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moisture content indicates it is an "apparent cohesion", relating to clay and water tensions, with little or no influence from carbonates.

Vertical and horizontal bore-hole shear tests at five additional locations in western Iowa now indicate that horizontal shear strength is not consistently different from vertical, but averages about the same. The horizontal shear strength is more variable, probably relating to faint sandy stratification observable on weathered faces of the bluff-line deposits. These shear data are included in an article accepted for publication in the Journal of Geology, Vol. 76, 1968.

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Ground Water Geology of the U.S. Gypsum Company, Sperry Mine

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Abstract. The geology relating to the U. S. Gypsum Company Sperry Mine, Des Moines County, Iowa, is discussed. Maps of the bedrock configuration, structure, and bedrock geology are presented and reviewed in light of the ground water condition existing in the area. Criteria which could cause mine flooding are investigated and evaluated.

The occurrence of an undesirable amount of water in an entry to a planned mining block in 1951 in the U.S. Gypsum Company Sperry Mine prompted this study. The amount of water encountered was small, approximately 10 gpm, but its presence pointed to a potential hazard. The flooding of U.S. Gypsum's Shoals, Indiana, mine, in 1960, caused the management to move cautiously.

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The mine is 610 feet below the surface in Devonian strata, and located approximately 11 miles north of the city limits of Burlington, Iowa, Des Moines County, on U.S. Highway 61 (NE¼, NW¼, Sec. 3, T 71 N, R 2 W). This places the mine approximately 2 miles south and 1 mile west of the rural community of Mediapolis, Iowa.

In order for a ground water hazard to exist, several contributing factors must be present simultaneously; they are: 1) a source of water; 2) availability of large quantities of water; 3) a mechanism to move the water from the source to the mine; 4) a medium to transport the water from the source to the mine. If the water is derived from a surface source, such as a stream or a near-surface aquifer, large quantities of water are available. The mine is 610 feet below the surface; therefore, an elevation head exists. The remaining criteria are the path and medium to transport the water.

The method of study involved the compilation of existing data from the literature and well logs on file at the Iowa Geological Survey, a survey of farm wells to obtain information of a geological nature, a drilling program in the mining area, measuring and recording water level fluctuation in bore holes, and mapping the mine to obtain all geological information available.

Geological Study

Geological study was aimed at better evaluating the criteria necessary for a ground water hazard.

Surface Geology

Pleistocene till and alluvium comprise the major units exposed at the surface. Rocks which crop out in the area are Pennsylvanian in the northern half of the county, and Mississippian in the southern half. Several known outcrops of Devonian (?) Maple Mill shale are also present. Outcrops of Mississippian strata occur along the bluffs of the Mississippi River, which borders the county on the east.

Subsurface Geology

The buried bedrock surface is dissected by deep, steep-walled valleys which are probably pre-Pleistocene age. The bedrock on the buried upland surface is Mississippian; the Devonian Maple Mill shale, and occasionally the Devonian Cedar Valley limestone, constitute the bedrock in the deep buried valleys.

The thickness of the glacial till varies from a few feet to approximately 100 feet on the upland surface, and up to 300 feet in the buried valleys.

The Mississippian limestones are part of the Kinderhook series. In places they have been removed by erosion during the

formation of the buried valleys and also thinned on the upland surface to an average of 45 feet.

The Devonian (?) Maple Mill shale has a thickness of 300 feet where overlain by Mississippian limestone. The shale is absent in isolated areas located beneath the bottom of the deep valleys.

The Devonian Lime Creek dolomite (approximately 10 feet thick) and the Cedar Valley limestone (approximately 120 feet thick) are generally present in full thickness.

The Wapsipinicon formation is composed of five members, of which only the upper three members are present in this area. They are, from youngest to oldest: Davenport limestone, Spring Grove dolomite, and Kenwood shale. The Otis and the Coggen members are absent. Total thickness is approximately 75 feet.

The Spring Grove member has an overall thickness of approximately 35 feet. The gypsum is located near the middle of this member. The Spring Grove member is fine-grained, thinly laminated, saccharoidal, buff to brown dolomite, and contains abundant steeply dipping calcite fractures. The top of the gypsum bed forms a sharp stratigraphic break with the dolomite, and the lower contact is gradational with dolomite below. The contact of the Spring Grove member with the underlying Kenwood shale is also gradational.

Structure

The study area is located near the Mississippi Arch (Howell, 1935) between the Forest City Basin, to the southwest, and the Illinois Basin, to the east. The axis of the Arch roughly parallels the Mississippi River. The regional dip to the west is 6 feet per mile, and to the east 12 feet per mile.

As a result of a recent study of Harris and Parker (1964) on a subregional basis, and by the writer on a local scale, smaller folds have been found superimposed on the regional structure. These folds have a NW-SE trend and display an enechelon pattern of doubly-plunging anticlines and synclines. The mine is situated near the crest of one of these anticlines.

A structure contour map representing the top of the Cedar Valley formation is shown in figure 1. It can be seen that the anticlinal trend is NW-SE, and the structure is higher in Louisa County and in Illinois than at the mine site.

During the mapping of the mine, joints were observed in the gypsum as smooth, near-vertical faces. From the small number of joints observed in the mine, a vertical joint set is postulated, with one group having an attitude of N 8-12° E, and the other N 45° E.

Bedrock Geology

Figure 1 also shows the distribution of the bedrock units ex-

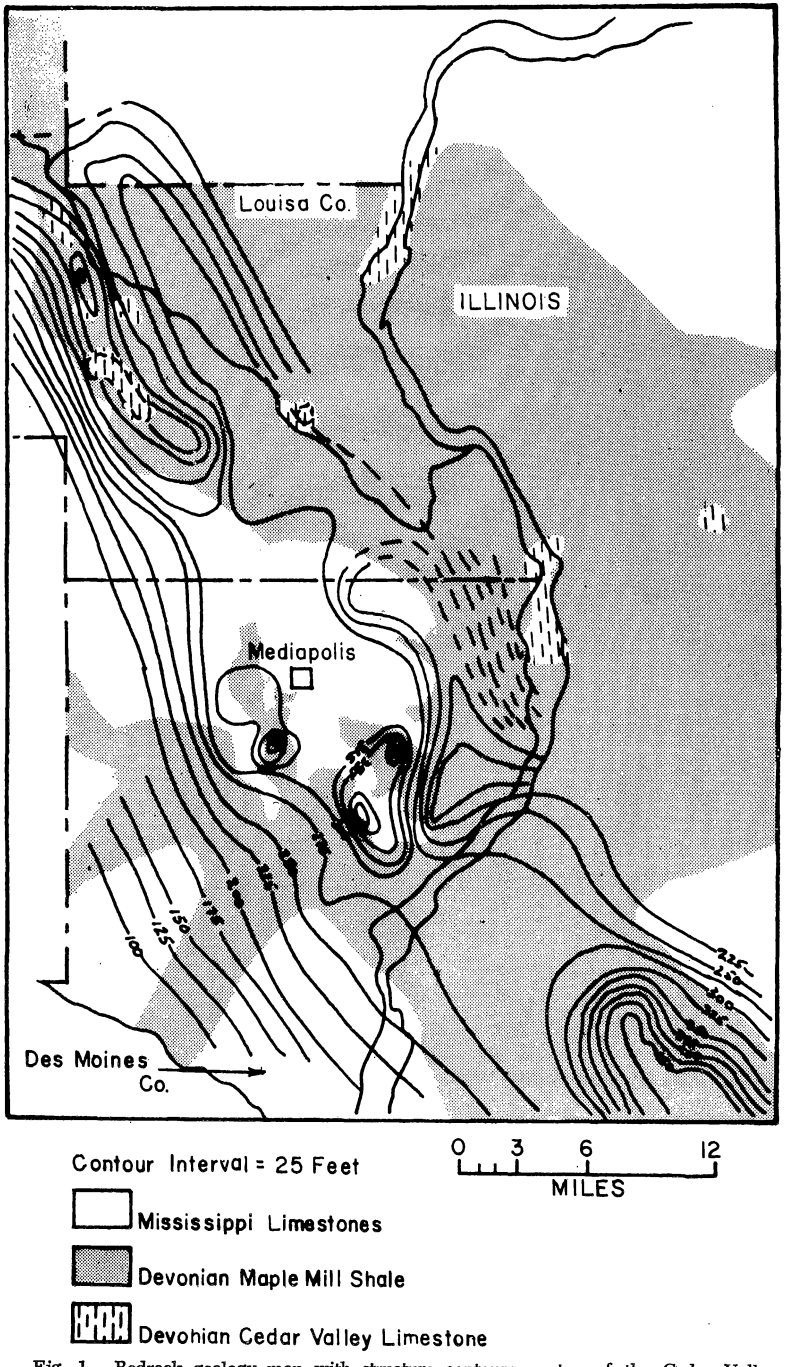

Fig. 1. Bedrock geology map with structure contours on top of the Cedar Valley formation.

posed beneath the overburden. Of interest here is the occurrence of Devonian Cedar Valley limestone. These outcrop areas are shown on the map. In general, these exposures occur west of the anticlinal trend. The closest location of one of the outcrops to the mine is beneath the Mississippi River north and east of Mediapolis.

Bedrock Configuration

The bedrock configuration can be observed from figure 1. The Devonian (?) Maple Mill outcrops in valley bottoms and therefore its pattern approximates the valleys. One main channel, the Poweshiek Channel, dominates the map in Louis County and trends NW-SE. A smaller channel, Washington Channel, lies to the south of the Poweshiek Channel and intercepts it beneath the Mississippi River. Many smaller tributaries are present on both the Poweshiek and Washington channels, and the edges of the valleys are very steep-sided, probably similar to the modern Mississippi River high bluffs.

Permeability Characteristics of Selected Units

A review of the literature shows that the Devonian rocks are not used for domestic or industrial purposes, as an aquifer, except when the Silurian rocks are present below, in which case the section produces large quantities of water. Therefore, the Devonian is not considered an aquifer in the absence of the Silurian.

The Mississippian rocks at the base of the glacial till contain a well-integrated system of joints and solution cavities. This unit supplies water for the city of Mediapolis, the Sperry plant, and farm wells able to penetrate this horizon.

Solution cavities have been encountered in both Louis and Des Moines counties at the Wapsipinicon horizon. In Louisa County, this was found by the loss of water during drilling, in Des Moines County by observations in the mine and loss of water during core drilling. Solution channels are considered common in gypsiferous zones; however, water was lost in only one of 18 holes drilled in the mine area, while a large percentage of the holes drilled in Louisa County lost water at this horizon, thus indicating that the solution activity is more widespread in this area. In Louisa County where solution cavities were encountered, the gypsum horizon was absent. In the vicinity of the mine, solution cavities occurred where a full section of gypsum is present. In holes outside of the gypsum deposit that penetrated the would-be gypsiferous zone, cavities were not encountered.

Drilling Program

A drilling program conducted in 1957 as part of the exploration

investigation provided some data in the form of drilling logs and core description. The 1957 drilling program placed holes on approximately 1/2-mile centers. A second drilling program conducted in 1961 spaced the holes on 400-foot centers in the vicinity of the mine shaft.

The holes were drilled by rock bit to the base of the Maple Mill shale and cored into the underlying Maquoketa shale. Casing was cemented into the top of the Maple Mill shale.

After each core run, the water level in the hole was measured, and after 30 minutes the water level was re-measured. If a change had occurred, another 30 minutes were allowed to pass, and a third measurement was made. When the holes were cased properly, the water level in the holes dropped sharply when the base of the Davenport member of the Wapsipinicon formation was reached.

A second type of measurement was made in selected holes to obtain an approximate value of the permeability. A packer was lowered into the hole and 5-foot increments between the packers were tested by pumping water under approximately 500 psi pressure into the 5-foot zone.

Discussion

Water may be derived from surface reservoirs, such as streams, lakes, or the shallow subsurface aquifer present at the base of the glacial drift. Water may also be derived from the Silurian aquifer, which is stratigraphically lower than the gypsum mine, but structurally higher to the northwest.

In order for surface water to enter the mine, it must pass through approximately 300 feet of Maple Mill shale. If the Maple Mill shale has not been breached in the vicinity of the mine, water could not get to the mine elevation from the surface. However, if the shale is cut at any location, this point becomes a potential source area. The first phase of this study involved mapping the bedrock configuration, structure, and bedrock geology in the vicinity of the mine. The results of these studies are shown in figure 1. It can be seen that the irregular bedrock surface is reflected in the outcrop pattern; that is, where the bedrock valleys are deep, Maple Mill shale is exposed in the bottom of the valley. On the buried upland surface the bedrock exposures are Mississippian limestone. In places where the rocks have been folded upward, and buried valleys exist above these structures, the Maple Mill has been completely removed and Devonian limestones are exposed in the valley floor. It also can be seen that several areas of Devonian Cedar Valley occur beneath the Pleistocene and alluvial deposits. One such area is to the north and east of the Plant site beneath the Mississippi

River. Another area lies directly north, approximately 11 miles, of the Plant beneath the Iowa River. Several other areas exist to the north and west approximately 15 miles north of Mediapolis on the crest of the structure. All of these areas could act as a source of water, especially the regions beneath major streams.

All of these outcrops occur between elevation 375 and 425. The elevation of the mine is approximately 170 feet above sea level; therefore, a minimum of 200 feet of head exists between potential source areas and the mine.

A deep aquifer source of water, such as the Silurian, would not only need a path, but also a driving mechanism. The base of the Silurian occurs near elevation 290 approximately 15 miles to the northwest of the mine. Should a sufficient quantity of water be available in the Silurian, and should it be as good an aquifer as it is further to the north and northwest, it could create a potential hazard to the mine. The Silurian is absent in the vicinity of the mine; however, the relationship between the Silurian and the Devonian Wapsipinicon formation is such that the total thickness combined for these two units is 75 feet and relatively constant throughout Louisa and Des Moines counties. Fifteen miles to the northwest of the mine, the Wapsipinicon is 20 feet thick and the Silurian is 55 feet thick. At the mine location, the Silurian is absent and the Wapsipinicon 75 feet thick. To the south and east, just across the Mississippi River in Illinois, the Wapsipinicon pinches out and the Silurian attains a thickness of approximately 75 feet. The question is, do these units vary in thickness or does a facies change exist?

The permeability of the Devonian rocks above the Davenport member of the Wapsipinicon appears to be very low. Because the Wapsipinicon does not outcrop beneath the Pleistocene drift and alluvial deposits in the area, the possibility of large quantities of water moving from the surface through this member is greatly reduced.

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