ROLE OF A STATE GEOLOGICAL SURVEY IN THE DEVELOPMENT OF LIMESTONE AND DOLOMITE RESOURCES[1]

LAWRENCE F. ROONEY

Indiana Geological Survey, Bloomington, Indiana

ABSTRACT

The wide distribution of limestone and dolomite and the decentralization of the depedent industries give the State Geological Survey a major role in the development of these mineral resources. The amount of geological information necessary for efficient exploration is so large that few companies can afford to do the necessary basic field work or store the data. The state surveys fill these responsibilities and thus might be said to serve as the geological research departments of the limestone and dolomite industry.

At the Indiana Geological Survey, the data of most value to limestone producers are in the form of unpublished measured sections, well records, cores, chemical analyses, directories, and geologic maps. Much of this information is published in summary form. The Survey also assists individual members of industry in exploration and evaluation of mineral deposits. In addition, a progressive State Survey provides the geological information necessary for the development of new resources which do not appear to justify industry's own preliminary efforts.

The important role of a State Geological Survey in the development of limestone and dolomite, in fact, in the development of most industrial minerals, is inherent in the nature of the raw materials, the nature of the industry, and the abundance of data. Limestone and dolomite are cheap, widely distributed commodities, used in large tonnages. A significant percentage of limestone production is in the hands of small businesses, which, unlike the oil companies, cannot afford an exploration staff. The amount of data on limestone distribution and composition is so vast that even a large corporation would find difficulty in storing it in a retrievable manner.

These related facts, then, the decentralization of the industry, the wide distribution and low value of the raw materials, and the sheer abundance of data, give the State Survey its major role: to gather, organize, store, and distribute geological information to anyone interested in developing the mineral resources of the state. To illustrate this role, I will draw specific examples from the work of the Indiana Geological Survey.

COLLECTION AND STORAGE OF DATA

Quarry sampling.—Of the numerous data gathered by a State Survey, probably the most useful to the limestone industry are measured sections and chemical analyses of rock units. In Indiana, an attempt is made to visit each active quarry at least once a year so that any stratigraphic units recently exposed may be measured and sampled. If the quarry has been expanded greatly since the previous sampling, the entire section may be remeasured and resampled.

The Cave Stone Company's quarry (fig. 1) near Paoli is an example. Because the quarry had been considerably enlarged subsequent to an earlier sampling, it was resampled in 1962 from bottom to top. In this process, the rock units were first measured and described, and then channel samples were taken, one for each of the units. Back in the laboratory, these samples were crushed, split, and powdered for chemical analysis. One of the copies of the resulting analysis, obtained partly by standard wet and dry methods, but mostly by emission spectroscopy, was sent to the owner of the quarry (table). As a result of this pro-

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Table giving chemical and spectrographic analyses (in per cent) of samples from the Cave Quarries, Inc. quarry, Orange County, Ind. (SW¼ sec. 29, T.2N., R.3W.)

Unit	Thickness (feet)	Rock Unit	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	S	CO_2
35	8.0	Reelsville Limestone	91.2	1.92	4.20	.99	1.11	.015	.062	.053	41.1
33–34	18.0	Sample Formation (sandstone)*									
32	8.5	Beaver Bend Limestone	96.4	.90	1.51	.64	.36	nd**	.016	.021	43.1
31	6.5	Beaver Bend Limestone	88.2	4.98	3.88	.74	1.72	tr***	.020	.013	41.6
30	13.0	Bethel Formation (shale)*									
29	2.5	Paoli Limestone	96.4	.55	2.00	.67	.16	tr	.008	.019	42.6
28	2.0	Paoli Limestone	42.7	1.08	50.0	3.45	.88	.42	.009	.30	18.9
27	5.0	Paoli Limestone	95.4	.68	2.79	.72	.17	.013	.003	.078	41.7
26	4.3	Paoli Limestone	95.3	.77	2.82	.66	.21	.010	.004	.10	42.4
25	0.2	Paoli Limestone (shale)*									
24	4.7	Paoli Limestone	42.4	4.76	44.1	3.94	2.88	.89	.030	.61	22.3
23	2.0	Paoli Limestone	97.7	.64	.65	.64	.15	nd	tr	.050	43.2
22	3.3	Paoli Limestone	96.1	.73	2.21	.64	.14	.011	tr	.027	42.2
21	1.1	Paoli Limestone (shale)*									
20	3.8	Paoli Limestone	88.3	3.22	6.89	.72	.37	.017	.004	.11	39.2
19	2.0	Paoli Limestone (shale)*									
18	1.4	Paoli Limestone (sandstone)*									
17	0.5	Paoli Limestone (shale)*									
16	5.0	Ste. Genevieve Limestone, Levias Member	89.2	.45	8.82	.75	.29	.012	tr	.012	38.0
15	6.3	Ste. Genevieve Limestone, Levias Member	97.6	.41	1.40	.31	.074	nd	nd	.003	43.0
14	12.0	Ste. Genevieve Limestone, Levias Member	98.2	.36	1.03	.12	.043	nd	nd	.005	43.7
13	3.3	Ste. Genevieve Limestone, Levias Member	96.1	.62	2.21	.73	.10	.008	nd	nd	42.4
12	5.0	Ste. Genevieve Limestone, Levias Member	86.2	8.71	3.36	.85	.36	.016	.005	.025	41.1
11	2.8	Ste. Genevieve Limestone, Levias Member	97.6	.44	1.42	.23	.065	nd	nd	nd	43.0
10	1.8	Ste. Genevieve Limestone, Levias Member	98.2	.45	.82	.27	.052	nd	nd	nd	43.1
9	0.8	Ste. Genevieve Limestone, Levias Member	94.5	2.21	2.00	.58	.16	.008	nd	.005	42.9
8	2.1	Ste. Genevieve Limestone, Levias Member	95.8	1.58	1.81	.47	.11	.007	nd	.004	42.9
7	3.0	Ste. Genevieve Limestone, Levias Member	96.2	1.08	1.97	.43	.066	tr	tr	.008	43.3
6	8.0	Ste. Genevieve Limestone, Levias Member	92.9	4.46	1.80	.44	.15	.014	tr	.016	43.3
5	3.0	Ste. Genevieve Limestone, Rosiclaire Member	83.1	6.31	8.72	.98	.38	.045	.004	.066	37.6
4	0.3	Ste. Genevieve Limestone, Rosiclaire Member (mudstone)*									
3	3.0	Ste. Genevieve Limestone, Fredonia Member	96.8	1.31	1.32	.33	.046	nd	tr	.015	43.3
2	0.2	Ste. Genevieve Limestone, Fredonia Member (mudstone)*									

*Not sampled. **nd—not detected. ***tr—trace.

gram of systematic sampling and analysis, begun in 1947, measured sections and chemical analyses are now on file for all the active and many of the inactive quarries in the state, as well as for a number of natural exposures.

Cores and well records.—Measured quarry sections, of course, are not the only stratigraphic data useful to the limestone industry. The records of thousands of wells, including cuttings, drillers' logs, mechanical logs, and lithologic strip logs, drilled in the exploration for oil and gas, provide much information on limestone and dolomite resources.

Cores provide some of the best basic geologic data and should therefore be readily accessible for study. At the Indiana Survey, a split half of each core is stored so that no more than two small boxes need be handled at one time. Air-conditioned facilities are provided for visitors who wish to study the rocks in detail. Anyone who has struggled with cores in their usual habitat of dimly lighted basements or barns—alternately frigid or hot, depending on the season—appreciates the advantages of examining them where a large part of one's energy is not expended in just staying alive.

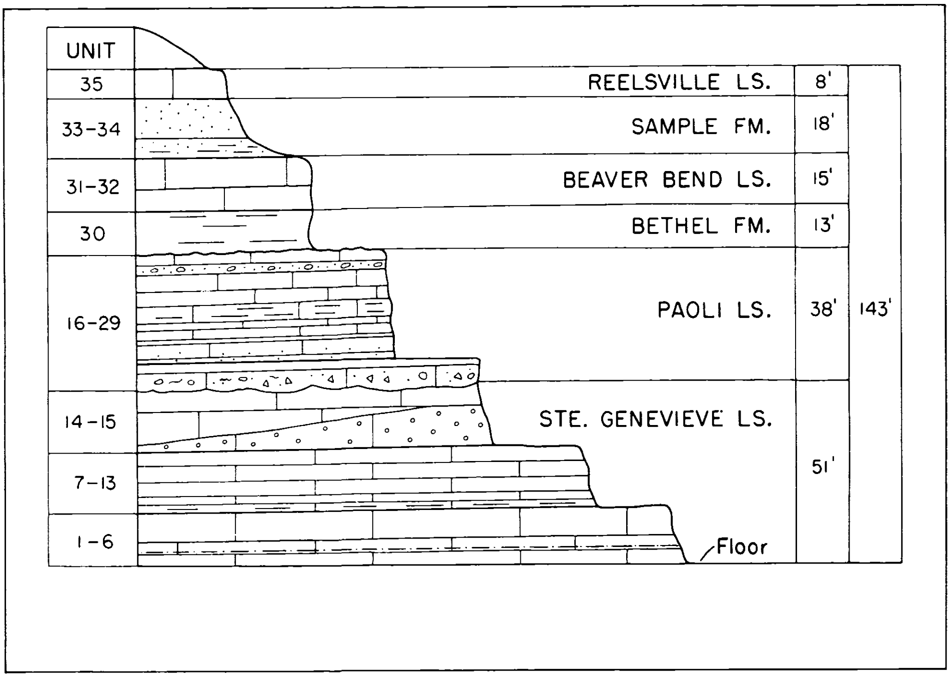

FIGURE 1. Columnar section of the rock exposed in the quarry of the Cave Stone Company Inc. near Paoli, Indiana.

Directories.—At the same time that the quarries are sampled, statistical data are obtained for use in mineral directories. Although directories are among the most useful publications printed, their usefulness is generally short-lived, for part of the information is out-of-date before it reaches print. Furthermore, the process of obtaining, tabulating, proofing, and printing such information is more expensive than the process required to bring out publications of more enduring value.

But the demand for mineral directories continues. Operators are interested in learning about competition in areas into which they might expand. Highway planners wish to know where aggregate producers are located with regard to proposed routes. Out-of-state industries desire to learn where specialty products such as high-calcium limestone or high-purity dolomite may be obtained in Indiana. Manufacturers of equipment wish to know their potential markets.

In an attempt to produce a directory that will answer these needs, be up-to-date, and yet be inexpensive, the Indiana Survey has made use of a digital computer. This computer can process and store large quantities of information, yet additions or deletions can be made easily and information can be printed-out in response to specific requests. Thus, it is not necessary to print large numbers of directories, many of which might never be needed. These directory print-outs would be prohibitively expensive in computer time, if it were not that the computer can print-out a few directories at little actual cost during its "free time." When a large number of the directories are needed at one time, a print-out can be made on a ditto master from which additional copies can be run off.

Maps.—Maps, of course, are a convenient form for summarizing and storing information, although control data must also be printed on the map in order to be able to distinguish between fact and interpretation. Except in a few parts of the United States, most published geologic maps are of such small scale that they are useful only in reconnaissance exploration. In the files of the Survey are some unpublished maps which are particularly useful in locating quarry sites.

In past years, the Survey has mapped three counties (Monroe, Lawrence, and Washington), in the southern part of the State, where much of the bedrock is not covered by glacial drift. Although none of these maps has yet been published, the 7½′ topographic quadrangle maps showing the geology are available for study in the Survey offices. Several characteristics make these maps highly useful in limestone exploration. The scale is large enough so that the geologic detail necessary to the selection of a quarry site can be shown. The topographic contours make it possible to estimate the thickness of the mapped units and evaluate drainage problems. Cultural landmarks, such as small towns, country churches, and country lanes, make it possible to foresee zoning and transportation contingencies. When the county reports are published, the 7½′ quadrangles will be collated and reduced in scale, but they will be otherwise unchanged.

One of the Survey's roles in the future, therefore, will be to continue this program of bedrock mapping on 7½′ quadrangles in other areas of Indiana.

Personnel.—Not all information of value to the limestone producer is to be found in the Survey files or publications. Much information, some of it of the most complex, subtle, and detailed kind, is stored in that best of all files, the human brain. Survey geologists spend their lives exploring, hammering on, and thinking about the rocks of their state. Specialists in allied fields, such as chemistry and physics, are available for consultation. Many requests can be answered directly from the experience of these men. It is surprising that all members of industry do not avail themselves of this resource; in my experience, those members of industry who come to us at all, come repeatedly.

SERVICE WORK

An important part of Survey work is service, both to private citizens and to industry. Some of the requests are inconsequential, such as requests for mineral identification. Many requests, however, come from industry, often for general information, such as the distribution of high-calcium limestone in the state. On the basis of data gathered mainly over the past 20 years, responses can be made quickly and effectively to most of these requests.

For example, a steel corporation came to the Indiana Survey in search of a supply of high-calcium fluxstone. Its representatives were directed to quarries which seemed likely sources, based on measured sections and chemical analyses. When the corporation had selected its supplier, based on analyses made by the corporation, the Survey was able to provide the quarry owner with the geological information necessary to maintain production of a high-quality fluxstone.

The owner of a quarry near Richmond, Indiana (fig. 2), asked for assistance in finding additional sources of stone because a new zoning ordinance was forcing him out of his present location. In the Richmond area, quarry sites are difficult to locate for two reasons: much of the limestone bedrock contains interbedded shale, and thick drift covers much of the area. A core, taken several years ago by the Survey near a stream about 2 miles northeast of Richmond, had penetrated some 40 feet of fair-to-good stone. On the basis of this information, the company put down a number of auger holes near the core site, but found that thick drift covered the bedrock. However, when the Survey was consulted some months later, an area was outlined where geological evidence suggested that the drift was thin. The company cored the area, found the geological evidence to be correct, leased the land, and is now quarrying.

Such service work brings up the matter of consulting, which probably troubles every State Survey one way or another. Some persons may feel that the purpose of a State Survey is to benefit everyone in general and no one in particular. But such an attitude leads to inactivity. A Survey benefits society by helping both individuals and corporations, and it is a wide gray boundary which separates the legitimate functions of a State Survey from those of a private consulting firm. It would be a mistake for a State Survey to permit fear of overstepping this vague boundary to inhibit its response to reasonable requests for assistance. If a limestone producer asks for information on high-calcium limestone along the Ohio River or for assistance in locating a quarry, he receives a summary of all such information available in the Survey files, unpublished as well as published material. When consultants come with the same requests, they receive the same response. Where it fits the Survey's overall research effort, staff geologists accompany interested persons to the field.

The real boundary that separates the Survey's work from consulting is in that elastic phrase, *where it fits the Survey's overall research effort.* Industry is assisted from the strength of accumulated experience, guided by what seems best for the state as a whole. If information can serve an immediate practical goal, it is so used. Unlike a true consultant, however, the Survey is not committed to any project designed to benefit any single member of industry. The Survey maintains the direction of its work and makes all results available to everyone.

PUBLICATIONS

If all the information gathered by a State Survey were kept only in open files, the public would not obtain the maximum benefit from it. Only by publishing the data can it conveniently reach the hands of the consumer. But, if all the Indiana Survey publications of possible value to the limestone and dolomite producer were to be listed here, the list would probably contain most of the literature published since the first annual report of 1869.

Much of the Indiana Survey's information is not published, however, and a substantial part of what is published is not readily available to most mineral producers. Even on the Survey itself, a new employee acquires a knowledge of all the diverse sources of information only over a period of years. The net result of such dispersal of data is that the mineral producer must come to the Survey even for much published information, or do without it.

In a sense, it would be desirable to publish all the raw data collected, because they are the bases for all our interpretations. However, such a procedure would be prohibitively expensive, and would require every one who used the data to go through their own delightful, but slow process of synthesizing the details into useful generalizations. It would be best if both the data and the generalizations could be published at moderate cost. That, in effect, is what the Indiana Survey is attempting to do in two current studies on limestone.

The purpose of these two studies is to summarize and to bring up-to-date all available information on the Mississippian Blue River Group (the Paoli, Ste. Genevieve, and St. Louis Limestones) and the Devonian and Silurian rocks (fig. 2), which together account for the major part of the limestone production in Indiana.

When published, each of these reports will present in complete or summarized form the most significant data available from both published and unpublished records. As planned, the appendices will be several times as long as the texts. For example, the report on the Devonian and Silurian rocks, now in its final stages, includes unpublished measured sections of all active quarries, chemical analyses

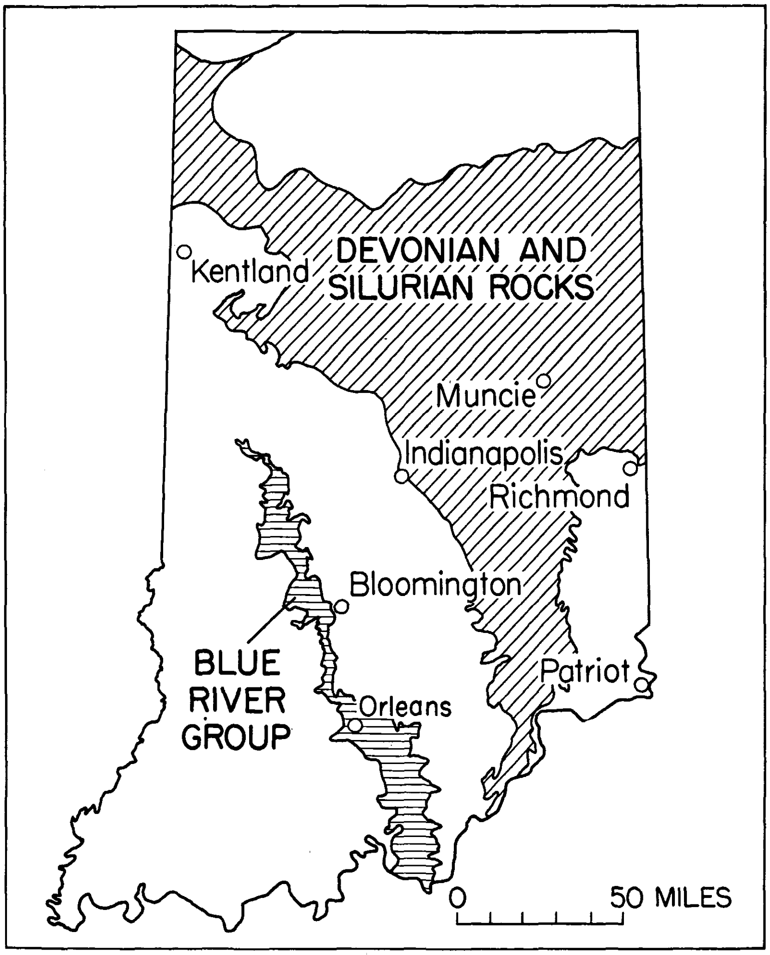

FIGURE 2. Map of Indiana showing distribution of the Blue River Group and Devonian and Silurian rocks.

of the rock units, core descriptions, and a list of published stratigraphic sections arranged by county. Thus, if a mineral producer wishes to know what information is available on the limestone resources of the Muncie area (fig. 2), he will find in this report the descriptions and chemical analyses of the rocks exposed in the three active quarries near Muncie, the average physical properties of the rocks, descriptions and partial analyses of two cores, references to descriptions of two abandoned quarries, and geological maps of the area. The same sort of information will be available in a concise and organized form for the rest of that part of Indiana covered by this report.

For most people, convenience is a big factor in following up ideas. With this report at hand, members of the mineral industry will be able to check out even random suggestions immediately, at least insofar as geological information is available.

NEW RESOURCES

Thus far, what might be considered the normal or typical activities of a State Survey with regard to the development of limestone resources have been discussed. One other important role remains to be mentioned: the development of new resources which, for one reason or another, do not justify industry's own preliminary efforts. This role has paid dividends in the past. For example, the Indiana Survey's investigation, in the early 1950's, of the Ohio River Formation

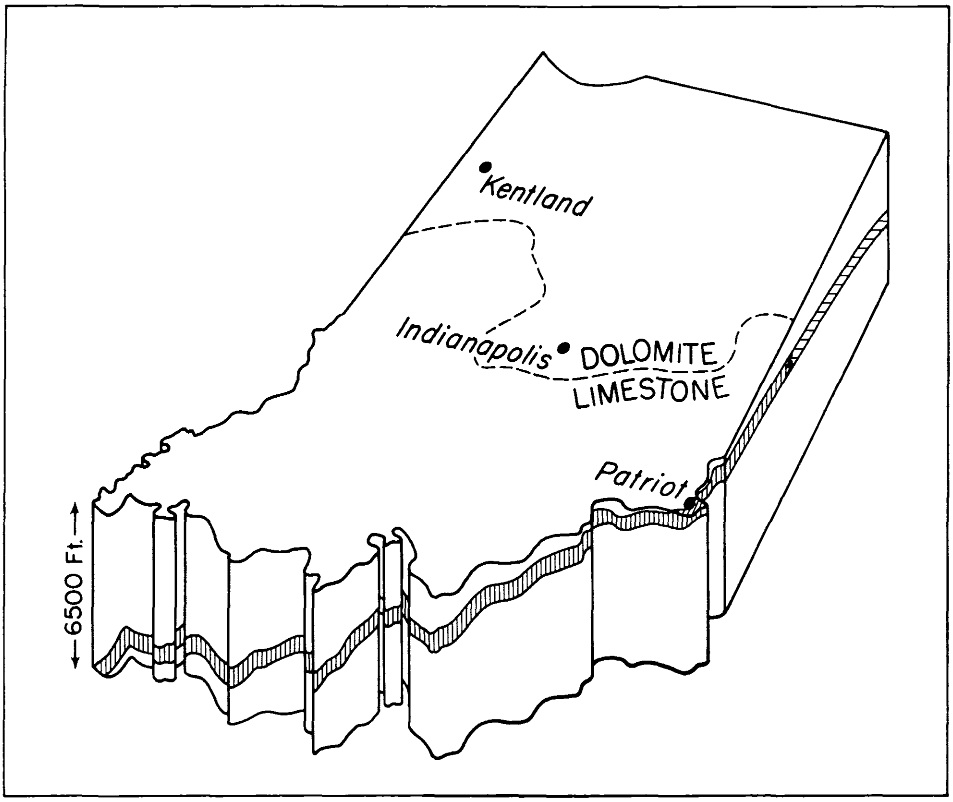

FIGURE 3. Block diagram of Indiana showing the Trenton and Black River Limestones and equivalent formations in cross-section.

as a source of high-silica sand led to the development of a new industry in 1963. It is hoped that the Survey's discovery, in 1964, of thick gypsum beds in northern Indiana will stimulate industrial exploration of those deposits.

More pertinent here is the Survey's effort to delineate the areas of high-calcium limestone deposits in the state, which might support new industries. The thickest exposed deposits of high-calcium limestone in Indiana are found in the Salem Limestone. However, the Ste. Genevieve Limestone contains lenses of oölitic limestone of even higher chemical purity and greater whiteness. It is believed that these lenses are probably beach bars, but not much evidence has been gathered to support this interpretation. Using the Failing 1500 drilling rig, which is one of the Survey's most useful research tools, it is planned to take a number of closely spaced cores in order to determine the shape, size, and orientation of at least one lens of Ste. Genevieve oölite. Many geologic relationships can be determined in quarries, such as the concordant, but non-interfingering nature of the contact between the oölite lenses and the superjacent and adjacent rocks (see unit 14 in fig. 1), but only by coring can the size and shape of the limestone body be determined. This information should aid industry in prospecting for similar oölitic limestone bodies which have been observed from Orleans to the Ohio River (fig. 2).

In addition to the Jeffersonville, Salem, and Ste. Genevieve Limestones, the Trenton and Black River Limestones merit consideration as a source of high-calcium limestone. Trenton and Black River rocks underlie all of Indiana, but are shallowest (200 to 650 feet) in the southeast corner of the state (fig. 3). Because these rocks are not exposed in Indiana (except in the unusual domal structure near Kentland), the Survey has only a few chemical analyses, but it is known that the Trenton and Black River rocks are dominantly dolomite in northern Indiana and dominantly limestone in southern Indiana (fig. 3). Rocks of equivalent age are utilized for high-calcium limestone elsewhere in the midwest.

Because underground mining of high-quality limestone has proved economical under certain conditions (such as at Barberton, Ohio, where the Pittsburgh Plate Glass Company has been producing limestone from a depth of 2,200 feet since 1942), the Indiana Survey also wishes to determine the state's high-calcium resources at depth. As part of this project a core has recently been taken through the Trenton and Black River Limestones near the Ohio River in southeastern Indiana, where the Trenton is closest to the surface (fig. 3).

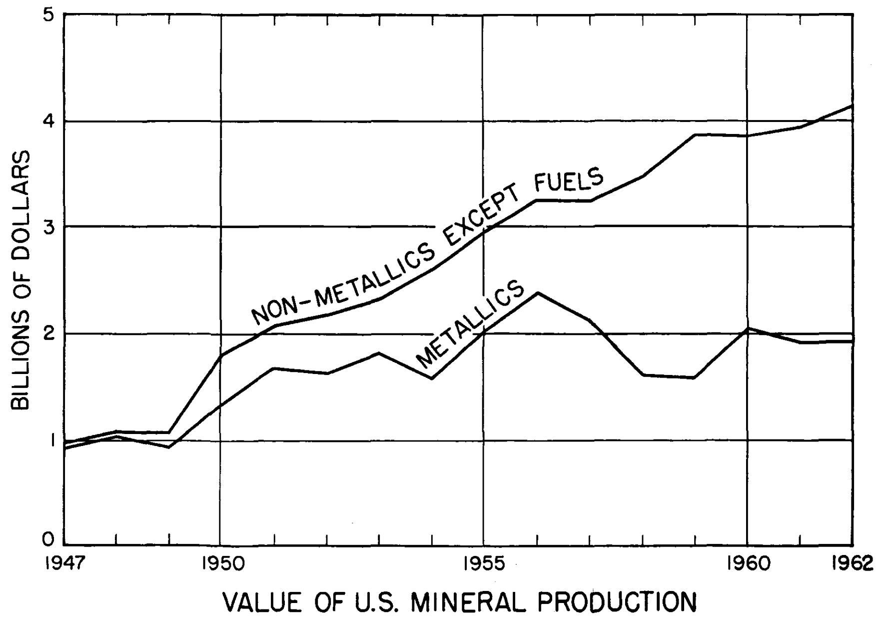

FIGURE 4. Production of minerals in the United States from 1947 to 1962, by value. (Data from U.S. Bureau of Mines, *Minerals Yearbook.*)

THE FUTURE

The absolute and relative importance of the nonmetallic minerals, including limestone and dolomite, in the nation's economy is increasing (fig. 4). In Indiana, the value of all industrial minerals increased from 37 to 55 per cent of the state's mineral production between 1951 and 1963 (fig. 5). The value of the stone (mainly limestone) produced in Indiana during the same period increased by 50 per cent (fig. 6). For the past 10 years, the total value of stone has equaled the value of petroleum; in the future, it will probably draw ahead.

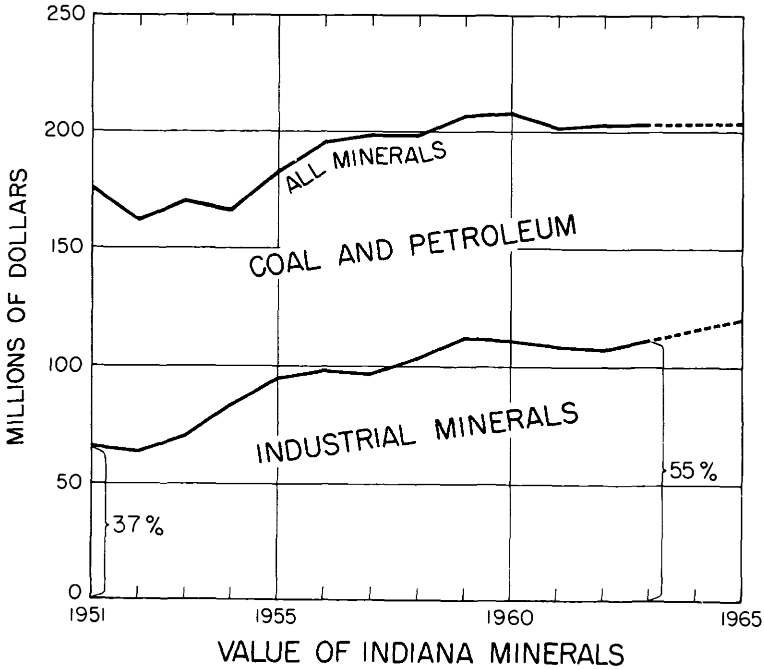

FIGURE 5. Production of coal and petroleum and industrial minerals in Indiana from 1951 to 1963, by value. (Data from U.S. Bureau of Mines, *Minerals Yearbook.*)

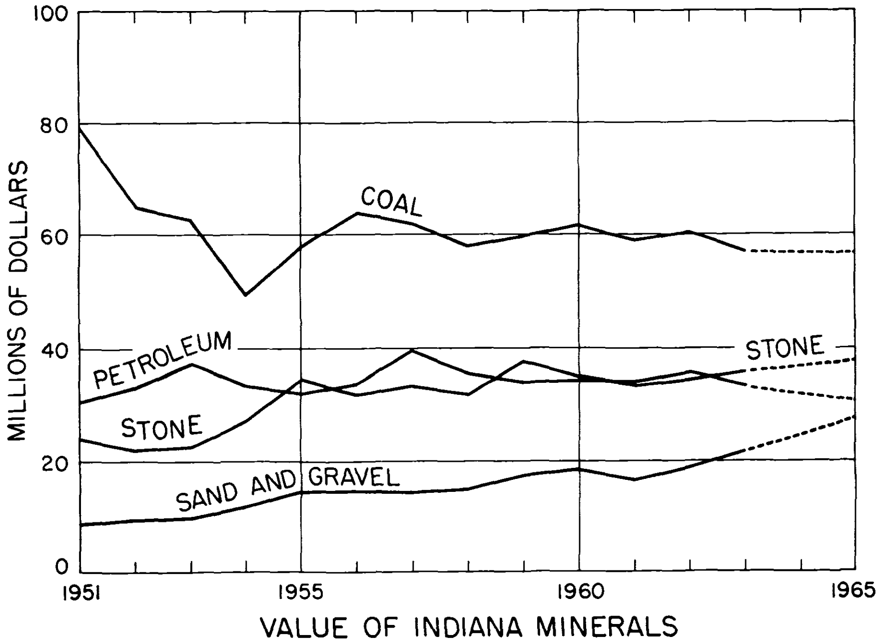

FIGURE 6. Production of coal, petroleum, stone, and sand and gravel in Indiana from 1951 to 1963, by value (Data from U.S. Bureau of Mines, *Mineral Yearbook.*)

What is true for Indiana is very likely true for most of the United States. The production of industrial materials, especially limestone and dolomite, will continue to increase more rapidly than will the production of metals and fossil fuels. But the geological and economic considerations which have given State Surveys their prominent role in the development of industrial minerals will probably not change appreciably. Industry will continue to rely upon State Surveys to provide the basic geological data on which to base exploration.

CONCLUSION

As the demand for limestone and dolomite continues to accelerate, the specifications to become more stringent, and the known reserves of high-quality stone to diminish, mineral producers in the United States must have available more and more precise information on the distribution and composition of limestone and dolomite resources. The volume of pertinent data and the cost of both gathering and storing this data are too large for the mineral producers to bear separately. The State Surveys have assumed these roles and also that of distributing these data, and should continue to do so. Industry should feel free to call upon the Surveys for information and assistance.

For maximum efficiency, however, the State Surveys must go farther and gather information beyond the fringe of present industrial endeavors so that the mineral producer will know the other options available to him. If industrial questions are anticipated, research time can be spent more wisely than if it is only used in hurried responses to immediate demands. Survey geologists, whose careers are based on understanding a state's mineral resources, can thus provide industry with new opportunities in industrial minerals.