STATE OF OHIO
MICHAEL V. DISALLE, Governor
DEPARTMENT OF NATURAL RESOURCES
HERBERT B. EAGON, Director
DIVISION OF GEOLOGICAL SURVEY
RALPH J. BERNHAGEN, Chief

REPORT OF INVESTIGATIONS NO. 44

PRECAMBRIAN IN OHIO AND ADJOINING AREAS

BY

CHARLES H. SUMMERSON

COLUMBUS
1962

Price 50 cents plus tax

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ABSTRACT

Thirty-eight wells have been drilled to the Precambrian rocks in Ohio. From elevations of the top of the Precambrian rocks in these wells and in those of adjoining areas, a contour map of the Precambrian surface, with a 500-foot interval, has been compiled. Major structural features shown are the Appalachian geosynclinal border in the east and the Ohio Platform in the west joined by a hingelike structure extending north-south across the State. In the north the platform shows a topographic high, and in the south a major fault trend which forms part of its border in central Kentucky. Rocks in the wells are grouped genetically and their distribution is shown on the map. Stratigraphic conditions at the contact are interpreted to be similar to those of the Ozark region. The ages of the rocks from some of the wells along the east side of the platform, as determined from their radioactivity, are approximately 1,000 million years. These ages are correlative with those of rocks from a number of localities in northeastern North America.

ACKNOWLEDGMENTS

Many people aided in gathering information for the map of the Precambrian rocks and surface and the summary presented here. The latest well data were obtained with the assistance of the following: M. E. Biggs of the Indiana Geological Survey; W. W. Hagen and E. Nosow of the Kentucky Geological Survey; G. D. Ells of the Michigan Geological Survey; Thomas Arkle of the West Virginia Geological Survey; and G. R. Thomas of the United Fuel Gas Company, Prestonberg, Kentucky. Profs. C. A. Lamey and G. E. Moore, Jr., of The Ohio State University Department of Geology, read the manuscript and made several helpful suggestions.

Ohio Division of Geological Survey Report of Investigations 41, "Petrology of Precambrian Rocks of Ohio," by George R. McCormick, was of particular value to this summary, as was the assistance of Warren L. Calvert, of the Ohio Division of Geological Survey, in the obtaining of the most recent drilling data.

INTRODUCTION

Because of the absence of outcrops of Precambrian rocks in Ohio, knowledge of the basement is confined to information obtained from wells and to the interpretation of results of geophysical exploration. Therefore, until recently, very little information has been available. In 1932, on the basis of data from five wells available at the time, Hubbard attempted a very general description. Moss (1936) included Ohio in his Precambrian surface map of the eastern United States. Within the last few years, increased drilling activity has supplied additional data which, together with detailed petrographic descriptions, has made possible further interpretation of the Precambrian rocks of Ohio.

The following is a summary of the information from the wells drilled to the basement to July 1, 1962, with a description of the nature of the record, the lithological data, and available geophysical data. The discussion is illustrated by a map (pl. 1) showing the Precambrian topography and the distribution of major rock types.

DESCRIPTION OF WELLS

The first well in Ohio to penetrate the Precambrian, the D. L. Norris well in Hancock County, was drilled in 1912 and described by Condit in 1913. During the next 43 years, only 11 additional wells were drilled to the Precambrian rocks, all in western Ohio. Of these, the best known and most studied is the Vance well, located in Delaware County and described by Stout and Lamey (1940). Since 1955 there has been steadily increasing deep-drilling activity, with 26 additional wells completed to the Precambrian rocks, 5 in 1959 and 1960, and 6 in 1961; and several basement tests are planned for the latter half of 1962.

Several factors undoubtedly have influenced the recent increase in deep drilling: first, the interest in exploration of "new" petroliferous zones, which require drilling to greater depth; second, the geologic knowledge to be obtained, particularly that pertaining to structural control which may be a guide for future exploration; third, the chance of finding mineral deposits known to be associated with Precambrian rocks; and, fourth, the publication of the map of the gravity survey of Ohio by Heiskanen and Uotila (1956). Of the wells drilled since publication of the gravity map, over half are located in areas of strong positive gravity anomalies.

The wells drilled to the Precambrian are concentrated in the western half of the State, from northern Highland County in the south, to Erie and Sandusky Counties in the north. Most of them are located in the area of the "Cincinnati Arch." Somewhat off the trend are two wells in eastern Medina County and one in Guernsey County. Descriptions of locations, names of drillers, and general stratigraphic intervals are available in a summary tabulation of all sub-Trenton wells through 1960 and 1961, compiled by the Ohio Division of Geological Survey. The majority of wells in western Ohio are concentrated in two areas: in the north in parts of Hancock, Seneca, and Wyandot Counties; and in the south in parts of Fayette and Clinton Counties; both are areas of strong gravity anomalies.

Drilling depths of the wells to the Precambrian over the State range from 2,796 feet (Hetrick well) in Sandusky County to 8,325 feet (Marshall well) in Guernsey County. In southern Ohio, Fayette and Clinton Counties, depths to the Precambrian surface range from 3,200 to 3,500 feet.

In about half the wells, penetration of the Precambrian rocks is less than 100 feet. Of the rest, four wells have an unusually deep penetration. The deepest of these is the Parsell well in southern Wyandot County. It is reported to have gone 2,592 feet into the Precambrian rocks; unfortunately, however, the samples have been lost and the identification of the top of the Precambrian is based on the driller's log. Other wells with exceptional penetration are the Vance well in Delaware County, with 446 feet of Precambrian rocks; the Friend well in Clark County, with 1,279 feet, described by Wasson (1932); and the Hopkins well in Fayette County, with 1,163 feet, described by McCormick (1961).

TOPOGRAPHY AND RELIEF

Plate 1 is a map of the Precambrian surface of Ohio, shown with 500-foot contours. In the compilation, some interpretation was necessary in determining the elevation values. The problem of distinguishing between arkosic sediments and weathered or fresh granite makes identification of the top of the Precambrian section difficult. Therefore, values of the Precambrian elevations may vary with different descriptions. The elevations used here for most of the Ohio wells are those determined by McCormick (1961); for the rest, either the published elevation or the driller's record is used. Variations among these sources are probably insignificant in this compilation.

Because of the large contour interval and the limited control from only 38 wells in Ohio, the surface relief shown on the map is greatly generalized. However, by augmenting the number of elevations from Ohio with those of the wells to the basement in nearby areas, it has been possible to extend the contours over the entire State. A map of the Precambrian surface in Indiana by Gutstadt (1958) was most useful in determining the position of the contours along the western border. A similar map of New York compiled by J. G. Broughton, in Heck (1948), helped to determine the contour positions in the northeastern border area. Numerous basement wells in Ontario and several near the Ohio border in Michigan furnished control points along the northern border. Scattered wells across Kentucky from Lincoln County east to Carter and Breathitt Counties gave control to the southern part of Ohio. The remaining southwestern portion was interpreted from elevations estimated by means of extrapolation of the stratigraphic interval for the deepest wells available. The control points were fewest in the east, for the Wood and Mason County wells in West Virginia and the Kardosh well in Crawford County, Pa., are the only wells that penetrate the Precambrian section along that border.

Green (1957, p. 640) estimated the relief of the Precambrian surface in central Ohio to be as much as 1,600 feet between the Vance well in Delaware County and the Friend well in Clark County. However, this figure was based on the correlation of the lower 1,279 feet of the Friend well as Paleozoic rather than Precambrian as it is now interpreted. The relief between the Friend and Vance wells, according to present interpretation, is approximately 800 feet. Although the large contour interval of the map precludes depiction of topographic detail, the relatively close spacing of wells in Fayette, Clinton, and Highland Counties allows some estimate of the local relief. Here, within the approximate area of an average Ohio county, the elevations of the basement vary within a 400-foot interval. In the somewhat larger area of the topographic high centering in Hancock County, the relief is about 500 feet. The total relief on the surface of the Precambrian in the central area of the platform is approximately 1,000 feet, similar to the relief on the present day surface, but the Precambrian surface is probably more dissected.

STRUCTURAL FEATURES OF THE PRECAMBRIAN

The general features of the Precambrian surface closely parallel the known structural trends of Ohio. In the western half of the State there is close correlation between the broad platform area of the Precambrian surface and the area of the "Cincinnati Arch" as shown in Green (1957) by structure contours on the top of the Trenton. However, contrary to the configuration of the surface of the "Arch" on the Trenton map, the high on the Precambrian surface is to the north in the region of

Hancock, Seneca, and Wyandot Counties, rather than in the Cincinnati region. Also, the west border of the "Arch", or platform, is parallel to and close to the Indiana-Ohio boundary rather than farther west as shown on Green's map. As pointed out by Green, this structure of western Ohio is better described as a platform than as an arch. Therefore, it may be called more appropriately the Ohio Platform. Northeastward from the Ohio Platform the basement surface slopes toward the Chatham sag, then rises toward the present Precambrian outcrop in Ontario, the configuration of the contours closely paralleling those of the Trenton surface. From the information available in northwestern Ohio and adjoining Indiana there is only a slight nose to suggest the extension of a structural high into Indiana. To the north, the outline of the Michigan basin is suggested in the limited area shown; this conforms in general to the interpretation by Cohee (1945). To the south of the platform high, the gentle gradient of the surface of the Precambrian is the reverse direction of that of the Trenton, suggesting some tilting in the intervening interval.

The Indiana side of the platform as shown by Gutstadt (1958) has a rather regular north-south trend and a very gentle gradient sloping westward into the Illinois basin. To the south of Ohio the platform area continues into Kentucky with a gentle though increasing slope. Lack of control makes it impossible to define the southwest outline of the platform or to identify a terminating structure.

The eastern half of Ohio is interpreted as a somewhat regular, sloping surface forming the west side of the Appalachian geosyncline. The gradient of this surface is approximately four times that of the west side of the platform and about 20 percent greater than that indicated by the surface of the Trenton. The surface of the basement is assumed to have a uniform gradient along the edge of the platform and between the wells in central Ohio and those east of the Ohio border. Within this area the only control is a single well, recently completed in Guernsey County. To test the interpretation of this east-sloping surface, estimated intervals to the basement were made for several deep wells in the area. The resulting elevations fell within the proper contours or required only a minor shift of spacing. Undoubtedly more elevations will show a surface of greater complexity, but the general trend and gradient shown seem reasonable.

The surface of the Precambrian changes from a generally southerly slope in the New York-Pennsylvania region to an easterly slope across Ohio, forming the northwest outline of the Appalachian geosyncline. The gradient and trend of the sloping surface continue across Ohio to just south of the Ohio River. There, south of a line between the Mason County well in West Virginia and the Elliot County well in Kentucky, an abrupt change in elevation of the basement takes place. The wells in Lewis, Carter, and Elliot Counties in the east and in Lincoln County in central Kentucky define rather clearly the southeastern and southern border of the platform area, with basement elevations ranging from -3,632 to -4,220 feet. To the south, in Kentucky, wells with greatly increased depth to the basement--that is, approximately -13,000 feet in Martin County, -10,208 feet in Breathitt County, and -8,233 feet in Leslie County, to the southwest--mark an abrupt change in basement elevation. This border structure is quite different from the general character of the Precambrian surface elsewhere around the periphery of the platform. At the present time there is insufficient evidence to identify the structure responsible for this major difference in relief of the basement surface. The area between the controlling wells of the platform border and those of the basin coincides with the surface structural trend known as the Kentucky River-Paint Creek-Irvine fault system.

In a paper describing the stratigraphic sections in wells to the basement in eastern Kentucky, Thomas (1960) shows constant intervals for the Shady-Tomstown and the Conasauga units on the platform and in the basin; however, for the intervening Rome unit he shows a thickening from 270 feet in Carter County to approximately 4,560 feet in Martin County and 3,830 feet in Breathitt County. The rapid change in

thickness suggests deposition compensating for movements along this fault system as early as Cambrian time. However, it is probable that there are no Lower or Middle Cambrian beds in the platform wells and that the thickening instead represents Lower and Middle Cambrian sediment, the movement having occurred as early as Precambrian or as late as post-Middle Cambrian. Any Lower or Middle Cambrian deposits north of the fault would have been removed by pre-Late Cambrian erosion. In either case, later movements probably caused a persistent expression of this fault system at least into youngest Paleozoic time. Possibly, upward movements of the platform block to the north during this early period of activity allowed the development of the Trenton high in the Cincinnati area. Other movements involving tilting of the platform may have been responsible for the Waverly arch described by Woodward (1961).

Because of the limited evidence of the nature of this fault, other interpretations may be considered. For example, the grabens common along the Kentucky River fault system suggest the possibility of a major strike-slip or wrench fault in the basement. Eastward shifts of the platform block on the north, and westward shifts on the south, might well explain the offset of the platform border, the slope of which to the south is suggested by the shallower depth of the Breathitt County well.

More careful study of the surface structures and additional information on the basement will be necessary for the unraveling of the structural history of this area. Whatever interpretation later study may develop, this structure strongly influences the shape and elevation of the Ohio Platform, and movement along the fault trend seems to have started at least as early as Cambrian time.

PETROGRAPHY

The rocks below the Paleozoic have been referred to as "crystalline," "basement," "basement complex," or (widely but often erroneously) "granite." These terms are used somewhat interchangeably by drillers, and to some extent by others. Fortunately, as a result of the recent studies of McCormick (1961), the rocks of most of the Ohio wells have been more precisely identified. Descriptions of older Ohio wells, including identification of the Precambrian rock types, are in Condit (1913), Wasson (1932), and Stout and Lamey (1940); those of Indiana wells are in Kottlowski and Patton (1953). One well in Kentucky has been described by Brown (1951); one in West Virginia, by Bass (1959). Less detailed identifications of Precambrian rocks of wells in Pennsylvania are given by Lyttle (1960), and in Kentucky by Thomas (1960). Samples are available from most of the Ohio wells, and cores are available from three of them.

Detailed description of igneous and metamorphic rocks from samples of well cuttings is made difficult by the small size of fragments. Recognition of such characteristics as coarse texture, foliation or banding, and contact relationships is usually impossible. Attitudes are unrecognizable, and mineral grains of different lithologic types are often mixed.

The following description of the general rock types is chiefly a summary of McCormick's study combined with the older reports. The rocks are grouped into generally genetic categories, and for convenience their areal distribution is plotted on the map. Symbols are indicative of the general rock types; no attempt has been made to depict contacts, relative ages, or other properties.

IGNEOUS ROCKS

Granite and Related Rocks

Granite occurs in the basement in six Ohio wells (table 1, Nos. 11, 19, 21, 23, 24, 29); three additional wells are reported to have "granite" or "granite wash" (Nos. 22, 25, 30), but their samples are unavailable. The granite typically contains pink orthoclase or microcline, some oligoclase, gray plagioclase, quartz, biotite, hornblende, and such accessories as magnetite, hematite, pyrite, zircon, garnet, leucoxene, tourmaline, and augite. In Indiana two wells in Henry and Wayne Counties (Nos. I-2, I-6) contain micrographic hornblende granite. Two Ohio wells (Nos. 14, 27) contain rhyolite composed of orthoclase, quartz, and hematite,with accessory apatite, garnet, zircon, hornblende, leucoxene, hypersthene, and biotite. One rhyolite is somewhat porphyritic; the phenocrysts are plagioclase and biotite. In three Ohio wells (Nos. 8, 18, 26) the rocks are classified as trachyte porphyry or trachyte-latite porphyry with potassium feldspar, magnetite, and quartz conspicuous in the groundmass, and phenocrysts of andesine, oligoclase, or orthoclase. Accessory minerals include hematite, leucoxene, hornblende, garnet, zircon, biotite, and others.

Although there is a compositional relationship between these various rock types, there is no evidence to show that they are related in age. Indications of flow structures suggest that some of the rhyolites and trachytes may have been flows covering rocks of quite different character. However, there is an association of the acidic types in a belt across the center of the platform,with the different subtypes grouped within this area.

Granitic pegmatite is present in the cores from the Hopkins well (No. 9), where it cuts the amphibolite or occurs along the contact between the amphibolite and marble. Samples from several other wells contain large grains of feldspar and quartz, many of which are mixed with fragments of other rock types; they also have been interpreted as pegmatite dikes.

Other Igneous Rocks

In the Adams well (No. 4) in Clinton County, medium-grained dark fragments of basic composition are interpreted as diorite. The minerals include andesine, epidote, magnetite, hematite, chlorite, and small amounts of hornblende, biotite, and leucoxene. In the Long well (No. 20) in Pickaway County, a fine-grained gabbro occurs; because it is below marble it is not shown on the map. It contains labradorite, hypersthene, magnetite, augite and hornblende, and traces of chlorite, biotite, and pyrite. In the Allen County, Ind., well (No. I-1), the basement rock is identified as an augite andesite microporphyry.

METAMORPHIC ROCKS

Metamorphosed Sedimentary Rocks and Metamorphosed Basic Igneous Rocks

Because they occur in close association, metamorphosed sedimentary rocks and amphibolites of possibly either sedimentary or igneous origin are considered

together here and are plotted as a group on the map (pl. 1). The metasedimentary rocks occur in the wells of two areas: one in east-central Indiana, along the west edge of the Ohio Platform; the other in Clinton, Fayette, and Pickaway Counties, Ohio, in the southeast part of the platform. Sedimentary rocks showing little evidence of metamorphism occur in the Friend well (No. 1) in Clark County. In Indiana, the Howard County well (No. I-3) has yellow to reddish-brown iron-impregnated quartzite at the basement surface. A tan to pink to black siliceous argillite (siliceous shale or siltstone) has been reported in the Jay County, Ind., well (No. I-5). Similar argillites occur in a neighboring well (No. I-4) under 30 feet of marble (Kottlowski and Patton, 1953). Dolomitic marble has been found at the basement surface in the Hopkins and Smith wells (Nos. 9, 17). The Hopkins well (No. 9), described in detail by McCormick (1961), has pyroxene hornfels and amphibolites associated with the marble.

In close association with the sedimentary rocks in the southeast Ohio Platform area are dark gray to black medium- to fine-grained amphibolites. They consist of labradorite, hornblende, hypersthene, biotite, hematite, chlorite, garnet, and other minerals. McCormick interprets some of the amphibolites in the Hopkins well as metamorphosed sediments and others as altered basic igneous rocks. These basic igneous rocks, along with the sediments, were altered to a degree corresponding to the hornblende hornfels facies. Amphibolites occur at the basement surface in wells 2, 3, 7, and 9. They are also associated with granite gneisses in wells 10 and 24. In some samples there is a suggestion of banding and foliation.

Gneiss and Schist

A second group of metamorphosed rocks includes gneiss and some schist. They are found in eight Ohio wells (Nos. 5, 6, 10, 13, 15, 16, 17, 28) and in West Virginia and Pennsylvania. There is considerable variation in composition and texture from one locality to another. In samples containing larger fragments the rock is banded with alternating suites of minerals--in the lighter bands, orthoclase, microcline, quartz, muscovite, and biotite; in the darker ones, plagioclase, hornblende, biotite, and chlorite. These rocks, like the granite, undoubtedly represent a variety of rock units, grouped here to show general distribution. In the Long well (No. 20) in Pickaway County, the oligoclase and biotite are arranged so as to produce foliation, and the rock has been identified as a biotite gneiss. In the Arting well (No. 13) in Huron County, samples recovered include quartz and biotite, with some plagioclase, which is interpreted as a biotite schist.

DISTRIBUTION

When plotted on the map these broadly grouped rock types form a recognizable pattern. The granite group, with the exception of one occurrence of trachyte in the southeast, is concentrated along the center of the platform from the high in the Hancock County, Ohio, area southwest to Henry and Wayne Counties in Indiana. Within this area the granite is concentrated toward the north, and the rhyolite and trachyte are in the center and to the south. Most of the wells containing metamorphosed sedimentary rocks and amphibolites are in a relatively small area in the southeastern part of the platform in the region of Clinton and Fayette Counties. Two wells in Jay County, Ind., (I-4 and I-5) also contain metamorphosed sedimentary rocks. The relationship between these and the metamorphosed sedimentary rocks in Ohio cannot

be determined at this time. To the north of the platform and on the east-sloping surface, granite gneisses predominate.

PETROGENESIS

In interpreting the genesis of the Precambrian rocks in Ohio, Stout and Lamey (1940) described the sequence in the Vance well as a series of basic intrusives or interbedded flows that were later altered by granitic magma and subjected to regional metamorphism. McCormick (1961) interprets the Precambrian in the Hopkins well (No. 9) as a sedimentary sequence of carbonates and shales with basic intrusives or interbedded flows, altered by granite magmas and regional metamorphism. Pegmatitic dikes represent late phases of the granitic magma activity. A general pattern of events is suggested in each of these interpretations and in those of several other wells whose records are sufficient to allow interpretation. Dating of this period of granitic activity and metamorphism by Rb-Sr dating methods suggests a common age for the rocks of several wells in the eastern part of Ohio (see table 1). It is not yet clear where, in such a sequence, the rhyolites and trachytes fit.

COMPARISON WITH OTHER REGIONS

The suggested relief, the lithologic character, and the nature of the overlying sediments (including arkoses, red sandstones, and orthoquartzites) suggest a comparison with a better known Precambrian terrain such as the Ozarks. It is to be expected that the depth to the basement will vary locally within the relief suggested. The contact may be difficult to identify locally, and the composition of the overlying sedimentary rocks may vary. These variations in sedimentary lithologic character in basal formations may be rapid both laterally and vertically--for example, arkose to orthoquartzites, as in the Lamotte Sandstone of the Ozarks or the Mt. Simon of Wisconsin. As a result of the variation in rock types and the local relief on the Precambrian surface, identifying or predicting the position of the top of the Precambrian very closely will continue to be difficult.

OTHER SOURCES OF INFORMATION

Of the various geophysical activities in Ohio, only the gravity studies of Heiskanen and Uotila (1956) cover the whole State. Comparison of the contours of their Bouguer anomaly gravity map with those of the Precambrian surface map shows a general parallel trend in a north-south direction along the east border of the platform. However, the several local high-gravity areas do not coincide with the larger recognizable topographic features of the Precambrian. In a geologic interpretation of the gravity map, Pincus (1960) indicates that the major influences causing strong local anomalies must be below the Paleozoic section; but it is not yet clear from available information how much the anomalies are due to local topography and how much to composition of the rocks. The most probable controlling influence is the composition. The grouping of marble and amphibolite in the Clinton-Fayette County area may be partially responsible for the gravity high in that area.

Another source of information is the Rb-Sr age determination of Precambrian rocks. Ages have been determined for rocks from several wells in Ohio and adjoining areas; they are reported in Tilton and others (1960), Bass (1960), and Davis and others (1959-1960). The ages obtained fall in an interval between 870 and 980 million years. These ages are similar to others (about 1,000 million years) reported from the Precambrian in a large area of eastern North America. On the basis of the ages, the presence of marble, and the generally gneissic character of the rocks from the wells on the east side of the platform, Bass suggests that they be correlated with the Grenville province and that the carbonates such as those of the Friend well may be compared to the Mistassini series of Canada which lies just to the northwest of the Grenville "front." Through the center of the platform the Precambrian rocks are of a granitic type, lacking foliation or recognizable structural trends. The boundary between these two rock types is marked by Bass as the extension of the front. Because gneisses and carbonate sedimentary rocks are present in the wells drilled to the Precambrian surface in Indiana west of the granite belt, and because the ages thus far determined are all from the east side of the "front," this interpretation of the presence and location of this province boundary may have to be reconsidered as more ages are available.

Age determinations of rocks from other wells, as they become available, offer the best means of outlining and correlating the rock units of the Precambrian section and ultimately interpreting their geologic history.

CONCLUSIONS

From the available elevations of the basement, a general interpretation of the surface of the Precambrian in Ohio can be made; the two main features are the Ohio Platform in the west and the east-sloping side of the Appalachian geosyncline in the east. The prevalence of granite gneiss in the area east of the platform and the coincidence of the east boundary of the granite gneiss with the break in slope of the basement surface at the platform edge suggest a major structural boundary. Coincidental trends of the gravity contours with the contours on the Precambrian surface and the grouping of the rocks on the basis of their ages as known at present, determined from the radioactivity of the rocks, add evidence to this interpretation. Surface evidence along this trend, including high-angle faults, grabens (Bowman, 1961), and the Serpent Mound structure in Adams County, offers additional support. If correct, this lineation may mark one of the major structural trends in Ohio. The local relief on the surface in the area of the platform is interpreted to range from 400 to 500 feet. A variety of rock types is found at the Precambrian surface; the most prevalent are granite, rhyolite, hornblende granite gneiss, amphibolites, and metamorphosed sedimentary rocks, marble being the most common. Some of the rocks have been dated by means of Rb-Sr isotopes, with ages generally about 1,000 million years, which are comparable to ages characteristic of the Precambrian rocks in eastern North America.

Enough is known about the Precambrian in western Ohio to predict generally what will be found by drilling. As new information becomes available, topographic details not yet discernible may be identified. Topographic highs on the basement may form stratigraphic traps or structural closures in overlying strata, which may be potential petroleum reservoirs. Many details remain to be discovered that will increase our knowledge of the kind and distribution of the rocks and of possible mineral resources. It is hoped that the preliminary interpretation of the Precambrian geology offered here will be useful to further study and exploration.

Table 1. - WELLS TO THE PRECAMBRIAN IN OHIO AND ADJOINING AREAS
(Location of wells shown on plate 1)

Well No.	County	Township	Name	Location[1]	Elevation of well head (feet above sea level)	Depth to Precambrian (feet)	Total depth (feet)	Lithologic character	Age[1] (Rb-Sr) (millions of years)
1	Clark	Madison	Friend	11½ mi. SE of Springfield, near S. Charleston, L-2066	1087	3368	4647	Dolomite, dark gray; limestone, black carbonaceous; arkose	
2	Clinton	Wayne	McVey	330 NW/CL Rd., & 330 SW/farm line, MS-808	1087	3465(?)	3465	Amphibolite	
3	Clinton	Wayne	Van Pelt	1095.65 NE/SW farm line & 1811.1 NW/SE farm line, MS-1065	1084	3210	3259	Amphibolite	
4	Clinton	Wayne	Adams	N45°E/330 SW farm line & S43°45'E/330 NW farm line, MS-1065	1081	3390	3457	Diorite	
5	Delaware	Orange	Vance	L-11, S-3	920	3810	4291	Granite and hornblende gneiss	950
6	Erie	Florence	Sayler	1350 NL 1200 WL, L-48	817	4400	4424	Granite gneiss	
7	Fayette	Concord	Wilson	330/SE farm line & 330/ Miami Tr. Rd., L-1002	1017	3340	3494	Amphibolite and granite pegmatite	930
8	Fayette	Jasper	Barnes	990 EL & 330 SL, MS-5351	1044	3380	3410	Trachyte porphyry	940
9	Fayette	Union	Hopkins	330 E/Rock Mills Rd. & 990 N/farm line, MS-663	965	3545	4708	Amphibolite, pegmatite, and marble	940-980
10	Guernsey	Adams	Marshall	--	994	8330	8602	Granite gneiss and amphibolite	
11	Hancock	Marion	Norris	S-3	830	2770	2980	Granite pegmatite, hornblende	
12	Highland	Fairfield	Pavey	N68°E/WL & 771 N/SL farm, 2 mi. N/Leesburg	1035	3482	3512	--	
13	Huron	Peru	Arting	S-2	749	3901	4270	Granite gneiss	920

Well No.	County	Township	Name	Location[1]	Elevation of well head (feet above sea level)	Depth to Precambrian (feet)	Total depth (feet)	Lithologic character	Age[1] (Rb-Sr) (millions of years)
14	Logan	McArthur	Johns	66 SL 161 EL farm, L-9930	1190	3255	3361	Rhyolite	
15	Lorain	Henrietta	Born	1150 EL 700 SL, L-8	848	4570	4590	Granite gneiss	
16	Medina	Granger	Warner	Remsen Tr., 786 WL 540 NL, L-42	1117	6650	6731	Granite gneiss	
17	Medina	Hinckley	Smith	821 WL 853 NL, L-69	1200	6930	7040	Granite gneiss	
18	Miami	Lost Creek	Walker	330 SL 990 EL, NW¼, S-13	1030	3255	3513	Trachyte-latite porphyry	
19	Miami	Washington	Levering	330 EL 990 SL NW¼, S-3	995	3282	3411	Granite	
20	Pickaway	Monroe	Long	S86°45'E 460 FCL Palestine Rd. & 35 N/Well No. 1, L-4290	856	3145	3257	Marble, biotite gneiss, and gabbro	
21	Putnam	Liberty	Barlage	SW¼ SW¼ SW¼, S-29	740	3350	3377	Granite	
22	Sandusky	Rice	Hetrick	S-30	590	2701	2796	"Granite wash"	
23	Sandusky	Townsend	Haff	1320 SL 1000 WL NW¼, S-33	641	3090	3123	Granite	
24	Sandusky	Woodville	Bruns	3 mi. S/Woodville NW¼, S-9	655	2667	2822	Granite and amphibolite	940
25	Seneca	Pleasant	Watson	200 NL 350 SL SW¼ NE¼ S-28	704	2900	2935	Granite	
26	Shelby	Perry	Nelson	350 WL 330 NL SW¼, S-24	1050	3140	3276	Trachyte porphyry	
27	Shelby	Salem	Fogt	330 WL 330 NL NW¼, S-3	1038	3288	3360	Rhyolite	
28	Wood	Liberty	Killian	600WL, 675SL SW¼ SE¼, S-12	685	2884	2927	Granite gneiss	950
29	Wyandot	Crawford	Heck	990 NL 1650 WL, S-18	860	2795	2801	Granite	
30	Wyandot	Jackson	Parsell	NE¼ NE¼ NE¼, S-36	810	3040	5632	"Granite wash"	

Table 1. - WELLS TO THE PRECAMBRIAN IN OHIO AND ADJOINING AREAS (con.)

Well No.	County	Township	Name	Location[1]	Elevation of well head (feet above sea level)	Depth to Precambrian (feet)	Total depth (feet)	Lithologic character	Age[1] (Rb-Sr) (millions of years)
(Wells drilled in 1961 and first half of 1962, but not yet studied petrographically)									
31	Clark	Pleasant	Brown	3399 SL 1598 WL, MS L-4673	1240	3597	3644	--	
32	Hardin	Jackson	Jones	660 NL 660 EL SW¼, S-30	931	2791	2834	--	
33	Knox	Pike	Cunningham	1700 EL 960 NL NE¼, S-9	1239	5640	5745	--	
34	Licking	Mary Ann	Crowley	590 WL 550 NL, L-15	1054	5980	5991	--	
35	Marion	Claridon	Mitchell	660 SL 660 WL NE¼, S-27	989	3672	--	--	
36	Morrow	Canaan	Myers No. 3	1980 WL, 660 NL NW¼, S-33	1013	3996	4100	--	
37	Union	Union	Zenith	800 NL 800 WL, MS L-7474	990	3348	3352	--	
38	Wayne	Chippewa	Steiner No. 2	1197 WL 270 SL SW¼, S-21	950	6904	6919	--	
INDIANA									
I-1	Allen	--	Gibson	Line No. 14, S-33, T. 29 N. - R. 12 E.	821	3476	3517	Augite andesite	
I-2	Henry	--	Ohio Oil Co.	Line No. 1662, S-12, T. 16 N. -R. 5 E.	1031	3649	3670	Hornblende granite	
I-3	Howard	--	Greentown	Line No. 1675, S-32, T. 24 N. -R. 5 E.	831	3895	3996	Quartzite, marble, argillite, and green-slate	
I-4	Jay	--	Binegar	Line No. 1799, S-29, T. 24 N. -R. 13 E.	944	3351	3404	Argillite, and dolomitic marble	
I-5	Jay	--	Binegar	Line No. 1800, S-29, T. 24 N. -R. 13 E.	949	3333	3395	Silicious argillite	
I-6	Wayne	--	Doddridge	Line No. 5415, S-23, T. 15 N. -R. 5 E.	957	3439	3907	--	

Well No.	County	Township	Name	Location[1]	Elevation of well head (feet above sea level)	Depth to Precambrian (feet)	Total depth (feet)	Lithologic character	Age[1] (Rb-Sr) (millions of years)
				KENTUCKY					
K 1	Breathitt	--	Williams	Carter Coordinates 13-M-75	762	10,970	11,130	"Granite"	
K 2	Carter	--	Stamper	Carter Coord. 3-V-77	856	5058	5085	"Granite"	
K 3	Elliott	--	Litton	Carter Coord.	968	5190	5394	--	
K 4	Leslie	--	Fordson Coal Co.	Carter Coord. 8-I-73	1179	9412	9432	"Granite"	
K 5	Lewis	--	Shepherd	Carter Coord. 13-Y-76	902	4535	4550	"Granite"	
K 6	Lincoln	--	Spears	45 mi. SW of Lexington	1125	5765	6115	Dacite porphyry	
K 7	Martin	--	James	Carter Coord. 19-Q-84	659	14,200(est.[2])	14,172	--	
K 8	Mason	--	Wilson Rawlings	--	764	3275	3314	"Granite"	
				MICHIGAN					
M 1	Lenawee	Riga Swanton quadrangle	Taylor	$SE\frac{1}{4}NE\frac{1}{4}SW\frac{1}{4}$ S-32, T. 8 S. - R. 5 E	715	3855	3902	Granite and granite gneiss	890-970
M 2	Washtenaw	Salem S. Lyon quadrangle	Troy-Roddenberry	$NE\frac{1}{4}SE\frac{1}{4}NE\frac{1}{4}$ S-27, T. 1 S. - R. 7 E	886	6071	6094	Chlorite schist	
				PENNSYLVANIA					
P 1	Crawford	Summerhill, Linesville quadrangle	Kardosh	1.04 mi. S/41°50' N. lat. & 1.75 mi. E/80°25' W. long.	1326	7899	8030	Granite gneiss	

Table 1. - WELLS TO THE PRECAMBRIAN IN OHIO AND ADJOINING AREAS (con.)

	County	Township	Name	Location [1]	Elevation of well head (feet above sea level)	Depth to Precambrian (feet)	Total depth (feet)	Lithologic character	Age[1] (Rb-Sr) (millions of years)
				WEST VIRGINIA					
	Mason	Glenwood quadrangle	Arrington	Clendenin District, 2. 5 mi. S/lat. 38°45' & 4. 12 mi. W/long. 82°22'	597	8558	8635	Hornblende gneiss	
	Wood	Marietta quadrangle	Power Oil Co.	SE	1039	13, 272	13, 331	Gneiss, amphibolite	870
				ONTARIO, CANADA (see Caley, 1940a, 1940b, and 1941)					

1. Abbreviations: CL - Center line; EL - East line; L - Lot; MS - Military Survey; NL - North line; R - Range; Rb-Sr - Rubidium-Strontium age determination; Rd. - Road; S - Section; SL - South line; T - Township; Tr. - Tract; WL - West line.

2. Depth of Precambrian inferred from depth of Cambrian rock at bottom of well.

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PLATE I

Ohio Division of Geological Survey
Report of Investigations No. 44

MAP OF PRECAMBRIAN SURFACE SHOWING DISTRIBUTION OF ROCK TYPES

Compiled by C.H. Summerson
assisted by Lynn Matheny
1962

LEGEND

- Granites.
- Fine-grained acidic rocks including rhyolite and trachyte.
- Andesite.
- Metasediments and metamorphosed basic igneous rocks including marble, amphibolite, and pyroxene hornfels.
- Metasediments including siliceous argillite, marble, and quartzite.
- Metamorphic rocks including granite gneiss and schist.
- Hypothetical fault.

Contour interval 500 feet

K2 — Wells identified in Table I.

−2281 — Elevation of Precambrian surface, in feet below sea level.

Note: The above arrangement is without age significance. Well No. 4 in Clinton County contains a diorite, but it is not shown by a separate pattern.

0 25 50
SCALE IN MILES

DIANA B. PFANNEBECKER, Draftsman