The Economic Potential of the Spergen Formation

in Seven Southeastern Iowa Counties

by
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in cooperation with
Iowa Geological Survey

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General Introduction

The middle Mississippian (Meramec Series) units include the Spergen Formation, the St. Louis Limestone and the Ste. Genevieve Formation which outcrop sporadically within a curvilinear subcrop band trending through southeastern and central Iowa (Fig. 1). Studies of these units as they occur in Iowa have been cursory in the past, especially with regard to the lowermost occurring Meramecan unit, the Spergen Formation.

The Spergen Formation, as it occurs in southeastern Iowa is being considered as a desirable concrete aggregate source. At present, the depth of occurrence, thickness variations and geographic extent are very poorly known and the nature of lithologic variation in Iowa is obscure. Due to a paucity of information of its thickness, extent and nature of rapid lateral facies variations, the full economic potential of the unit has not been realized in some areas of southeastern Iowa. This is especially disheartening in view of the decline of acceptable concrete aggregate source materials in southeastern Iowa.

This report is an attempt to synthesize subsurface and surface data in order to present a more coherent picture of the depth, thickness and lithologic variations of the Spergen Formation. Recommendations have been made for the exploration of specific areas within the field area for future development of surface quarrying and subsurface mining operations where thickness, lithology and depth characteristics deem consideration.

Due to the lack of adequate data points in some quadrants of the field area, some of the recommendations are drawn on rather tenuous grounds, but a concerted effort has been made to be conservative in these judgements.

Area of Study

Samples from the Spergen Formation were collected at 6 localities and mapped in the subsurface in a seven county area in southeastern Iowa (fig. 1). The field area includes Wapello, Monroe, Jefferson, Van Buren, Henry, Davis, and Des Moines Counties. Previously an effort had been made to include Louisa County into the consideration of the distribution of the Spergen Formation, but the unit was consistently recorded as not occurring in well logs, therefore providing no subsurface data to work with.

The localities sampled for petrographic analysis include the Heinold Quarry, Des Moines County, Cedar Creek Quarry, Jefferson County, Henry County Quarry, Henry County, Lewis Quarry, Davis County, and the Douds Mine, Van Buren County. A portion of a 375 foot drill core from a gypsum test near Albia, Monroe County was obtained from the Iowa Geological Survey for petrographic analysis. Collected section descriptions appear in the Appendix section of this report.

Method of Investigation - Maps

Isochore (depth to the top of the unit), thickness overlay and structure contour maps were constructed on base maps at a scale of 1:127,620. The base map was originally prepared by the Iowa Geological Survey as computer printout plots of well log locations for each county within the field area. Only well logs having precise locations to quarter of quarter sections or better were utilized, as well as logs having precise land surface elevations. In Henry County, land surface elevations had not been recorded for a number of older wells. Iowa Geological Survey personnel determined the elevation of these few points through altimetry during the summer of 1977. Well logs were selected from a computer printout supplied by the Iowa Geological Survey. The data

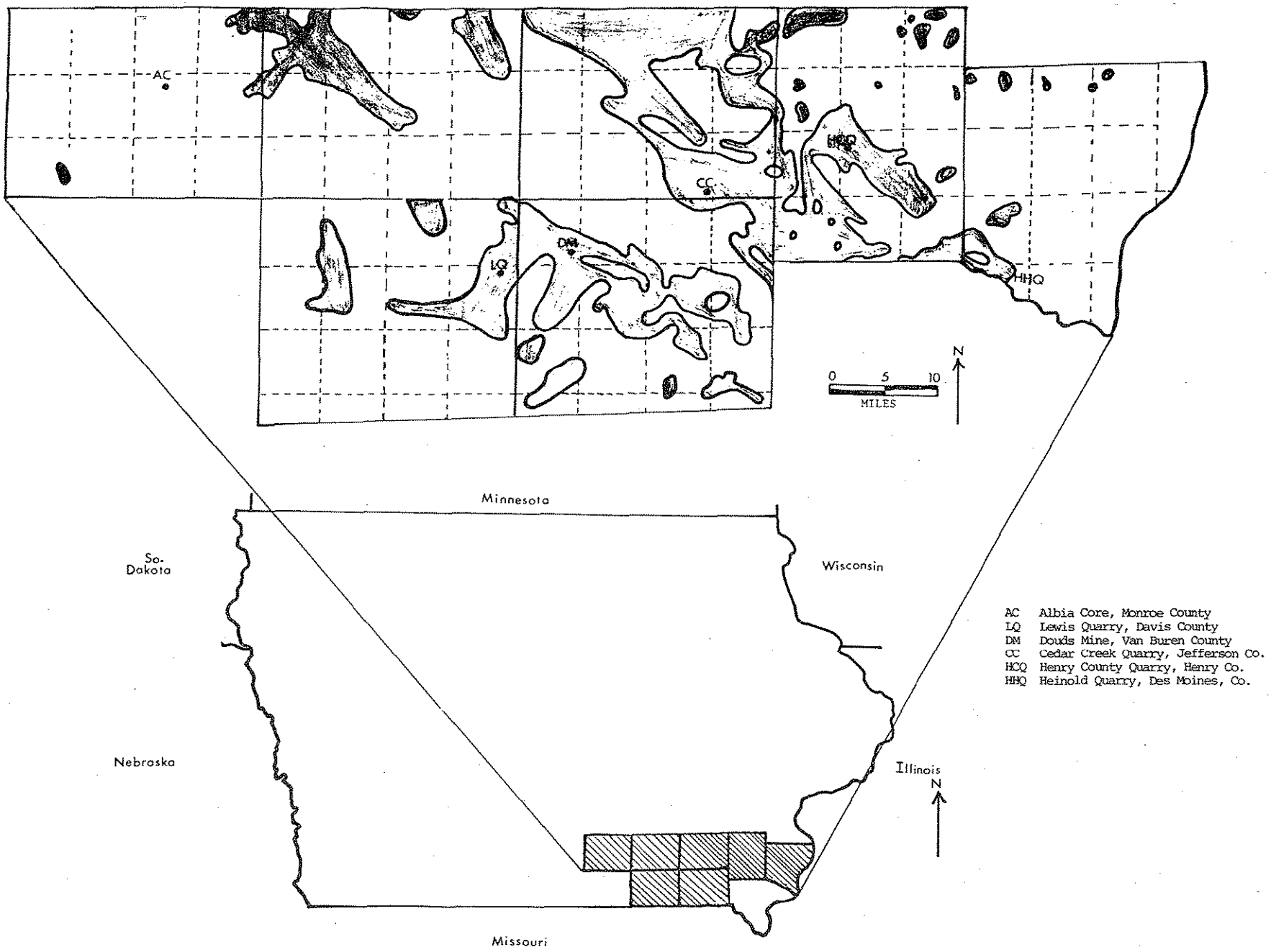


Figure 1 Distribution of Meramecan Bedrock in Southeastern Iowa: Distribution of Localities Sampled

used in this study included all of the well data available as of July 1978 for county numbers 26, 51, 90, 68, 44, 29 and 89. Wells available in counties numbered 62, 63, 54, 56 and 4 were used for stricter control along map borders.

Data specifically plotted include the elevations of both the top and bottom of the Spergen Formation, depth of overburden to the top of the unit (all unconsolidated sediments and stratigraphically higher Mississippian and Pennsylvanian units) and thickness of the unit. Contour intervals were determined by statistical analysis. Due to the complexity of the raw data, zero points (where no Spergen interval was logged) were removed from the isochore and structure contour maps (elevation of upper and lower Spergen Surface). This was done in order to smooth the upper and lower surfaces of the unit. However, zero points were plotted on the thickness overlay where no Spergen rock strata was recorded. This was performed to show the presence or absence of the unit necessary for economic evaluation, especially in areas of high zero data point distribution. A further discussion of the problems related to the numerous zero data points proceeds this section. Wells with partial penetration of the unit were used in the preparation of the thickness overlay and structure contour maps. Where only partial penetration of the unit occurred, a cross symbol plus the given value appears on the maps.

The quality of the well data varies considerably with the logging procedures used by individual workers. Due to a traditional confusion in the identification of the highly variable Spergen Formation, it is suspected that the unit has often been misidentified as the lower St. Louis Formation and recorded as such in well data. It is believed however, that gross trends in depth, structural configuration and thickness are adequately portrayed.

Petrographic Examination

The record of sedimentation of the Spergen Formation was closely examined at each of the field localities. In all cases, samples were collected of distinctive lithologies wherever lithologic changes were noted. Additional samples within distinct lithologies were collected where unusual sedimentary structures or fossils were observed. Seventy-five 46 x 23 millimeter thin sections were prepared commercially. Slides were stained by standard procedures (Dickson, 1965) for carbonate rocks with Alizarene Red S and potassium ferricyanide to determine the presence of dolomite, ferroan dolomite, calcite and ferroan calcite.

Lithologies were divided into 5 primary lithotypes, plus shales based mainly on the presence of dolomite, quartz sand, invertebrate fossil, and argillaceous components. These basic lithotypes are recorded in the collected section descriptions in the Appendix. A detailed petrographic study was done in order to characterize the Spergen lithology at working quarries. Except for the consistent presence of the five basic lithotypes, regional trends were not able to be discerned due to the great variability in lithology from one location to another. Petrographic analyses were made to characterize the carbonate facies of the Spergen Formation and to attempt to relate it to the general lithologic trends within local areas of each county under consideration.

A more detailed report of the petrography including the paleontology, diagnenesis and depositional environments of the Spergen Formation will be presented in a thesis in 1979.

ZERO DATA POINTS

Numerous data points recording zero thickness of the Spergen Formation are scattered within the field area, especially in a large portion of the northeast and central area of Henry County. The zero data points indicate areas where

the Spergen was logged to be nonexistent, with the St. Louis Formation recorded to directly overly the Warsaw Shale. A serious problem presents itself in the interpretation of the distribution and configuration of the Spergen Formation in the consideration of these zero data points. Zero points often occur in very close proximity to data points with considerable recorded thicknesses of the Spergen Formation, resulting in a very unusual surface and thickness configuration when mapped and contoured.

Two possibilities present themselves, the first being that the Spergen surface is a highly irregular, erosional "karst" surface, with the distribution of the high spots resembling "haystacks". Low points between the haystacks would then correspond to the points of zero thickness, the second consideration is that the transition of lithologies from the Spergen Formation to St. Louis strata is often unrecognizable in well cuttings. This would prevent the recognition of the Spergen as a distinct interval and be subsequently included as lower St. Louis Formation and not recorded as occurring.

After deposition of the Spergen Formation, a period of uplift and erosion most likely occurred. This period of erosion has most assuredly removed portions of the section, and in local areas, the St. Louis Formation may in fact be directly overlying the Warsaw Shale. However, field studies do not suggest the presence of large scale solution or "Karst" features. It is the author's contention that although total removal of the Spergen interval may have occurred in local areas, the unit has a more consistent distribution than is evidenced by numerous zero data points. More than likely, the Spergen Formation was not differentiated from the St. Louis Formation and was logged as not occurring. This complex lithologic transition is supported by field studies as well as the literature of previous investigations of the unit in the midcontinent.

Therefore, recorded well log thicknesses were not contoured but merely plotted as a thickness overlay to be used in conjunction with the isochore map, as a guide in gross thickness trends. The thickness overlay is a most useful tool in evaluating the economic potential of areas where high concentrations of zero data points occur, such as in eastern Henry County.

Mode of Interpretation

To facilitate interpretations of a rather complex array of Spergen subsurface data points, each county in the study area was divided into four quadrants and discussed separately in terms of subsurface depth and thickness trends as well as degree of lithologic variation. Map III records the location of all well logs used in the interpretations for each county. Following general discussions of the trends within quadrants are recommendations for further exploration for the development of surface quarrying or subsurface mining operations. Summary statements of the recommendations made for each county follow quadrant discussions. Areas have been designated as primary or secondary importance for further exploration consideration primarily on the basis of depth to the top of the Spergen.

As will be shown, primary lithologies consistently appear as dolomite, but secondary, tertiary and quaternary lithologic components are more variable locally. The detailed aspects of the variations of the lesser components of the Spergen lithology will be clearer only when additional local sampling can be done. A recommendation is made, however to make a statistical study of the ancillary components of the Spergen lithology as they are recorded in Iowa Geological Survey well logs. A study of this nature may provide a more coherent picture to the nature of the rapid lateral facies changes in the unit.

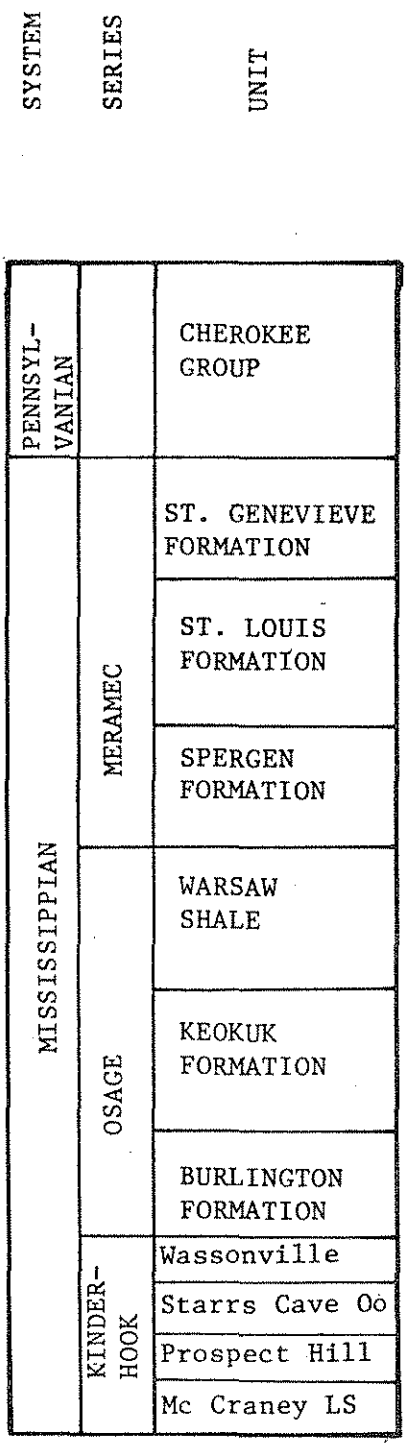
Areas of Spergen subcrop, where depths do not range deeper than 200 feet, where lithologies appear consistently as carbonates, and where thicknesses are not highly variable are recommended as areas for "primary" exploration. Areas designated as "secondary" refer to regions where high depth values, insufficient data points, or a high percentage of zero data points preclude a recommendation for immediate exploration.

Recommendations for subsurface mining operations are given where consistent lithologies, thickness values and high (greater than 200 feet) depth values appear. Areas designated as "tertiary" are not recommended for further exploration on the basis of high depth values, poor lithologies and a general lack of data points. Map IV is a summary of all recommendations for the seven county area, as well as showing the present distribution of working quarries.

General Geology

The Spergen Formation is the lowermost unit in the Meramecan Series, the middle of three Mississippian series recognized by the Iowa Geological Survey (fig. 2). In Iowa, the Spergen conformably overlies the Warsaw shale and is conformably overlain by the St. Louis Formation except where pre-Pennsylvanian, pre-Cretaceous and Cenozoic erosion has removed portions of the section (Campbell, 1966).

As a general rule, the Spergen Formation is distinguished from the Warsaw Shale by the amount of argillaceous detritus present. The upper Warsaw Shale is less pure carbonate than the Spergen and is represented by bluish gray shale beds intercalated with fine grained, dolomitic limestone lenses. The overlying St. Louis Formation is characterized by white to light tan, microcrystalline, arenaceous limestone and is extremely difficult to differentiate from the Spergen Formation on a lithologic basis. The selection



* NOT TO SCALE

Fig. 2 MISSISSIPPIAN STRATIGRAPHIC NOMENCLATURE IN SOUTHEASTERN IOWA

of a Spergen-St. Louis contact is highly difficult to discern within the Spergen outcrop area in Missouri, Southwestern Illinois and Iowa.

The contact has been drawn more or less arbitrarily by most workers in this tri-state area (Baxter, 1960). The selection of the Spergen-St. Louis contact in southeastern Iowa has traditionally been placed at a dolomite-limestone interface. Secondary dolomitization is not a uniform process and does not necessarily preferentially affect one unit over another. Therefore, depending upon dolomitization as a primary criteria for differentiating two units is not always reliable.

Pryor and Sable (1974) describe the Salem (Spergen) of Iowa, Illinois and Indiana as the first fluctuation in a tripartite succession of Meramecan rock units. The succession consisted of 1) the deposition of bioclastic and pelletoid carbonate sediments (Spergen Fm) 2) the deposition of fine grained carbonate precipitates and evaporites (St. Louis) and 3) the deposition of oolitic and arenaceous limestones and sandstones (Ste. Genevieve).

The Mississippian sediments of southeastern Iowa, Illinois and northeastern Missouri are believed to have been deposited on the margin of the Eastern Interior Basin (Illinois Basin) which appears to have been a slowly subsiding region with a vague north-south structural axis (Swann, 1963). The Meramec Series of Iowa represents oscillating periods of deposition and erosion under rapidly changing environmental conditions. Most likely, Meramecan seas were extremely shallow and periods of minor tectonic warping were able to cause distinct changes in sedimentation. The complexity of microfacies represented by the Spergen Formation of southeastern Iowa may be the result of the position of the Mississippi River Arch which stood as a structural high during the Mississippian. Minor movements of the arch would

cause the migration of shorelines and the chemical restriction of local areas. The complexity of the Spergen Formation in southeastern Iowa is not incongruous when considering the close proximity of the site of Spergen deposition to the Mississippi River arch.

Lithologies

Five basic lithotypes of the Spergen Formation have been designated as the result of petrographic microscopic analysis. Each lithotype will be discussed in a brief section, with mineralogical constituents reported. The mineralogy has been estimated on the basis of a series of point counts on representative slides of each basic lithotype. Photomicrographs of each of the basic lithotypes are shown in figures 3 through 10.

LITHOTYPE I

Lithotype I is characterized by light-colored carbonate rocks ranging from light gray to medium brown, on fresh surface, thin to medium bedded, dense and with a well developed subconchoidal fracture. Beds are even in configuration, most commonly, but undulose, laminated beds occur. Hand samples indicate a virtual lack of invertebrate skeletal debris as well as unusual textural features. Thin green shale microlaminations occur commonly in this lithology. A high percentage of these rocks are heavily dolomitized and have subsequently developed varying degrees of porosity. Patchy silicification features and associated chert nodule growth are representative of lithotype one.

Carbonate allochems comprise less than 1% of the overall rock volume and consist of indeterminate micritic grains and trace amounts of unidentified invertebrate skeletal debris. Quartz sand and silt-sized grains are a minor constituent, again comprising less than 1% of the rock

volume. The micritic matrix has been differentially recrystallized and inverted to dolomite within the microspar size range and comprises approximately 92% of the rock volume. Rare authigenic minerals and void spaces comprise the remaining percentage of the rock volume of lithotype I.

LITHOTYPE II

Lithotype II is characterized by light-colored rocks varying from light gray to medium brown on fresh surfaces and is medium to thinly bedded, well indurated and displays a well developed subconchoidal fracture. The samples of lithotype II rarely display any invertebrate skeletal debris. This lithology is commonly arenaceous and contains associated trace amounts of glauconite or chloritic clay minerals. Chert nodules are common, as are irregular patchy silification features.

Carbonate allochems comprise less than 1% of the overall volume, consisting of rare bioclastic debris and micritic or dolomitized intraclasts. Quartz grains, both silt and sand-sized average 10-11% of the total volume and are bimodally size sorted. Approximately 75% of the rock volume is composed of a differentially dolomitized microspar. Non-ferroan calcite, dolomite and ferroan calcite spar are present as void fill in amounts of 1-2%. Lithotype II has well developed porosity features which may or may not be filled with carbonate spar, or rarely with evaporite minerals. Authigenic minerals are present in trace amounts including microcrystalline chert, botryoidal chalcedony, macrocrystalline quartz, rare void filling glauconite, chlorite and opaque mineral concentrations.

LITHOTYPE III

Lithotype III is characterized by light tan to light gray highly arenaceous limestones to carbonate cemented

sandstones that are medium to thickly bedded and contain green argillaceous partings. Textures include laminated, draped, brecciated, and homogenous types. Rare invertebrate skeletal elements are present, as are silicification features, mainly nodular cherts.

Carbonate allochems comprise less than 1% of the overall volume, consisting of bioclastic debris and differentially dolomitized micritic intraclasts. A few of the samples appar to have a much higher concentration of intraclasts. Quartz grains, both sand and silt sized, comprise approximately 42% of the rock volume. This percentage is equally distributed between silt and siliceous detritus. Chert, tourmaline, perthitic feldspar, zircon, glauconite, and other unidentifiable minerals comprise 1-2% of the volume. Approximately 57% of the rock volume is comprised of irregular heavily dolomitized matrix which has been altered to dolomicrospar. Authigenic minerals are present in trace amounts, including microcrystalline chert, botroidal chalcedony, void filling chlorite or glauconite, celestite and altered pyrite.

LITHOTYPE IV

Lithotype IV is comprised of four subgroups which were divided on the basis of general percentages of micritic matrix, sand, invertebrate fossil debris, oolites, pellets intraclasts and void filling spar. The follow percentage distribution of the four subgroups of lithotype 4 was determined by point count analysis.

Distribution

	Mud	Sand	Bioclasts	Oolites	Pellets/ Intraclasts	Spar (void fill)	
Group 1-	27	0	35	0	7	31	%
Group 2-	92	0	5	0	2	TR	%
Group 3-	12	TR	13	0	42	33	%
Group 4-	26	20	44	TR	5	4	%

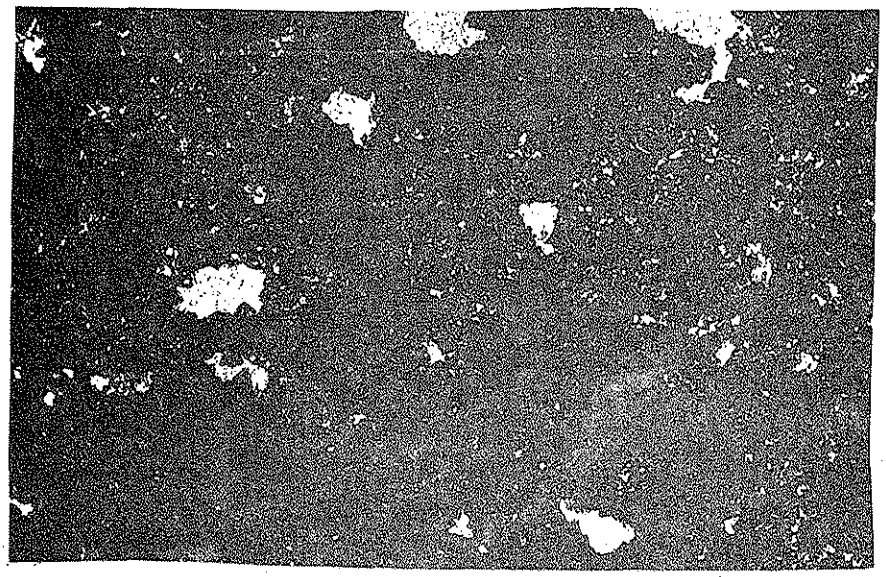


Figure 3 Lithotype I

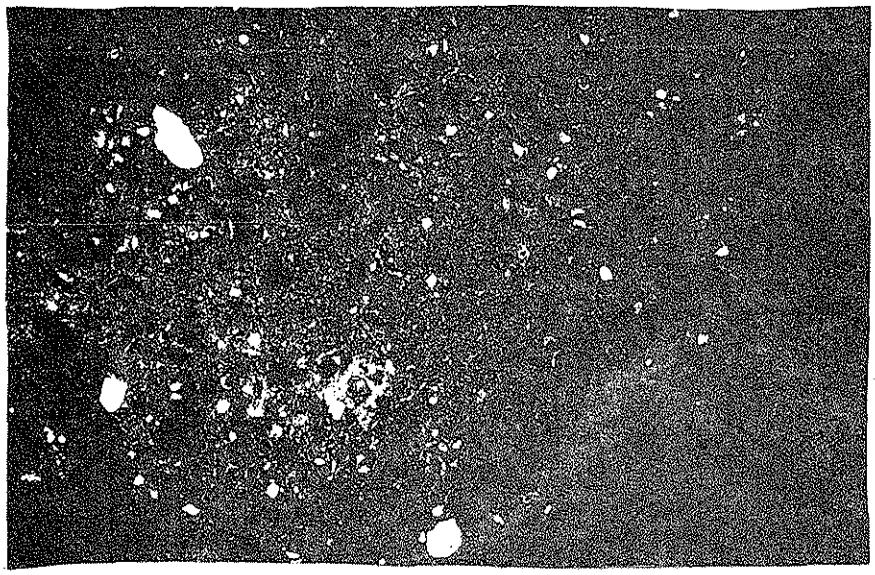


Figure 4 Lithotype II

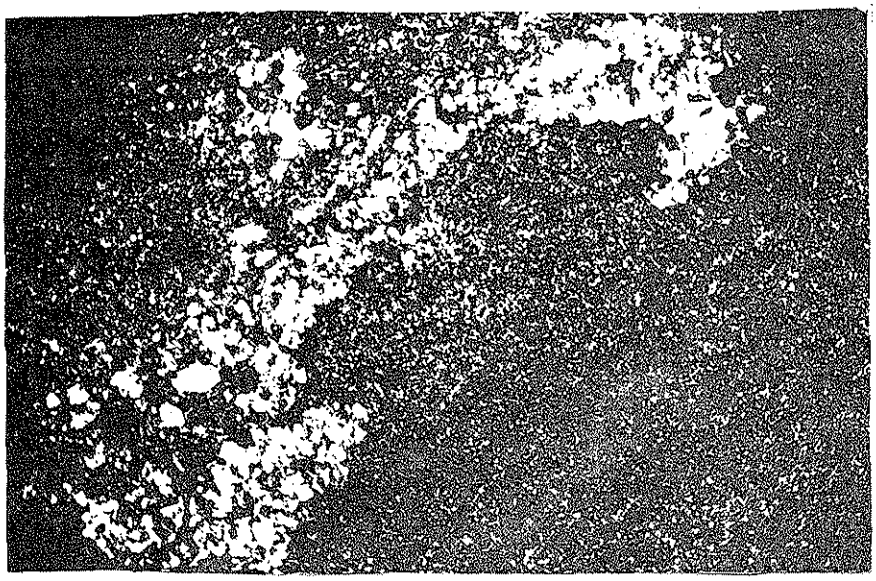


Figure 5 Lithotype III

Figure 6 Lithotype IV, Group I

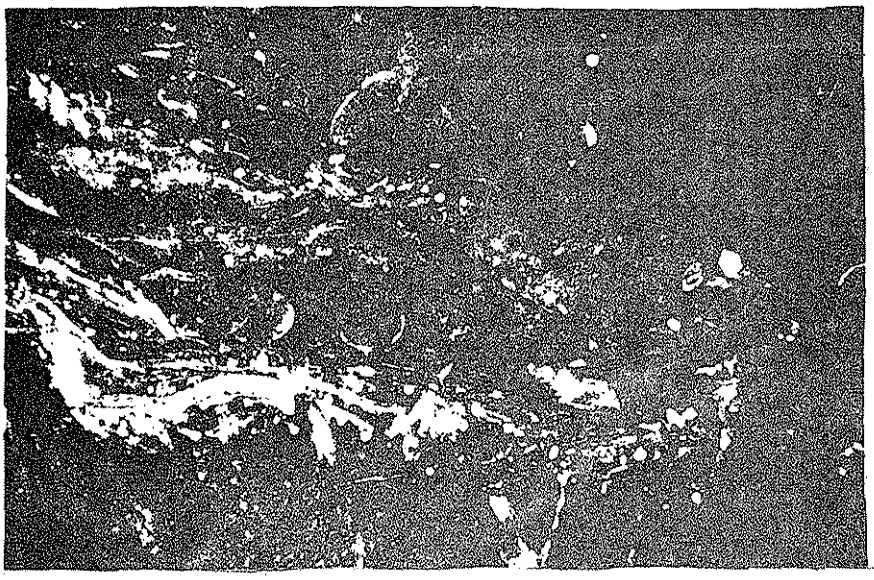


Figure 7 Lithotype IV, Group II

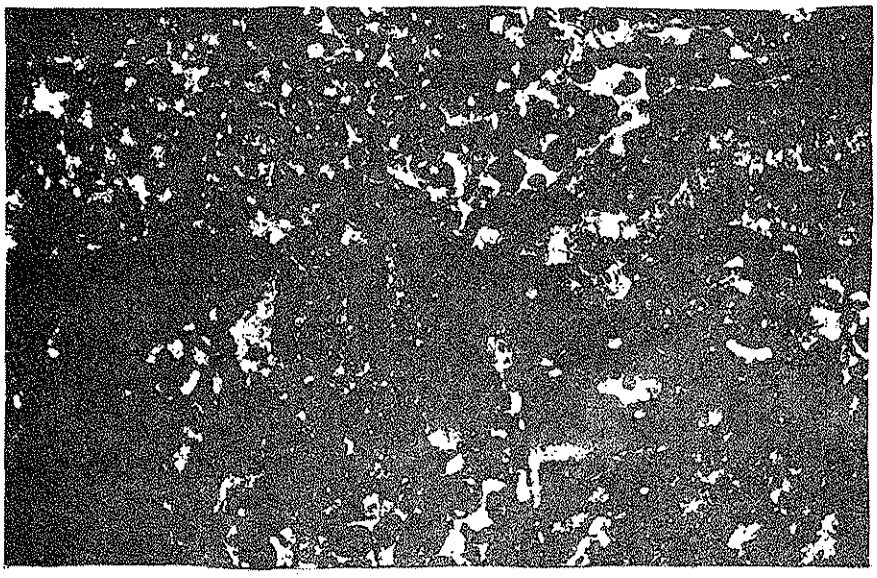


Figure 8 Lithotype IV, Group III

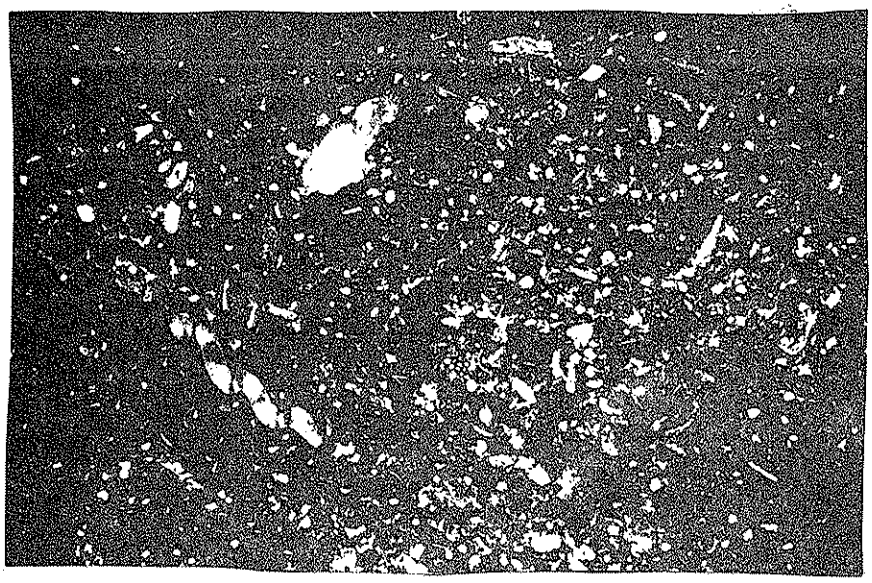


Figure 9 Lithotype IV, Group IV

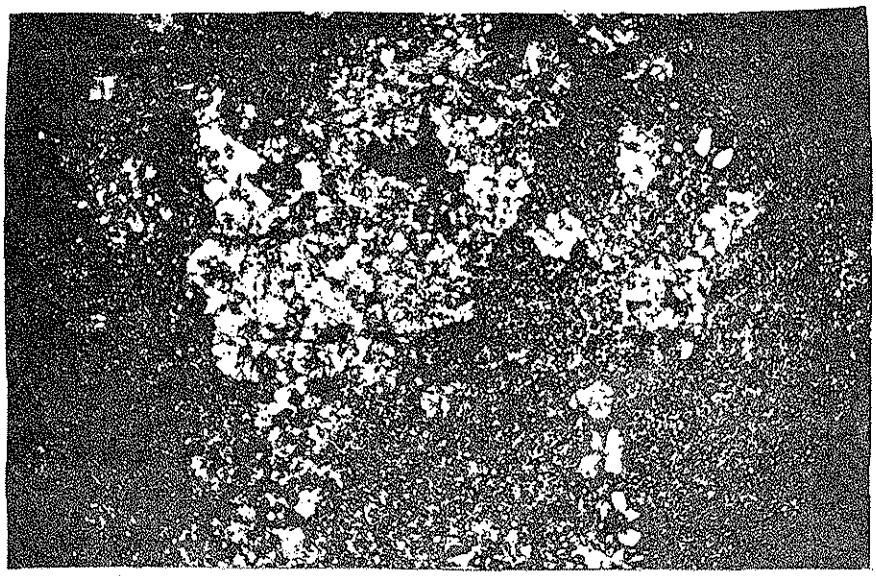


Figure 10 Lithotype V

The samples of lithotype IV tend to be light colored carbonate rocks, well indurated with fossil rich zones. Quartz sand and silt occur rarely, but in subgroup appear to be an important constituent comprising 26% of the rock volume. Dolomitization is rarely present in lithotype IV.

The dominant mineralogy is that of ferroan calcite. A further discussion of the petrographic details of each subgroup is beyond the scope of this report.

LITHOTYPE V

Lithotype V characteristically consists of highly silicified limestones, appearing in fresh outcrop surface to be of a brecciated nature. The secondary silica is variable in morphology ranging from microcrystalline chert to macrocrystalline quartz and botryoidal chalcedony. Bioclasts are not present in lithotype V, most likely the result of heavy silicification and destruction of original fabrics.

MONROE COUNTY

GENERAL TRENDS

Only the eastern one-half of Monroe County has been mapped and discussed in this report, because of the lack of data to the west of T 73 N, R17 W and T 72 N, R17 W. Only three data points exist that record Spergen in Monroe County, one point being a core taken from a gypsum test near Albia, which was used as one of the petrographic samples.

Thickness values of the Spergen Formation vary from 25 to 40 feet at wells numbered 08679 and 08109 respectively (Map I, III). Depth values in this small area range from 285 feet (08679) to 325 feet (08109) (Map II).

RECOMMENDATIONS

This area has a very thick cover of overburden, but is recommended as a secondary area, for the possible development of subsurface operations. The secondary designation has been given mainly on the basis of fairly noteworthy recorded thicknesses of the unit in this area, with a dominant carbonate lithology. The extreme northeastern corner of the northeastern quadrant is recommended for primary exploration based on the interpolated presence of a southeast-northwest trending zone of low isochore values (Map II) which is also easily viewed in the northwest corner of Wapello County.

DAVIS COUNTY

GENERAL TRENDS

The thickest occurrence of the Spergen Formation appears at well #1901 in the northwest quadrant of the county where interbedded evaporites have been logged as occurring within the Spergen interval (Map I). The thinnest non-zero point in the county occurs at well #18123 in the southeastern portion of the southwestern quadrant. Depth to the top of the Spergen internal varies from a high value of 418 ft. at #18123 to a low value of 146 ft. at well #20715 in the east central portion of the northeastern quadrant. Lithologies are recorded dominantly as dolomite at all locations with associated secondary amounts of limestone, sandstone and chert. A dominant occurrence of sandstone logged as the Spergen Formation is recorded at well #18123 in the southwestern quadrant.

NORTHEASTERN QUADRANT

The northeastern quadrant of Davis County has the greatest number of Spergen control points consisting of wells numbered 20175, 17988, 22324, as well as a number of data

points where no Spergen was recorded, but where the St. Louis Formation was logged as being present. The depth of the overburden in the northeastern quadrant thins considerably at well #20715 to a value of 146 feet, but thickens to the north and thickens southwest to 300 feet at well #22324. Thicknesses range from 25 feet to 49 feet within this quadrant. Lithologies are recorded as combined carbonates (dolomites and limestones) at #17988, but appear consistently as dolomite, with secondary limestone and chert at wells #22324 and #20175. The isochore map indicates a depth range of 250 to 150 feet which trends almost due north-south across the northeast quadrant, deepening to the west.

RECOMMENDATIONS

Due to the consistency of lithologies, thickness and depth ranges of 150 to 200 feet, the northeast and southeast quarter of the northeastern quadrant is recommended for primary exploration and development. The rest of the northeastern quadrant is given a secondary recommendation designation on the basis of a lack of base data and depth value trends on the isochore map.

SOUTHEASTERN QUADRANT

The southeastern quadrant of Davis County consists of one recorded Spergen data point (#12741) along the northernmost boundary of the quadrant line. At this data point the Spergen has been logged as consisting of approximately 30 feet of dolomite, limestone, and chert at a 300 foot depth. The depth interpolations of the isochore map (Map I) indicate a southwestward increase of overburden from data point (#12741). No data points exist along the eastern and southeast portion of this southeastern quadrant, except for a number of data points where varying thicknesses of 76 to 50 feet of St. Louis strata, occurring at depths of 288 to

395 feet have been logged. These lithologies consist primarily of limestone with associated sandstone, chert, dolomite and shales. The lack of recorded Spergen data and the great thickness of the St. Louis may indicate that this is an area where the Spergen Formation was too difficult to be separated on a lithologic basis from the overlying St. Louis Formation.

RECOMMENDATIONS

Due to the fairly high thicknesses of limestone, and other associated lithologies, the southeastern quadrant should be considered an area for further exploration in terms of a subsurface mining operation. A secondary recommendation designation is given on the basis of depth values. Due to the paucity of rock of acceptable standards in Davis County, consideration of a subsurface mining operation in the southeastern quadrant of Davis County is not a radical idea.

SOUTHWESTERN QUADRANT

The southwest quadrant consists of one data point (#18123) where the Spergen Formation has been logged as a sandstone approximately 7 feet thick at a depth of 418 feet. Due to the great thicknesses of recorded overburden, lack of data points and an undesirable sandstone lithology, the southwest quadrant of Davis County is not recommended for further investigation and is assigned a "tertiary" recommendation.

NORTHWESTERN QUADRANT

The northwestern quadrant consists of one data point (#1909) where approximately 85 feet of evaporite-bearing dolomite and sandstone has been logged as Spergen lithology. Depth to the top of the Spergen interval in this location is recorded as 415 feet at (#1909). Due to the presence of

inadequate base data, as well as isochore trends indicating a northeast-southwest trending zone of high depth values, this area is not recommended for immediate exploration.

GENERAL RECOMMENDATIONS

Two working quarries (Lewis Quarry and Hootman Quarry) are located in the eastern sector of Davis. Available isochore, thickness and lithologic data indicates that the main area for exploration emphasis is the northeastern and east central sector of the county including T 70 N, R12 W, T 69 N, R12 W, and T 69 N, R13 W. Due to the lack of high quality aggregate materials in Davis County, the southeastern quadrant should be pursued as a plausible area for carbonate rock exploitation. This recommendation is made on the basis of the presence of 76 to 50 foot thicknesses of carbonate strata of fairly consistent lithologies which have been ascribed to the St. Louis Formation. Because of the increase in overburden thickness, presence of sandstone and evaporite bearing carbonate rocks and lack of data the southwest and northwest quadrants are not recommended for further exploration efforts.

WAPELLO COUNTY

GENERAL TRENDS

Coverage by well data is much better in Wapello County than many of the western counties of the map area, facilitating economic evaluation.

The thickness of the Spergen Formation varies widely throughout Wapello County and has been logged as not occurring in numerous northwest and south-central localities where again, St. Louis and Spergen strata most likely were combined as one unit during logging. The Spergen interval, where present ranges from 50 feet (#13685) in the southwest corner of

Wapello County to a thin interval of 5 feet (16311) in the east central portion of the county, representing a rather wide variation in thickness values. Depths range from 440 feet (#13685) to 60 feet (#14290) in the center of the county.

NORTHEASTERN QUADRANT

Data from the northeastern quadrant of Wapello County indicates that the depth to the top of the interval ranges from 155 feet (#13110) in the northwest to 320 feet (#16311) in the southwest. The thickness of the unit in the northwest sector of the quadrant ranges from an anomalously low value of 5 feet (#16311) to a high value of 28+ feet in the northwest corner of the northeastern quadrant (#16667), where wells only partially penetrated the Spergen Formation, indicating the possibility of greater thicknesses. Lithologies of the northeastern quadrant of the county are primarily dolomite with secondary sandstone and chert, with rare argillaceous material present in the southwest corner of the northeastern quadrant.

RECOMMENDATIONS

Due to the great thicknesses of overburden ranging from 440 feet to 60 feet, with averages of 200 feet, this area should only be evaluated for subsurface exploitation purposes, but not for surface operations. The northeast quarter of the northeastern quadrant has been given a "primary" rating on the basis of low depth values.

SOUTHEASTERN QUADRANT

The southeastern quadrant of Wapello County shows a range of thicknesses of the Spergen Formation when it is present, from 40 feet (#12922) to 9 feet (#16688) in the northwest quarter with depth ranges of 250 to 335 feet through

the central portion to a lower value of 175 feet (#12922) in the southeast section. Lithologies consist primarily of dolomite, with secondary and tertiary components of limestone, sandstone, chert and shale.

RECOMMENDATIONS

Due to the thickness of overburden the recommendations for the southeastern quadrant of Wapello County are for consideration as a plausible area for subsurface operations. A secondary designation is given for all of the southeastern quadrant, except for the southeasternmost corner, where depth values of 200 feet warrant closer inspection for the possible development of surface operations.

SOUTHWESTERN QUADRANT

The southwestern quadrant of Wapello County Spergen thickness values range from a high value of 50 feet (#13685) in the central portion of the southwest quadrant to a low of 15 feet (#22144) in the northwest corner. Depths range from 440 feet (#13685) to 198 feet (#13100) in the northeast section of the southwestern quadrant. Lithologies are again primarily dolomite, with secondary and tertiary chert, shale, sandstone and limestone. Trends indicate a greater argillaceous component in the Spergen Formation within the southwest quadrant of Wapello County.

RECOMMENDATIONS

Due to the great recorded thicknesses, recommendations are secondary and should be considered only for subsurface development, only where lithologies appear to be less argillaceous. An area of lower depth values in the northeastern corner of the southwestern quadrant is included in a primary recommendation zone.

NORTHWESTERN QUADRANT

Thickness values vary from 45+ feet (#22359) in the northwest corner of the northwest quadrant to 14 feet at #06949. Well #03089, between these two points has been logged as not containing the Spergen interval. The data appears to be anamolous at this point. Depths to the top of the interval range from 236 feet (#07238) in the northwest corner of the quadrant to a low value of 60 feet at well #14290 in the southeast corner of the northwestern quadrant. Lithologies again are recorded as dominantly dolomite, with secondary and tertiary sandstone, chert and minor amounts of shale.

RECOMMENDATIONS

Depth values are quite high in the northwestern quadrant, but due to the overall average lower depth values than the three previously discussed quadrants, primary consideration should be given to this quadrant for subsurface and possibly deeper surface quarrying operations.

GENERAL RECOMMENDATIONS

Wapello County should be recommended for exploration for future subsurface mining operations in most of the northeastern, southeastern, and southwestern quadrants. However, due to the presence of a large isochore low trending northwest-southeast through the northwestern quadrant (Map II). this area may be the best location for shallow subsurface or deep surface quarrying operations. Thicknesses in the northwest quadrants consistently fall within a range of 20 to 35 feet. Thickness values coupled with the apparent consistency of dolomite lithologies throughout the northwest quadrant indicate that this area has the highest potential for further exploration efforts. The present distribution of working quarries (Wagner Quarry, Glenn Quarry) fall within the recommended area.

JEFFERSON COUNTY

GENERAL TRENDS

Jefferson County has a high density of well control points in the eastern sector of the county, facilitating interpretation of thickness and depth variations. The high and low values for thickness of the Spergen interval are at 58 feet (#16605) in the northeastern quarter of the southeast quadrant, and 10 feet (#03896) in the northeast quarter of the northeast quadrant. Depth to the top of the Spergen interval varies between 295 feet (#17450) in the far western portion of the northwest quadrant to 35 feet (#19246) in the south central portion of the southeastern quadrant.

NORTHEASTERN QUADRANT

Thickness values of the Spergen interval in the northeastern quadrant range from a high value of 50 feet (#10001) in the northeast corner to a low value of 10 feet (#03896), excluding points with partial penetration of zero Spergen recorded. The depth to the top of the unit varies from 165 feet (#06343) at the north-central border to 60 feet (#07339) in the northeastern corner. Lithologies of the Spergen interval are primarily dolomite, sandstone, chert and shale, but well (#06887) records a primary lithology of limestone.

RECOMMENDATIONS

The entire northeast quadrant displays an exceedingly high consistency in both thickness of the Spergen Formation and depth to the top of the unit, as well as a consistency in reported carbonate lithologies. This area is recommended highly for further exploration, especially where reasonable thicknesses coincide with the 100 to 200 foot isochore contour area. A "primary" recommendation designation is given to the entire northeastern quadrant.

SOUTHEASTERN QUADRANT

Thickness of the Spergen interval in the southeastern quadrant ranges from a high value of 58 feet (#16605) in the northeast corner to a low value of 20 feet (#18015) where Spergen strata have been completely penetrated. Depths to the top of the Spergen interval range from a high of 210 feet (#18015) to 35 feet (#19266) in the south-central portion of the quadrant. Except for control points #13181 and #18015, depth and thickness values appear to be quite consistent throughout the southeastern quadrant. However, values of thickness and depth appear to lessen dramatically in the south central portion of the southeastern quadrant, including wells #19246 and #16604. The lithologies in the southeast quadrant consist of dolomite with secondary and tertiary sandstone, chert, limestone and shale.

RECOMMENDATIONS

The southeastern quadrant is recommended highly for exploration as a potential surface quarrying operation, due to relatively low overburden values, consistent thickness values and dominant carbonate lithotypes. The extreme south-central portion of the quadrant, in the area of wells #10064 and #19246 show excessively low overburden values and the area should be immediately evaluated for quality of carbonate lithology. A primary recommendation designation has been assigned to the southeastern quadrant, where depth values increase.

SOUTHWESTERN QUADRANT

The southwestern quadrant consists of four Spergen data points concentrated on the eastern border of the south-west quadrant (#01480, #16054, #17776, #14809). Thickness values of the unit range from 32 feet (01480) to 25+ (#17776)

where only partial penetration of the Spergen was accomplished. Depth to the top of the unit ranges from 222 feet (#14809) to 145 feet (#16054). A general trend in increase of depth to the top of the interval is noted in the eastern sector of the southwest quadrant.

RECOMMENDATIONS

The primary lithology of the unit recorded at these well locations is dolomite, with varying amounts of sandstone, chert and shale. The lack of lithologic data in the western sector of the southwest quadrant, combined with a general westward increase in depth values in western Jefferson County trending into Wapello County indicate that this area should not be considered for exploration for surface quarrying operations.

A secondary recommendation is assigned to this zone of high depth values, but the remaining portion of the southwestern quadrant has been given a primary designation for exploration and development.

NORTHWESTERN QUADRANT

Thickness values range from 40 feet (#19011) on the northern map boundary to 20 feet at #14774 and #17450. Depth values range from 180 feet (#14774) to a high value of 295 feet, indicating a westward depth increase into Wapello County. Lithologies are primarily dolomite, or limestone with secondary chert, shale and sandstone.

RECOMMENDATIONS

Lack of data to demonstrate the lithologic and thickness continuity, as well as the observed westward depth increase indicate that this area not be considered as a potential area for surface quarry development.

A secondary recommendation has been assigned to the westward trending area of high, depth values, but a primary designation has been given to the remaining portion of the northwestern quadrant.

GENERAL RECOMMENDATIONS

Jefferson County appears to have great potential for increased carbonate rock exploitation, especially with regard to the following areas: T 73 N, R8W, T 73 N, R9W, T 72 N, R10W, T 72 N, R9W, T 72 N, R8#, T 72 N, R9W, and T 71 N, R8W. Fairly consistent values of depth, lithology and thickness of the Spergen interval support this recommendation. The large westward trending zone of high depth values observed in the western sector of Jefferson County and projecting into Wapello County, combined with a lack of base data indicate that this area should not be considered as a potential site for carbonate rock exploitation. This area is given a secondary recommendation. This area is recommended only for subsurface mining operation development.

VAN BUREN COUNTY

GENERAL TRENDS

Van Buren County Spergen thicknesses range from a high value of 48 feet (#08788) to a low value of 5 feet (#08784) in the southeast corner of the northwest quadrant. The close proximity of the two points displaying the high and low values further demonstrates the problems of differentiating the unit in well cuttings. Depth ranges are from 260 feet (#09496) on the eastern boundary of the southwest quadrant to 22 feet (#17167) in the west central portion of the southwest quadrant. Average Spergen lithologies are primarily dolomite, with secondary limestone, sandstone, chert and shale components.

NORTHEASTERN QUADRANT

The northeastern quadrant indicates depths from 177 feet in the southeast corner ranging to 175 feet in the northwest corner of the quadrant, with average depths in the west central, southwest and southeast portion of the quadrant of about 100 feet. Corresponding thickness variations average 26 feet in the southeast corner and average 23 feet in the western sector of the quadrant. In this western sector, well #C0140 shows only partial penetration of the Spergen to 4+ feet where the true Spergen thickness may in fact be much greater in this area. Lithologies of the unit in the northeast quadrant are primarily dolomite, with secondary chert, sandstone and shale.

RECOMMENDATIONS

A primary designation has been given to all of the northeastern quadrant on the basis of low depth values and consistent lithologies.

SOUTHEASTERN QUADRANT

The southeastern quadrant of Van Buren County shows Spergen thickness values that range from 45 feet at well #13590 in the northeast corner to 51 feet in the southeast corner (#10225). Lithologies again are primarily dolomitic, with secondary and tertiary chert, sandstone, shales and combined carbonate lithologies (dolomites and limestones).

RECOMMENDATIONS

Interpretation of thickness, depth and lithologic data indicates that the Spergen occurs generally within an overburden range of 100 to 200 feet and has an average thickness of 29 feet, making this area economically attractive.

SOUTHWESTERN QUADRANT

Thicknesses range from 48 feet (#16218) in the northeast corner to 15 feet (#04599) slightly southwest of the greatest reported local thickness. Depths range from 260 feet at (#09496) to 50 feet (#09496) in the northeast corner of the quadrant. Lithologies are consistently dolomite, but well #09496 records a lithology of combined carbonate strata (dolomites and limestone).

RECOMMENDATIONS

Average depths to the top of the unit appear to be greater in the southwestern quadrant of Van Buren County than in the previous quadrants. Stratigraphic control is very poor in this area, so recommendations for further explorations are given only with great reservation, especially with the consideration of the isochore map trends. Recommendations for further exploration in the southwestern quadrant are directed towards the most northeasterly section of the quadrant where, although depths are irregular, the unit has a consistent thickness averaging 25 feet.

NORTHWESTERN QUADRANT

The northwestern quadrant of Van Buren County has a severe lack of data points, especially in the extreme northern area. Thickness ranges of the Spergen interval are from 5 feet (#08784) in the southeast corner to 41 feet in the east central portion of the quadrant at well #16667. Depth ranges have decreased considerably to values of 152 feet (#14278) in the southwest to 40 feet (#08784, #16747) in the southeast and north-central areas. Lithologies are primarily dolomite, but have fairly consistent secondary and tertiary lithologies of chert and sandstone. Secondary limestone is reported at well 14278 .

RECOMMENDATIONS

The northwest quadrant has the thinnest average overburden values and is recommended for further exploration. General trends indicate a northwest-southeast trending positive structure with increasing depth to the top of the Spergen off the southwestern flanks of the structure (Map II). Present quarry distribution in Van Buren County is located along this trend. Further expansion of activities off of the axis of this depth trend is recommended. Depth values along this trend fall within the range of 50 to 100 feet with rather consistent thicknesses of 25 to 35 feet. Persistent dolomite lithologies also support the recommendation for primary exploration efforts. The presence of reasonable Spergen thicknesses as well as thin overburden in the central portion of the county indicates another area for further investigation. This area has not been highly developed by quarry operators at present.

HENRY COUNTY

GENERAL TRENDS

The distribution of depth values with all zero points removed suggests that the whole of Henry County be recommended for primary exploration as surface quarrying operations. All depth values are under 200 feet and would recommend consideration for the development of surface quarrying or shallow subsurface mining operations. However, due to a large proportion of zero thickness points, particularly in the northeastern quadrant of Henry County, certain areas are given "secondary" recommendations.

NORTHEASTERN QUADRANT

The northeastern quadrant has been removed from economic consideration due to the very high percentage of zero

data points. Wells #03113 and #09588 locally record thicknesses of Spergen strata of 10+ and 20 feet respectively. The decision to remove this quadrant from economic consideration is supported by the fact that the Spergen appears to have been totally removed to the north in Louisa County as well. This may indicate that this local area may have been subjected to much more intense erosion than the surrounding quadrants.

SOUTHEASTERN QUADRANT

The western one-half and the southeastern one-quarter of the southeastern quadrant of Henry County displays a large amount of Spergen data points, but these are scattered among a high number of zero data points. Depth values range from a high in the south-central quarter of 125 feet (#10202) to a low value of 20 feet at well #05732 in the north-central portion of the quadrant. Thickness varies considerably from an anomalously high value of 50 feet at #08332 to a low value of 5 feet at well number #10392.

Lithologies are primarily dolomite with secondary and tertiary chert and sandstone. The presence of a primary lithology of limestone is recorded at well number 17542.

RECOMMENDATIONS

The western one-half of the southeast quadrant and the southeastern quarter of the southeastern quadrant are recommended for primary exploratory measures on the basis of fairly consistent lithologies and low depth values. The northeastern quarter and eastern half of the northwest quarter of the southeastern quadrant displays too high a percentage of zero data points to recommend the area for primary consideration.

SOUTHWESTERN QUADRANT

The largest number of control points were recorded in the southwestern quadrant of Henry County. Depths vary from 130 feet at wells #08774 and #10021 in the western one-half of the southwest quadrant, to a low depth value of 26 feet at well #15695 in the northeast quarter of the southwestern quadrant. Depths appear to increase to the northwest of the southwestern quadrant and decrease to the northeast of the southwestern quadrant.

RECOMMENDATIONS

The southwestern quadrant of Henry County has been given a primary recommendation rating, due to the low depth values recorded and primary carbonate lithology.

NORTHWESTERN QUADRANT

The northwestern quadrant of Henry County has very few data points recording the Spergen interval. The eastern one-half is removed from serious economic consideration due to the large number of zero thickness data points. The depths to the top of the Spergen appear to be the greatest in a northeast-southwest trending trough mapped through the center of the northwestern quadrant. Thickness values range from 30 feet at #06118 in the northeast quarter of the northwestern quadrant to 10 feet at well #17569 in the western section of the quadrant.

Lithologies are primarily dolomite except at well #02463 where limestone is recorded as the main lithologic component. Sandstone, chert and shale comprise the ancillary components of the Spergen lithologies in the northwest quadrant.

RECOMMENDATIONS

The extreme northwest and northeast quarters of the northwestern quadrant are not recommended for primary exploration efforts, but doe to depth and thickness values, the southwest and the southeast quarters of the northwest quadrant are given a primary rating. The presence of a southeast trending zone of low depth values originating in Jefferson County further supports the designation of this area as a region for primary exploration efforts.

DES MOINES COUNTY

GENERAL TRENDS

Only the extreme western sector of Des Moines County has been dealt with in this discussion, due to a lack of base data points east of the mapped area, possibly indicating erosion of the unit. Data points are clustered near the northern map boundary of the county and the southern boundary of the western sector of the county.

Thickness values range from 44 feet at #16785 to 10 feet at #01572 in the southern portion of the map. Depth values range from 134 feet at #17199 on the north boundary to 25 feet at #C0048 in the southwest corner of the county. All depths to the Spergen in the western sector of Des Moines County range between 63 and 134 feet except for a local area of low depth value at #C0048. Lithologies are consistently dolomite, with shales, sandstones and chert as secondary and tertiary components.

RECOMMENDATIONS

Due to the presence of a small area of Spergen recorded in the northern extreme, this area is recommended for primary exploration. Thickness, depth and lithology appear to be fairly consistent within this zone, but the unit is limited

areally. The southwestern margin of Des Moines County is included in the primary area of recommendation, extended from a zone in southeastern Henry County. Large areas in the west central section of the western boundary of Des Moines County show no Spergen recorded. This area has been given a secondary rating, mainly on the basis that the unit may have been confused during logging with the St. Louis Limestone, and the unit may actually be present.

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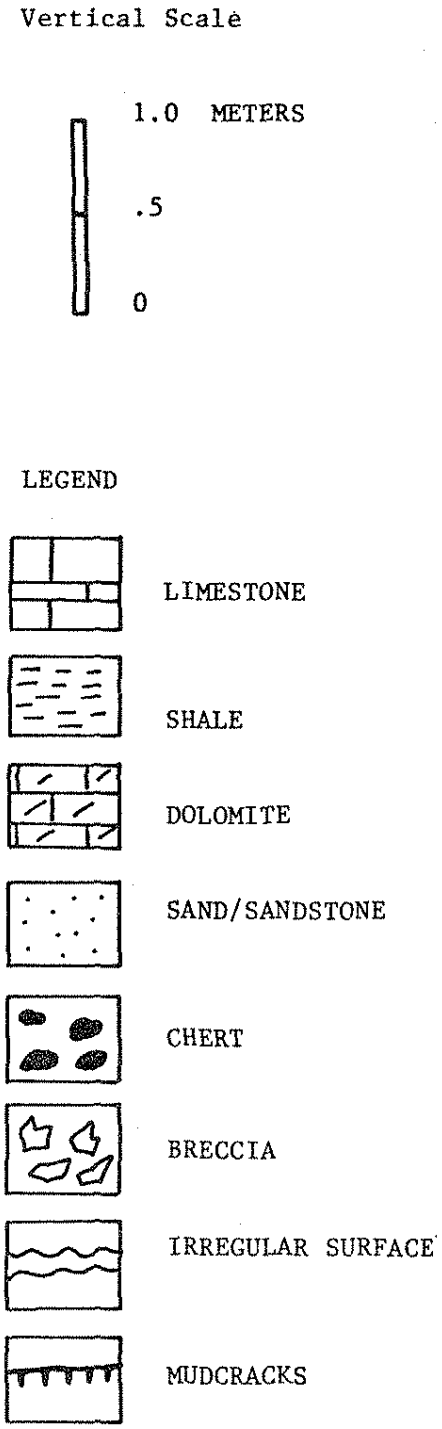
APPENDIX I

Figure 11

Lithologies Appearing
on Stratigraphic Sections



ALBIA CORE, MONROE COUNTY

*Spergen Formation

Bed 1 0. - 1.44 meters
Tan limestone, arenaceous, unfossiliferous with clayrich gypsum filled vugs overlain by a medium tan dolomite, some disseminated sand grains, unfossiliferous. Base, lithotype 3, top, lithotype I.

Bed 2 1.44 - 2.18 meters
Tan limestone, slightly dolomitic, fossiliferous, cherty, minor glauconite. Lithotype 4, Group 3.

Bed 3 2.18 - 2.84 meters
Medium grayish-brown limestone, fossiliferous. Lithotype 4, Group 2.

Bed 4 2.84 - 3.02 meters
Light grayish-tan limestone, fossiliferous, slightly dolomitic, minor glauconite. Lithotype 4, Group 1.

Bed 5 3.02 - 4.56 meters
Tan limestone, fossiliferous, minor glauconite. Lithotype 3.

Bed 6 4.56 - 4.76 meters
Dark brown dolomite, arenaceous, gypsum filled vugs. Lithotype 2.

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*Bedding characteristics not discernible from core samples.

Bed 7 4.76 - 4.92 meters
Light tan dolomite, minor glauconite. Lithotype 2.

Bed 8 4.92 - 5.07 meters
Green shale.

Bed 9 5.07 - 5.15 meters
Light brown dolomite, fossiliferous, containing tabular gypsum crystals. Lithotype 2.

Bed 10 5.15 - 6.05 meters
Medium grayish-brown dolomite, arenaceous, glauconitic. Lithotype 2.

Bed 11 6.05 - 6.62 meters
Tan dolomite, unfossiliferous, cherty zones. Lithotype I.

Bed 12 6.62 - 7.29 meters
Tan dolomite, unfossiliferous. Lithotype I.

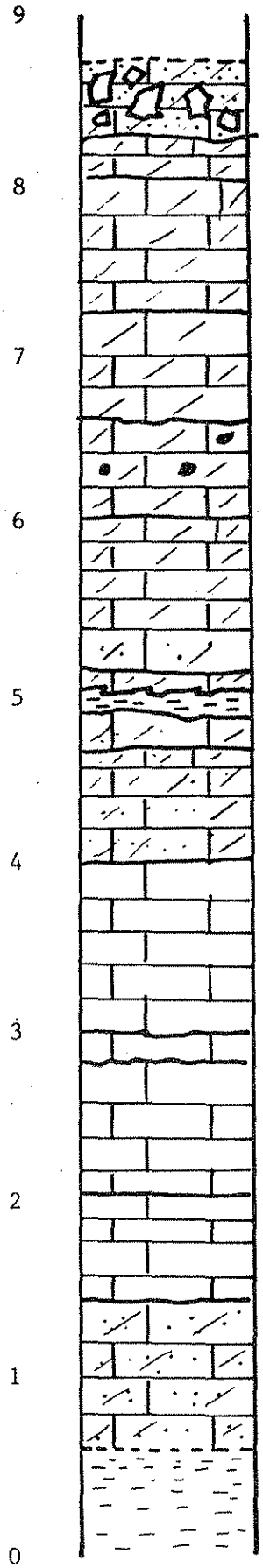
Bed 13 7.29 - 8.03 meters
Tan dolomite, unfossiliferous; mottled texture. Lithotype I.

Bed 14 8.03 - 8.35 meters
Medium brown dolomite, unfossiliferous, glauconitic, dark brown shaly partings. Lithotype I.

St. Louis Formation?

Bed 15 8.35 - 8.73 meters
Grayish-tan dolomite, brecciated, arenaceous, cherty zones. Lithotype 3.

Albia Core, Monroe County
NE¼, NE¼, Section 9
T 72N, R 17W



LEWIS QUARRY, DAVIS COUNTY

Spergen Formation

Bed 1 0. - 0.93 meters
Thinly bedded light grayish brown limestone, arenaceous, fossiliferous with gray chert nodules. Grades into a medium bedded gray limestone, unfossiliferous, dense chert nodules. Lithotype 4, Group 1, grading to Lithotype 1.

Bed 2 .93 - .98 meters
Thinly bedded medium gray limestone, fossiliferous, slightly argillaceous, glauconite rich laminations. Lithotype 4, Group 1.

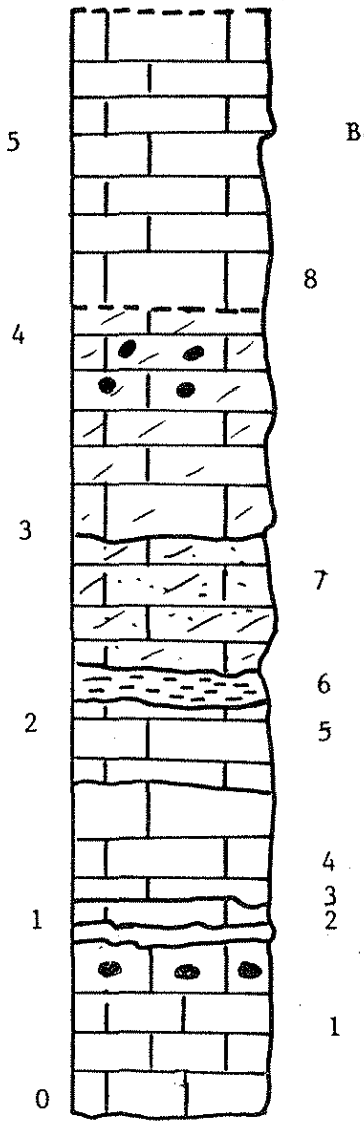
Bed 3 .98 - 1.19 meters
Medium bedded gray limestone, arenaceous, fossiliferous. Lithotype 4, Group 1.

Bed 4 1.19 - 1.67 meters
Medium bedded light brown limestone, fossiliferous, numerous green shale partings; weathers white. Lithotype 4, Group 1.

Bed 5 1.67 - 2.19 meters
Thinly bedded tan limestone, fossiliferous, minor glauconite in pods, green shale partings. Lithotype 4, Group 3.

Bed 6 2.19 - 2.35
Green shale.

Lewis Quarry, Davis County
N½, Sw¼ and SE¼, NW¼
Section 2, T 69N, R 12W



Bed Number

Spergen Formation

Meters above quarry floor

Base of Quarry Floor

Bed 7 2.35 - 2.97 meters
Medium bedded light gray dolomite, arenaceous. Lithotype 2.

Bed 8 2.97 - 5.62 meters
Thickly bedded gray, dolomite, fossiliferous, cherty near top, slightly glauconitic; grades into a medium bedded brown limestone, fossiliferous, with large ovoid chert nodule development. Lithotype 2.

CEDAR CREEK QUARRY, JEFFERSON COUNTY

Spergen Formation

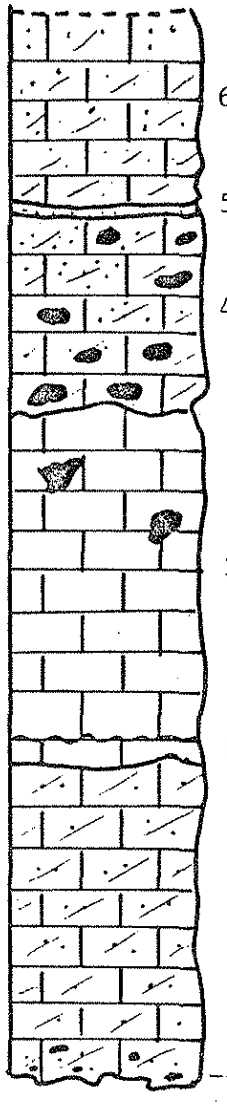
Bed 1 0. - 1.64 meters
Very thickly bedded light tan arenaceous dolomite, unfossiliferous, with thin green shale laminae. Upper meter is cherty; unit tends to weather chalky white. Lithotype I.

Bed 2 1.64 - 1.74 meters
Thinly bedded medium grayish brown limestone, fossiliferous. Lithotype 4, Group 2.

Bed 3 1.74 - 3.44 meters
Thin to medium bedded light tan limestone, slightly dolomitized, with undulatory green shale partings. Sand concentrated in pods or lenses, with areas of dark gray nodular silicification. Lithotype 2.

Bed 4 3.74 - 4.34 meters
Thickly bedded light brownish gray dolomite. Unit is intensely brecciated, with quartz sand and

Cedar Creek Quarry, Jefferson Co.
NE¼, NW¼, Sections 35 and 36,
T 71N, R 9W
Composite Section



Bed 4 (continued)
glauconite concentrated between breccia clasts. Highly cherty with characteristic black, gray and white banded chart nodules with axes parallel to bedding planes. Lithotype I.

Bed 5 4.43 - 4.46 meters
Very thinly bedded light gray quartz sandstone, medium to coarse grained, friable, calcite cemented, with pods and lenses of glauconite. Lithotype 3.

St. Louis Formation?

Bed 6 4.46 - 5.50 meters
Medium bedded light gray brown very fine dolomite, arenaceous, unfossiliferous; brecciated to some degree. Lower 40 centimeters is cnerty with continuous bands of dark gray chert blebs and nodular chert development. Lithotype I.

DOUDS MINE, VAN BUREN COUNTY

Spergen Formation

Bed 1 0. - 1.10 meters
Thickly bedded medium tan to brown limestone, arenaceous, fossiliferous, slightly dolomitic with lenticular chert nodule development. Lithotype 2.

Bed 2 1.10 - 1.50 meters
Medium bedded light tan limestone, fossiliferous, with numerous one centimeter thick green shale partings. Lithotype 4, Group 2.

Bed 3 1.50 - 1.68 meters
Medium bedded medium brown dolomite, arenaceous, minor glauconite. Lithotype 2.

Bed 4 1.68 - 2.54 meters
Medium bedded tan limestone, arenaceous, fossiliferous, mottled texture slightly dolomitized. Thin green shale overlying this bed. Lithotype I.

Bed 5 2.54 - 2.70 meters
Medium bedded gray dolomite, unfossiliferous, minor glauconite. Lithotype I.

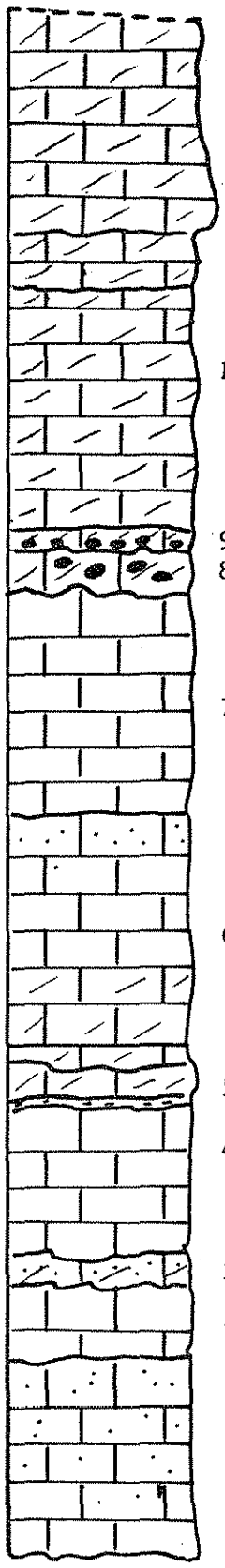
Bed 6 2.70 - 4.14 meters
Medium bedded light tan dolomite, unfossiliferous with minor glauconite, grading vertically into a medium bedded light gray limestone, arenaceous, unfossiliferous; grades into a thickly bedded medium brown limestone, arenaceous, sparsely fossiliferous. Lithotype 3.

Bed 7 4.14 - 5.34 meters
Medium bedded grayish brown limestone, arenaceous, slightly dolomitic, grading into a medium bedded brown unfossiliferous limestone, minor glauconite development in pods and lenses. Lithotype 3.

Bed 8 5.34 - 5.45 meters
Thinly laminated medium brown dolomite, unfossiliferous with thin discontinuous green shaly pods, numerous chert nodules. Lithotype 1.

Bed 9 5.45 - 6.80 meters
Basal black, gray and white chert bed 10 cm thick

Douds Mine, Van Buren County
NE¼,SE¼, Section 25, T 70N, R 11W
Composite Section



Bed 9 (continued)
overlain by a medium bedded medium brown dolomite, unfossiliferous with minor glauconite. Lithotype I.

Bed 10 6.80 - 7.22 meters
Thirdly laminated medium to dark brown dolomite, sparsely fossiliferous, glauconite in pods, highly weathered unit. Lithotype I.

Bed 11 7.22 - 8.46 meters
Very thickly bedded dark grayish brown dolomite, unfossiliferous; forms massive overhanging ledge. Lithotype I.

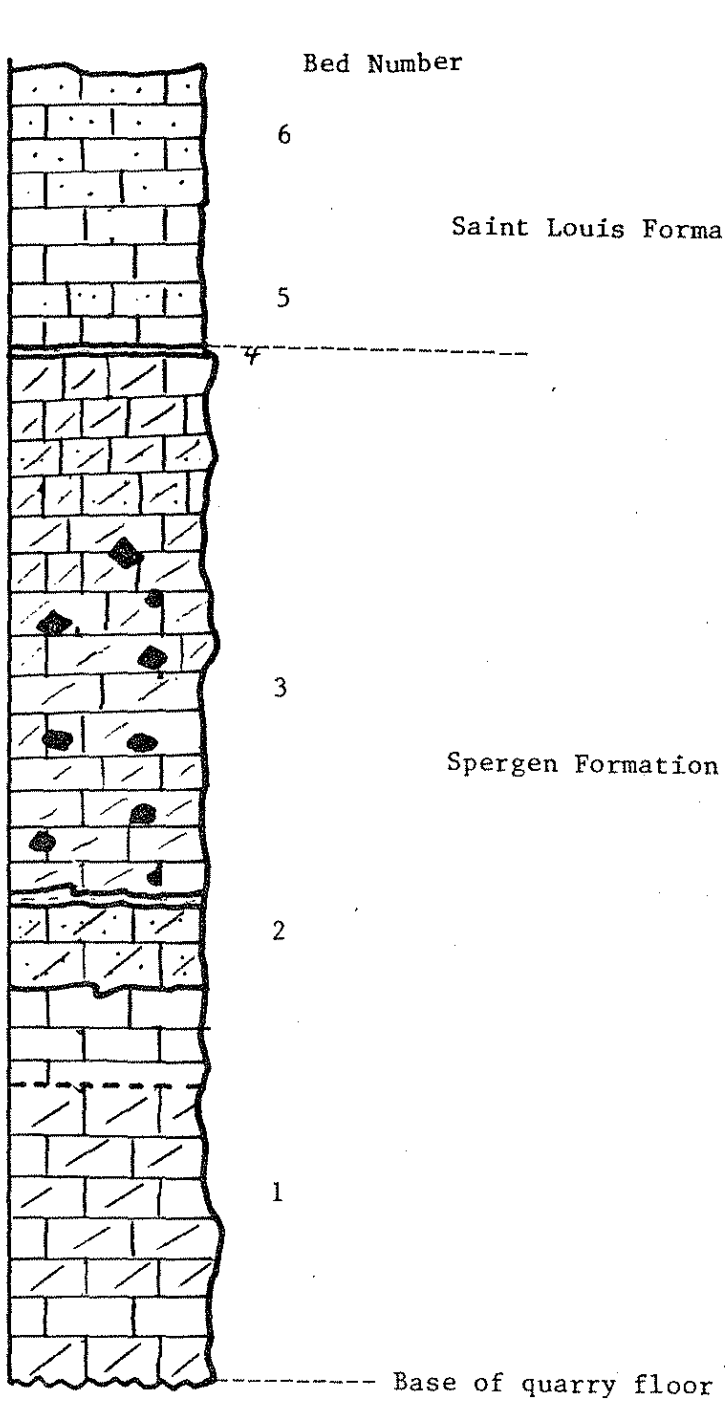
HENRY COUNTY QUARRY

Spergen Formation

Bed 1 0. - 2.0 meters
Medium bedded dark brown dolomite, unfossiliferous, mottled with spotty silicification features. Glauconite concentrated in pods and vugs. Grades into a medium bedded light gray fossiliferous limestone in the upper .05 meter, with vague bioclast alignment parallel to bedding. Numerous 1.0 cm green shaly partings. Lithotype I.

Bed 2 2.0 - 2.53 meters
Medium bedded brown dolomite, arenaceous, unfossiliferous, grading into a green shaly zone. Lithotype I.

Henry County Quarry, Henry County
NW¼, NE¼, Section 18, T 71N, R 6W



Bed 3 2.53 - 5.24 meters
Medium bedded dark brown dolomite, unfossiliferous, pitted weathering, with 3.0 mm dark gray chert fragments. Grades vertically into a medium bedded laminated arenaceous dolomite. Lithotype III.

Bed 4 5.24 - 5.27
Brown shale overlain by green shale, thinly laminated.

St. Louis Formation?

Bed 5 5.27 - 5.99
Thinly bedded coarse chalcedony, chert and macrocrystalline replaced limestone, grading vertically into a light tan to green brecciated limestone, slightly dolomitic grading vertically into a coarse light tan brecciated limestone slightly arenaceous. This unit interfingers laterally with a medium bedded light gray limestone, laminated, unfossiliferous. Lithotype 5, grading to Lithotype I.

Bed 6 5.99 - 6.78 meters
Medium bedded light to medium gray arenaceous limestone, slightly dolomitic, vague mottled texture, weathers a distinctive white. Lithotype 3.

HEINOLD QUARRY, DES MOINES COUNTY

Spergen Formation

Bed 1 0. - 1.0 meters
Thickly bedded medium grayish-brown dolomite, unfossiliferous, glauconite in minor amounts. Lithotype I.

Bed 2 1.0 - 2.40 meters
Medium bedded light grayish-brown limestone, fossiliferous, slightly dolomitic. Lithotype 4, Group 3.

Bed 3 2.40 - 3.03 meters
Medium bedded light to medium gray limestone, fossiliferous, arenaceous, green shale partings, glauconite. Lithotype 3.

Bed 4 3.03 - 3.20 meters
Medium bedded light tan limestone, arenaceous, fossiliferous, slightly dolomitic. Lithotype 3.

Bed 5 3.20 - 3.40 meters
Thinly bedded pinkish-orange chalcedony breccia, calcite cemented. Lithotype 5.

Bed 6 3.40 - 3.99 meters
Medium bedded light brownish gray dolomite, unfossiliferous, laminated. Whole unit is intercalated with thin green shale partings. Lithotype I.

Bed 7 3.99 - 4.27 meters
Thinly bedded light tan limestone, unfossiliferous, mudcracked upper surface. Lithotype I.

Bed 8 4.27 - 4.66 meters
Medium bedded, medium gray limestone, fossiliferous, slightly dolomitic. Lithotype 4, Group 1.

Bed 9 4.66 - 4.73 meters
Thinly bedded olive green shale, fossiliferous.

Bed 10 4.73 - 5.11 meters
Medium bedded light brown limestone, fossiliferous. Lithotype 4, Group 1.

Bed 11 5.11 - 5.15 meters
Olive green shale. Beds 9 and 11 converge laterally at the expense of bed 10.

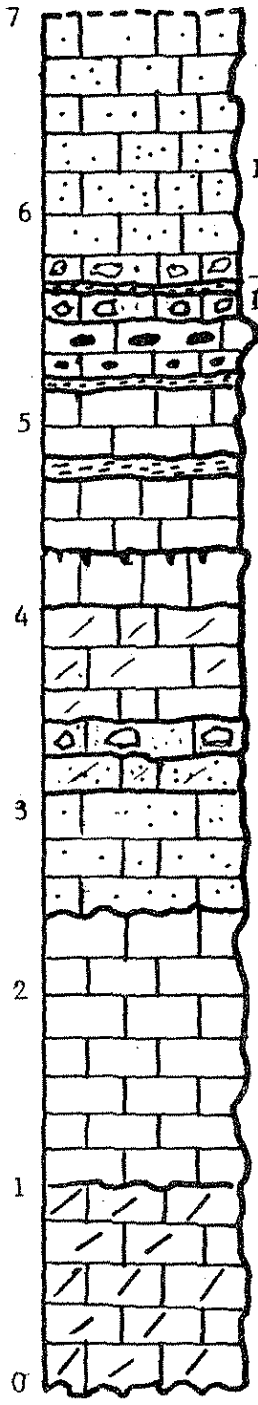
Bed 12 5.15 - 5.43
Medium bedded gray limestone, unfossiliferous, chert clasts near base; large 8 cm long chert nodules near top. Lithotype I.

Bed 13 5.43 - 5.63 meters
Medium bedded pink chalcedony and quartz sand breccia; dolomite cement. Upper 2.0 mm consists of green shale. Lithotype 5.

St. Louis Formation?

Bed 14 5.63 - 7.03 meters
Very thickly bedded light grayish-brown limestone, arenaceous, cherty, brecciated near base. Lithotype 4, Group 4.

Heinold Quarry, Des Moines County
SW ¼, NW¼, and NW¼, SW¼ ,
Section 10, T 69N, R 4W



LIST OF QUARRIES AND LOCATIONS
APPEARING ON MAP IV

1. Eddyville Quarry #3 W ½, NE ¼, Sec. 2, T 73 N, R 16 W.

2. Glenn Quarry NE ¼, Sec. 29, T 73 N, R 14 W.

3. Wagner Quarry SE ¼, NE ¼ and part of SW ¼, NE ¼, Sec. 16, T 72 N, R 14 W.

4. Harold Cassill #1 SE ¼, NW ¼, Sec. 11, T 70 N, R 15 W.

5. Hootman Quarry SW ¼, NE ¼, Sec. 15, T 70 N, R 12 W.

6. Lewis Quarry N ½, SW ¼ and SE ¼, NW ¼, Sec. 2, T 69 N, R 12 W.

7. Anderson Quarry SE ¼, SE ¼, Sec. 21, T 73 N, R 8 W.

8. Dodds Quarry W ½, NE ¼, Sec. 34, T 71 N, R 9 W.

9. Cedar Creek Quarry NE ¼, NW ¼, Sec. 36, T 71 N, R 9 W.

10. Nedrow Quarry NE ¼, Sec. 19 and NW ¼, NW ¼, Sec. 20, T 70 N, R 11 W.

11. Douds Stone NE ¼, SE ¼, Sec. 25, T 70 N, R 11 W.

12. Gardner Quarry W ¼, NW ¼, Sec. 16, T 79 N, R 11 W.

13. Winsell Quarry E ½, SE ¼, Sec. 22, T 69 N, R 11 W.

14. Van Buren County Quarry SE ¼, SW ¼, Sec. 21, T 69 N, R 10 W.

15. Camanche Quarry SE ¼, SE ¼, Sec. 5, T 67 N, R 8 W.

16. Hoaglin Quarry SW ¼, NE ¼, Sec. 13, T 70 N, R 8 W.

17. Rhum Quarry SW ¼, Sec. 13 and NW ¼, Sec. 24, T 71 N, R 7 W.

18. Smith Quarry W ½, SE ¼, except NW 17 acres and SE 22½ acres, Sec. 17, T 71 N, R 6 W.

19. Henry County Quarry NW ¼, NE ¼, Sec. 18, T 71 N, R 6 W.

20. Beattie Quarry NW ¼, NW ¼, Sec. 26, T 70 N, R 5 W.

21. Heinold Quarry SW ¼, NW ¼, and NW ¼, SW ¼, Sec. 10, T 69 N, R 4 W.

22. Prospect Hill Quarry NE ¼, NE ¼, Sec. 27, T 69 N, R 3 W.

23. Sullivan Slough Quarry SE ¼, Sec. 30, T 69 N, R 2 W.

24. McLaughlin Quarry NE ¼, Sec. 12, T 71 N, R 4 W.

25. Mediapolis Quarry #134 SE ¼, SE ¼, Sec. 1, T 71 N, R 4 W.

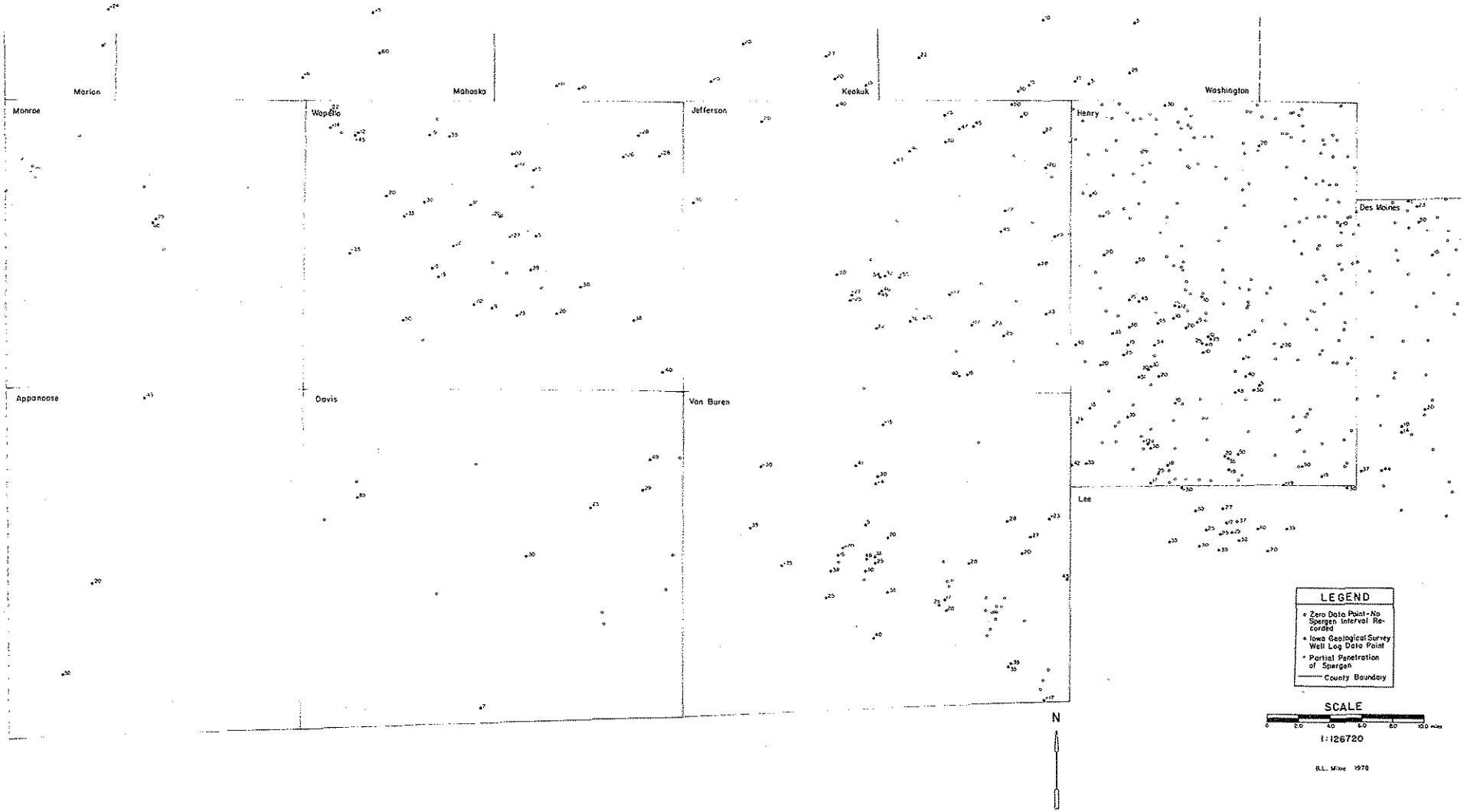
26. Nelson Quarry SW ¼, NE ¼, Sec. 26, T 72 N, R 2 W.

27. Ping Quarry E ½ of SE ¼, Sec. 23 and SW ¼, Sec. 24, T 72 N, R 2 W.

APPENDIX II

THICKNESS OF SPERGEN FORMATION

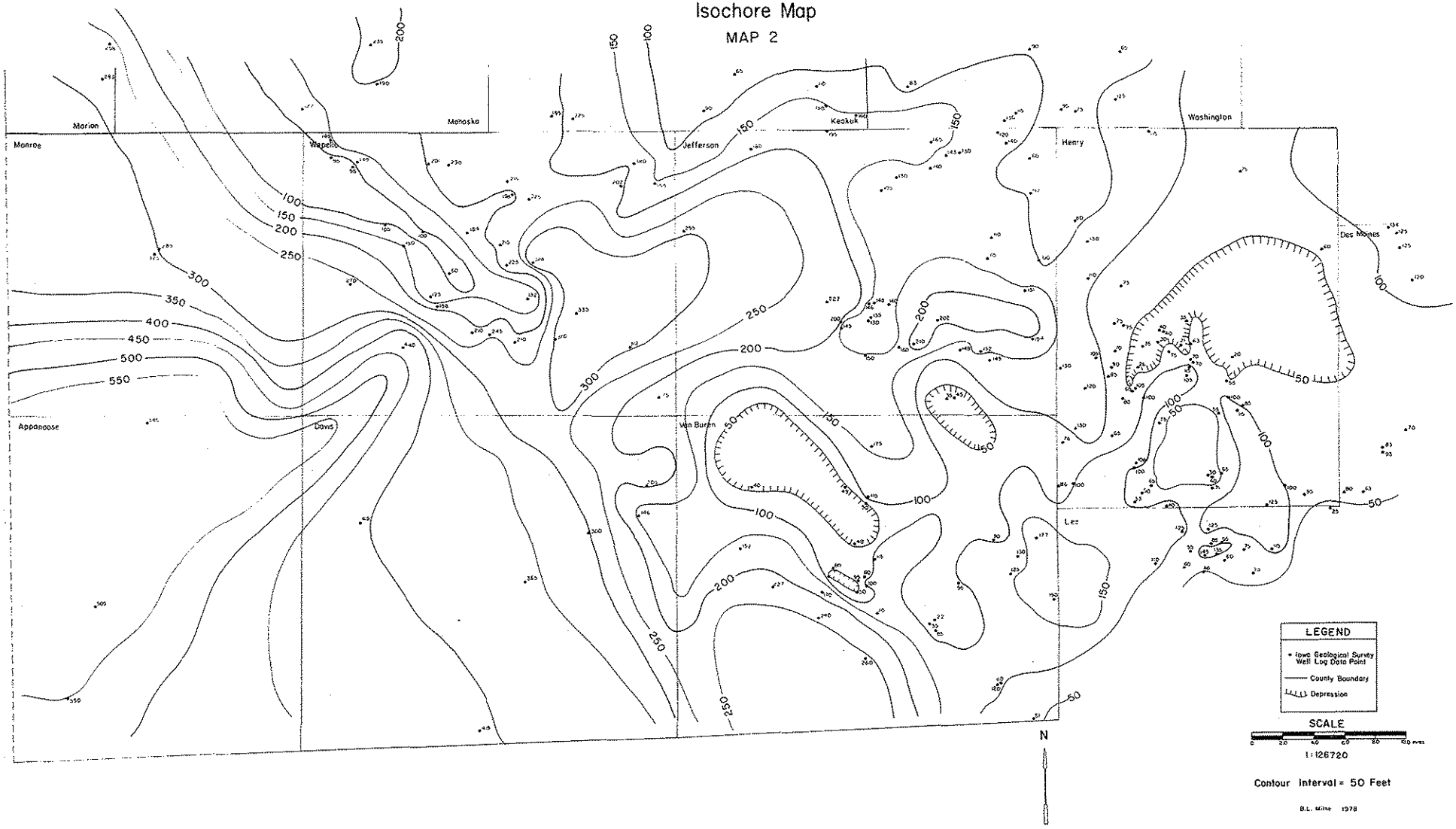
MAP I



DEPTH TO TOP OF SPERGEN FORMATION

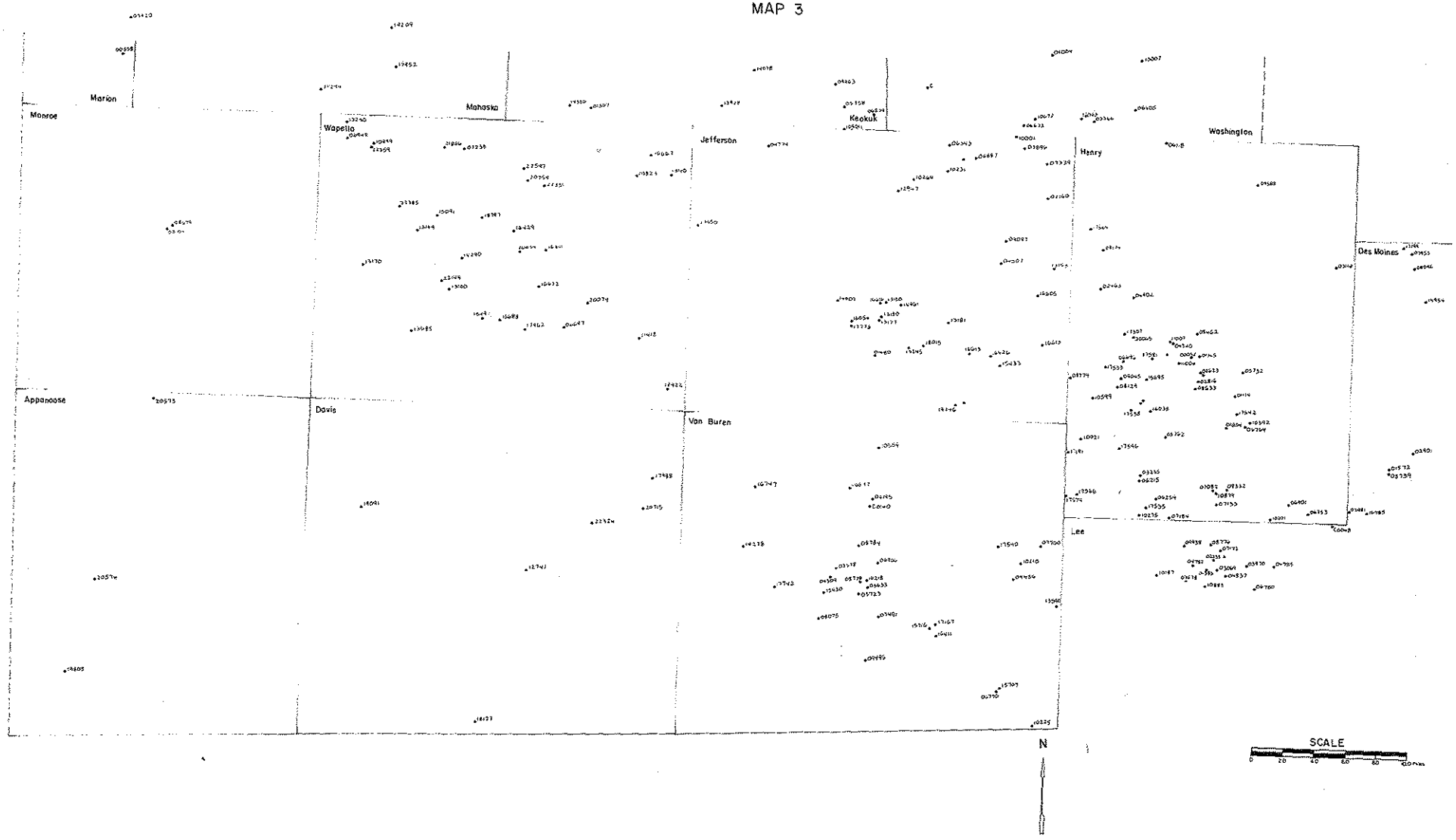
Isochore Map

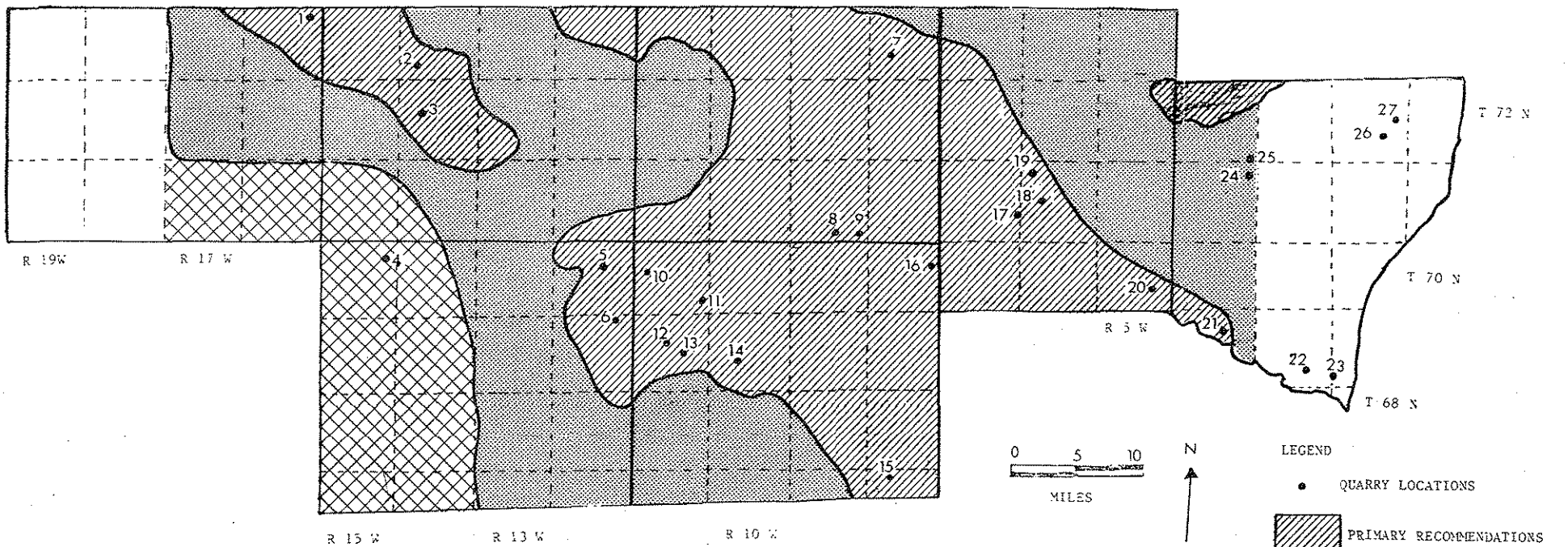
MAP 2



DATA POINTS

MAP 3





MAP IV Recommendations Map and Distribution of Present Working Quarries in Southeastern Iowa. Township and Range locations of Quarries listed in the Appendix section.