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INTRODUCTION

Until recently all interest in gypsum in Iowa, with the exception of brief activity at Centerville, was centered around the shallow deposits in the Fort Dodge area. During the past five years, however, interest in deeper gypsum has developed in the southern part of the State and both industry and civic groups have participated in exploratory drilling programs. With the exception of the Centerville area, this interest started with information obtained from the files of the Iowa Geological Survey.

Currently five areas in southern Iowa have been explored with the diamond core drill. They are: Bussey, in Marion County; Albia, in Monroe County; Centerville, in Appanoose County; Ottumwa, in Wapello County; and Burlington, in Des Moines County. The cores from Albia and Ottumwa have been received for study by the Iowa Geological Survey and arrangements have been made to study the cores from other areas in the future.

It is the purpose of this paper to outline the methods of study used in the preliminary exploration program carried on at Albia and Ottumwa and to record some of the features observed in these cores. Since this paper does not attempt to solve any of the stratigraphic problems encountered, the writers have conformed to the nomenclature of the Geological Society of America correlation charts. A more complete study of the occurrence of evaporites in Iowa is under way and it is hoped that a report concerning the stratigraphy, geographic extent, and economic factors will be completed by next year.

ACKNOWLEDGMENTS

The Industrial Development Committee of the Albia Chamber of Commerce and New Industry for Ottumwa, Inc. paid the cost of exploratory drilling in their respective areas and have kindly loaned us the cores for study and have given permission to use the information obtained from that study.

Field personnel from several of the gypsum companies have given helpful suggestions as the study progressed.

The study of these cores and well cuttings has been done as a regular part of the activities of the Iowa Geological Survey. Staff members of the Iowa Geological Survey and of the United States

Geological Survey have been helpful in many ways. The information contained in this paper is presented with the permission of Dr. H. G. Hershey, State Geologist. To all of these we express our sincere appreciation.

METHOD OF STUDY

Gypsum and anhydrite occur together as a calcium sulphate, evaporite. Since, at the present time, only the hydrated calcium sulphate, gypsum, has economic value, it is necessary to have a rapid semi-quantitative means of differentiating gypsum from anhydrite. Although hardness, color, and crystal shape are useful, it is quite difficult to distinguish gypsum from anhydrite visually by use of the binocular microscope alone. Therefore, the writers have used both the petrographic microscope and heavy liquids in their study. Some of the physical and optical properties of gypsum and anhydrite are listed below.

GYPSUM: $CaSO_4 \cdot 2H_2O$; monoclinic; cleavage, three directional, rhombohedral with plane angles of 66° and 114°. Hardness 1.5 to 2. Specific gravity 2.314 to 2.328. Color usually white to light tan. Indices of refraction lie between 1.520 and 1.529. The interference figure is biaxial positive with moderate axial angle. Extinction parallel to the best cleavage in sections parallel to (010).

ANHYDRITE: $CaSO_4$; orthorhombic; cleavage, three directional at right angles, parallel to (100), (010), and (001). Hardness 3 to 3.5. Specific gravity 2.899 to 2.985. Colors, white to light bluish gray. Indices of refraction lie between 1.570 and 1.614. The interference figure is biaxial positive with moderate axial angle. Extinction, parallel to the cleavage traces.

In the cores taken at Albia and Ottumwa both gypsum and anhydrite appear as a massive, coarsely crystalline rock that is somewhat translucent and is softer than the associated rocks. In rotary or cable tool drill cuttings the evaporite is usually easily distinguished from other sediments because of its relative softness and pearly luster.

In using the petrographic microscope cleavages are readily apparent. The Becke line is a quick convenient way to determine the relative indices of refraction. To do this an oil with a refractive index of 1.55 was used. The refractive indices of gypsum are lower than 1.55 and the refractive indices of anhydrite are higher. When raising the tube of the microscope the Becke line moves toward the medium with the higher index of refraction; when lowering the tube the Becke line moves toward the medium with the lower index. The angle of extinction is also useful. In anhydrite the extinction is parallel to the cleavage in all directions. In gypsum the extinction is parallel only to the one cleavage trace that is parallel to (010); in the other directions it is inclined to the cleavage.

In order to determine the relative amounts of gypsum or anhydrite in a mixed sample heavy liquids were used. By this method it was possible not only to separate the gypsum from the anhydrite, but also to separate them from other impurities that might be contained in the sample. Following is a list of the common sedimentary minerals and their specific gravities.

Gypsum	2.314—2.328
Quartz	2.653—2.660
Calcite	2.72 —
Dolomite	2.8 —2.9
Anhydrite	2.899—2.985

In using heavy liquids two mixtures of bromoform and alcohol were prepared. One mixture, having a specific gravity of 2.5, will float gypsum but will allow the other material in the sample to settle. The other mixture, having a specific gravity of 2.89, will allow the anhydrite to settle and will float all the other associated material. In order to have a constant check on the gravity of the liquid, changes being brought about either by temperature or evaporation, chips of known mineral composition are kept in the solution. It should be noted that the gravities of dolomite and anhydrite are very nearly the same. Dolomite, however, is rarely pure and rocks containing dolomite are usually of lower specific gravity than pure dolomite.

Sampling from the cores for both the petrographic examination and the gravity separation was done by making overlapping diagonal cuts with a coarse-toothed saw, collecting the powder throughout each 1-foot interval. A small amount of this powder was retained for study with the petrographic microscope. The remainder was screened on a Tyler 60-mesh sieve. That part retained on the sieve was then added, in equal amounts, to two test tubes containing the heavy liquid mixtures. The material passing a 60-mesh sieve is so fine that it remains in suspension in both liquids and retards the rate of separation. Observation of the materials separated in the two liquids gives a semi-quantitative estimate of the relative percentages of gypsum, anhydrite, or other impure substances contained in the sample.

When sampling from well drill cuttings, the evaporite chips were separated from the sample by use of the binocular microscope and these chips were then placed in the heavy liquid. The relative percentages were estimated in the same manner as when using the powder from cores. These results were then checked with the petrographic microscope.

Stratigraphy

Other than in the Fort Dodge area, the gypsum occurring in Iowa has been confined to two systems, the Mississippian and the Devonian. As far as is known at this time, the Mississippian gypsum occurs in the Warsaw formation with traces of it persisting upward

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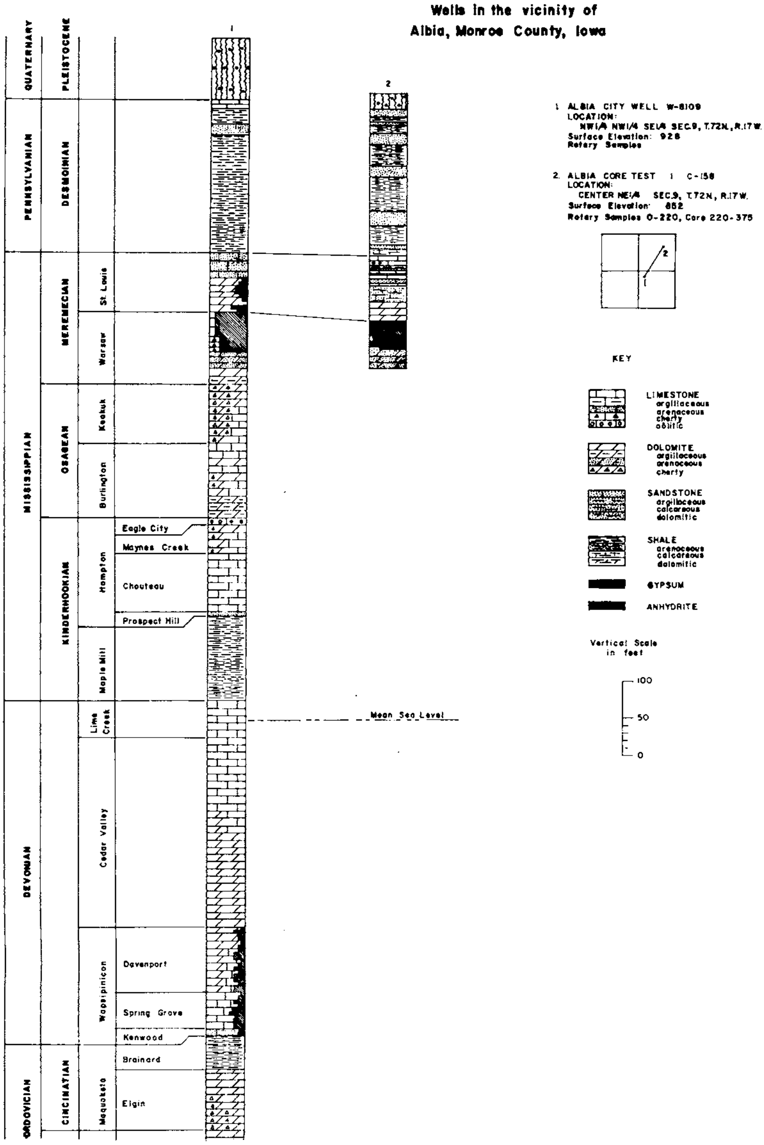
through the St. Louis formation. Future study may show that some of the gypsum, now placed in the Warsaw, actually belongs in the St. Louis. The Devonian gypsum occurs from the Rapid member of the Cedar Valley formation, downward throughout the entire Wapsipinicon formation.

PLATE I

Wells in the vicinity of Albia, Monroe County, Iowa



Two wells and two core tests were chosen for purpose of discussion in this paper. The Albia city water well (Plate 1) was drilled for the city of Albia in 1956. In studying the samples from this well it was found that a thick evaporite section occurs in the Mississippian system. Another, less pure, occurs in the Devonian system. The youngest Mississippian evaporite is found as scattered occurrences of both gypsum and anhydrite in the St. Louis formation. The upper 60 feet of the Warsaw is almost all evaporite. Of this 60 feet, the upper 5 feet is nearly pure gypsum, the lower 5 feet is gypsum with about 10 percent dolomite. All of the Warsaw between the intervals just mentioned is anhydrite except for a small amount of gypsum 20 feet above the base of the evaporite section.

In the Devonian portion of this well the main body of evaporite occurs in the Wapsipinicon formation with slightly more than a trace continuing upward into the Cedar Valley formation as high as the Rapid member. The evaporite occurring in the Wapsipinicon formation varies in amount from 10 to 30 percent but there is no part of the Devonian evaporite section in this well that is pure gypsum. At the very top of the Wapsipinicon formation, where evaporite comprises 10 percent of the total sample, 60 percent of the evaporite portion is gypsum and 40 percent is anhydrite. In the bottom 45 feet of the Wapsipinicon section, where the evaporite comprises 15 to 40 percent of the total sample, the gypsum portion of the evaporite varies from 10 percent to 60 percent and the anhydrite from 40 to 90 percent.

Because of the information obtained from this well the business men of the city of Albia formed an Industrial Development Committee, within their Chamber of Commerce, and raised the money to drill an exploratory hole through the Mississippian evaporite section. The Iowa Geological Survey worked closely with them on this project and the core hole, shown on Plate 1, was put down at a location about 1,500 feet north of the city water well. The evaporite section was encountered at a depth of 310.5 feet. The upper 7 feet is massive, medium to coarsely crystalline gypsum, so pure that in our sampling not a trace of anhydrite was detected. The next two feet is a mixture of gypsum and anhydrite is about equal amounts. Below this, from 320 feet to 329 feet, is a section of almost pure anhydrite with only scattered traces of gypsum. Gypsum is dominant again from 329 feet to 334.5 feet but with thin beds of agrillaceous limestone scattered through the section. The section is almost completely limestone from 334.5 to 336 feet but from 336 feet to 343 feet the section is again nearly pure gypsum. There is a 1-foot bed of pure anhydrite at 343 feet but from 344 feet to 348.5 there is again nearly pure gypsum. Limestone, with only traces of gypsum, occurs from 348.5 feet to the bottom of the hole at 375 feet.

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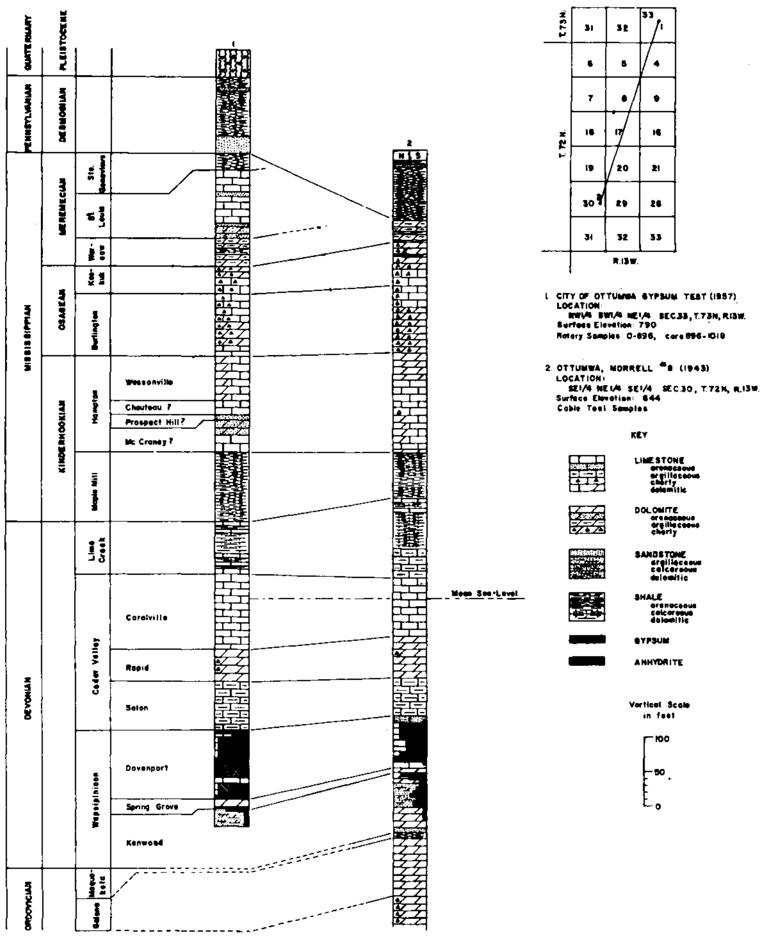
PLATE 2

Wells in the vicinity of Ottumwa, Wapello County, Iowa



A thick Devonian evaporite section was found in a well (Plate 2) completed for Morrell Packing Company of Ottumwa in 1945. In this well all of the evaporite occurs in the Wapsipinicon formation. In the Davenport member of this section, evaporites comprise from 50 to 80 percent of the total section. Our sampling of the cuttings show that the entire Davenport evaporite is anhydrite. The Spring Grove member, which occurs between 890 and 905 feet, is all limestone and dolomite. The Kenwood member of the Wapsipinicon has an evaporite section about 45 feet thick. The evaporite, which comprises about 50 percent of the sample, is almost all gypsum. The remainder of the sample is siltstone and shale.

Because of the amount of evaporite found in the Morrell well and because a similar occurrence was found in wells both at Hedrick and at Richland, in Keokuk County, the New Industry for Ottumwa, Inc. decided to drill and core an exploratory hole for gypsum north of Ottumwa. No Mississippian evaporite was found in this hole and all of the Devonian evaporite was found in the Wapsipinicon formation. At the top of the Davenport member there is a relative pure bed of gypsum about 2.5 feet thick. This is followed by about 90 feet of gray, crystalline anhydrite interbedded with thin limestones and with a few brown shale partings. At the very bottom of the Davenport section there is another section of light-gray, crystalline gypsum in a matrix of limestone breccia. The underlying Spring Grove member, about 13 feet thick, is a brown, porous, saccharoidal dolomite that contains irregular particles of anhydrite surrounded by gypsum (Figure 1B). In the Kenwood just below the Spring Grove-Kenwood contact there is another evaporite zone about four feet thick in which the upper two feet is light brown to gray gypsum speckled with dark brown and black spots of foreign material. The lower two feet is anhydrite with very little gypsum. Below this, the Kenwood member becomes silty and the anhydrite occurs as indi-

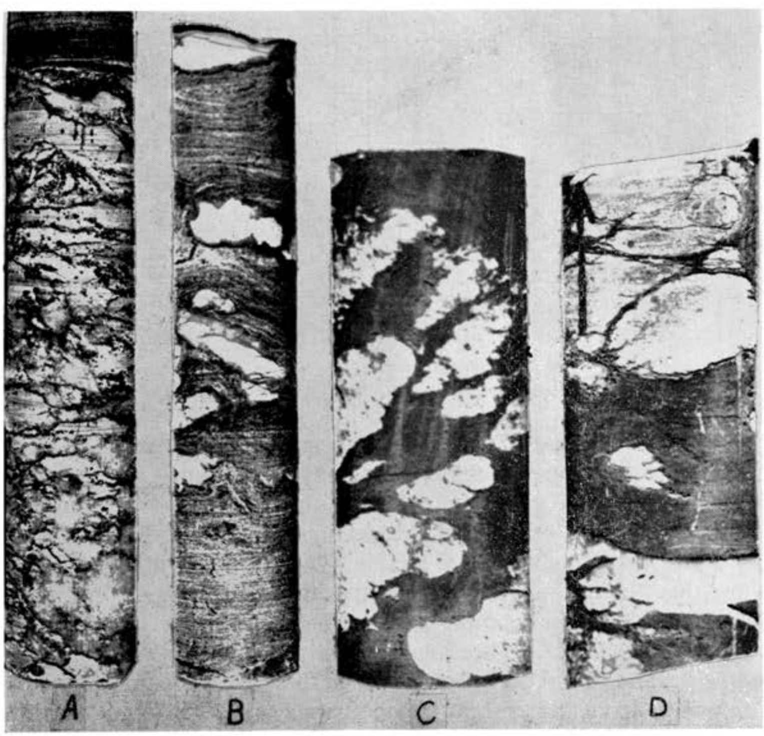


Figure 1. Diamond drill cores.

vidual nodules and the gypsum occurs as veins of satin spar emplaced secondarily along fractures.

Significant Features

Although it is not intended, at this time, to attempt to solve the problems of origin of the gypsum, there are some features that have been noted in the study of these cores that may be worthy of mention. In each occurrence of evaporite, referring to Plates 1 and 2, it will be noted that the gypsum occurs at the top and at the bottom of the deposit. In each instance the center of the deposit is nearly pure anhydrite.

Just above the Davenport-Spring Grove contact (Figure 1A) the gypsum and anhydrite occurs as a breccia in a limestone matrix. Below this contact at the top of the Spring Grove (Figure 1B) fragments of anhydrite are embedded in the porous brown dolomite. The band of material separating each fragment of anhydrite from the surrounding dolomite is recrystallized gypsum. Figure 1B also shows strong deformation in the dolomite around the gypsum-anhydrite nodules. It is only in the Spring Grove member that this recrystallization has developed to such a high degree.

The core shown in Figure 1C is from the Kenwood. The Kenwood is a very fine-grained, shaly, siltstone or silty shale, dense and relatively impermeable. In it the fragments of anhydrite show very little if any recrystallization around the edges. There are, however, veins of satin spar following fracture surfaces, as can be seen in Figure 1D.

These examples are too few to be considered as more than an indication, but they do suggest that at one time the entire evaporite deposit may have been anhydrite and that hydration from anhydrite to gypsum has taken place with the movement of water along bedding or fracture surfaces or in the more porous horizons.

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