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The basement of North Dakota

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THE BASEMENT OF NORTH DAKOTA

by

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Chairman

Dean of the Graduate School

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handicapped by having very little reliable information from deep test wells, and by lack of well samples. To a large degree the present writer is under the same handicap as his predecessors.

Related Studies--In no place in North Dakota are the basement rocks exposed at the surface; thus, any conclusions which may be drawn as to basement configurations and composition must be made from well samples and surface mounted geophysical devices.

In discussing the stratigraphy of North Dakota, Kline (1942, pp. 336-379) considers the basement rocks as being Precambrian in age. Kline's information on the basement rocks was derived from a few water wells in the Red River Valley and from the few oil exploration wells which had penetrated to the basement rocks at that time. Prior to Kline's report on the stratigraphy of North Dakota, Hall and Willard, (1905, p. 2) give a very short description of "ancient granite" in the Casselton and Fargo quadrangles. Their information was derived from water wells in the area and they note that the basement was,

> "...of unknown thickness, deeply buried and it does not seem likely that it will ever yield either water or valuable minerals."

They also note that green to vari-colored clay immediately above "hard" granite,

> "...shows that the granite has been decomposed and much altered and was long exposed to the action of atmospheric agencies before the submergence of the old land surface."

Laird (1941), compiled a list of selected deep well records in which three wells are mentioned as penetrating to basement rocks. The above wells were drilled prior to 1930 and the samples are not available for study. The reliability of the descriptions of the basement rocks in these three wells is much in doubt by the writer, especially when one well is described as containing "blue granite" interbedded with "white sand".

Haraldson (1953) made a geomagnetic survey of parts of Pierce, Benson, Sheridan and Wells counties and compiled in the course of his study a basement structure map for that area.

For a number of years the Ground Water Branch of the Unites States Geological Survey has been conducting an intense search for water in North Dakota with the result that a number of test wells have been drilled in the Red River Valley which are reported to penetrate to basement rocks.

The most recent work on the basement in North Dakota is that of Hansen (1957), who compiled a structure map on the Pre-cambrian (basement).

The writer is of the opinion that in the state of North Dakota the terms basement and Precambrian may be used synonymously. Kline (1942) and Hansen (1957) both use the term Precambrian in reference to the basement; hence, the writer will not deviate from the present trend in this respect.

CHARACTER OF THE BASEMENT

Topography--In the southeastern portion of the state the basement rocks are approximately 695 feet below the surface (H. W. Snowden, Ruddy Bros. Number 1 well, NW 1/4, SW 1/4, Sec. 11, T. 132 N., R. 58 W., Approximately 5 miles north of the town of Crete in Sargent County). In the northern portion of the Red River Valley the basement rocks are approximately 897 feet below the surface in the town of Hamilton Well, Pembina County (Sec. 35, T. 162 N., R. 53 W.). The above depths were computed by the writer on the basis of water well logs. The basement exhibits an even slope to the west from Grand Forks and attains a maximum depth of 12,435 feet below sea level in the SE 1/4, SW 1/4, Sec. 16, T. 156N., R. 95 W., Williams County. The nearest town to this location is Tioga, approximately 6 miles to the northwest in Williams County. Basement profiles were constructed by the writer (Plates II and III) by use of information obtained from available oil well data. Profiles A-A' and A-B (Plate II) are north-south profiles. Profiles C-C', D-D', and E-E' (Plate III) are east-west profiles (Basement Base Map, Plate I). The profiles on Plate II graphically illustrate the even slope of the basement.

Along the Red River Valley the basement rocks are deeply weathered where Cretaceous rocks are absent. The basement rocks in this area are directly overlain by glacial drift. Drilling operations in the Red River Valley have indicated the presence of numerous basement ridges or basement "topographic highs". These ridges or "highs" are thought by Paulson (1953, p. 35) to be the result of both variations in the depth of weathering "...and because of glacial erosion which in some places caused the removal of all the decomposed zone." Dennis (Dennis et al., 1949, p. 28) states:

> "The presence of fragments of shale, granite, and basic igneous rocks in some of the well cuttings from the granite contact suggests that the upper part of this zone was reworked by the glacier and some glacial material was incorporated within the decomposed zone."

In all cases these ridges or "highs" on the basement are aligned in a northwest-southeast direction. The writer was unable to find any indication as to whether the ridges or "highs" on the basement were composed solely of weathered igneous material or weathered igneous material which had been reworked by glacial action.

Structure--A basement ropographic map (Plate IV) was prepared from available oil well data. Information from existing water wells in the Red River Valley was not incoroprated in the compilation of this map because the available information is not definitive. Surface elevations are lacking for over 90 percent of the water wells. Topographic maps of this area are either lacking or are contoured on such an interval as to be of very little help in a study of this type.

Throughout the major portion of the state basement control points are either far apart or entirely lacking and for these reasons the majority of the contours shown on the basement topographic map are inferred (dashed lines). Only in the narrow belt between longitudes 98 degrees west to 100 degrees west is there any type of positive control. Contours in this latter area are represented on the above mentioned map by solid lines. The contour interval is 200 feet and sea level is taken as the vertical datum plane.

The features exhibited by the configurations of the 1600 foot contour (SE 1/4, Sec. 18, T. 146 N., R. 62 W. at the town of Glenfield, Foster County) and the 2000 foot contour (NE 1/4, NE 1/4, Sec. 23, T. 146 N., R. 66 W., approximately four miles east of the town of Carrington, Foster County) are interpreted by the writer as reflecting an east-west trending fault. Another explanation of the contour pattern is that of an erosional remnant. Further evidence indicating the presence of a fault is that the electric log for one of the wells in this area has an anomalous curve which could be interpreted as indicating fault gouge; however, "granite wash"might be indicated. According to Howell (1957, p. 128) granite wash may be defined as,

> "...The material eroded from outcrops of granites, syenites, diorites, granodiorites, monzonites and their fine-grained or aphanitic equivalents...and redeposited, forming a rock having approximately the same major mineral constituents as the original rock."

Examination of samples from these areas indicates a slight degree of weathering. The writer does not feel that the feature may be explained as an erosional remnant as he is of the opinion that the intense degree of weathering needed to produce such a feature did not occur in this part of the state. It is very doubtful is weathering alone could produce such a feature. For the following reasons the writer would like to infer an east-west trending fault in this area. The anomalous curve on the electric log could be interpreted as either granite wash or fault gouge; however, the samples derived from the wells in this area showed very little indication of weathering and all of the mineral grains have very angular corners and edges. The extreme angularity of the samples indicates fault gouge rather than granite wash. The samples show very little weathering whereas granite wash should show considerable weathering. The anomalous curve on the electric log indicates an increase in permeability; however, the samples indicate dense igneous rock which has been considerably fractured. Basement profiles C-C', D-D' and E-E' would further emphasize the probable presence of this fault. Vertical displacement near the eastern end of the inferred fault is approximately 122 feet and near the western end approximately 226 feet.

A fault is inferred between wells number 1231 (NE 1/4, Sec. 2, T. 155 N., R. 96 W.) and 1385 (SE 1/4, SW 1/4, Sec. 16, T. 156 N., R. 95 W.). Evidence for this fault consists of thickening of the sediments between the basement and the base of the Winnipeg sand. In well 1231 the base of the Winnipeg is listed as 11239 feet below sea level and the top of the basement is listed as 11299 feet below sea level which gives a total thickness of 60 feet of enclosed sediments. In well number 1385 the base of the Winnipeg sand is listed at 11805 beet below sea level and the top of the basement is listed as 12268 feet below sea level which gives a total thickness of 663 feet of enclosed sediments. In well 1385 approximately 200 feet of ...

of these sediments can be explained by basinward thickening of sediments. By inferring a fault between the two wells the remaining 400 feet of enclosed sediments may be explained. The inferred regional dip in this area is approximately 33 feet to the mile

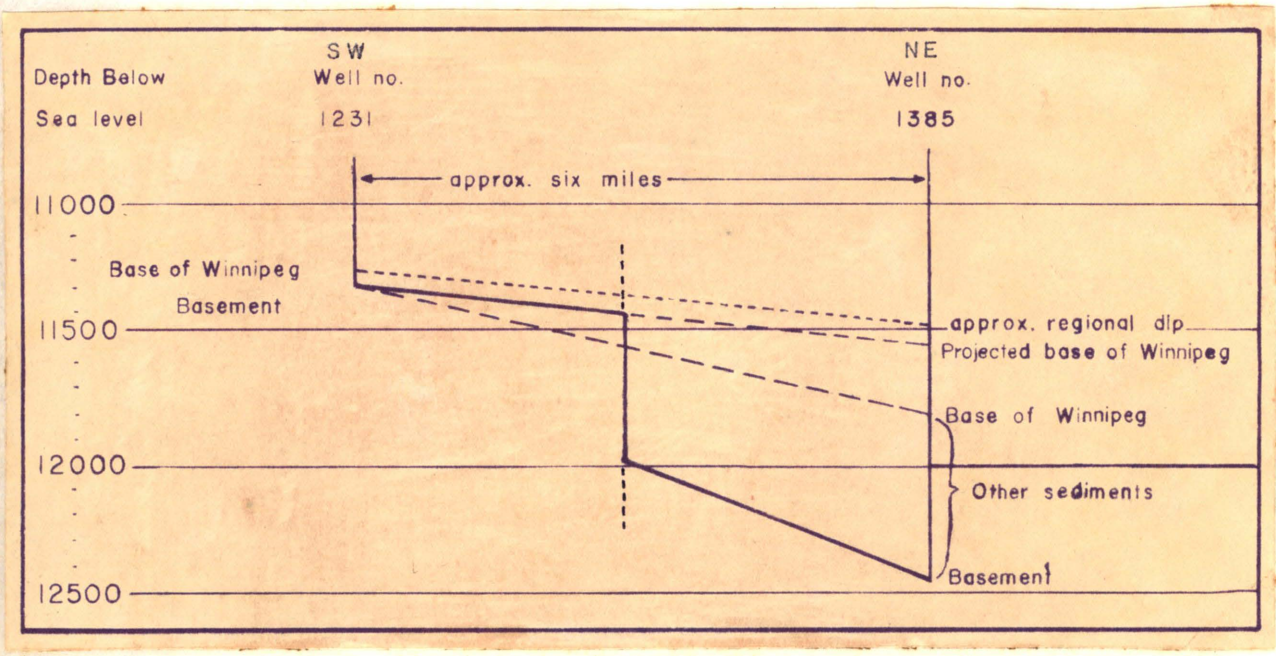

Fig. 1.--Diagrammatic profile between wells number 1231 and 1385.

The writer would also like to propose that a fault may exist between well number 1231 (NE 1/4, Sec. 2, T. 155 N., R. 96 W., approximately 8 miles north of the town of Hofflund, Williams county) and well number 1403 (NE 1/4, Sec. 15, T. 155 N., R. 96 W., approximately 6 miles north of the town of Hofflund, Williams county). The vertical difference in elevation of the basement between the two wells amounts to 672 feet in approximately two miles. There is relatively little thickening or thinning of the overlying Paleozoic sediments between the two wells. The writer bases his evidence for this fault on the differences in the basement elevation between the two wells and their close proximity. The staff members of the North Dakota Geological Survey are of the opinion that any thickening or thinning of sdeiments in this area may be explained by basinward thickening or compaction (Clarence Carlson, oral communication).

Only one known fault in North Dakota appears as significant in connection with the study at hand. This fault is northwest-southeast trending and is located approximately two miles east of Hofflund, Williams County (NE 1/4, T. 154 N., R. 95 W.) to approximately 6 miles southwest of Verendrye National Monument, McKenzie County (SE 1/4, Sec. 36, T. 152 N., R. 54 (94?) W.). This fault is known as the Sanish fault and has been mapped by the United States Geological Survey (Bateman, 1957). It is unknown at the present time whether this fault extends to the basement as basement control in this area is very poor. It is quite possible that the Sanish fault is a reflection of basement structure.

The directions and the lengths of the inferred faults in the basement of North Dakota, with the exception of the Sanish fault, are unknown at the present time. Other faults and structural features may exist on the basement but until more wells penetrate to the basement and better control is established they will remain hidden.

Composition--The following very brief discussion is included at this time to give completeness to the section on characteristics of the basement. A longer and more detailed discussion of the composition of the basement is given in the section on Petrography.

The basement rocks of North Dakota, which have been sampled by deep test wells, are dominately adamellite (more than 1/3 but less than 2/3 alkali feldspar and not less than 10 percent quartz) and diorite. The eastern portion of the state, in the Red River Valley, is deeply weathered to depths ranging from 100 to 1000 feet, as computed by the writer from available well records. The writer is inclined to be quite skeptical of this latter figure as it is quite improbable that there would have been sufficient intervals of exposure for this degree of weathering to take place. According to Kohanowski (oral communication) weathering does not extend below 500 feet unless along open fissures. With the exception of the Red River Development and Oil Company, Edgar Berg Number 1 well, Grand Forks County, which penetrated 1551 feet of weathered quartzite, all information as to the depth of weathering in the Red River Valley was obtained from water well logs.

Amphibolite occurs in one well approximately 6 miles southeast of the town of Yucca (SE 1/4, SE 1/4, Sec. 18, T. 141 N., R. 81 W.), Oliver County.

THE GEOLOGIC HISTORY OF THE BASEMENT

As noted by Kline (1942), and Hansen (1957), the basement of North Dakota is considered to be Precambrian in age. In many parts of the state the basement is directly overlain by Cambrian sediments. To the writer's knowledge no age determinations based on radioactive decay have ever been made on any of the basement material from North Dakota.

On the basis of Barth's modification of Bowen's reaction series (Williams, et al., 1955) it will be found that basic minerals should form from a magma before acid minerals. By this same reasoning it should hold true that from the same magma, basic rocks should consolidate before acid rocks. If this general supposition is true then it may be concluded, providing external factors do not influence the reaction, that gabbro is the first rock type to form, followed in order by diorite, monzonite, granodiorite, adamellite and finally by granite. The above supposition would only hold true in such cases where the rocks are derived from the same magma and only in such instances when the magma is not acted upon by internal or external conditions.

To the writer's knowledge, various processes may be happening in the chamber where the magma is confined. Border facies may be formed by magmatic stoping of the containing walls and roof of the chamber. The fragments may be incorporated into the magma and disseminated homogeneously or they may be acted upon by the magma. The original nature of the magma may in this way be changed chemically. If the chamber is formed by siliceous sediments, action of the magma upon these sediments may increase the acidity of the parent magma. In the same way calcareous sediments may cause the magma to become more basic. When the magma has partially consolidated a liquid phase still remains. The liquid phase may react with the material which has consolidated, causing it to redissolve, thus changing the composition of the liquid phase and the resulting rocks which would ultimately form. Collapse of the magma chamber may force an ejection of the liquid phase from the chamber before it has time to consolidate. Recharge from the magma reservoir may occur in the magma chamber thus further complicating the cycle of events.

The rocks which now compose the basement may at one time have been sediments which became granitized or recrystallized.

At the present time, considering the samples available, it is not possible to determine the type body to which the North Dakota basement rocks owe their origin. For the same reason it is not possible to determine if all of the basement rocks of North Dakota are the result of the same magma body. The writer did not find any rocks in the North Dakota basement which would correspond to the Beltian system of Montana, Idaho, eastern Washington and British Columbia. The only basement rock of North Dakota which could possibly be a metasediment is the weathered quartzite found in the Red River Development and Oil Company, Edgar Berg number 1 well, Grand Forks county (SW 1/4, Sec. 35, T. 162 N., R. 51 W.).

Following the emplacement of the igneous basement rocks, varying degrees of erosion and deposition took place. Metamorphism as exhibited by the amphibolite in the Carter Oil Company, E. L. Semling number 1 well (SE 1/4, SE 1/4, Sec. 18, T. 141 N., R. 81 W., approximately five miles west of the town of Yucca, Oliver county) took place.

The subsequent history of the basement may be considered to parallel that of an intracratonic basin. The basement proceeded to sink progressively as sediments were laid down. The subsidence was not continuous as there are several unconformities noted in the post-Precambrian sediments of North Dakota; however, it is the writer's opinion that subsidence in North Dakota has been fairly continuous since Precambrian time.

METHOD OF PREPARATION AND EXAMINATION OF SAMPLES

All of the samples petrographically analyzed in this report by the writer were derived from oil wells in the state of North Dakota. Due to the fact that all samples were derived from oil exploration wells rather than from surface outcrops the samples fall into three general classes based on particle size. The three general classes are: 1) core samples, 2) well cuttings (coarse cuttings), 3) sands (fine grained well cuttings). Core samples are the easiest to work with as they are large enough for megascopic examination. Depending on the size of the available samples one of two methods was used in their examination.

The least time-consuming and the best method for examining the fine well cuttings is to use the Heinrich method (Heinrich, 1957, pp. 7-8) whereby the sample is crushed to a fineness (in most cases the samples were fine enough as they came from the well) so that all the grains are free. After the grains have been liberated by crushing they are examined by means of the petrographic microscope and the minerals determined by the use of index of refraction liquids and other optical microscopy procedures.

The second method of examining the well cuttings is to prepare petrographic slides (thin sections). Thin sections are easily made from the larger cuttings and cores; however, they may also be made from material ranging in size down to 1/4 millimeter.

Various methods have been proposed for the making of petrographic slides from fine well cuttings. Leroy (1951, pp. 178-179) proposes one method for preparation of thin sections of fragments or heavy concentrates. He suggests using raw Canada balsam and transferring the fragments from one slide to another (by dissolving the Canada balsam with xylene) when grinding is partially completed. The disadvantage of this method is that it "...requires some practice, as it must be accomplished quickly and at a given time." Smith (1953, p. 86) suggests mounting the specimen or small fragments on a slide with Canada balsam. The fragments are then ground to approximately half their thickness, the balsam dissolved with xylene, the grains turned over onto their ground sides by the use of tweezers and placed on freshly cooked Canada balsam. If the fragments are large enough this method might prove useful; however, the writer has found that this process requires a very steady hand and considerable time if small fragments are used.

It has been the writer's experience that the fastest and most trouble-free method of preparing slides from small fragments is to follow one of the following methods, depending on the size of the specimen. If the specimen is larger than 1/4 of an inch in diameter the standard method of grinding and mounting thin-sections is employed. This procedure is to grind and polish one side of the specimen, mount the ground side on a glass slide, continue grinding and polishing until the standard thickness of 0.03 millimeters is obtained, and then cover by cementing a cover glass to the top surface of the ground specimen and the adjacent portions of the slide.

For samples with a diameter of less than 1/4 of an inch several methods were tried but with varying degrees of success. Wafers of "Duco" cement were made and the small specimens were placed on these wafers, after which they were covered with a thin layer of "Duco" cement. This method did not prove satisfactory as numerous air bubbles developed around the specimen, causing the specimen to spall when grinding neared completion. In addition the cement became clouded when the wet method of grinding was employed. The use of metallographic papers did not improve this situation as the cement was too flexible and could not be ground by use of the dry method.

Wafers of Canada balsam made in the same manner as the "Duco" cement wafers have many disadvantages. If the wafers are made on paper they may be readily ground on one side; however, when the section is completed enough to mount on a glass slide many problems arise. If the wafer is subjected to heat the specimen grains will loose their orientation and it is not possible to obtain a section with an even thickness. The wafers may be mounted on a slide with the use of liquid Canada balsam; however, this method requires that the slide be allowed to age for several days before the final grinding may be completed. If the wafers are formed on a glass slide it is very difficult, if not impossible to grind and polish both sides of the specimen without extensive damage being done to the section.

The best method to use on fine-grained well cuttings is to impregnate them on a glass slide with Lakeside 70 (a synthetic resin distributed by Wards Natural Science establishment). The specimen may then be ground and polished on the exposed side and covered with another slide. The excess glass on the original slide is broken away very carefully so as not to damage the specimen. The remaining glass is ground away, the specimen is then ground and polished and covered with a cover glass. It may be noted that the sample may be impregnated on a cover glass rather than on a regular slide with the result that the excess glass is easily removed, there being less glass to grind away before the sample is reached. This latter method has the disadvantage that cover glasses are very easily broken especially when the first grinding is in progress.

All of the available samples from the deep test wells in North Dakota which penetrate to basement rocks were examined with the petrographic microscope by the use of either thin sections or by Heinrich's method. Percentages of mineral composition were calculated from grain counts; the results of these counts are given in Appendix II. The percentages of mineral composition as given in Appendix II are the result of three to four grain counts per specimen; hence, all columns total to 100 plus or minus 5 percent.

<u>Location of the Samples</u>--All samples are located in the repositories of the North Dakota Geological Survey, Grand Forks, North Dakota. Petrographic slides prepared in conjunction with this report were deposited with the Department of Geology, University of North Dakota.

The location of all oil wells drilled to the basement are shown on the basement base map (Plate I). Included are all oil wells known to have penetrated to the basement as of January 1, 1958. The index numbers of these wells are those employed by the North Dakota Geological Survey (North Dakota Geological Survey Circular Number 5, 1957). Basic data for the above wells are given in Appendix I. Data for all United States Geological Survey test water wells are given in Appendix III. Data pertaining to the latter wells have not been plotted on the basement base map.

Numerous water wells are said to have penetrated to the basement (Philip Randich, oral communication) in the Red River Valley, but reliable data are available only on the United States Geological Survey test water wells (Appendix III).

Problem of Distribution--Inspection of the basement base map (Plate I) will show that the majority of the oil exploration wells which penetrate to the basement are located in a narrow belt extending from the Canadian to the South Dakota borders and within longitude 98 degrees west to longitude 100 degrees west. A few wells are located outside of this narrow belt but they are so randomly scattered as to be entirely lacking in good sampling and contouring control. Numerous water wells located in the Red River Valley entirely lack surface elevations.

Any conclusive evidence which may be derived from a study of this type will need more wells penetrating to the basement and especially more wells in the western and southern parts of the state.

Validity of Samples--In any study where the samples are taken from well cuttings rather than from fresh surface exposures, there is a certain degree of contamination. In deep wells this problem is manifold. Depths from which samples are derived are calculated by the return rate of the drilling mud and by the number of strings of drill stem pipe. Some samples may lag behind others in the drilling mud and thus the calculations as to the sample depth may be in error by a number of feet. Through usage drill stem pipe may stretch; hence, a string of drill stem pipe may be longer than it was originally.

Unintentional deviations of the drill hole from the prependicular may cause an error in depth measurement of plus or minus 40 percent (Kohanowski, oral communication); however, most wells in North Dakota deviate very little (Laird, personel communication). The most reliable method of picking formation tops is by use of the electric logs in combination with the samples.

Further contamination of samples may arise from various sources, whether by design or through ignorance of good sampling practices is unknown. The driller may contaminate the samples by not collecting them at the proper time, placing the wrong markings on the sample bags, or by placing the incorrect samples in the sample bags. The latter practice has been known to happen repeatedly (Kohanowski, oral communication), especially among water well drillers.

All of the water well samples were not examined petrographically by the writer. Basic data for water wells reported to penetrate to the basement by the United States Geological Survey as well as partial well logs for these wells are given in Appendix III. "Granite" and "decomposed granite" are placed in quotation marks to indicate that the validity of this determination is in question. In all cases where "hard" rock was encountered in the drilling of these water wells, drilling ceased and it was assumed by the driller that the basement had been reached. There is no recorded evidence of an attempt by the drillers to gather samples of the basement "hard" rock.

Several of the published descriptions of the basement rock are held in suspicion by the writer. One water well in Pembina County drilled in 1889 as reported by Kline (Laird, 1941, p. 29) bottoms in the Precambrian (basement) which is described as being "blue granite" interbedded with "white sand". Several wells in the central part of the state as reported by Heraldson (1953) bottom in "greenstone". The writer was not able to observe "greenstone", although provided with the same samples.

PETROGRAPHY

Composition of the Basement--In very general terms the composition of the basement may be divided into three lithologic categories. The first group is that of the weathered or "decomposed granite" of the Red River Valley. The second group comprises basic and intermediate rocks (gabbro, diorite, and monzonite). The third group is the acid rocks (granodiorite, adamellite and granite). Only one metamorphic rock (amphibolite) was found by the writer.

For the most part the grain size and the structural fabric of the basement rocks cannot be ascertained due to the size and type of samples obtained. When samples are obtained in which the grain size is less than 1/8 inch in diameter and the grains are completely dissagregated, it is only possible to determine the composition of the parent rock from a mineralogical standpoint and the degree of weathering. In order to determine the fabric of the rock, samples over 1/4 of an inch in diameter are needed. For the above reason several of the rocks which the writer has determined may actually be gneisses.

The composition of the basement in the Red River Valley is taken from water well driller's logs (U.S.G.S. open file reports) and from the available ground water publications. This material is presented in Appendix III to give as complete a coverage of the basement as is possible at the present time. According to the water well logs the basement in the Red River Valley is made up of "decomposed granite" which has weathered to; pink, blue, green, brown, white, and black clays. The Ground Water Branch of the United States Geological Survey as reported by Paulson (1953, p. 36) made electron microscope determinations of the samples from U.S.G.S. test hole 475 (Sec. 20, T. 130 N., R. 47 W.). The findings of the United States Geological Survey indicate that the samples are composed mainly of kaolin group clay minerals (principally kaolinite with a few tubes of halloysite present) and traces of quartz and feldspar.

A geologic map of the basement was compiled by the writer to show the distribution of basement lithologies (Fig. 2). It will be noted from the basement geologic map that there are no appreciable trends as to lithologic orientation, with the exception of the weathered zone along the Red River. All contacts between various lithologies are shown as inferred contacts (dashed lines) owing to poor sampling control. Large areas of the map are left blank where the basement has not been sampled. In addition to lithology, the inferred basement faults are shown on figure 2.

The basement rocks of North Dakota were identified by the writer in accordance with the classification given by Williams, et al. (1955). This classification is based on the ratio of alkali feldspar to plagioclase feldspar. On this basis three divisions of rocks are used; basic rocks contain up to 1/10 alkali feldspar, intermediate rocks contain between 52 and 66 percent silica, and acid rocks contain at least 10 percent quartz and not less than 1/8 alkali feldspar. In all cases due to the size of the available samples the coarser-grained rock names were used.

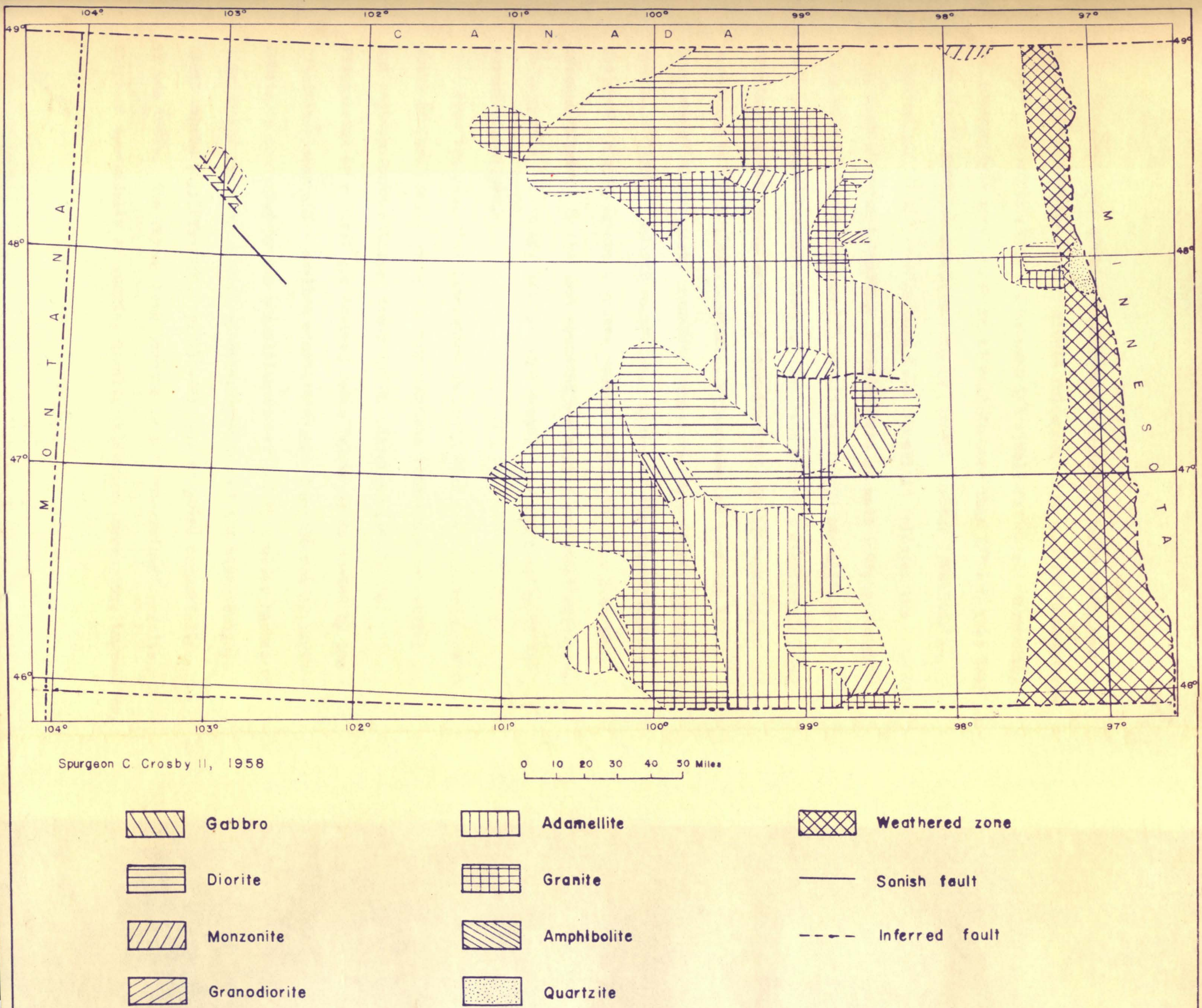

Fig. 2—Basement Geologic Map

By use of the above classification gabbro, a basic rock, was found to contain up to 1/10 alkali feldspar. Diorite, an intermediate rock was found to contain less than 1/3 alkali feldspar. Monzonite, an intermediate rock was found to contain more than 1/3 and less than 2/3 alkali feldspar and less than 10 percent quartz. Syenite, an intermediate rock, contains more than 2/3 aklali feldspar but less than 10 percent quartz. Granodiorite, an acid rock, contains more than 1/8 and less than 1/3 alkali feldspar. Adamellite, an acid rock, contains more than 1/3 but less than 2/3 alkali feldspar. Granite, an acid rock, contains more than 2/3 alkali feldspar. According to other classifications, which were not used for the purposes of this report, monzonite containing more than 10 percent quartz is termed a quartz monzonite. By use of the classification followed in this report a quartz monzonite contains from 2 to 10 percent quartz. If the rock contains the proper ration of feldspars to term it a monzonite, but contains over 10 percent quartz, it is termed adamellite.

From the published literature it would seem that the basement rocks of North Dakota are, in many respects like those of central and eastern South Dakota. According to Stevenson (1958) the Precambrian of central and eastern South Dakota is dominated by two granitic masses and a smaller dioritic mass. The basement of North Dakota is dominated by two adamellite masses and by smaller masses of diorite and granite. The Precambrian granites of the Black Hills, South Dakota (Taylor, 1935, pp. 278-291) are composed essentially of two types. The Harney Peak Granite is a "fine-grained" granite composed essentially of quartz, alkalic feldspars, muscovite, tourmaline, and garnet; it is very light gray-white in color. The Little Elk Gneissoid Granite is composed essentially of quartz, feldspars and biotite and is light gray in color. According to the author these two granites are very easy to tell apart due to their distinctive colors. In addition the igneous rocks exposed in the Black Hills in the area around Keystone, South Dakota are granites, closely associated pehmatites and amphibolites. On the basis of color alone, the Black Hills granites are not like those found in the state of North Dakota. For the most part all of the North Dakota basement rocks are pink in color. From the few cores of North Dakota basement rock which are available, the writer is of the opinion that the Black Hills granites which he has seen <u>in sito</u> are coarser grained than the North Dakota rocks.

In Saskatchewan (Parke and Ambler, 1956, p. 117) cores and samples of the basement in the Meadow Lake area, the northern edge of the Williston Basin, are of granitic rocks, foliated or gneissic rocks. Quartz, feldspars, biotite and occasionally hornblende are the main minerals. In the southern part of the province a wider variety of minerals are recognized, darker minerals being more prominent. Weathering in this area is variable and has been recognized to a depth of 170 feet.

Because of the many methods of rock classification (microscopic, megascopic and chemical) it is exceedingly difficult to compare the descriptions of the various authors when they do not list the percentages of mineral composition.

<u>Quantitative Measurements</u>--All available samples of the basement

rocks of North Dakota were examined with the petrographic microscope. Preliminary examination of the samples was made by the use of the binocular microscope to determine an initial classification as to rock type. Petrographic examinations were conducted by means of the Heinrich method except when it was found desirable to cut thin sections.

Percentages of mineral composition were determined as given in Appendix II by taking an average of three grain counts per sample and recording the total average percentage. It has been found by the writer that one grain count would be sufficiently accurate for determinations of this type.

In their order of occurrance only one well was found to contain amphibolite. This amphibolite is found in well number 15 and is composed of 40 percent potassium feldspar, 37 percent hornblende, 9 percent quartz, 7 percent pyrite, 5 percent biotite mica, 2 percent muscovite mica and 1 percent sphene.

Well number 29 was found to contain an extreme thickness of weathered quartzite. It is quite possible that this quartzite might be equivalent to the Sioux quartzite of southeastern South Dakota, and southwestern Minnesota. The material from this well is completely disaggregated. It is composed of: 50 percent quartz (crystalline), 20 percent biotite, 15 percent plagioclase, 10 percent hornblende, and 2 percent anorthoclase feldspar.

Only well number 408 was found to contain granodiorite. The granodiorite from this well contained; 39 percent potassium feldspar, 27 percent quartz, 23 percent kaolinite, 6 percent plagioclase feldspar, 2 percent magnetite and 1 percent garnet, biotite mica and sphene.

The presence of the relatively large amount of kaolinite (23 percent) would indicate that there has been quite a bit of weathering or hydrothermal alteration in this area.

Wells number 23, 24, and 120 were found to contain gabbro. The average gabbro from these three wells would contain 56 percent potassium feldspar, 30 percent quartz, 7 percent biotite, 3 percent plagioclase feldspar, 2 percent sphene, and 1 percent magnetite, hornblende and augite.

Five wells were found to contain monzonite. The monzonite from wells number 227, 403, 515, 700 and 1385 has an average composition of: 41 percent anothoclase feldspar, 32 percent plagioclase feldspar, 25 percent potassium feldspar, 6 percent quartz, 2 percent magnetite, 1 percent sphene and garnet.

Sixteen wells were found to contain granite. The granite from wells number 16, 19, 20, 27, 38, 89, 151, 155, 246, 334, 390, 406, 407, 572, 580, and 706 has an average composition of: 36 percent quartz, 34 percent potassium feldspar, 6 percent biotite, and 1 percent augite, garnet and sphene.

Eighteen wells were found to contain quartz diorite. The quartz diorite from wells number 39, 40, 83, 94, 171, 207, 230, 295, 316, 383, 434, 435, 644, 670, 671, 672, 1231, and 1356 has an average composition of: 30 percent potassium feldspar, 30 percent quartz, 11 percent plagioclase feldspar, 10 percent biotite mica, and 1 percent leucoxene, apatite, garnet, sphene, chlorite, augite and anorthoclase feldspar.

Twenty-two wells were found to contain adamellite. The adamellite from wells number 5, 43, 100, 134, 194, 196, 411, 437, 620, 621, 622, 632, 668, 669, 673, 768, 1112, 1211, 1274, 1394, and 1415 has an average composition of: 46 percent quartz, 33 percent potassium feldspar, 10 percent plagioclase, 2 percent anorthoclase feldspar, 6 percent biotite mica, 2 percent hornblende, and 1 percent muscovite mica, magnetite and garnet.

CONCLUSIONS

This study of the nature of the North Dakota basement rocks is limited to information derived from well samples. In North Dakota the study of the basement is hindered by having very few wells penetrating to the basement, not all of which are located so as to give structural control. Large areas of the state, such as the area south of the Missouri River completely lack wells which penetrate to the basement.

The surface of the basement of North Dakota is basin shaped and may be described as an autogeosyncline. Only the Sanish fault may have any bearing on the problem at hand. This fault is northwest-southeast trending and is located in the NE 1/4, T. 154 N., R. 95 W., approximately two miles east of Hofflund, Williams county, the southeastern extreme of this fault is located in the SE 1/4, Sec. 36, T. 152 N., R. 94 W., approximately 6 miles southwest of Verendrye National Monument, McKenzie county. Whether this fault extends to the basement is unknown at the present time but it is the writer's opinion that it may be the reflection of basement structure. Three inferred faults are thought to exist: 1.) an east-west trending fault between the towns of Glenfield and Carrington in Foster county, 2.) a fault 6 miles north of the town of Hofflund in Williams county, the trend and dip of this fault are unknown and 3.) a fault 8 miles north of the town of Hofflund in Williams county, the trend and the dip of this fault are unknown.

Good structural control exists in a narrow belt extending from longitude 98 degrees west to longitude 100 degrees west and from the Canadian to the South Dakota border.

Samples of basement rock were obtained from oil exploration wells which penetrate to the basement. Identification of these samples was by optical means and the classification used was that of Williams, Turner and Gilbert, who base their classification on feldspar ratios. Twenty-two wells penetrate to adamellite, 18 to diorite, 16 to granite, 5 to monzonite, 3 to gabbro, 1 to granodiorite, 1 to amphibolite, and 1 to quartzite. Weathering of the basement rocks is very intense in the Red River Valley and no samples of fresh rock have been obtained to the writer's knowledge.

Samples obtained from oil wells which penetrate to the basement are valid; however, they have the disadvantage that most of the material is very small in size and few core samples exist.

Large portions of the North Dakota basement are unknown due to the lack of wells penetrating to a sufficient depth and to the lack of any type of well spacing for good sampling control. Further exploration of the basement may reveal various types of structure which would indicate the most likely places to drill for oil.

Was Reported Before January 1, 1958

Appendix I

N.D.G.S. Circ. #5. Well No.	Name of Well	Location	Depth below sea level	Basement Rock
5	Glenfield Oil Co. #1	SE Sec. 18-146-62	1730'	Adamellite
15	Carter Oil Co. E.L. Semling #1	SE SE Sec. 18-141-81	6817'	Amphibolite
16	Northern Ordinance, Franklin Investment Co. #1	NW NW Sec. 35-133-75	3450'	Granite
19	Continental-Pure, Davidson #1	SW SW SW Sec. 35-140-77	5048'	Granite
20	Union Oil Co., Aanstad #1	NE Sec. 29-158-62	1679'	Granite
23	Roeser-Pendleton, J.J. Weber #1	SE Sec. 35-133-76	3544'	Gabbro
24	Magnolia Petr. Co., Dak. A.	NE Sec. 36-141-73	3683'	Gabbro
26	Phillips-Carter Dakota #1	NW¼ Sec. 29-136-81	5799'	No sample
27	Union Oil Co., Chris Skjervheim #1	C NW NE Sec. 28-159-63	1855'	Granite
29	Red River Dev. & Oil Co., Edgar Berg #1	SW Sec. 35-152-51	344'	Quartzite (weathered)
37	Union Oil Co., Los Neitos, Restad #1	SW NW Sec. 26-162-64	1750'	No sample Red River
38 √	The California Co., Blanche Thompson	SW SE Sec. 31-160-81	6700'	Granite
39	Hunt Oil Co., W.S. Shoemaker #1	NE/4 SW/4 Sec. 3-157-78	5738'	Diorite
40	Barnett Drilling Inc. John Caier #1	NW NW Sec. 11-141-67	2288'	Diorite
43	Peak Drilling Co., Olhauser #1	NE SE Sec. 8-132-78	4065'	Adamellitte Gran
47	William Herbert Hunt Estate, Moe D. & Anna Wald #1	SE SW Sec. 23-155-81	7050'	Granite on Electric Log

N.D.G.S. Circ. #5 Well No.	Name of Well	Location	Depth below sea level	Basement Rock
64	Hunt Oil Co., Oliver Olson #1	SW NW Sec. 18-163-77	4899'	Granite on Electric Log
83	Lion Oil Co., Peder & Lillie Sebellus #1	NE NE Sec. 23-161-75	3873'	Pink Granite
89	General Atlas Carbon Co., A. Ketterling #1	NE NW Sec. 15-131-73	2701'	Granite
94	Champlin Refining Co. Elmer Heim #1	NE NW Sec. 12-133-65	1173'	Diorite
100 ✓	Union Oil of Calif. Arne & Heimi Saarl #1	C SW Sec. 35-161-68	2782'	Adamellite
110	Lion Oil Co., Huss #1	NW SW Sec. 23-163-75	4232'	Granite on Electric Log
120	General Atlas Carbon Co., A.Peplinski #1	SE NW Sec. 21-142-63	1436'	Gabbro
134	General Atlas Carbon Co., F.Barthel #1	SW NE Sec. 15-142-65	1876'	Adamellite
145	Conitnental Oil Co., Paul E. CmCay #1	NW NW NW Sec. 32-137-76	4316'	No sample
149 ✓	Pollard & Davis, Dwane Gussette #1	NW NW Sec. 20-142-61	1053'	No Sample
151	Hunt Oil Co., Emma Kleven #1	SW SW Sec. 18-140-80	6205'	Granite
155	Continental Oil Co., Dronen #1	NE NE Sec. 9-140-75	4254'	Granite
171	F.H. Rhodes, Murphy #1	NW NE Sec. 18-163-65	2182'	Diorite
174	Continental Oil Co.,	NW NW Sec. 3-140-77	4883'	No sample
194	F.H. Rhodes, R.R. Gibbens #1	SW SE Sec. 17-157-65	2272'	Adamellite
196	Carter Oil Co., Allyn MacDiarmid #1	NE NE Sec. 16-154-65	2269'	Adamellite
207	Continental Oil Co., Lueth #1	NE NE Sec. 27-146-73	4098'	Diorite
227	Nat. Bulk Carriers Inc. E.L. Hild #1	SE SW Sec. 31-158-66	2570'	Monzonite

N.D.G.S. Circ. #5. Well No.	Name of Well	Location	Depth below sea level	Basement Rock
230	Carter Oil Co., N. Dak. State #1	NE SE Sec. 16-143-71	3264'	Diorite
246	No. Natural Gas Pro. Co., Raymond & Blanche Lee #1	C NE NE Sec. 36-154-63	1756'	Granite
287	Frazier-Conroy Drilling Co., Sarah Dunbar #1	NW NW Sec. 13-146-63	1608'	No sample
295	T.M.Evans, Bailey #1	SW NE Sec. 26-145-62	1395' ?	Granite Wash, pink
316	T.M.Evans, A.L.Johnson #1	NW SW Sec. 23-160-70	3281'	Diorite
334	T.M. Evans, Christian Erickson #1	NE SE Sec. 24-145-64	1760'	Granite
370	Herman-Hanson Oil Synd., Reg Ogilive #1	NW NW Sec. 21-140-65	1720'	Granite on Electric Log
383	S.D. Johnson, M.D. Wolf #1	NW NW Sec. 17-158-62	1724'	Diorite
390	Midwest Exploration Corp., Union Central Life Ins. & H. Amann #1	SE SE Sec. 24-160-67	2529'	Granite
403	Pure Oil Co., J.M. Carr #1	NE NE Sec. 15-146-66	2012'	Monzonite
406	Herman Hanson Oil Synd., M.M. Mueller Well #1	NE NE Sec. 20-140-65	1740'	Granite
407	Calvert Exploration Co., Carl & Olive Jack #1	NE SW Sec. 13-153-63	1792'	Granite
408	Calvert Exploration Co., Wendell Haley #1	SW SW Sec. 1-153-63	1763'	Granodiorite
411	S.D.Johnson Co., Edwin Werner #1	SW SE Sec. 11-158-63	1789'	Adamellite
422	McLaughlin, Inc., Wolfe #1	NE SW Sec. 33-158-62	1666'	No sample

N.D.G.S. Circ. #5. Well No.	Name of Well	Location	Depth below sea level	Basement Rock
434	Midwest Exploration Co., H.P. Juntenen #1	NW NW Sec. 27-163-68	2676'	Diorite
435	Midwest Exploration Co., Heckman #1	SW NE Sec. 12-158-69	3001'	Diorite
457	Calvert Exploration Co., N. Dak. State #1	NW NW Sec. 16-150-67	2760'	Adamellite
469	Turner Oil Co., Dwight Holmes #1	SE NE Sec. 8-163-55	506'	No sample
515	Hermon Hanson Oil Synd., Harold Billey #1	SE NW Sec. 11-129-63	440'	Monzonite
572	Hermon Hanson Oil Synd., John Bell #1	NE NW Sec. 14-129-63	416'	Granite
580	A.J. Scott A.J. Scott #1	NE NE Sec. 15-151-53	41.5'	White Granite
609	Caroline Hunt Trust Estate, George Leitner #1	NE SW Sec. 14-148-71	3581'	No sample
620	Calvert Exploration Co., C.C. Nitschke #1	NE SE Sec. 13-130-69	1552'	Adamellite
621	Calvert Exploration Co., Nitschke #1	NW NW Sec. 19-130-69	1774'	Adamellite
622	Calvert Exploration Co., Karl Schock #1	SW NW Sec. 17-131-69	1701'	Adamellite
632	Calvert Exploration Co., Arthur J. & Ida John & Gina Stedum #1	NW SE Sec. 31-154-70	3507'	Adamellite
644	Gordon B. Butterfield, Rudolph Trautman #1	SE SE Sec. 5-139-68	2460'	Diorite
668	Calvert Exploration Co., Margaret Meyers #1	SE SW Sec. 25-137-67	1793'	Adamellite
669	Calvert Exploration Co., Christ Rau #1	SE SW Sec. 35-139-68	2220'	Adamellite
670	Calvert Exploration Co., D.C. Wood #1	SE SW Sec. 24-139-67	1827'	Diorite

N.D.G.S. Circ. #5. Well No.	Name of Well	Location	Depth below sea level	Basement Rock
671	Calvert Exploration Co., Geo. Ganser #1	NW SW Sec. 12-140-67	2089'	Diorite
672	Calvert Exploration Co., Vincent Wanzek #1	NW NW Sec. 12-139-67	2032'	Diorite
673	Calvert Exploration Co., F.L. Robertson #1	NE NE Sec. 26-138-67	1763'	Adamellite
700	Turner Oil Co., Theodore Belanus #1	NE SE Sec. 28-164-56	635'	Monzonite
706	Shell Oil Co., Gifford Marchus #1	SE SE Sec. 23-157-70	3356'	Granite
768	Calvert Exploration Co., State #1	NE NE Sec. 8-150-65	2304'	Adamellite
1112	Cardinal Drilling Co. N.A. Graves & Fed. Land Bank #1	NE NE Sec. 23-146-66	2274'	Adamellite
1211	Calvert Drilling Co. Francis Zwinger #1	NE NE Sec. 8-146-68	2787'	Adamellite
1231	Amerada Petr. Corp. Iverson-Nelson Unit #1	NE/4 Sec. 2-155-96	11308'	Diorite
1274	Wetch, Zachmier & Disney Drilling Co.	SE SE Sec. 9-148-62	1525 '	Granite Wash pink
1356	North Plains Petr. F.F. Danner #1	SW SE Sec. 24-152-54	98.9'	Diorite
1385	Amerada Petr. Corp. N.D. "A" Unit #9	SE SW Sec. 16-156-95	12435'	Monzonite
1394	Calvert Drilling, Inc. Marvin Kamm #1	NW NW Sec. 5-129-66	970'	Adamellite
1403	Amerada Petr. Corp. Boe-Olson Unit #1	NE¼ Sec. 15-155-96	11980'	No sample
1415	North Plains Petr. Inc. C.O. Haugen #1	SE SE Sec. 22-152-54	135'	Adamellite

Appendix II

Percentage Mineral Composition for North Dakota Basement Wells

N.D.G.S. Circ.#5 Well Number	Leucoxene	Apatite	Kaolinite	Muscovite	Garnet	Sphene	Pyrite	Magnetite	Sericite	Epidote	Chlorite	Biotite	Hornblende	Augite	Quartz	K-feldspar	Plagioclase	Plagioclase An
5				1				1				6	3		48	31	10	
15				2		2	7					5	37		9	40		
16					5	1		1				8			35	31	24	
19					5	5						6		1	36	34	21	
20	2				3	1		1				10			35	31	20	
23								1				9			25	58	6	
24						3		1				2	5	2	35	53	3	1
26																		
27			40									14	1		28		6	1
27												11			22	13	45	18
27								1				10	1		20	2	46	20
29												20	10		50		15	2
38								1				6			33	32	25	
39						2		1				3			36	55	10	
40						1					1	12		1	27	41	12	2
43						2		1				9		1	32	40	14	1
47																		
64																		
83	1	4			5	1		1				3			35	54	4	
89	2				3	1		1				10			35	31	21	
94	1	4					1			4	1	1			28	43	8	1
100							1			1		8			20	51	19	

N.D.G.S. Circ. #5 Well Number	110	120	134	145	149	151	155	171	174	194	196	207	227	230	246	287	295	316	334	370	383
Plagioclase An		1	1										26	1			2		15		6
Plagioclase		5	9			24	13	3	22	22	18	17	31	9	23		13	6	34		10
K-feldspar		52	45			31	32	54	35	33	31	38	32	29	36		42	59	26		40
Quartz		31	30			34	33	37	35	35	37	28	9	42	33		27	24	8		28
Augite															1						
Hornblende		1	1																		
Biotite		5	10			8	6	2	7	6	4	14		16	5		6	9	23		13
Chlorite																					
Epidote							1			5	1										1
Sericite																					
Magnetite		1	1			1	8	1	1	1	2	1	1	2			2	1	1		2
Pyrite																					
Sphene		1	2			1	1	3		1	2			1	1		1				
Garnet		1	1			5	1			5		1	1		1		1		1		
Muscovite																					
Ka olinite		1					2				3						3				
Apatite																					
Leucoxene		1					1				2	1					3				

Plagioclase An		48	1	10								50		10			2	4					
Plagioclase	24	32	49	50	6	23		5	15	21		32	16	41		20	18	16	16	11	12	14	6
K-feldspar	31	10	23	11	39	32		54	40	33		8	24	10		34	37	31	34	37	34	33	40
Quartz	34	5	25	18	27	34		34	32	35		5	35	20		37	40	35	37	35	40	35	26
Augite																1							
Hornblende								1	1														
Biotite	8	2	2	11	1	9		2	11	8		2	13	14		6		11	6	7	8	14	1
Chlorite																							
Epidote																			2	4			
Sericite																							
Magnetite	1	1			2	1		1	1	1		3	7	2			1	1	3	3	4	2	1
Pyrite																							
Sphene	1	1			1	1		3		1						1	1	1		1		1	1
Garnet	1	1			1	1				1			5			1	1	1	1	1	2	1	1
Muscovite					23									3									24
Ka olinite																							
Apatite																							
Leucoxene																			1	1			
N.D.G.S. Circ.#5 Well Number	390	405	406	407	408	411	422	434	435	437	469	515	572	580	609	620	621	622	632	644	668	669	670

N.D.G.S. Circ. #5 Well Number	671	672	673	700	706	768	1112	1211	1231	1274	1356	1385	1394	1403	1415
Plagioclase An						4			3			24			
Plagioclase	11	8	17	16	20	13	15	11	8	11	5	35	20		18
K-feldspar	34	37	30	34	35	29	30	35	34	35	36	30	35		30
Quartz	30	32	34	38	36	37	33	38	31	33	32	8	38		27
Augite															
Hornblende															
Biotite	13	14	16	10	7	17	15	14	10	12	13		5		22
Chlorite															
Epidote									7						
Sericite															
Magnetite	5	4	1		1	4	4		2	4	5	1			1
Pyrite	1									1	2				
Sphene			1	1	1	1		1	1			1	1		1
Garnet	1	1	1	1				1	4			1	1		1
Muscovite															
Ka olinite	1	1				2	1			1	3				
Apatite															
Leucoxene	4	3				3	3			3	4				

Appendix III

Basic Data and Partial Well Logs for Water Wells Penetrating to the Basement

Name	Location	Depth Below Surface	Type rock reported
U.S.G.S. #813	17-130-49	383'	"Decomposed granite": clay, white-grading downward to green
Ruddy Bros. #1	11-132-58	550' 695'	"Granite", gray to light greenish, decomposed, micaceous. Gneissic granite, schist chips
U.S.G.S. #13	7-132-50	420'	"Decomposed granite", light grayish-white
U.S.G.S. #14	12-132-50	410'	"Decomposed granite", grayish-white
U.S.G.S. #5	7-132-51	550' 570'	Clay, reddish with quartz crystals Clay, light greenish-gray and white with quartz crystals
U.S.G.S.#481	5-129-47	183'	Unaltered "Granite" (no sample)
U.S.G.S. #482	8-129-47	160'	Unaltered "Granite" (no sample)
U.S.G.S. #485	6-130-47	270'	"Granite," decomposed:Clay, brown.
U.S.G.S. #484	8-130-47	256'	"Granite," decomposed:clay, orange and white.
U.S.G.S. #483	17-130-47	206'	"Granite," decomposed;clay, white
U.S.G.S. #475	20-130-47	220'	Core, clay, white and pink, kaolinitic
U.S.G.S. #474	20-130-47	234'	"Granite", decomposed, clay, white and pink, green at depth.
U.S.G.S. #473	21-130-47	198' 217'	Clay, green. Quartz grains Hard rock (no sample)
U.S.G.S. #472	21-130-47	176' 188'	Clay, green. Quartz grains Hard rock (no sample)
Thein test hole	21-130-47	170'	Hard rock (no sample)
U.S.G.S. #471	22-130-47	210' 215'	"Granite decomposed":clay, white kaolinitic Clay, white and green with imbedded quartz (some euhedral crystals)
U.S.G.S. #470	22-130-47	219'	"Granite decomposed ", kaolinitic, clay, white, euhedral quartz.
U.S.G.S. #479	29-130-47	203' 205'	"Granite" decomposed: Clay, green.

Name	Location	Depth below Surface	Type rock reported
U.S.G.S. #480	32-130-47	198'	Clay, white
		200'	Clay, green
U.S.G.S. #478	23-130-47	229'	Clay, light-green.
U.S.G.S. #477	25-130-48	251'	Clay, white
El Rancho well Dilworth	1-139-48	297'	Clay, white and sand
		300'	Clay, blue-green, with quartz grains and granite fragments.
Pierce Printing Co.	6-139-48		Decomposed "granite": sandstone
		280'	green
		395'	red
		400'	gray
Old Fargo City test well (Island Park)	7-139-48	365'	Clay, light green, gritty, decomposed gneiss
		475'	Chlorite-granite or gneiss, soft, red, feldspathic
		765'	Gneiss, mostly feldspathic and quartz, chloritic, fine grained
		1120'	Felsite (?) soft, greenish but finely red-mottled, fissle, chloritic
		1901'	Other granitic rock
Fargo City test	18-139-48	230'	Clay, white and some sand
U.S.G.S. test hole	1-139-49	178'	"Granite", decomposed
Great Northern R.R. well Fargo	1-139-49	200'	Marl (?), hard, whitesand
		230'	Sand, hard, dry, white and gray
U.S.G.S. test hole	1-139-49	197'	"Granite", decomposed: reddish brown
U.S.G.S. test hole	1-139-49	184'	"Granite", decomposed: white
U.S.G.S. test hole	1-139-49	198'	"Granite", decomposed
U.S.G.S. test hole	1-139-49	178'	"Granite", decomposed, white
U.S.G.S. test hole	1-139-49	188'	"Granite", decomposed
Fargo City test hole	1-139-49		"Granite", decomposed
		200'	Sandy, white
		202'	Clay, light green

Name	Location	Depth below Surface	Type rock reported
Fargo City test hole	1-139-49	199'	"Granite", decomposed, clay (kaolin), white, and some angular sand
Fargo City test hole	1-139-49	249'	"Granite", decomposed, clay, green, and fragments of quartz and granite
Fargo City test hole	1-139-49	254'	Sand, coarse, angular, white
		260'	Clay, green, and some angular granite pebbles
		265'	Clay (kaolin?), green, and pebbles of shist and granite
Cass County Well	1-139-49	251'	"Granite"
Old Well, Fargo	1-139-49	250'	"Granite"
U.S.G.S. test hole	2-139-49	285'	"Granite", decomposed
U.S.G.S. test hole	3-139-49	339'	"Granite", Decomposed, greenish gray
U.S.G.S. test hole	4-139-49	244'	Gravel and Sand (decomposed "granite" pebbles)
		249'	"Granite", decomposed, white
U.S.G.S. test hole	5-139-49		"Granite"
		215'	Clay, white
		225'	Clay, reddish brown (decomposed granite)
		234'	"Granite", decomposed, white
U.S.G.S. test hole	5-139-49	200'	"Granite", decomposed, white
		214'	"Granite", decomposed, greenish
Fargo City, old well	12-139-49		"Granite"?
		206'	"Rock", white, chalky
Fargo City test hole	12-139-49	210'	"Granite?" Clay (kaolin?), marly?, White
U.S.G.S. test hole	13-139-49	189'	"Granite", decomposed, light greenish gray
U.S.G.S. test hole	1-139-50	249'	"Granite", decomposed
U.S.G.S. test hole	5-139-50		"Granite", decomposed
		299'	Clay, white (kaolin)
		304'	Clay, white and light gray (kaolin)
		314'	Clay, light greenish-gray, (kaolin)

Name	Location	Depth below Surface	Type rock reported
(con't)		324'	Sand, quartz, angular, and light greenish-gray clay (kaolin)
		329'	Clay, light green (kaolin) and rock (granite?)
U.S.G.S. test hole	11-139-50		"Granite", decomposed
		245'	Clay, gray and white (kaolin)
		259'	Clay, dark greenish-gray and white
		264'	Clay, white, gray and reddish brown and considerable sand and gravel
		265'	Clay, reddish brown, and rock fragments
		269'	Clay, white and rock fragments
		279'	Rock, white or light buff
		289'	Rock, buff and black and red clay
		299'	Rock, buff and black and red and white clay
		304'	Rock, buff and black, and red and blue kaolin
		309'	Rock, and red and white clay
U.S.G.S. test hole	4-139-51		"Granite", decomposed
		389'	Clay, yellow and gray
		412'	"Granite", decomposed: gray clay and fine gravel
		419'	"Granite", decomposed (less decomposed than above)
U.S.G.S. test hole	6-139-51	376'	"Granite", decomposed
U.S.G.S. test hole	11-139-51		"Granite", decomposed
		329'	"Granite", pebbles and gray clay (kaolin?)
		344'	"Granite", white and grey clay (kaolin)
		349'	"Granite", decomposed
U.S.G.S. test hole	2-139-52	384'	"Granite", decomposed, white
U.S.G.S. test hole	10-139-53		"Granite", decomposed
		565'	Sand, quartz, angular, and some black clay
		585'	Sand, quartz, angular, and some black and white (kaolin?) clay
		608'	Sand, quartz, angular, and red and white clay; some shale (hard clay) and rock (granite) fragments near bottom of hole
Fargo City old well	31-140-48	317'	"Granite?" sand and clay
		338'	Sand

Name	Location	Depth below Surface	Type rock reported
American Crystal Sugar Co. test hole	32-140-48		"Granite", decomposed
		260'	Sand, coarse and gravel with some clay and many chips of pink granite and black schist
		265'	Granite, pink and schist, black, angular chips
U.S.G.S. test hole	16-140-49	176'	"Granite", decomposed, greenish gray
U.S.G.S. test hole	20-140-49	147'	"Granite", decomposed, dark to greenish gray
U.S.G.S. test hole	21-140-49	158'	"Granite", decomposed, green to gray
U.S.G.S. test hole	21-140-49	175'	"Granite", decomposed, greenish gray
U.S.G.S. test hole	28-140-49	194'	"Granite", decomposed, gray to green
U.S.G.S. test hole	34-140-49	160'	"Granite", decomposed, greenish gray
U.S.G.S. test hole	34-140-51	319'	"Granite", decomposed, white
U.S.G.S. test hole	34-140-51	338'	"Granite", decomposed, light gray
U.S.G.S. #10	33-147-52		"Granite, decomposed",
		447'	White to greenish gray clay and angular quartz crystals
		555'	Hard, compact mudstone, light greenish gray with thin bands of brick red clay, abundant angular quartz crystals, light colored mica
U.S.G.S. #1154	18-148-53		"Granite, decomposed"
		485'	Shale possibably Fuson mixed with "decomposed granite"
		490'	"Granite decomposed", clay, smooth white, grading to gray
U.S.G.S. #1193	15-148-51	466'	"Granite"; red feldspar, rich quartz crystals and plagioclase, mica particals
U.S.G.S. #1182	14-148-53	474'	"Granite, decomposed" Clay, gray, green, brown, black to white

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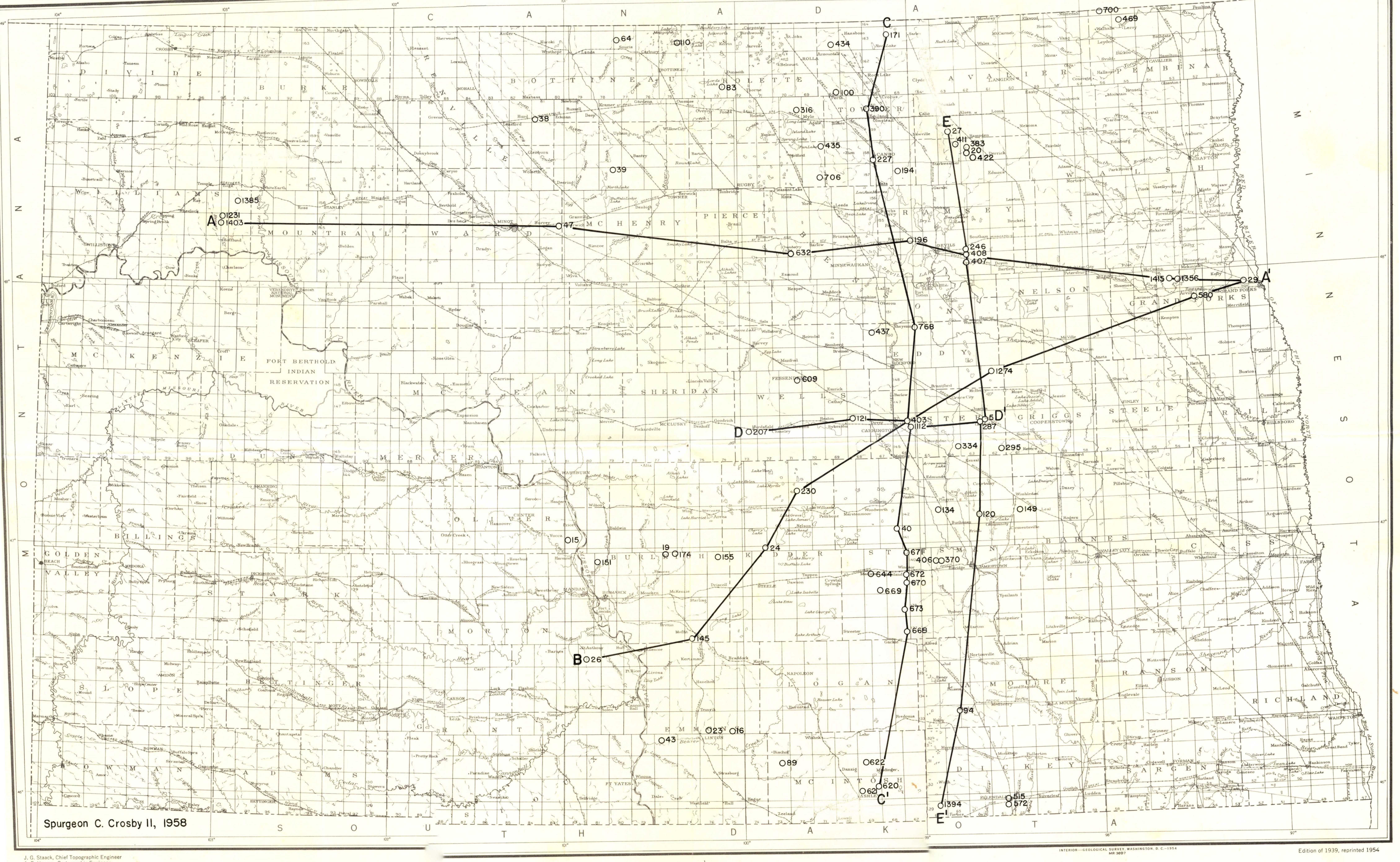
PLATE I
INDEX MAP TO BASEMENT WELLS AND PROFILES

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

NORTH DAKOTA



J. G. Staack, Chief Topographic Engineer
A. F. Hassan, Cartographic Engineer
Compiled in 1920

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1954

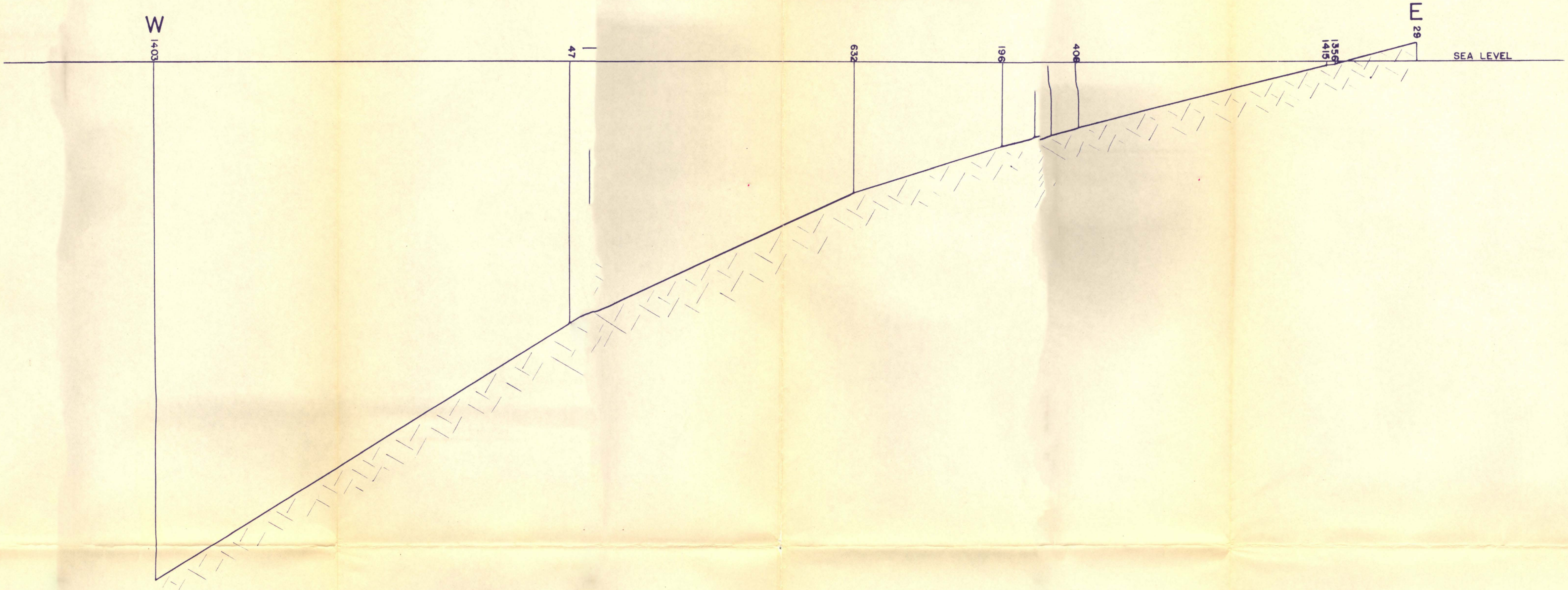
Edition of 1939, reprinted 1954

Scale 1:1000000

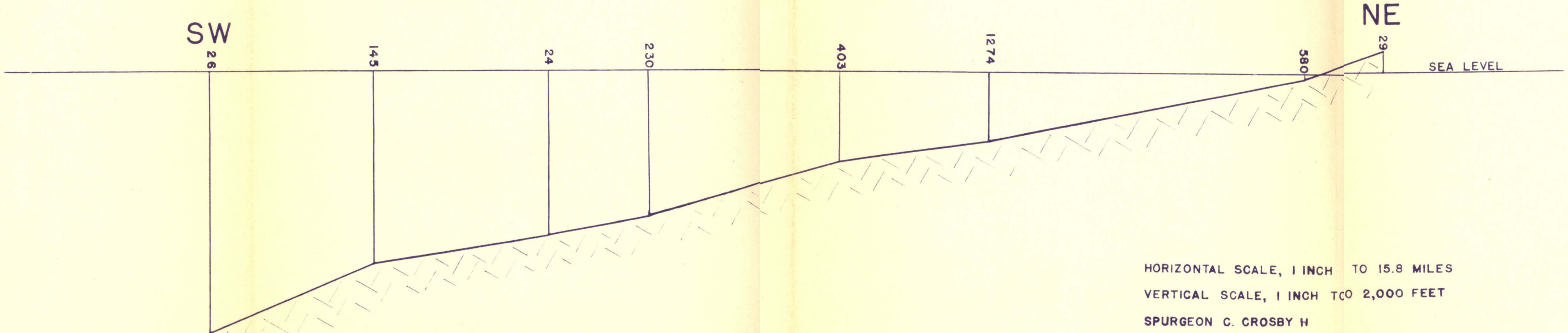
Projection is polyconic (modified)
Horizontal datum is North American

PLATE II

BASEMENT PROFILE A-A'



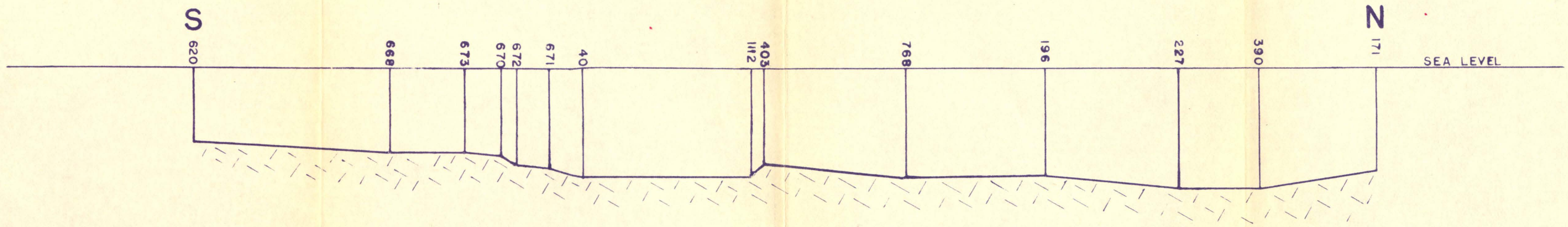
BASEMENT PROFILE A'-B



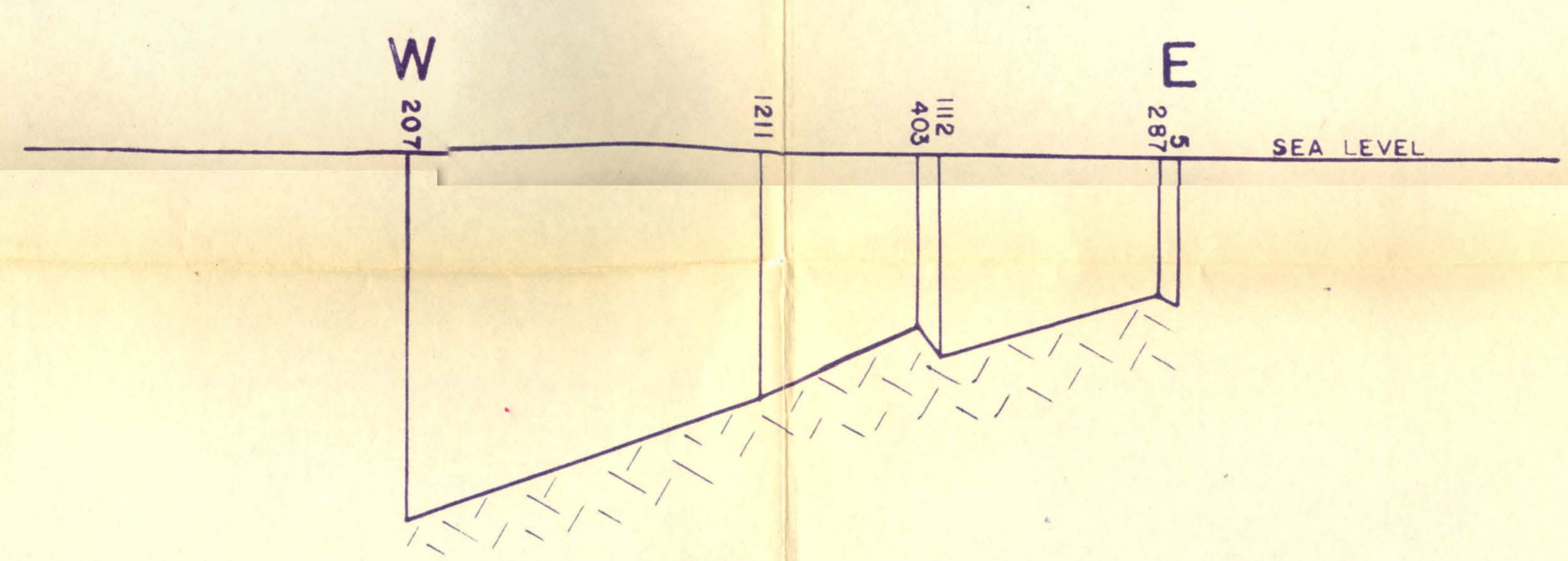
HORIZONTAL SCALE, I INCH TO 15.8 MILES
VERTICAL SCALE, I INCH TO 2,000 FEET
SPURGEON C. CROSBY II
1958

PLATE III

BASEMENT PROFILE C-C'



BASEMENT PROFILE D-D'



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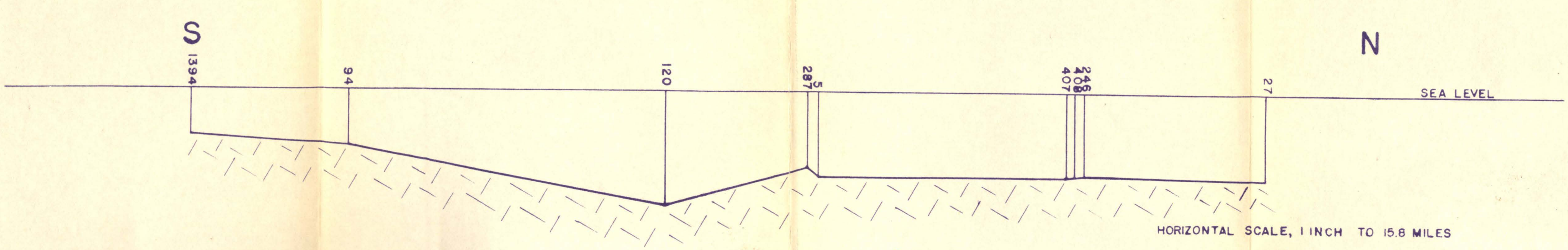


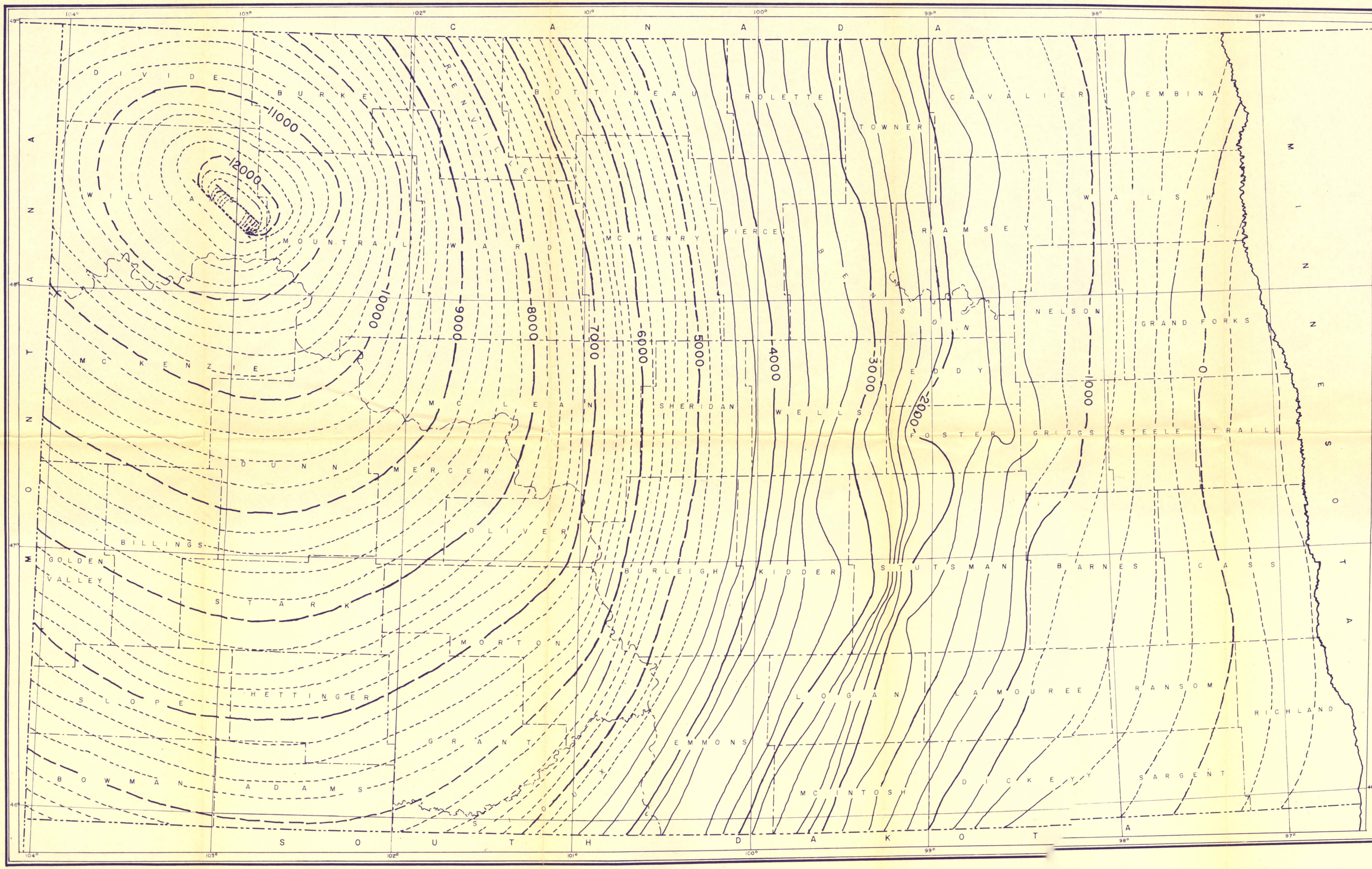
HORIZONTAL SCALE, 1 INCH TO 15.8 MILES

VERTICAL SCALE, 1 INCH TO 2,000 FEET

SPURGEON C. CROSBY II

1958

PLATE IV
BASEMENT TOPOGRAPHIC MAP



Spurgeon C. Crosby II, 1958

10 0 10 20 30 40 Miles
10 0 10 20 30 40 50 Kilometers

Projection is polyconic (modified)
Horizontal datum is North American
Vertical datum is mean Sea Level
Contour interval 200 feet
Scale 1:1000000