IOWA GEOLOGICAL SURVEY
IOWA CITY, IOWA
H. Garland Hershey, Director and State Geologist

REPORT OF INVESTIGATIONS 3

PRELIMINARY REPORT ON BASEMENT COMPLEX ROCKS OF IOWA

by
W. HERBERT YOHO

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PRELIMINARY REPORT ON BASEMENT

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W. HERBERT YOHO

ABSTRACT

Crystalline basement rock has been encountered in the bottom-hole samples of about 45 wells in Iowa. Fairly detailed studies of the samples from most of these wells have been made. Granite is the predominant rock type thus far encountered, followed by diabase in order of abundance. A summary description of the different kinds of crystalline rocks that have been encountered is presented along with a convenient table listing the pertinent data for each well. An index map showing the location and relationship of these wells one to another is included. Detailed descriptions are available in the open files of the Iowa Geological Survey.

INTRODUCTION

PURPOSE AND SCOPE OF REPORT

This report summarizes a rather extensive study of the bottom-hole samples of all wells in Iowa which penetrate to basement complex rock. Of the thousands of wells drilled in the state, only about 45 reached crystalline rock and these are unequally distributed in 18 counties, as shown by table 1 and plate 1. Samples are available from only 38 of the wells.

The intention of the writer is (1) to tabulate in convenient table form all wells which reach basement complex rock; (2) to show the location and relationship of these wells one to another on an index map and; (3) to present a summary description of the different kinds of crystalline rocks that have been encountered.

METHODS OF STUDY

This report is based largely on binocular and petrographic study of well cuttings and on study of thin sections of available cores. Also, much use was made of immersion methods applied to crushed drill chips, acid treatment of selected fragments, and magnetic susceptibility checks.

Most of the samples consist of cuttings taken at various intervals. Samples from the lower portions of many wells were examined in search of the first particles of non-sedimentary rock to appear. The depth at which the first igneous or metamorphic particles were found was taken as the approximate basement top. A few chips of the crystalline material were selected from several samples, in most instances including the bottom-hole sample. Thin sections were made from representative particles chosen by binocular study.

If the sample contained no rock fragments large enough for sectioning, a portion of the sample was crushed by steel mortar and pestle, washed and screened to obtain clean particles between 120 and 200 mesh size. Portions of these particles were studied by the standard immersion procedures to obtain indices of refraction of the various mineral constituents. If the powder contained a significant amount of black or dark opaque particles,

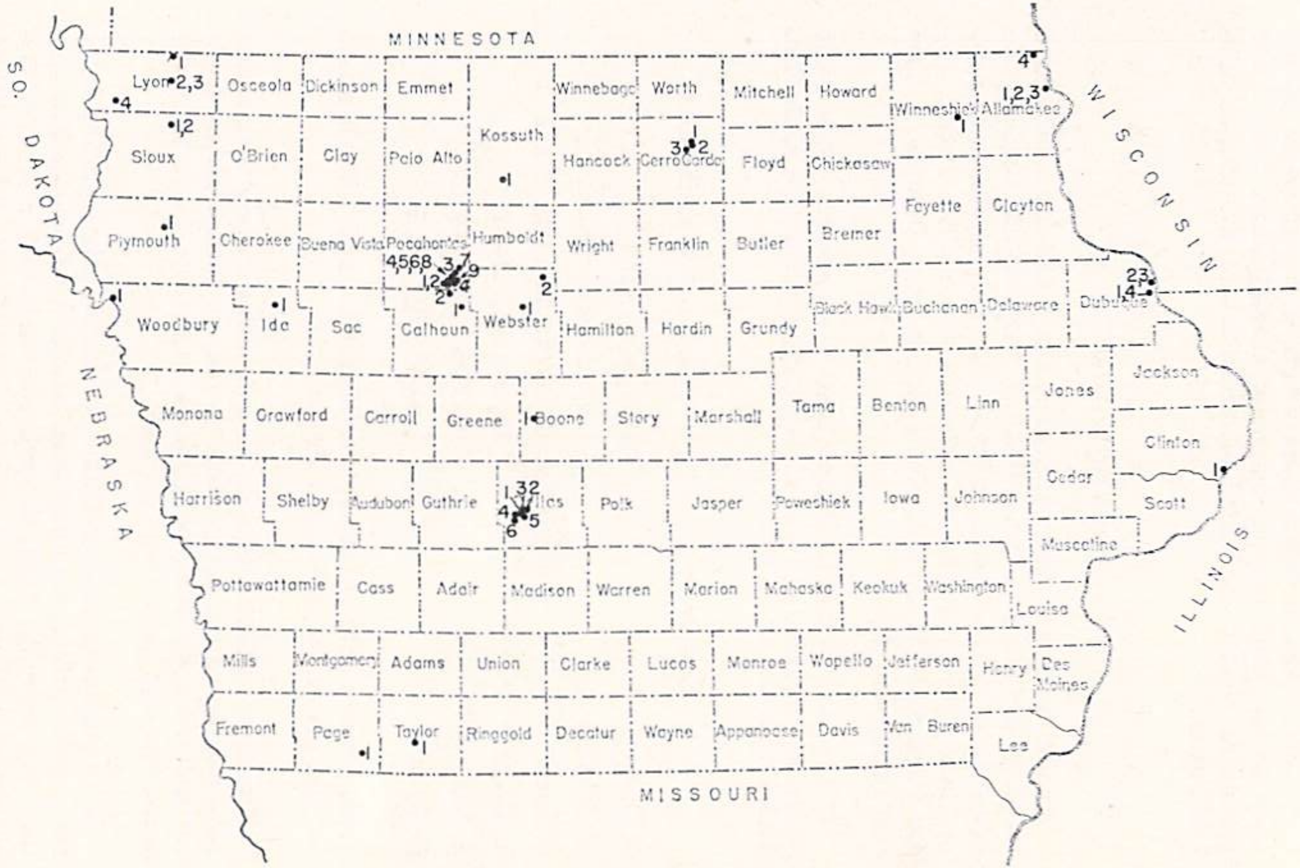

Plate 1. Map of Iowa showing distribution of wells completed in crystalline rocks.

a magnetic separator was used to effect a separation of the particles on the basis of magnetic susceptibility. This latter procedure greatly facilitated identification of the opaque mineral grains.

PREVIOUS WORK

Prior to 1923, according to Lees (1923, p. 445-450), only three wells were known to have reached rocks which normally lie below Huronian quartzites. In that year Lees wrote an account of these three wells which were (1) Sioux City, Magee, (2) Le Mars, and (3) Pioneer No. 1 Bakke, near Decorah, a deep test for oil and gas.

In the same Academy report Lees mentioned six other wells which had been interpreted as reaching Precambrian materials. These wells are as follows:

County	City and Well Number
1. Sioux	Hull, city No. 1
2. Allamakee	Lansing, city No. 1
3. Linn	Cedar Rapids, city No. 1
4. Cedar	Tipton, city No. 1
5. Ida	Holstein, city No. 2
6. Lyon	Inwood, city No. 1

Later studies have indicated that numbers 3 and 4 in the above list did not reach undisputed Precambrian.

Numerous student assistants and other Survey employees have worked on the bottom-hole samples of Iowa wells throughout the years, but most of the work was incidental to the preparation of logs on the various wells.

Some studies of the crystalline basement rocks were the basis for reports published in the Iowa Academy of Science Proceedings. For example, Keith E. Anderson made such a study of the granite from Dubuque city well No. 8 and his report is published in volume 57 for 1950.

During the early 1950's Richard Murray did a great deal of work on bottom-hole samples, and he and assistants prepared a considerable number of thin sections. These sections were used in the present report.

The writer also did considerable petrographic work on the igneous and metamorphic bottom-hole samples, both by thin section and immersion methods, during a part of 1950-51. The information gained remained as unpublished file data until late 1959 when the writer began adding to the previous studies new data obtainable from deep wells drilled after 1951.

The unusual structural and stratigraphic conditions encountered in the Manson area of Calhoun and Pocahontas Counties spurred sufficient interest to drill a core near Manson, a cooperative project by the Iowa and United States Geological Surveys in 1952. J. E. Dryden, a graduate student at the University of Iowa in 1954-55, made a study of the core as a Master's thesis, and in 1958, Hoppin and Dryden published a report on the crystalline rocks of the Manson area in the Journal of Geology.

ACKNOWLEDGEMENTS

The writer is indebted to many members of the Iowa Geological Survey staff for their respective roles in the collection of the data summarized in table 1.

Special thanks are due Dr. H. Garland Hershey under whose direction the entire work on the crystalline rocks was done. His advice, as well as that of Dr. Charles N. Brown, has been most helpful as the research and writing of the report proceeded.

The study was aided greatly by funds made available to the writer by the Iowa Geological Survey for travel to Iowa City for the purpose of selecting the sample materials and for the making of the thin sections.

Gratitude is expressed to the many companies and individual well drillers who have provided the Survey with sample materials, both cores and cuttings, from the deep wells. Without their cooperation, this study would not have been possible.

Lastly the writer wishes to thank Orville Van Eck of the Iowa Geological Survey and Dr. R. A. Hoppin, Department of Geology, University of Iowa, for critical reading of the manuscript. Mr. Van Eck also aided in compiling table 1 in its final form.

SUMMARY OF BASEMENT ROCK TYPES

INTRODUCTION

The different types of crystalline rocks encountered in the 38 wells from which samples are available may be grouped into five general classes:

(1) Granites and other granitic-textured felsic rocks
(2) Diabase and related mafic rocks
(3) Cataclastic rocks
(4) Rhyolite porphyry and related volcanics, including tuff and devitrified glass
(5) Metamorphic rocks including quartzite, gneiss and schist.

Some of the Precambrian materials were relatively unaltered and undeformed, but most samples showed widespread alteration, both weathering and hydrothermal, and also evidences of brecciation or microbrecciation. Neither foliation nor lineation was extensively developed. In many instances the cracks produced by deformation were healed by secondary carbonate deposition.

GRANITES

Granitic rock is the predominant type of basement rock thus far encountered in the eastern part of the state. Granite is encountered at a depth of 728 feet (68 feet below sea level) in Allamakee County in the northeastern corner of the state, and in a well in Dubuque County at a depth of 1,765 feet (1,155 feet below sea level). Still farther south, in Clinton County, granite is encountered at a depth of 3,204 feet (2,616 feet below sea level). These elevations indicate a marked southward slope of the granitic basement surface in the eastern part of the state.

Granite has also been encountered at moderate depths in the northwestern part of the state. In Ida County granite was reached at a depth of 2,020 feet (568 feet below sea level), and granite has been reported at 1,320 feet (45 feet below sea level) in Plymouth County. In sharp contrast, near Clarinda, Page County, in southwestern Iowa, the granite is found at a depth of 5,206 feet (4,239 feet below sea level). However, this granite is considerably weathered and may represent a granite wash rather than a true Precambrian surface.

Granite, or a related silicic, granitic-textured rock was encountered in bottom-hole samples in 20 of the 38 wells from which samples are available, and granite is reported in 4 of the 7 additional wells that are listed as having reached basement complex, but for which no samples are available. In 4 of the 20 wells the samples contained fragments that were identified as biotite and oligoclase-bearing monozonite and another one contained fragments of leucosyenite.

Biotite granite is the most common and widespread rock type, having been found in nearly all of the granite-bearing wells. Most of the granites are altered, either hydrothermally or by weathering, or both.

DIABASE

Next in frequency of occurrence is intermediate to fine mafic rock, here called diabase if plagioclase laths in random orientation are either actually present or the outline of their former presence can be detected. Most of the samples are altered diabases, for much of the feldspar has weathered to clay. If plagioclase laths were not observed, but the mineral composition was otherwise similar, the rock was identified as basalt. Some of the basalt was almost fine enough to be identified as devitrified basaltic glass. A few samples were sufficiently coarse-grained to be classed as gabbro.

The area in which the basement is composed of mafic rock, insofar as can be outlined with present information, extends in a narrow arc-shaped zone from Decorah in Winneshiek County on the northeast where olivine gabbro was encountered, southwestward to Cerro Gordo, Webster, Boone and Dallas Counties. Recent aeromagnetic studies indicate that the mafic body near Decorah probably is not related to the mafic bodies to the southwest. The mafic rock may be abundant southwest of these counties, but no deep wells have been drilled within 65 or more miles in that direction.

Diabase has been identified as the principal bottom-hole rock in 13 of the 38 wells for which samples are available. Olivine gabbro, occurring most probably as a sill, was found in one well, and some gabbro, basalt or diabase is present, mixed with other rock types in 5 other wells in the Manson area of Calhoun and Pocahontas Counties.

Most of the diabases are extensively altered, by weathering and hydrothermal or deuteric alteration, and replacement. One of the most extreme instances of decay of the mafic rock occurs in the Northern Natural Gas Company No. 1 Peterson well near Vincent in Webster County. The residuum of the crystalline rock, presumed to be mafic because of the high content of iron impregnating the clay, was so completely decayed that it was impossible to state with certainty that the original rock was diabase. A thin section made from core at 2,183 feet (about 1,040 feet below sea level) was largely very dark red to brownish-red iron-impregnated clay. There was more quartz in the thin section than would be expected in diabase. However, the quartz, which was of two types, cryptocrystalline and consisting of chert, and crystalline milky to colorless quartz, was probably, at least in part, of secondary origin. Some of the quartz occurred as the filling in small, vug-like cavities.

CATACLASTIC ROCKS

Rock chips obtained from some of the wells in the northwestern quarter of the state, especially in the Manson area, have proved to be difficult to diagnose. In Manson city well No. 2, Calhoun County, the light-colored rock with essentially the composition of granite has been variously labelled by different investigators as granite, tuff, arkose[1] or breccia. There is granite like rock present in many of the wells near Manson, but much of the material with the composition of weathered granite does

1. In the log of Manson city well No. 2, published in Iowa Geological Survey volume 33, page 248, the samples below about 1,000 feet are described as arkose. Under "Notes," pages 249-254 a discussion of the unique and anomalous geologic section found in this well is given.

not have the grain relationships of granite. Also, none of the samples show any evidence of sedimentary deposition in air or water, as would be expected in the case of arkose and tuff.

Because of the presence of abundant breccia in the U.S.G.S. core 2A (Pocahontas County), and if the mode of emplacement of these mixed and crushed rocks is considered to be cryptovolcanic (Hoppin and Dryden 1958, p. 698), it seems that a good term to apply to such cataclastic rocks might be cryptovolcanic breccia. If the cataclastic rock is of impact origin, as more recent consideration of the structure suggests (Hoppin, oral communication, 1967), it might be termed a cryptoexplosion breccia. For that portion of the rock which is very fine grained with no preferred orientation of the grains and where no recrystallization is evident, the term cataclasite might be used.

Cataclastic rocks are relatively abundant, especially in the region surrounding Manson. Various types of breccias were noted in 8 wells in Calhoun and Pocahontas Counties (table 1). These crushed rocks occur at various depths in the well ranging from less than 100 feet deep (approximately 1,150 feet above sea level) in the U.S.G.S. core 2A to a probable depth of about 968 feet (264 feet above sea level) in Manson city well No. 2.

RHYOLITE PORPHYRY ROCKS

Beyer (1893, p. 165-169) reported the presence of quartz porphyry in city well No. 1 at Hull in Sioux County. He considered the rock to be Carboniferous or younger in age. In contrast, Norton (1897, p. 199) in referring to the same well wrote that "nothing is known of the strata of the first 755 feet of the boring. Below that depth the drill passed through at least six beds of ancient lava intercalated between saccharoidal sandstones. This assemblage of strata, unique in the records of the geological history of Iowa, probably belongs to the Algonkian."

In city well No. 2 at Hull similar rock, referred to in this report as rhyolite and rhyolite porphyry, was first encountered at 724 feet (703 feet above sea level).

About 15 miles north of the wells at Hull, near Rock Rapids, in Lyon County, two wells fairly close together contain some dense materials presumably occurring as flows or falls of very fine ash and dust intercalated with beds of quartzitic sandstone. One of the wells, Rock Rapids No. 1, which has a total depth of 397 feet, yielded a variety of volcanic rock types in various stages of alteration in the depth zone between 375 and 390 feet.

The sample materials from Rock Rapids No. 2 are mostly quartzite, but there are a few pale greenish-gray very fine-textured rock fragments that presumably represent lava flows or falls of very fine volcanic ash or dust interlayered with the quartzite.

Among the many volcanic rock samples, very few were found with typical glassy texture. Scattered fragments were found in samples from several different wells, particularly in the Manson area, that were identified as volcanic glass, but in most samples devitrification is practically complete. One fragment has been identified as chloritized devitrified basaltic glass from city well No. 2 at Manson from the depth range 1,040 to 1,050 feet (182 to 192 feet above sea level).

Partial alteration of the basaltic glass to chlorite occurred most prominently along the flow lines where the chlorite shows some rhythmic banding or zoning, which developed during the process of alteration or replacement. Some cocks-comb type structures developed on adjacent sides of the fractures.

MATAMORPHIC ROCKS

Quartzites

If a very broad and inclusive definition of quartzite is allowed, so as to include those quartzose rocks that show some secondary grain enlargement and silica cementation, but limited suture grain contacts, it would mean that quartzites in the state are rather abundant and widespread. However, quartzite of undisputed Precambrian age was encountered in only 5 wells, 4 of which were listed above as having rhyolites, tuffs and other volcanic materials intercalated with the quartzites. Sioux quartzite is the only rock of Precambrian age to crop out in Iowa, and it occurs in a very small area in the northwestern corner of the state (Beyer, 1897, p. 69-112). Little detailed work was done on the quartzites in the present study except to identify them in the samples and to note their locations, depths, and in most instances elevations of their tops (table 1). One slide was made from a sample of quartzite from 540 to 545 feet from Rock Rapids well No. 2 in Lyon County. The thin section contained many grains that were well rounded, some almost perfectly round. The rounded grains are outlined by clay dust impregnated by red hematite. The interstices are filled with colorless quartz, mostly in optical continuity with each rounded grain that the quartz filling contacts, thus greatly reducing the appearance of grain roundness under crossed nicols. This sample of quartzite is rather pure quartz except for the hematite-stained dust bordering many of the grains, a very few grains that are dusky and iron stained throughout, and two or three minute particles in the interstices that appear to be carbonate, but may be what Beyer (1897, p. 102) identified as sericite. Also, most of the quartz grains contain extremely small inclusions.

Samples taken from the Tiezen No. 1 Gisolf well in Lyon County from a depth of 430 to 434 and 436 to 441 feet are not as pure quartz as the samples from the Rock Rapids wells. It is probable that the original sediment was arkosic, so that after alteration the quartzite is rather argillaceous with many dusky grains representing atleration products of feldspar. Some, but not nearly all, of the dusky grains are iron stained. Also, some of the quartz grains, instead of being optically continuous or exhibiting undulatory extinction, are composed of many very small quartz particles. The rock also contains some small particles of pyrite, and a considerable number of small, ragged, opaque particles that appear nearly pure white under reflected light. Beyer (1897, p. 102-103) reported very abundant "quartz needles" or rutilated quartz in his study of the Sioux quartzite. Although no needles of rutile are present in the sample from Tiezen No. 1 Gisolf, the white opaque particles which probably are leucoxene, may be alteration products of rutile.

Other Metamorphic Rocks

Very few samples in thin section exhibited gneissic or schistose characteristics except for a few samples from various depth ranges from six different wells in the Manson area, five of them in Pocahontas County and the sixth in Calhoun County. No well has been drilled in Iowa in which the entire suite of basement complex samples is gneissic or schistose with the possible exception of two wells for which samples are not available, the Le Mars well in Plymouth County and the Magee well in Woodbury County. As for the Le Mars well, Meinzer and Norton (1912, p. 1,076) reported possible gneiss consisting of orthoclase, quartz and muscovite from 960 to 1,060 feet, gneiss consisting chiefly of feldspar and mica from 1,060 to 1,325 feet, and changing to micaceous schist from 1,325 feet to a total depth of 1,560 feet. On the basis of this log the top of the basement complex might be taken at 960 feet (315 feet above sea level) instead of the figure given in the body of the report where it was stated "the floor of crystalline rocks was unquestionably reached at 1,060 feet, or 215 feet above sea level." No further description is made of the gneiss and schist, but reference is made to the fact that the nearly five hundred feet of "sandstone" above the crystalline rocks may be comparable to the rhyolite-bearing quartzite found in the Hull city wells Nos. 1 and 2 in adjacent Sioux County, and that this material may be Precambrian, thus possibly placing the basement complex top at 810 feet above sea level.

Information on the Magee well is also meager. Miller and Norton (1912, p. 1,098) reported schist or gneiss in the Magee well at a depth of 1,160 feet, or 35 feet below sea level. For the depth range 1,160 to 1,260 feet they described the cuttings as "schist, soft, fine-grained; speckled with white and dark green-gray; so friable that a microsection could not be obtained; when pulverized it is seen to be composed of quartz and chlorite."

About half of the total recovered core from the U.S.G.S. core No. 2A near Manson showed some gneissic characteristics. Of these foliated rocks, medium- to fine-grained altered gneisses are the most abundant, making up 35 to 40 percent of the total 385 feet of crystalline rock penetration. The second most abundant is a granitic type of rock, making up about 30 percent of the total. About half of this is gneissic and the remainder shows no evidence of grain orientation. Dryden (1958), in his study of the core from this hole, has given a rather complete account of the rock types, both igneous and metamorphic, typical of the Manson area.

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TABLE 1. SUMMARY OF WELLS COMPLETED IN CRYSTALLINE ROCK IN IOWA
Number preceding well name corresponds to number on Plate 1.

County	Well Name and Location (¼ sec., T., R.)	Type of Crystalline Rock	Altitude (feet) Surface	Altitude (feet) Top of crystalline rock	Depth to top of crystalline rock (feet)	Amount of penetration (feet)	Total depth (feet)
Allamakee	1. Lansing, city No. 4, NW NE SE 29-99N-3W	Biotite granite	643	—69	712	9	721
	2. Lansing, city No. 1, NW NE NE SE 29-99N-3W	Granite reported	660	—88	748	0.75	748.75
	3. Lansing, city No. 2, NW NE NE SE 29-99N-3W	Granite reported	----	----	440	-------	440
	4. New Albin, cen. NW NW 11-100N-4W	Granite reported	600±	—68±	728	-------	-------
Boone	1. Ogden, city No. 2, NE NW SW 32-84N-27W	Oligoclase leucodiabase	1,095	—1,735	2,830	22	2,852
Calhoun	1. Manson, city No. 2, NW cor. 17-89N-31W	Predominantly microbreccia; some gneiss, schist, and leucogranite; one grain of devitrified glass	1,232	264	968	243	1,211
	2. Moline Brothers, NW SW NW 6-89N-31W	Biotite granite and microbreccia	----	----	160±	92±	252
Cerro Gordo	1. Mason City, city No. 8, NW cor. NW NE SW3-96N-20W	Diabase, basalt and gabbro (one grain almost a chlorite schist)	1,098	—600	1,698	77	1,775
	2. C.M. & St. P.R.R. No. 1, Mason City, SW cor. SW 10-96N-20W	Diabase and basalt	1,120	—348	1,468	5	1,473
	3. Mason City No. 12, NE SE NE SE 16-96N-20W	Diabase	1,165	—402	1,568	17	1,585
Clinton	1. DuPont No. 5, Clinton, NW SW SE 22-81N-6E	Biotite granite	588	—2,616	3,204	12	3,216

County	Well Name and Location (¼ sec., T., R.)	Type of Crystalline Rock	Altitude (feet)		Depth to top of crystalline rock (feet)	Amount of penetration (feet)	Total depth (feet)
			Surface	Top of crystalline rock			
Dallas	1. Northern Natural Gas Co. No. 1 Nelson, NW SE SW 12-79N-29W	Diabase	1,027	—1,796	2,823	18	2,841
	2. Northern Natural Gas Co. No. 1 Maher, SE SE NE 1-79N-29W	Diabase	1,012	—1,901	2,913	3	2,916
	3. Northern Natural Gas Co. No. 1 Davis, NE NW NE SW 12-79N-29W	Diabase	1,045	—1,802	2,847	2	2,849
	4. Northern Natural Gas Co. No. 1 Walker, NE NE SW SW 11-79N-29W	Diabase	1,048	—1,851	2,839	4	2,903
	5. Northern Natural Gas Co. No. 1 Hummell, NW NE NW 18-79N-28W	Diabase	1,016	—1,762	2,778	12	2,790
	6. Northern Natural Gas Co. No. 1 Moncelle, NE NW SW SE 26-79N-29W	Diabase	1,070	—1,920	2,990	5	2,995
Dubuque	1. Farley & Loetscher, Dubuque, cen. S½ SE SE 24-89N-2E	Leuco-granite bordering on leucosyenite	608	—1,397	2,005	5	2,010
	2. Dubuque, city No. 5, SE SE 7-89N-3E	Biotite granite	623	—1,175	1,800	11	1,811
	3. Dubuque, city No. 8, cen. SL SE SE 7-89N-3E	Biotite granite	610	—1,155	1,765	16.7	1,781.7
	4. Dubuque Packing Co., No. 5, E½ NE SE 24-89N-2E	Perthitic biotite granite	----	----	1,955	10	1,965
Ida	1. Holstein, city No. 2, NW cor. 35-89N-40W	Biotite granite	1,452	—568	2,020	20	2,040
Kossuth	1. Algona, city No. 3, Ctr. NL SW 2-95N-29W	Perthitic biotite granite	1,212	—618	1,830	55	1,885
Lyon	1. Tiezen No. 1 Gisolf, SW SW NW 16-100N-45W	Argillaceous quartzite with intercalated rhyolite or tuff	1,367	967	400	43±	443±

TABLE 1. SUMMARY OF WELLS COMPLETED IN CRYSTALLINE ROCK IN IOWA — Continued
Number preceding well name corresponds to number on Plate 1.

County	Well Name and Location (¼ sec., T., R.)	Type of Crystalline Rock	Altitude (feet) Surface	Altitude (feet) Top of crystalline rock	Depth to top of crystalline rock (feet)	Amount of penetration (feet)	Total depth (feet)
Lyon cont.	2. Rock Rapids, city No. 1, 5-99N-45W	Quartzite with intercalated volcanics	----	----	375	22	397
	3. Rock Rapids, city No. 2, SE SW5-99N-45W	Quartzite with apparently alternating zones of rhyolite or tuff	----	----	520	29	549
	4. Inwood, city No. 1, SE SE SE 18-98N-47W	Sioux quartzite	1,466	991	475	439	914
Page	1. No. 1 Wilson, Clarinda, NE cor. 25-68N-37W	Biotite granite, some perthitic	967	—4,239	5,206	99	5,305
Plymouth	1. LeMars, 16-92N 45W	Quartzite porphyry at 960 feet; gneiss? at 1,060 feet; granite? at 1,320 feet	1,275	215(?)	1,060	500	1,560
Pocahontas	1. Leon Sauter, Blanden, SE SE SW 36-90N-32W	Predominantly microbreccia and breccia; some lithic fragments; a little basalt and gabbro	1,233	988	245	50	295
	2. E. E. Zehr, Blanden, SW NW NE 35-90N-32W	Biotite granite, some slightly gneissic; some syenite or monzonite, glassy basalt and microbreccia	1,240	851	389	485	874
	3. Peters Farm, Blanden, SE SE NE 19-90N-31W	Microbrecciated biotite granite	1,238	1,038±	200±	26±	226
	4. Carster Brothers, Blanden, NE NE NE 31-90N-31W	Oligoclase diabase; also biotite monzonite and hornblende gneiss	1,244	1,147	97	268	365

County	Well Name and Location (¼ sec., T., R.)	Type of Crystalline Rock	Altitude (feet)		Depth to top of crystalline rock (feet)	Amount of penetration (feet)	Total depth (feet)
			Surface	Top of crystalline rock			
Pocahontas cont.	5. Perry Miller, Palmer, NW NE NW 36-90N-32W	Quartz oligoclase biotite gneiss, smaller amounts of diabase and microbreccia	1,245	1,048	197	73	270
	6. Gerber, Palmer, SW NW NW 17-90N-31W	Microbreccia and biotite monzonite	1,230	815±	415±	225±	640
	7. Anna Vinkie, Palmer, SW cor. NW 35-91N-31W	Carbonate-bearing micro-breccia; some biotite gneiss, diabase and biotite granite	1,192	507	685	275	960
	8. County Home, Blanden, SE NE NE 25-90N-32W	Biotite monzonite	1,230	1,125	105	49	154
	9. U.S.G.S. Core No. 2A, Manson, SW SW SW 29-90N-31W	Predominantly biotite gneiss and granite; some diabase	1,244	1,150	93	385	478
Sioux	1. Hull, city No. 2, SW NW SW 26-97N-45W	Rhyolite porphyry	1,427	703	724	44	768
	2. Hull, city No. 1, NW SW 26-97N-45W	Quartz porphyry alternating with sandstone or quartzite	1,433±	678±	755	508	1,263
Taylor	1. Cline No. 1 Long, NW NW NW 20-68N-34W	Biotite granite	1,097	—2,656	3,753	94	3,847
Webster	1. Fort Dodge, city No. 15, NE SE SW 19-89N-28W	Diabase	980	—1,310	2,290	17	2,307
	2. Northern Natural Gas No. 1 Peterson, NE NE NW10-90N-27W	Product of complete alteration of basalt, diabase or other mafic rock	1,133	—1,033	2,166	20	2,186
Winneshiek	1. Pioneer No. 1 Bakke, Decorah, SE SW 30-98N-7W	Olivine gabbro; one sample from 2,500 feet	1,100±	—620+	1,720	1,580	3,300
Woodbury	1. Magee Well, Sioux City, 29-89N-47W	Gneiss or schist	1,125	—135	1,260	851	2,011