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FRED H. DORHEIM

The Devonian System, in Iowa, is exposed in a belt about 50 miles wide extending along a line from Mason City to Muscatine (Figure 1).

The Devonian System, in Iowa, includes the following units:

SYSTEM	SERIES	GROUP	FORMATION	
Devonian	Upper	Yellow Spring	English River Maple Mill Aplington Sheffield	
			Lime Creek	Owen Cerro Gordo Juniper Hill
			Shell Rock	Nora Rock Grove Mason City
	Middle		Cedar Valley	Coralville Rapid Solon
			Wapsipinicon	Davenport Spring Grove Kenwood Otis Coggon Bertram
	Lower		LaPorte City	

With the exception of the Shell Rock Formation the Upper Devonian is essentially clastic, dominantly shale. The Middle Devonian is dominantly carbonate, and the lower Devonian, known only from subsurface, appears to be dominantly chert with minor amounts of carbonate (Parker, 1967).

Rocks of Devonian age probably have a greater variety of economic uses over a larger geographic area than the rocks of any other single system in Iowa. At the present time Devonian rocks are a source of aggregate, agricultural limestone, chemical limestone, raw material for cement manufacture and for the heavy ceramic industry, and are a source of gypsum. Rocks of this system are also used for storage of liquid petroleum gas and are the source of water for municipal and farm supply. These uses, with the exception of water supply, extend over a twenty-three county area. If

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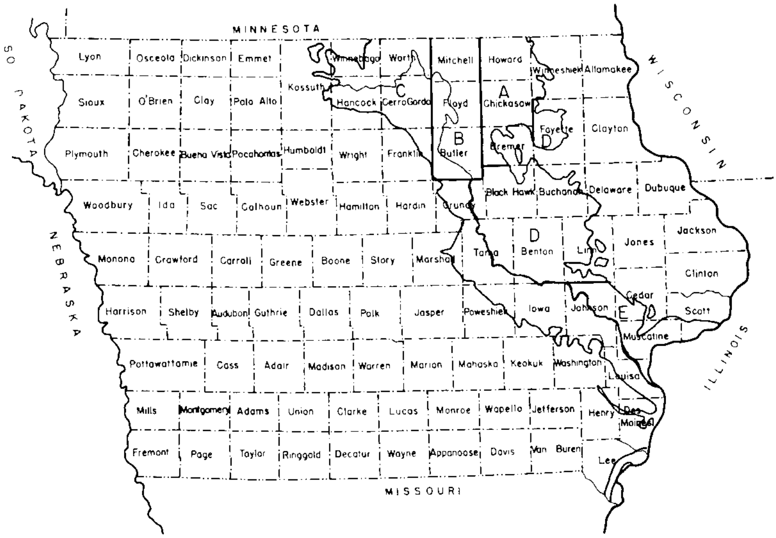

Fig. 1. Area of outcrop of Devonian in Iowa with five depositional regions designated.

water supply is considered as an economic use the area is greatly extended. According to the Iowa State Department of Health (1964) 121 municipalities in a forty-county area obtain all or part of their water from the Devonian. A tabulation of farm wells would undoubtedly enlarge this area.

Aggregate

The production of limestone aggregate for road construction and maintenance is the largest activity in Iowa's minerals industry. The total limestone industry produces over 25 million tons of stone each year. About 75 percent is used as aggregate in new road construction or as maintenance material.

The requirements for use of rock as aggregate are: (1) it must be sound or durable; (2) it must be hard enough to resist abrasion; and (3) for some purposes it must be relatively inert chemically.

Limestone and dolomite, or dolomitic limestone, from the Shell Rock, Cedar Valley, and Wapsipinicon Formations are used in the aggregate industry in Iowa. Of the 498 quarries now considered active or potentially active, 121 of them are worked in the Devonian.

I have divided the area of Devonian carbonate deposition into five geographic regions which, I think, are significant in relation to aggregate uses. In discussing these regions some broad generalizations will be made. In each region there may be exceptions to some of these generalizations.

In region A (see fig. 1) the bedrock that is quarried is from the Rapid or Solon Members of the Cedar Valley Formation. Throughout the region the rock is oxidized, rather completely dolomitized, porous, argillaceous, and soft. Generally it meets Iowa State Highway Commission specifications for lower grade (road surfacing and base construction) aggregate but fails, or very nearly fails, to meet higher grade specifications. There are a few quarries in area A that do not reveal the characteristics noted above. For example, one quarry northwest of Cresco does not show the deep weathering, oxidation or complete dolomitization characteristic of most of the rocks of the area.

Almost all of the quarries in region B are operated in the Coralville Member of the Cedar Valley. The deepest quarries extend a short distance into the Rapid. In these instances, and in exposures along major streams, the Rapid appears to have characteristics similar to those observed in region A.

The Coralville of area B in many respects resembles the Coralville of area D; it is hard, lithographic to sub-lithographic and has relatively few fossils. It differs from the Coralville of area D in that in area B the Coralville contains beds of shale often as much as a foot thick and the limestone itself is more argillaceous. For this reason it is not generally acceptable for high-grade aggregate (aggregate for portland cement).

In area D most of the bedrock consists of the Rapid and Solon, the lower two members of the Cedar Valley, or from the Wapsipinicon. There are local occurrences of Coralville. Other than the Rapid most of the carbonate units are less argillaceous in area D than in areas A and B. Several of the carbonate members do meet the specifications for the higher-grade aggregate (portland cement and asphaltic concrete).

Area E, in southeast Iowa, contains several quarries that penetrate the entire Cedar Valley and Wapsipinicon section. According to Iowa State Highway Commission records the Coralville, Davenport, Spring Grove, and Otis from this area provide high-grade aggregate and the other carbonate units provide aggregate for other road uses.

In area C most of the quarries are operating in the Shell Rock Formation and in the Owen Member of the Lime Creek Formation. For the most part these members meet the requirements for high-quality aggregate. The only quarries that are opened in the Cedar Valley in this area are in or near Mason City. The "cement ledges", formerly correlated as Rock Gove, and the underlying dolomite, formerly correlated as the Mason City, have been placed in the Cedar Valley by Koch (1967). The "Rock Grove" (Coralville of the Mason City area) is a high-calcium, lithographic to sub-lithographic limestone. The "Mason City" (also Coralville) is a coarsely crystalline dolomite. Both make high-quality aggregate. Although, in the "Mason City" dolomitization is just as complete as in the Cedar Valley of area A, these beds are not argillaceous (as in areas A and B) nor are they weathered.

In speculating on reasons for the variation in rock characteristics in these areas one sees that in region A the drift cover generally is thin. Also, to the best of our knowledge, outliers of Upper Devonian or later sediments are not known in A. We may then reasonably assume that this area was subjected to a long period of weathering both before and after the Pleistocene. The rock is deeply oxidized and more completely dolomitized in this region than in most of the area of occurrence of the Rapid and Solon.

The carbonate rocks of area C were deposited during late Middle Devonian and Upper Devonian in a more restricted basin. Apparently conditions did not provide as much clastic sediments, during periods of carbonate deposition, as in adjacent regions. There rocks do not appear to have undergone the long period of weathering that seems to have occurred in A.

Middle Devonian rocks of regions B and D have a greater percentage of argillaceous material as an integral part of the carbonate units than the rocks of region E.

Considering the Devonian area as a whole it appears that during the Middle Devonian the seas to the southeast were farther from sources of clastic sediments than were the seas farther north. Long periods of weathering and nearness to the shoreline were major factors in controlling the quality of the Devonian carbonate units.

Fine-Ground Limestone

Agricultural Limestone. About 10 percent of the total limestone production in Iowa is marketed as agricultural limestone. Approximately one-fourth of the active quarries in Iowa operate in the Devonian. Rocks of Devonian age then become a very important factor in the production of agricultural limestone.

Although we think of agricultural limestone primarily as a means of increasing crop production, and this is certainly an important economic aspect, there are other very important applications. Dr. J. B. Peterson (1968) in speaking of the role of agricultural limestone in national health says,

"Limestone is particularly important to human health largely because it contains calcium. . . . The major direct role of limestone in national health is the influence of the calcium released from it to be absorbed by the exchange complex of soils, taken up by plants and eventually by animals, including man. The role of calcium in human metabolism is spectacular. Not only does it function in the development of bones and teeth but also in regulating membrane permeability, in regulating neuro-muscular excitability, in clotting of blood, in regulating water metabolism and acidbase equilibrium, in holding cells together, in influencing respiration of such organs as the liver, kidney, spleen, brain and intestinal mucosa . . . and possibly increasing resistance to cancer.

Considering the great acreage of humid lands in this country which produce most of our foods and considering that this humid land area is naturally deficient in calcium in the zone of greatest root activity the importance of limestone, or of all agricultural liming materials for that matter, in our national health is apparent."

Limestone Dust. Another aspect of the uses of fine-ground limestone is brought out by E. A. Zawadzki (1969) of the National Air Pollution Control Administration. He says that one of the most serious elements of air pollution is SO_2. Stationary combusion units (electric utilities) are responsible for 81 percent of this emission. Although control of these emissions is still in the experimental stage, it appears at this time that one of the more successful controls is by injection of either wet or dry limestone or dolomite dust. The dry process is from 50 to 60 percent efficient; the wet process is about 90 percent efficient. Early in the control program it appeared that the wet process presented a problem of waste disposal which merely removed the pollution from the air and placed it in the water. Progress is being made, however, in removing the SO_2 from the water, probably producing an economically useful by-product.

Over the United States 1.7 million tons of sulphur were emitted during 1969. It would require from 10 to 11 million tons of limestone annually to control this emission. This is a relatively new market for limestone that may become increasingly important.

Cement Manufacturing

Although cement is an age-old product, portland cement is relatively new. The first patent for portland cement was granted in England in 1824 (McCoy, 1958). Portland cement was first manufactured in the United States in 1874.

The basic raw materials used in the manufacture of cement are: limestone, shale, sand and gypsum. The first three of these products are reduced to a fine grind and blended. This blend, composed of approximately 80 percent lime, 15 percent silica, and 5 percent alumina, (D. L. Erdenberger, personal communication, Feb. 1970) is burned in a rotary kiln to produce a clinker. Kiln temperatures are around 2700°F. The clinker is then reground and from 3 to 5 percent gypsum added to produce the final product—portland cement. The gypsum in the mix acts as a retarder. Without it the cement would set too fast to be workable.

Of the five cement plants operating in Iowa three obtain their limestone from the Devonian and two obtain both the limestone and the shale from the Devonian.

The two plants at Mason City, Lehigh Portland Cement Company and Northwestern States Portland Cement Company, obtain limestone from the Coralville Member of the Cedar Valley Formation. The shale used is the Juniper Hill Member of the Lime Creek Formation. Dewey Portland Cement Company, at Davenport, obtains limestone from the Rapid and Solon members of the Cedar Valley Formation and from the Davenport Member of the Wapsipinicon Formation. In the Mason City area the limestone used is a high-calcium limestone. Although for cement manufacturing the stone need not be high-calcium quality it must not be dolomitic. Dolomite, in either the limestone or the shale, increases the growth of the cement during the curing of the concrete and causes the concrete to become unsound. In the Davenport area the Rapid and Solon members are argillaceous limestone with large pockets of shale, the Davenport is a high-calcium limestone. The argillaceous limestone and the shale pockets provide part of the alumina that is required in the blend.

The Juniper Hill Shale used in the Mason City area does have a higher alkali content than is desirable and gumbotil is added in order to reduce the amount of alkali.

Clay Products

The Upper Devonian in Iowa is characterized by a dominance of clastic sediments—thick shales, siltstone, and silty shales with lesser amounts of carbonate. Two of these shale units have economic use in the heavy ceramics industry; the Juniper Hill Member of the Lime Creek Formation and the Sheffield Formation, lowest member in the Yellow Spring Group (Dorheim, Koch, and Parker, 1969). The Juniper Hill was mentioned previously in connection with the cement industry. In the Mason City area and at Rockford, about 15 miles southeast of Mason City, the Juniper Hill is used in the manufacture of brick and tile. At Sheffield, 18 miles south of Mason City, the formation named for that community (Sheffield) is used for the same purpose.

In order to be used in the manufacture of brick and tile or sewer pipe a shale must have these characteristics: (1) it must burn with a good color, (2) it must vitrify without warping, and (3) it must vitrify at an economical temperature. Color control is important in the marketing of brick. A producer must be able to produce a brick of desirable color and must be able to match that color in his brick production year after year. Warping, for obvious reasons, cannot be tolerated. Low vitrifying temperature is a matter of competitive economics.

At one time there were over 400 clay plants in Iowa. At the present time there are about 20 plants operating in the State. Competition and upgrading of specifications are the main reasons for the depletion in the number of plants. Most of those still operating produce a product that is competitive in a market that reaches from coast to coast and from Canada to the Gulf.

Gypsum

Gypsum is one of a group of three rock products that are classified collectively as evaporites. These three are: gypsum ($CaSO_4 2H_2O$), aanhydrite ($CaSO_4$), and halite ($NaCl$). Since salt (halite) is not known to occur in Iowa in economic quantities this discussion will be limited to gypsum and anhydrite. Of the two, gypsum has the greater economic use. Because one and one-half molecules of water can be removed from gypsum and later returned as water of crystallization when water is available, gypsum is the major raw material used in the manufacture of plaster, plasterboard and gypsum lath, structural gypsum block, and plaster-of-paris for medical and art uses. Both gypsum and anhydrite may be used as a source of calcium in soil treatment and as a retarder in cement manufacture.

Gypsum and anhydrite occur at two stratigraphic horizons in the Devonian, the Cedar Valley and the Wapsipinicon. The area in Iowa within which Devonian gypsum is known to occur is shown in figure 2 (Dorheim, 1966).

At this time the only production of gypsum from the Devonian of Iowa is at the U.S. Gypsum Company mine located about one

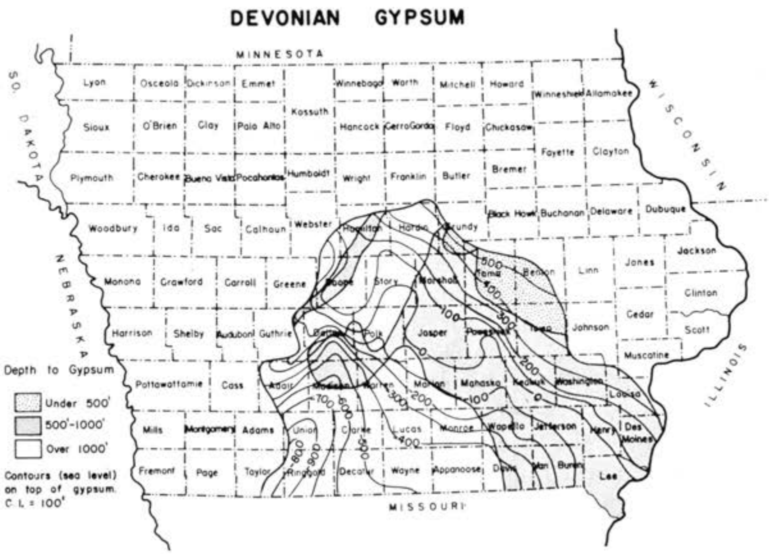

Fig. 2. Map showing area of evaporite deposition in the Devonian of Iowa.

mile southwest of Mediapolis. Here a 10-foot layer of gypsum is mined in the Wapsipinicon at a depth of 610 feet. From studies conducted at the Iowa Geological Survey it appears that in the Devonian sediments the probability of gypsum occurrence is best along the margins of the area and that deeper in the basin anhydrite will be the dominant evaporite. When the Fort Dodge gypsum deposits are depleted a logical area to explore would be along the northeast margin of the gypsiferous basin in Grundy, Tama, and Marshall Counties (see fig. 2).

Gas Storage

Although there are no petroleum refineries in Iowa, local storage of liquid petroleum gas (L.P.G.) is a very important factor in the economy of the distribution of this by-product. The gas is brought to Iowa through a system of pipe lines. During the low demand periods it is stored underground. By doing this, greater quantities are available for delivery to the consumer during periods of peak demand. Underground storage is safer and far more economical than surface storage. Shale in the Devonian, as well as other stratigraphic units, provide geologic conditions suitable for underground storage.

Near Des Moines L.P.G. is stored in a cavern excavated in the Sheffield Formation. The depth to the top of the cavern is 575 feet. The cavern itself is 20 feet from ceiling to floor and is constructed on a room and pillar pattern, common in mining practice. This particular cavern has a storage capacity of 200,000 barrels of L.P.G. (D. L. Koch. pesonal communication, Mar. 1970.)

Future of Economic Development in the Industrial Minerals of the Iowa Devonian

Over the past several decades Iowa has moved from a period of mud roads through a period of surfaced roads and narrow paving into a period of paved secondary roads and four-lane primary roads. The increased demand for construction materials places an additional responsibility on the aggregate industry. Furthermore, many Iowa counties that once thought they had an endless supply of Pleistocene gravels for road surfacing are finding their supply being rapidly depleted. Limestone mines will indoubtedly replace the gravel sources in supplying this market. The demand for food supply will not permit us to allow our farm-to-market road system to revert to mud.

According to agronomists much of our agricultural land has not been brought up to desired standards of soil fertility. In recent years the annual use of "ag-lime" in Iowa has been close to 3 million tons. The general figure used on lime requirements for Iowa is 7 million tons per year (F. W. Schaller, personal communication, Mar. 1970). About 1.6 million tons per year are required just to neutralize the nitrogen fertilizer used each year. The use of agricultural limestone has increased about 3 percent during the last ten years. With the increasing demand for food we can expect this to be even greater in the future.

Since it appears that limestone dust could possibly be one of the important methods for controlling air pollution it may become an ever greater factor in the market for fine-ground limestone.

According to the Public Housing Administration the establishment of new family units exceeds the construction of new family dwellings in a ratio of about two to one. If this trend continues the demand for constructional materials, including aggregates, cement materials, gypsum and clay products can be expected to increase appreciably in the foreseeable future.

As more and more of the easily available sources of raw materials are depleted and problems of pollution control, both air and water, increase, the demands on the geological profession are going to become more and more acute. We must, if we are to maintain a position of respect in society, accept our responsibility in helping to secure and protect the availability of the raw materials for this rapidly growing market.

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