls. Mbr. (Shelburn Fm.)	1	1	2.69	24.5	17.6	0.8
Mississippian rocks:						
Glen Dean Ls.	13	2	2.46-2.69	24.7-32.4	4.3-27.2	0.5- 1.5
Golconda Ls.	4	1	2.56-2.65	28.8-35.7	10.7-17.6	0.8- 2.0
Beaver Bend Ls.	3	1	2.2 -2.4	31.7-37.9	8.8-27.8	5.3- 7.7
Paoli Ls.	5	3	2.60-2.67	27.9-31.9	2.5-24.5	0.6- 2.7
Ste. Genevieve Ls.	51	12	2.37-2.7	23.1-42.7	2.6-31.4	0.3- 3.7
St. Louis Ls.	20	5	1.91-2.70	19.7-67.7	3.8-32.2	0.3-13.6
Salem Ls.	14	4	2.29-2.70	21.8-44.6	5.3-39.9	1.8- 2.9
Harrodsburg Ls.	6	2	2.58-2.70	25.5-34.4	6.4-20.0	0.6- 1.4
Devonian rocks:						
North Vernon Ls.	15	9	2.5 -2.72	24.7-45.5	6.5-23.7	0.6- 6.4
Jeffersonville Ls.	32	11	2.2 -2.73	22.3-44.0	0.9-30.5	0.4- 7.7
Geneva Dol.	10	4	2.34-2.68	27.9-37.6	1.9-12.0	2.3- 5.0
Silurian rocks:						
Kokomo Ls. Mbr. (Salina Fm.)	1	1	2.61	25.3	2.1	1.7
Huntington Lithofacies (Wabash Fm.)	39	11	2.46-2.77	19.7-39.5	0.9-20.2	0.4- 2.8
Liston Creek Ls. Mbr. (Wabash Fm.)	11	3	2.48-2.78	23.2-28.8	2.7-48.0	1.1- 3.5
Louisville Ls.	25	10	2.43-2.78	22.9-37.1	3.5-34.4	0.7- 4.8
Laurel Mbr. (Salamonie Dol.)	15	5	2.36-2.71	32.1-52.1	0.5-23.7	1.3- 3.9
Laurel Mbr. (Salamonie Dol.)	29	9	2.52-2.80	23.5-36.8	1.0-43.6	0.5- 2.7
Brassfield Ls.	2	1	2.62-2.76	28.3-35.6	6.2-11.2	0.7- 2.6

must be met for landowners to qualify for the federal government cost-share program. To qualify for the federal program in Indiana, agricultural limestone must meet the following minimum specifications (U.S. Department of Agriculture, 1968, p. 1):

1. It must contain at least 80 percent calcium carbonate equivalent.
2. It must contain all the fine particles obtained in the grinding process and be ground fine enough for no less than 25 percent to pass through a U.S. Standard No. 60 sieve and 80 percent through a U.S. Standard No. 8 sieve.
3. Either the calcium carbonate equivalent or the percentage passing through a U.S. Standard No. 8 sieve or both must be greater than the minimum, so that the product of the two equals or exceeds 7200.

FILTER STONE

Crushed stone is used in filter beds, which serve as hosts for sewage-purifying bacteria. Because of the high chemical activity of sewage and the severe mechanical weathering processes, the selection of filter material is largely determined by its durability. Impurities in the stone, such as shale, clay, and pyrite, are objectionable. The stone should be free of fines and should retain its shape and size after 20 cycles of the sodium sulfate test. Any stone losing more than 10 percent of its volume through a ½-inch sieve is considered unfit for this type of application (American Society of Civil Engineers, 1937).

RAILROAD BALLAST

Stone used for railroad ballast should possess the physical properties of premium aggregate; that is, it should be sound, durable, and relatively free of soft and friable particles (table 3). In addition to the normal attack of weathering processes, stone used as railroad ballast is subject to mechanical forces, such as those imparted by heavily loaded railroad cars and impact delivered by tamping tools (Goldbeck, 1948, p. 199-200). Thus stone for railroad ballast should have a relatively low loss in the abrasion test.

Table 3. Physical specifications for railroad ballast
 [From American Railway Engineering Association, 1964, p. 2-3]

	Maximum percentage
Deleterious substances:	
Soft and friable pieces -----	5
Material finer than 200 sieve -----	1
Clay lumps -----	0.5
Abrasion: Loss in the Los Angeles abrasion test -----	40
Soundness: Loss after five cycles of sodium sulfate soundness test -----	10

RIPRAP

Riprap is large angular rock fragments that are placed around the bases of piers, abutments, dams, and other construction subject to abrasion by water. Specifications vary considerably, but only sound stone is accepted by the Indiana State Highway Commission. Stone of unknown or questionable weathering characteristics is subjected to a soundness test consisting of five cycles of the sodium sulfate bath or 50 cycles of freezing and thawing. Any stone losing more than 25 percent of its initial volume through a No. 12 sieve after the test is considered unsuitable.

OTHER USES

Many uses of crushed stone, such as cement and flux stone, rely mainly on the chemical properties of the stone. For information on these and other uses, the interested reader should refer to Lamar (1961), Rooney (1970), Rooney and Carr (in preparation), and Sunderman, French, and Rooney (in preparation).

Sources of Crushed Stone

All but three of Indiana's crushed stone quarries are in areas directly underlain by limestone and dolomite of Mississippian, Devonian, or Silurian age (pl. 2). Two quarries produce small quantities of crushed stone and agricultural limestone from Pennsylvanian rocks, but Pennsylvanian limestones are generally too thin to permit large production. One company in northwestern Indiana near Kentland quarries Ordo-



Figure 5. Underground mining of limestone at Hy-Rock Products Co., Marengo.

This company began an open-pit operation but changed to an underground operation when overburden became excessive.

vician limestones and dolomites that stand in a near vertical attitude, but this quarry is on an anomalous structure that appears to be unique in Indiana. The bedrock adjacent to this quarry consists of almost horizontal beds of Mississippian and Devonian shales and siltstones.

Glacial materials deposited over bedrock have had a profound effect on the location of quarry sites in Indiana (Patton, 1951, p. 259-261). There are many possible quarry sites in southern Indiana south of the Wisconsin glacial drift boundary. In this area overburden is generally limited to a few feet of soil or Illinoian till, except where bedrock itself must be removed because it is not of high enough quality to make good aggregate. When overburden becomes excessively thick, underground mining may be the best way to avoid high operating costs (fig. 5).

In northern Indiana most of the bedrock is covered by glacial materials, so that quarry site locations are more difficult to find.

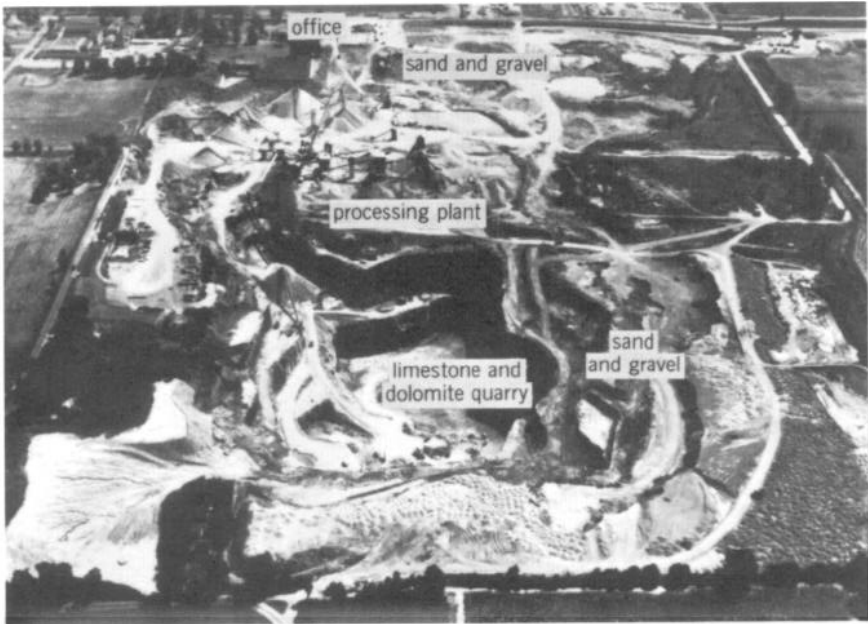


Figure 6. Sand and gravel pit and crushed stone quarry of the May Stone and Sand Co. near Fort Wayne. About 90 feet of glacial sand and gravel have been removed above the stone quarry.

In this glaciated part of Indiana, quarry sites are generally restricted to areas where streams have eroded through to bedrock or to areas where the glacial cover is thin. A few crushed stone quarries are second generation operations that were started in the bottom of sand and gravel pits after producers had processed and marketed several tens of feet of glacial material (fig. 6).

Most limestones and some dolomites vary considerably in their chemical and physical properties over short distances; hence, a limestone formation found acceptable for crushed stone aggregate at one location is not necessarily acceptable elsewhere. Although more than 20 limestone and dolomite units are used for crushed stone aggregate in Indiana, some are more desirable than others because they have consistently good service records at many different locations. For example, of the Mississippian formations, the Ste. Genevieve and Paoli Limestones contain premium limestones and are quarried

extensively in southern Indiana (Carr, in preparation). Of the Silurian formations in Indiana, the Huntington Lithofacies of the Wabash Formation, the Louisville Limestone, and the Salamonie Dolomite have good service records. Of the Devonian formations, the Traverse Formation, the Detroit River Formation, the Jeffersonville Limestone, and the Geneva Dolomite have fair to good service records.

PENNSYLVANIAN CRUSHED STONESOURCES

WEST FRANKLIN LIMESTONE MEMBER: The West Franklin Limestone Member of the Shelburn Formation consists of limestones in a predominantly sandstone and shale sequence. The West Franklin limestones are typically gray, micritic, and skeletal, and in some places they are argillaceous and cherty. The weathered surface is commonly mottled gray and tan. Where it is quarried in Sullivan County in southwestern Indiana, the West Franklin is about 5 feet thick, but in Vanderburgh County near the Ohio River it is more than 11 feet thick.

One quarry uses West Franklin limestones for agricultural limestone and road metal. Because of excessive soundness loss, this unit generally will not meet State Highway specifications for class A stone but can be used for class B requirements. Limestones of the West Franklin are thin and probably would not be used for crushed stone if they did not crop out in southwestern Indiana, an area where limestone is scarce. The removal of thick overburden must be especially considered in any economic appraisal of this unit as a source of aggregate.

PROVIDENCE LIMESTONE MEMBER: The Providence Limestone Member of the Dugger Formation consists of limestones in a sandstone and shale sequence between the Herrin and Hymera coals. The Providence consists of gray to brown skeletal-micritic limestones generally in 1- to 5-foot-thick beds that are separated by thin beds of clay or shale. Where they are quarried in Warrick County in southern Indiana, the limestones range from 5 to 12 feet in thickness, but they may exceed this thickness in places.

Providence limestones have not been sold commercially, but they have been used to build and maintain roads on the property of several coal companies in southwestern Indiana. These limestones reportedly serve this purpose very well.

MISSISSIPPIAN CRUSHED STONE SOURCES

GLEN DEAN LIMESTONE: The Glen Dean Limestone consists of buff to gray fine- to coarse-grained skeletal limestones that are oolitic in places. Thin shale laminae are common. Limestones of the Glen Dean average between 20 and 30 feet in thickness in Perry and Crawford Counties, where they have been quarried most extensively.

Glen Dean limestone is quarried at two locations in Indiana and is used for crushed stone, agricultural limestone, and riprap. Most Glen Dean limestones will meet Indiana State Highway requirements for class A crushed stone, but in some areas the argillaceous content of the limestones increases enough to cause them to fail the sodium sulfate soundness test. In southern Indiana the Glen Dean Limestone is normally overlain by the Tar Springs Formation, a moderately thick sandstone and shale unit that must be removed and wasted during quarrying.

COLCONDA LIMESTONE: In southern Indiana the Golconda Limestone consists of gray medium- to coarse-grained skeletal limestones that are oolitic in places. Laminae and thin beds of shale are common. Dense gray chert replaces as much as 5 percent of the medium- to coarse-grained skeletal material in many places. Where it is quarried in Crawford and Perry Counties, the Golconda averages about 40 feet in thickness, but it may be almost 50 feet thick in some areas.

Golconda limestones are quarried at only two locations in Indiana, but in the past they were used in many places for aggregate. Limestones of the Golconda are currently used for crushed stone, riprap, and agricultural limestone. Shale partings and chert may cause the limestones to test as substandard concrete aggregate in some places; however, in general they test as class A aggregate. In southern Indiana the Golconda is normally overlain by the Hardinsburg Formation,

a moderately thick sandstone and shale unit that must be removed and wasted during quarrying.

BEAVER BEND LIMESTONE: The Beaver Bend Limestone consists of buff or light reddish-brown skeletal limestones that are oolitic in places. The thickness of the Beaver Bend ranges from about 11 feet in central Putnam County to about 20 feet in Crawford County. Where this unit is quarried in southern Indiana, it is characteristically 12 to 15 feet thick.

Limestones of the Beaver Bend are quarried with rocks of the Blue River Group at four locations in Indiana and are used for crushed stone, riprap and agricultural limestone. These limestones generally test as class A aggregate; however, because the Beaver Bend must be quarried with adjacent shaly units, the shales may cause the samples to test poorly in specific gravity, soundness, and absorption. The Beaver Bend is a relatively thin unit, which limits its use to those areas where it can be quarried with the thicker limestones of the Blue River Group.

PAOLI LIMESTONE: The Paoli Limestone consists generally of light-gray to gray fine- to medium-grained skeletal limestones. Beds of very light-gray oolitic limestone, which are nearly pure calcium carbonate, are common. Gray to green calcareous shales are almost always present near the middle and base of the formation, and many of them have a plasticity index greater than 5. Thickness of the formation is irregular along the outcrop, but it ranges from a few feet in Owen and Putnam Counties to about 30 feet in Harrison County.

Paoli limestones are quarried at 12 locations in Indiana and are used for crushed stone, agricultural limestone, riprap and cement. Most often the Paoli is quarried with the Ste. Genevieve Limestone. The Paoli makes an excellent aggregate and consistently tests class A according to Indiana State Highway specifications. The nearly white oolitic limestones are a potential source of high-calcium and special-purpose limestones.

STE. GENEVIEVE LIMESTONE: The Ste. Genevieve Limestone crops out

from west-central Putnam County in central Indiana to Harrison County near the Ohio River. The Ste. Genevieve is divided into three parts: the Levias Member, a middle impure carbonate member, and the Fredonia Member, in descending order.

The Levias Member consists mainly of light-gray to gray medium-bedded micritic and skeletal limestones that in many places are interbedded with thin calcareous shales. Beds of nearly white oolitic limestone, which are nearly pure calcium carbonate, are common. Thickness of the Levias ranges from nearly 20 feet along the northern part of the outcrop belt to about 60 feet along the southern part.

The middle member along the Indiana outcrop generally consists of an impure carbonate containing quartz silt and medium to coarse quartz grains, but in places the unit may consist of a calcareous shale or siltstone. Thickness of this member is irregular, but it ranges from a few inches to about 20 feet.

The Fredonia Member consists mainly of very light-gray to gray medium- to thick-bedded skeletal limestones, but white oolitic limestones commonly make up about 20 percent of the unit. Thickness of the member ranges from nearly 30 feet along the northern part of the outcrop to about 75 feet along the southern part.

The Ste. Genevieve, one of Indiana's most important industrial limestones, is quarried at 18 locations and is used for aggregate, riprap, agricultural limestone, and cement. The oolitic limestones of the Ste. Genevieve have been used for high-calcium flux stone and for manufacturing lime. The Ste. Genevieve consistently tests class A according to Indiana State Highway specifications. Near the turn of the century, the Ste. Genevieve was used as a dimension building stone, but it has not been used for this purpose in recent years. Reserves of Ste. Genevieve limestones are large and prospective quarry sites are well situated for the central and southern Indiana market.

ST. LOUIS LIMESTONE: The St. Louis Limestone can be conveniently divided into two lithologic units. The upper unit consists mainly of

gray to light-brown thin-bedded micritic limestones, and although thin shales are commonly present, they are not as abundant as in the lower unit. Considerable amounts of light-gray to bluish-gray dense chert, which occurs as nodules and thin discontinuous beds, are characteristic of the upper St. Louis limestones. The lower unit consists mainly of gray to brown thin-bedded dolomitic limestones that are commonly interbedded with black, gray, and green calcareous shales. In the subsurface, extensive deposits of gypsum and anhydrite are contained within these beds. The St. Louis ranges in thickness from 60 to 80 feet in Putnam, Owen, and Monroe Counties to about 250 feet in Harrison County near the Ohio River.

The upper part of the St. Louis Limestone is quarried along with the Ste. Genevieve Limestone at seven locations in Indiana. The St. Louis is used for aggregate, road metal, and agricultural limestone, and at one location it is used along with the Salem Limestone for manufacturing cement. Beds of argillaceous limestone and shale generally cause the St. Louis to fail Indiana State Highway Commission requirements for class A stone. The abundant chert limits the usefulness of the St. Louis as an aggregate, not only because of its deleterious reaction with concrete, but also because of its excessive wear and the damage it causes to crushing and processing equipment.

SALEM LIMESTONE: The Salem Limestone consists mainly of gray and buff limestones which range from the fine- to coarse-grained skeletal limestones used for dimension building stone to impure micritic limestones. Along the outcrop belt, the Salem ranges in thickness from less than 50 feet in southern Putnam County to about 100 feet in southern Harrison County near the Ohio River. Throughout the building stone district of Monroe and Lawrence Counties the Salem averages about 80 feet in thickness. Chemical analyses of the building stone lithology commonly range from 95 to 98 percent calcium carbonate.

The Salem Limestone is used principally as a dimension building stone, but it is quarried at three locations for aggregate and at another location for cement. Two additional plants use spalls from

the dimension limestone mills to produce ground limestone for agricultural limestone and various industrial uses. Some properties which allow the Salem to excel as a building stone hinder its use as a concrete aggregate. For example, many of the medium- and coarse-grained skeletal limestones have high loss in abrasion and soundness tests; consequently, these limestones do not meet the Indiana State Highway Commission specifications for class A aggregate. Nevertheless, some Salem limestones will pass State Highway Commission specifications for class A aggregate.

HARRODSBURG LIMESTONE: The Harrodsburg Limestone can be divided conveniently into two lithologic units that correspond to practical economic units. The upper part of the Harrodsburg consists mainly of blue-gray skeletal limestones, which contain some chert. This unit, which averages about 50 feet in thickness in Putnam County and about 70 feet in thickness in Washington County, is an important industrial limestone. The lower part of the Harrodsburg consists mainly of thin impure micritic and skeletal limestones, thin calcareous shales, and calcareous siltstones. Siliceous geodes are abundant in some localities. The lower part of the Harrodsburg has little economic importance as a source for crushed stone.

Harrodsburg limestone is quarried at five locations in Indiana for aggregate, riprap, and agricultural limestone. Soundness loss and chert may prevent some limestones from passing Indiana State Highway Commission specifications for class A aggregate, but these limestones are generally adequate for less stringent aggregate requirements and for agricultural limestone. The location of the Harrodsburg outcrop belt east of the Ste. Genevieve outcrop belt gives it a desirable geographic setting for some markets in east-central Indiana.

DEVONIAN CRUSHED STONE SOURCES (NORTHERN INDIANA)

TRAVERSE FORMATION: Normally, where found at the bedrock surface in northern Indiana, the Traverse Formation is covered by thick glacial deposits. About 60 feet of sand and gravel overlie the formation near Woodburn in Allen County, where the formation consists of brownish-gray calcareous dolomites and dolomitic limestones that

contain a few scattered chert bands and shaly layers near the base. Elsewhere in northern Indiana it contains shaly layers of variable thickness, but the formation is predominantly limestone and dolomite. The Traverse is 61 feet thick near Woodburn and may exceed 100 feet in extreme northeastern Indiana. Near LaPorte in northwestern Indiana it is 60 to 75 feet thick. Rocks of the same age are present in the North Vernon Formation in central and southern Indiana.

Open-pit quarrying is possible only where the overburden is exceptionally thin or where the overburden, such as sand and gravel, has commercial value. In Allen County class A stone is quarried from the Traverse for roadstone and for aggregate in bituminous surfacings. Tests of core samples from depths of 300 to 500 feet in parts of LaPorte and Marshall Counties indicate that much of the formation would make class A aggregate and some of the low-magnesium limestones are suitable for manufacturing cement (Rooney and Ault, 1970, p. 202).

DETROIT RIVER FORMATION: The Detroit River Formation consists mainly of brownish-gray fine- to coarse-grained limestones and dolomites. The limestones consist of both micritic and skeletal types; the coarser grained skeletal limestones typically contain well-preserved corals. Several sandy zones are present within the unit, one of which is characteristically found at the base of the formation. The Detroit River is 41 feet thick near Woodburn in Allen County and thickens to more than 150 feet in the northeast corner of the state. It averages about 80 feet in thickness in LaPorte and Marshall Counties but thickens from less than 40 feet to more than 150 feet within these counties. The formation contains large reserves of gypsum and anhydrite in the northern two tiers of counties. Detroit River rocks are probably the same age as part of the Jeffersonville Limestone in central and southern Indiana.

Rocks of Detroit River age are quarried for aggregate and agricultural limestone in Jasper and Allen Counties. In northwestern Indiana there is an economic potential for underground mining of

gypsum, limestone, and dolomite from the Traverse and Detroit River Formations.

DEVONIAN CRUSHED STONE SOURCES (CENTRAL AND SOUTHERN INDIANA)

NORTH VERNON LIMESTONE: The North Vernon Limestone consists of a gray phosphatic limestone (Beechwood Member), an argillaceous limestone (Silver Creek Member), and a thin argillaceous skeletal limestone (Speed Member). The formation attains a maximum thickness of 33 feet in southern Indiana, and rocks of approximately the same age are 25 feet thick near Logansport in Cass County.

In southern Indiana only limestones of the Beechwood and Speed Members are sound enough to be used as aggregate. The Beechwood limestones have a maximum thickness of 10 feet and are generally pure enough to be used for agricultural limestone. Limestones of the Silver Creek and Speed Members are used in manufacturing cement in one quarry in southern Indiana.

JEFFERSONVILLE LIMESTONE: The Jeffersonville consists mainly of grayish-brown carbonaceous limestones or dolomitic limestones, which are about 40 feet thick. Three faunal zones are present in the formation; the middle and upper zones (*Brevispirifer gregarius* and *Paraspirifer acuminatus* Zones) contain very thin argillaceous and pyritic laminae in places. The lower zone contains a profuse coral fauna and generally does not contain the argillaceous and pyritic laminae.

The Jeffersonville is used by eight quarries in southern Indiana, and it generally provides good aggregate. The argillaceous and pyritic laminae, however, are probably planes of higher porosity (Patton, 1954, p. 85) and may cause some of the aggregate to do poorly in soundness and absorption tests (table 2). One cement company uses the Jeffersonville in manufacturing portland cement. Chemical analyses (French, 1967b appendixes 2, 3, and 4) indicate that the formation is suitable for agricultural limestone and other uses requiring a relatively high calcium carbonate content.

GENEVA DOLOMITE: The Geneva Dolomite, consisting mainly of brown carbonaceous dolomite, is present in an area that extends from Hamilton County southward to Clark County and from Decatur County westward into Illinois. Excellent exposures are present in Rush and Shelby Counties, where the Geneva has a maximum thickness of about 35 feet. The Geneva contains very little noncarbonate material except at the base, where chert is commonly found in places.

Soundness and abrasion tests (table 2) indicate that the Geneva is generally acceptable as class A aggregate. The Geneva, however, contains some rock that tests low in specific gravity and high in absorption. Eight quarries in south-central Indiana use the Geneva for aggregate and agricultural limestone.

SILURIAN CRUSHED STONE SOURCES

SALINA FORMATION: The Salina Formation is the youngest Silurian formation exposed in Indiana. In northern Indiana the Salina is composed of two distinctly different lithologies, designated the Kenneth Limestone and the Kokomo Limestone Members. The Kenneth consists mainly of cherty micritic limestones in the type section at Kenneth Station in Cass County, but the limestones are much purer about 2 miles south where they are used by the Louisville Cement Co. Maximum thickness of the Kenneth is about 45 feet in Cass and Howard Counties. The Kokomo consists mainly of tan to gray dolomitic limestones with many carbonaceous laminae. The unit is about 44 feet thick near Logansport in Cass County and near Kokomo in Howard County.

Three companies quarry the Kenneth and (or) the Kokomo limestones for crushed stone, but the stone rarely meets Indiana State Highway Commission specifications for class A concrete aggregate. Both rock units appear to be suitable for road metal and less demanding uses.

WABASH FORMATION: The Wabash Formation consists of three major lithologies, which are exposed at many places in northern Indiana. The Huntington Lithofacies consists of reef, bank, and biohermal

deposits of coarse-grained porous dolomite that laterally replaces both the Mississinewa Shale Member and the Liston Creek Limestone Member in some areas. The Mississinewa Shale Member consists of dolomitic siltstones or silty dolomites in the type area in Wabash and Grant Counties. Along the south bank of the river at Wabash 75 feet of the Mississinewa is exposed, but its maximum thickness in the subsurface of the type area is about 110 feet. The Liston Creek Limestone Member overlies the Mississinewa and consists dominantly of cherty micritic limestones. About 26 feet of the Liston Creek is exposed in the type section in Wabash County, but west and southwest of the type section in the subsurface the unit thickens to about 100 feet.

Of the three major units that constitute the Wabash Formation only rocks of the Huntington Lithofacies are consistently a source of good aggregate (table 2). The Liston Creek is generally tough and can pass soundness and abrasion tests, but it contains abundant chert with a specific gravity less than 2.45. This factor alone appears to determine the utility of the Liston Creek because the lighter, porous cherts have a deleterious reaction effect in concrete. The Mississinewa has no economic value as an aggregate.

LOUISVILLE LIMESTONE: In southeastern Indiana the Louisville Limestone consists mainly of bluish-gray silty dolomitic limestones that contain varying amounts of shale. The Louisville is overlain by the Jeffersonville or the Geneva in eastern Clark County and by the Mississinewa in the subsurface of western Clark County. In northeastern Indiana the Louisville is a blue and gray mottled dolomite. Although no single exposure in Indiana contains more than about 60 feet of Louisville, cores and well samples indicate that the Louisville is approximately 40 to 144 feet thick in the subsurface.

Fourteen quarries from Clark County to Allen County use the Louisville for aggregate and agricultural limestone. The unit generally provides acceptable stone except in some areas of Clark County where a variable amount of silt and clay affect the toughness, soundness, and porosity of the rock. Chert and shaly laminae are present

in some areas, but they have not been found in sufficient quantity to make the entire unit unsuitable for aggregate.

WALDRON SHALE: The Waldron Shale grades from gray to green calcareous shale in Clark County to dark bluish-gray dolomite of the Waldron Formation in Adams County. The unit is 5½ to 12 feet thick in southeastern Indiana but increases northward to more than 30 feet in Allen County.

No commercial use has been found for the Waldron in southern Indiana. Two quarries in Clark and Scott Counties have been forced to remove the shale to deepen their working section. In Adams County, however, the Waldron is about 95 percent dolomite and is used with overlying and underlying rocks as a source of crushed stone and agricultural limestone.

SALAMONIE DOLOMITE: The Salamonie of northern Indiana consists mainly of white to tan porous dolomite; in some areas the dolomite contains abundant skeletal material. Southward from Wayne County the Salamonie grades into two distinct units: an upper cherty limestone and dolomite unit (Laurel Member) and a lower argillaceous dolomitic limestone unit (Osgood Member). The Osgood-Laurel contact appears to be transitional in Indiana. The exceptionally pure dolomite of northern Indiana averages 150 to 180 feet in thickness and may exceed 200 feet in extreme northeastern Indiana. In most of southern Indiana the Laurel is less than 50 feet thick and may be overlain by middle Devonian rocks or by the Waldron Shale. The Osgood Member consists of interbedded shale and dolomitic limestone about 10 to 30 feet thick in southern Indiana.

Fifteen companies use the Salamonie for aggregate in eastern Indiana. The unit is a generally acceptable source of crushed stone except for some areas in southeastern Indiana where the Osgood Member is too argillaceous and where a relatively high degree of porosity has developed in the Laurel chert. Most of the chert appears to be restricted to a conspicuous well-bedded zone about 8 to 16 feet thick. Samples of chert from Clark and Jefferson Counties indicate an average specific gravity of 2.45 (range 2.3 to 2.6), which is the

minimum acceptable by the Indiana State Highway Commission for class A aggregate. Because the amount of chert and its specific gravity vary considerably, the Laurel should be examined carefully before exploitation.

BRASSFIELD LIMESTONE: The Brassfield Limestone in southeastern Indiana consists mainly of reddish-brown and gray coarsely crystalline limestones. The unit is less than 12 feet thick in most of southern Indiana and is absent in parts of Ripley, Jennings, Scott, and Decatur Counties.

Because of the high cost of removing the overlying Osgood and the absence of underlying commercial rock, the Brassfield is quarried in only two places in southeastern Indiana. Although the Brassfield contains some argillaceous material, several areas in southern Indiana contain limestones that test as class A aggregate (Carr, French, and Blakely, 1970). Until recently, both the Brassfield and the overlying Osgood were quarried in Wayne County where they are a source of class A stone.

ORDOVICIAN CRUSHED STONE SOURCES

Rocks of Ordovician age are quarried for crushed stone at only one location in Indiana. The quarry is in the structurally disturbed complex at Kentland in Newton County. Ordovician dolomites, which normally lie more than 1,000 feet deep in this area, have been severely faulted and folded and now stand almost vertically at the bedrock surface. The folded and faulted strata present some quarrying problems and the sandstone and shale units must be discarded, but the 300 feet of the Trenton and Black River Limestones and part of the Knox Dolomite exposed generally provide good crushed stone aggregate.

Transportation

Most crushed stone aggregate produced in Indiana is used in concrete and highway construction and is transported to the site by truck. The advantage that trucking has over other means of transportation is its ability to deliver large quantities of material directly to the market

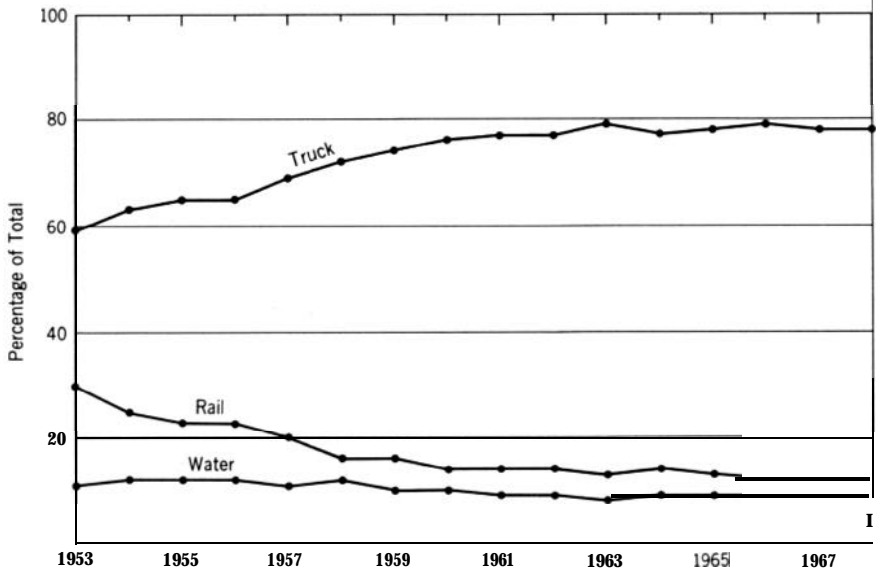


Figure 7. Percentage of crushed stone shipped by truck, rail, and water in the United States, 1953-68. Data from U.S. Bureau of Mines Yearbooks.

at the time the material is needed. During recent years, the percentage of crushed stone aggregate shipped by truck has increased, but the percentage of aggregate shipped by rail and water has decreased (fig. 7).

Because of the low unit value of the aggregate, the cost of transportation constitutes a large part of the price of delivered stone. Few quarries are isolated enough to be able to transport aggregate by truck farther than about 30 miles and still compete favorably with other quarries. The actual cost of road transportation is difficult to determine because it depends on many variables, but in 1967 one Indiana hauler charged 5 cents per ton-mile for the first 6 miles, 3 cents per ton-mile for the next 18 miles, and 2½ cents per ton-mile thereafter (French, 1969, p. 350). Long distance rates may be lower if return loads can be arranged. For example, aggregate can be hauled cheaply to southwestern Indiana where quarries are few because return loads of coal or sand and gravel reduce the cost.

Many aggregate operations in Indiana are near rail facilities, so that

crushed stone can be shipped to northern and western Indiana and to neighboring states. The northern one-sixth of Indiana contains no crushed stone quarries, so a large part of the crushed stone used in that area is imported by rail (Rooney and Ault, 1970, p. 186). A substantial amount of the crushed stone used in the Indianapolis area is supplied by rail from surrounding counties (French and Carr, 1967, p. 94). The cost of rail transportation varies considerably, but published rates in 1967 showed that the average charge was .61 cents per ton-mile plus 99 cents per ton minimum charge in southern Indiana and .92 cents per ton-mile plus \$1.84 per ton minimum charge in northern Indiana (French, 1969, p. 3.52).

Water transportation of aggregate produced in Indiana is limited to those quarries near the Ohio River. Large amounts of crushed stone for flux, cement, and lime are barged to northern Indiana via Lake Michigan, but these materials come from deposits in Michigan (Rooney and Ault, 1970, p. 182). Water transportation is much cheaper than other forms of transportation; according to French (1969, p. 352) it was “.4 to .65 cents per ton-mile for minimum barge loads of 1,200 tons (plus 50-100 cents per ton for loading and 100-200 cents per ton for unloading).” Some crushed stone from Indiana quarries have been shipped 200 to 400 miles on the Ohio River because of the economy of barge transportation. Rivers in Indiana are not able to accommodate heavy barge traffic at this time because of frequent low water level and river obstructions. Many quarries are conveniently located along the Wabash and Missis-sinewa Rivers, however, and should be able to supply aggregate to the aggregate-poor area of southwestern Indiana if water transportation becomes a reality.

Problems and Programs for Future Development

Crushed stone production in Indiana should continue its upward trend for some time because of the anticipated expansion of private and government construction. The crushed stone industry in Indiana is healthy and has large reserves that should last indefinitely.

Although stone reserves are large, they are not always in the most

desirable locations. Northern, southwestern, and southeastern Indiana are essentially lacking in surface stone deposits. These areas must import stone from surrounding areas or consider underground mining. Stone reserves, however, could be cut down drastically if they are made unavailable through either improper land use or injudicious zoning.

The rapid growth of urban areas in Indiana will create problems for the crushed stone producer. Noise, heavy-truck traffic, air pollution, and stream pollution are a part of nearly all stone operations and result in complaint and criticism by many people. And yet stone must be produced if construction is to keep pace with our expanding needs. Pollution abatement will therefore become a problem of increasing concern to the aggregate producer.

Rehabilitation of a quarry after production has ceased is also becoming a major problem for the aggregate producer. A derelict quarry can be a hazard and an eyesore to a community. The more progressive quarry operators in other states are finding that rehabilitation of a quarry site concurrent with quarrying can produce an attractive property suitable for conservation, recreation, or housing development. Some reclaimed quarries are proving to be more valuable than the stone that has been removed.

Literature Cited

American Railway Engineering Association

1964 - Ballast, pt. 2 of Engineering Division, AAR, specifications: 6 p.
American Society of Civil Engineers

1937 - Filtering materials for sewage treatment plants, in Manual of engineering practice, no. 13: New York, 40 p.

Blatchley, W. S.

1906 - A brief history of improved road building: Indiana Dept. Geology and Nat. Resources, Ann. Rept. 30, p. 1941.

Carr, D. D.

Crushed stone resources of the Blue River Group of Indiana: Indiana Geol. Survey Bull. _ [in preparation].

Carr, D. D., French, R. R., and Blakely, R. F.

1970 - Relationships between physical and chemical properties of the Brassfield Limestone (Silurian) in Indiana, Ohio, and Kentucky: Proc. Sixth Forum on Geology of Indus. Minerals, April 2-3, 1970, Ann Arbor, Michigan Univ.

Cottman, G. S.

1906 - The first thoroughfares of Indiana: Indiana Dept. Geology and Nat. Resources, Ann. Rept. 30, p. 41-53.

French, R. R.

1967a - Indiana's crushed stone industry, 1947-1965: Indiana Business Rev., v. 42, p. 7-11.

1967b - Crushed stone resources of the Devonian and Silurian carbonate rocks of Indiana: Indiana Geol. Survey Bull. 37, 127 p.

1969 - Transportation of mineral aggregates in Indiana: Indiana Acad. Sci. Proc. for 1968, v. 78, p. 348-354.

French, R. R., and Carr, D. D.

1967 - Geologic factors affecting the exploration for mineral aggregates in the Indianapolis area: Proc. 18th Ann. Highway Geology Symposium, April 20 and 21, 1967, Purdue Univ. Eng. Ext. Ser. 127, p. 86-103.

Goldbeck, A. T.

1948 - Mineral aggregates for railroad ballast, in Symposium on mineral aggregates: Am. Soc. Testing and Materials Spec. Tech. Pub. 83, p. 197-204.

Indiana State Highway Commission

1969 - Standard specifications: Indianapolis, 5 10 p.

Lamar, J. E.

1961 - Uses of limestone and dolomite: Illinois Geol. Survey Circ. 321, 41 p.

Mance, G. C.

1915 - Utilization of byproducts of Oolitic Limestone: Indiana Dept. Geology and Nat. Resources, Ann. Rept. 39, p. 237-312.

Patton, J. B.

1951 - Industrial limestone in Indiana: Sci. Monthly, v. 72, p. 259-265.

1954 - Petrology of laminated limestones in Indiana: Roads and Streets, v. 97, no. 8, p. 85.

Rooney, L. F.

1970 - High-calcium limestone and high-magnesium dolomite resources of Indiana: Indiana Geol. Survey Bull. 42-B, 20 p.

Rooney, L. F., and Ault, C. H.

1970 - Potential limestone and dolomite resources of northern Indiana, *in* Proc. Fifth Forum on Geology of Indus. Minerals: Pennsylvania Geol. Survey Mineral Resources Rept. M-64, p. 179-224.

Rooney, L. F., and Carr, D. D.

- Applied geology of industrial limestone and dolomite: Indiana Geol. Survey Bull. 46 [in preparation].

Sunderman, J. A., French, R. R., and Rooney, L. F.

- Cement raw material resources of Indiana: Indiana Geol. Survey Bull. _ [in preparation].

U.S. Bureau of Mines

- Minerals yearbooks and preprints [annual publication].

U.S. Department of Agriculture

1968 - Indiana agricultural conservation program handbook for 1968: 36 p.

Valton, P. A.

1947 - Limestone roads: London, Chapman and Hall Ltd., 112 p.

West, T. R., and Johnson, R. B.

1965 - Analysis of textural and physical factors contributing to the abrasion resistance of some Indiana carbonate aggregates: Indiana Acad. Sci. Proc. for 1964, v. 75, p. 153-162.

APPENDIX: PRODUCERS OF CRUSHED STONE IN INDIANA
(1970)

County	Producer	Quarry location	Stratigraphic unit quarried
Adams	John W. Karch Stone Co.	Geneva	Salamonie Dol.
	Meshberger Brothers Stone Corp.	Linn Grove	Louisville Ls., Waldron Fm., Salamonie Dol.
	Meshberger Brothers Stone Corp.	Pleasant Mills	Wabash Fm., Louisville Ls.
Allen	May Stone and Sand, Inc.	New Haven	Traverse Fm., Detroit River Fm., Salina Fm.
	May Stone and Sand, Inc.	Fort Wayne	Traverse Fm., Detroit River Fm., Wabash Fm., Louisville Ls.
	Midwest Aggregates Corp.	Edgerton	Traverse Fm., Detroit River Fm., Salina Fm.
	Stone Street Sand and Gravel Co.	Hessen Cassel	Wabash Fm., Louisville Ls.
	Midwest Aggregates Corp.	Fort Wayne	Detroit River Fm.
Bartholomew	Meshberger Stone Corp.	Columbus	North Vernon Ls., Jeffersonville Ls., Geneva Dol., Louisville Ls.
Blackford	J and K Stone Corp.	Montpelier	Louisville Ls., Waldron Fm., Salamonie Dol.
Carroll	Delphi Limestone Co.	Delphi	Wabash Fm. (Huntington Lithofacies)
Cass	Cass County Stone Corp.	Logansport	Kenneth Ls. Mbr., Kokomo Ls. Mbr.
	France Stone Co.	Logansport	Traverse Fm., Kokomo Ls. Mbr.
	Louisville Cement Co.* Engineering Asphalt Co.	Logansport Logansport	Kenneth Ls. Mbr. Kenneth Ls. Mbr.
Clark	T. J. Atkins and Co., Inc.	Jeffersonville	North Vernon Ls. Jeffersonville Ls.
	Louisville Cement Co.*	Speed	North Vernon Ls., Jeffersonville Ls.
	Appalachian Stone Div.	Utica	Jeffersonville Ls., Louisville Ls., Laurel Mbr.
	Sellersburg Stone Co., Inc.	Sellersburg	North Vernon Ls., Jeffersonville Ls.
Crawford	Hy-Rock Products Co.	Marengo	Ste. Genevieve Ls.
	Mulzer Crushed Stone Co.	Eckerty	Glen Dean Ls., Golconda Ls.
	Mulzer Crushed Stone Co.	Cape Sandy	Beaver Bend Ls., Paoli Ls., Ste. Genevieve Ls.
	Mulzer Crushed Stone Co.	Temple	Beaver Bend Ls., Paoli Ls., Ste. Genevieve

APPENDIX: PRODUCERS OF CRUSHED STONE IN INDIANA-Continued

County	Producer	Quarry location	Stratigraphic unit quarried
Decatur	Harris City Stone Co. New Point Stone Co.	Harris City New Point	Laurel Mbr. Laurel Mbr., Osgood Mbr., Brassfield Ls.
Delaware	Irving Bros. Stone and Gravel Corp. J and K Stone Corp. J and K Stone Corp.	DeSoto Eaton Muncie	Louisville Ls. Louisville Ls. Louisville Ls.
Grant	Pipe Creek Stone Co.	Sweetser	Liston Creek Ls. Mbr.
Hamilton	Stony Creek Stone Co., Inc. American Aggregates Corp. Irving Materials, Inc.	Noblesville Allisonville	Liston Creek Ls. Mbr. Liston Creek Ls. Mbr. Liston Creek Ls. Mbr.
Harrison	Corydon Crushed Stone and Lime Co., Inc. Davis Crushed Stone and Lime Co. Carl Mathes Stone Co.	Corydon Ramsey Corydon	Ste. Genevieve Ls., St. Louis Ls. Paoli Ls., Ste. Genevieve Ls. Ste. Genevieve Ls., St. Louis Ls.
Howard	Yeoman Stone Co.	Kokomo	Kokomo Ls. Mbr., Liston Creek Ls. Mbr.
Huntington	Erie Stone, Inc. Erie Stone, Inc.	Huntington Markle	Wabash Fm. (Huntington Lithofacies), Louisville Ls. Wabash Fm. (Huntington Lithofacies), Louisville Ls.
Jasper	W. C. Babcock Con- struction Co., Inc. Northern Indiana Stone Co. Baker Rockledge Products, Inc.	Rensselaer Pleasant Ridge Portland	Undifferentiated Devonian rocks, Kokomo Ls. Mbr., Wabash Fm. (Huntington Lithofacies) Undifferentiated Devonian rocks Salamonie Dol.
Jennings	Berry Materials Corp.	North Vernon	North Vernon Ls., Jefferson- ville Ls., Geneva Dol.
Lawrence	Bedford Ground Limestone Co.† Bloomington Crushed Stone Co., Inc. Lehigh Portland Cement Co.* Mitchell Crushed Stone Co., Inc. Oolitic Ground Lime- stone Co.	Springville Mitchell Georgia Bedford	(Uses spalls from Salem Ls) Beaver Bend Ls., Paoli Ls, Ste. Genevieve Ls., St. Louis Ls. St. Louis Ls. Salem Ls. Beaver Bend Ls., Paoli Ls., Ste. Genevieve Ls. St. Louis Ls., Salem Ls.

APPENDIX: PRODUCERS OF CRUSHED STONE IN INDIANA-Continued

County	Producer	Quarry location	Stratigraphic unit quarried
Madison	Concrete Materials Div.	Lapel	Wabash Fm. (Huntington Lithofacies), Louisville Ls.
	Anderson Rock Products, Inc.	Anderson	Jeffersonville Ls.
Miami	Kickapoo Sand and Gravel Corp.	Peru	Wabash Fm.
Monroe	Bloomington Crushed Stone Co., Inc. Bedford Ground Limestone Co.+	Bloomington	Paoli Ls., Ste. Genevieve Ls., St. Louis Ls. (Uses spalls from Salem Ls.)
Morgan	Clayton Winders and Sons	Lewisville	Harrodsburg Ls.
Newton	Newton County Stone Co., Inc.	Kentland	Cambro-Ordovician rocks
Orange	Calcar Quarries, Inc.	Paoli	Beaver Bend Ls., Paoli Ls., Ste. Genevieve Ls.
	Cave Stone Co., Inc.	French Lick	Beaver Bend Ls., Paoli Ls., Ste. Genevieve Ls.
	Radcliff, Inc.	Orleans	Paoli Ls., Ste. Genevieve Ls.
Owen	American Aggregates Corp.	Spencer	Paoli Ls., Ste. Genevieve Ls.
	Clayton Winders and Sons	Spencer	Ste. Genevieve Ls.
Perry	Mulzer Crushed Stone Co.	Derby	Glen Dean Ls., Golconda Ls.
Pulaski	Western Indiana Aggregate Corp.	Francesville	Wabash Fm. (Huntington Lithofacies)
Putnam	Harris Stone Service, Inc.	Bainbridge	Ste. Genevieve Ls., St. Louis Ls.
	Lone Star Cement Corp.*	Greencastle	Beaver Bend Ls, Bethel Fm., Paoli Ls., Ste. Genevieve Ls.
	Ohio and Indiana Stone Corp.	Cloverdale	Ste. Genevieve Ls.
	Ohio and Indiana Stone Corp.	Greencastle	Ste. Genevieve Ls., St. Louis Ls.
	Russellville Stone Co.	Russellville	St. Louis Ls., Salem Ls., Harrodsburg
	Concrete Materials Div. Concrete Materials Div.	Stilesville Manhattan	Harrodsburg Ls. Ste. Genevieve Ls.
Randolph	H and R Stone Co. Div. Baker Rockledge Products, Inc.	Ridgeville	Salamonie Dol. Salamonie Dol.
Ripley	Berry Materials Corp.	Versailles	Laurel Mbr.
	New Point Stone Co.	Napoleon	Laurel Mbr.

APPENDIX: PRODUCERS OF CRUSHED STONE IN INDIANA-Continued

County	Producer	Quarry location	Stratigraphic unit quarried
Rush	McCorkle Stone Co. Rush County Stone Co., Inc.	Milroy Moscow	Geneva Dol. Geneva Dol.
Scott	Scott County Stone Co.	Blocher	North Vernon Ls., Jeffersonville Ls., Louisville Ls., Laurel Mbr.
Shelby	Cave Stone, Inc. St. Paul Quarries, Inc.	Norristown St. Paul	Jeffersonville Ls., Geneva Dol., Louisville Ls. Laurel Mbr.
Sullivan	Kixmiller Brothers	Freelandville	West Franklin Ls. Mbr.
Switzerland	Tri-County Stone Co.	Cross Plains	Brassfield Ls.
Wabash	Creek Stone and Gravel Co.	Richvalley	Wabash Fm. (Huntington Lithofacies), Liston Creek Ls. Mbr.
Wanick	Peabody Coal Co.	Lynnville	Universal Ls. Mbr.
Washington	Hoosier Lime and Stone Co., Inc.	Salem	St. Louis Ls., Salem Ls., Harrodsburg Ls.
Wayne	DeBolt Concrete Co., Inc.	Richmond	Saiamonie Dol.
Wells	Erie Stone, Inc.	Bluffton	Wabash Fm. (Huntington Lithofacies)
White	Monon Crushed Stone Co., Inc. Ward Stone Co., Inc.	Monon Monon	Wabash Fm. (Huntington Lithofacies) Wabash Fm. (Huntington Lithofacies)

*Cement plant.

+Produces only ground limestone.

