NORTH DAKOTA GEOLOGICAL SURVEY

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REPORT OF INVESTIGATION 47

# THE NEWCASTLE FORMATION

## IN THE WILLISTON BASIN

## OF NORTH DAKOTA

by

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# FOREWARD

This report of investigations is based on a Master's Thesis submitted to the faculty of the University of North Dakota by Mark Reishus in May, 1967. The original Thesis, which contains an appendix listing the basic data concerning the formation tops for each well included in the study, is in the library of the University of North Dakota at Grand Forks, North Dakota. The original Thesis has been edited for publication with minor revisions to include recent exploration developments.

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# THE NEWCASTLE FORMATION IN THE WILLISTON BASIN OF NORTH DAKOTA

## ABSTRACT

The Newcastle Formation of the Black Hills area has been traced into the subsurface of the Williston basin in North Dakota. The Newcastle Formation of North Dakota is a very fine to medium grained, gray to white, quartzose sandstone, which occurs mainly in the eastern one-third and western one-fourth of the state. It is conformable with the underlying Skull Creek Shale and the overlying Mowry Shale, and is a coarse facies of these shales. In areas of non-deposition, an equivalent shale section was deposited, and the contact between the Mowry Formation and the Skull Creek Formation cannot be determined from well logs. In these areas, this section has been referred to as "undifferentiated Mowry-Skull Creek." The Newcastle has been assigned to the Lower Cretaceous on the basis of ammonites and foraminifers found near the type area.

Correlation between the Newcastle of eastern and western North Dakota can be traced through northern South Dakota and through a 25-mile by 100-mile area of siltstone and fine sandstone in south-central North Dakota. The Newcastle Formation is a marine sandstone that appears to have been deposited in a near shore environment. In eastern North Dakota, it occurs as a blanket sandstone that thickens toward Pleistocene covered erosion surface along the North Dakota-Minnesota border. Structure does not appear to have controlled deposition except for two small structural noses in the northeastern part of the state. In this area, the Newcastle and a thin underlying shale bed have an up-dip overlapping relationship over successively older units of the Dakota Group. In southeastern North Dakota, a large thickness of sandstone suggests an ancient delta complex.

In western North Dakota, the rapid thickening and thinning of the sandstone is due to deposition which was probably controlled by offshore currents. The Nesson anticline appears to have been a partial barrier which controlled the location of these currents. Three large thick areas

of sandstone extending into North Dakota from the southwest and west may indicate ancient delta complexes.

There are several good possible stratigraphic traps for oil accumulation in the Newcastle in North Dakota. These possibilities plus the factors of good reserves in previously developed fields in Wyoming, shallow depths and the easily drilled section overlying the Newcastle, should encourage exploration.

# INTRODUCTION

## General

Oil seeps were first noted in the Lower Cretaceous Formations of the Black Hills in the middle 1800's, and commercial production was found in 1900 (Wulf, 1962, p. 1371). Since then, many prolific oil fields have been found in the Newcastle Sandstone of eastern Wyoming and southeastern Montana. Production has also been found in the Viking, an equivalent sandstone, in southwestern Saskatchewan and southeastern Alberta (Stelck, 1958, p. 2).

Since the discovery of oil in the Williston basin in 1951, over 4,300 wells have been drilled in North Dakota. Many of these wells have penetrated a sandstone which has been called Newcastle because of its stratigraphic position. The purpose of this study was to map and provide a discussion of these rocks in North Dakota, to trace them through the subsurface by the use of well logs and correlate, if possible, with the type Newcastle of the Black Hills area in Wyoming. An effort was made to determine the possibilities of oil production from the Newcastle in North Dakota.

## Methods of Study

Mechanical logs of 496 wells in North Dakota were chosen for this study. In or near areas where the Newcastle Formation was present, all available control was used, except in field areas. In these areas, approximately two wells per township were used. In the central part of North Dakota where the Newcastle Formation is absent, a random sam-

pling of approximately one well per four or five townships was used where available.

Mechanical logs of 18 wells in South Dakota, 14 wells in Montana and 6 wells in Wyoming were studied. From these, logs of 12 wells were selected to trace the Newcastle Formation from North Dakota to the type section in Wyoming. The writer also studied approximately 150 well information cards in South Dakota and eastern Wyoming to determine the extent and thickness of the Newcastle Formation outside of North Dakota. Plates 1 and 5 show the well control used in the preparation of this study.

Log correlations were made throughout North Dakota and an isopachous map of the Newcastle Formation was prepared. A structure map was drawn using an easily traced log characteristic at the top of the Mowry Formation as a marker. Also, an isopachous map of the total interval of the Mowry, Newcastle and Skull Creek formations was prepared to indicate their inter-relationship. Five cross sections were made to illustrate the occurrence of the Newcastle in North Dakota. Two cross sections, extending from the subsurface of southeastern and southwestern North Dakota to a bore hole in Weston County, Wyoming, one mile southwest of the type section, were prepared.

Gamma ray and resistivity curves were used wherever possible because these logs were available on most wells, and they provide good definition of the strata involved. Sandstone thicknesses were taken from resistivity curves where they were available. The top of the Mowry Formation was picked from a distinctive kick (fig. 2) on the gamma ray curves of wells where this log was run. On these wells, the Mowry "top" from the gamma ray curve was correlated to the resistivity curve and the resistivity curves were then used to correlate with other wells that did not have a gamma ray log. Lithologic descriptions were taken from sample logs in the form of North Dakota Geological Survey Circulars and American Stratigraphic Company sample logs. The author logged Newcastle samples from representative wells in the eastern and western portions of the state.

The isopachous maps included in this report are actually isochore maps because thicknesses have not been corrected for dip or well deviation. However, since dips in the Williston basin generally do not exceed one degree, differences in real and apparent thicknesses are so small that they can for all practical purposes be ignored.

## PREVIOUS WORK

The Newcastle Formation was first described, but not named, by Darton (1909, p. 51) when he described the geology of the northern flank of the Black Hills. He considered it and the Mowry Shale Member, which he traced from the Bighorn Mountains, to be part of the Graneros Shale. The Newcastle was first named by Hancock (1920, p. 39) when he studied it in outcrop and in the oil fields that produced from it near Newcastle, Wyoming. Hancock did not designate a type section. Skolnick (1958, p. 795) proposed that the type section be located in the NW 1/4 NW 1/4 of sec. 28, T. 45 N., R. 61 W., Weston County, Wyoming, where the Newcastle is exposed on the northwest side of a road cut of U. S. Highway 85, 0.4 mile northeast of the junction with U. S. Highway 16, and 1 mile east of the town of Newcastle.

The Newcastle Formation is 93 feet thick in the type section where Skolnick (1958, p. 811) described it as consisting of interfingering sandstones, siltstones and shales ranging in color from dark gray to brownish gray to yellowish orange (5yR3/1 to 10yR7/6, Goddard et al., 1951). Fusain occurs in most parts and imparts a gray color to the section. There are occurrences of bentonite and bone coal. The sandstones are variably massive, thin-bedded and cross-bedded, very fine grained to fine grained, and well sorted. The light minerals are approximately 95% quartz, and only the most persistent heavy minerals, zircon, tourmaline, ilmenite and staurolite, are present.

Collier (1922, p. 81) thought that the Newcastle was deposited in shallow water close to tree-covered land, as indicated by the wood and coal content, ripple marks, cross-bedding and the occurrence of sandstone lenses in siltstone and shales. Dobbin (1947, p. 801) supported the theory of shallow water deposition with findings similar to Collier. In addition, he mentioned the occurrence of both continental and marine or brackish water fossils, and dinosaur bones. He described the Newcastle as a highly variable zone of discontinuous beds of sandstone, shale, sandy shale, impure lignite and bentonite.

Summerford, and others (1950, p. 1864), who worked with the Newcastle Sandstone in the Mush Creek oil field area in eastern Wyoming, drew subsurface cross-sections to illustrate intricate vertical and lateral changes in shale and sandstone lithofacies, which suggested near shore deposition. The presence of coal beds was thought to indicate shifting

of the strand line to temporary non-marine deposition. They interpreted the distribution of the sandstone beds to be the result of wave and current action similar to present day processes in the Gulf of Mexico.

The Newcastle Formation was traced from the type area into the subsurface of central and northwestern Montana by Cobban (1951). He found equivalent sandstone beds, with small chert pebbles, up to 20 feet thick in central Montana and 180 feet to 345 feet of greenish-gray glauconitic sandstone in northwestern Montana along the Sweetgrass arch.

Grace (1952) traced the Newcastle Formation from the type area into the subsurface of Wyoming and central and eastern South Dakota. He concluded that the Newcastle had a shallow water, offshore bar origin. Glaister (1959), in a study of the Lower Cretaceous of southern Alberta and adjoining areas, correlated the Viking Sandstone, which produces oil in Alberta and southwestern Saskatchewan, with the Newcastle equivalent sandstone beds of northern Montana.

A regional study was published by Gries (1954, p. 442-452) on the Cretaceous rocks of the Williston basin. This was a short generalized report based on the study of 38 well logs in South Dakota, North Dakota, Montana and Saskatchewan. Gries suggested that the Newcastle Formation may be a tongue of the Dakota Formation projecting westward into western South Dakota and Wyoming, and northward into North Dakota from a broad deltaic plain which lay to the east of the Black Hills.

Hansen (1955) studied the Cretaceous Greenhorn-Lakota interval in the subsurface of North Dakota, and from the study of logs and samples of 146 wells prepared several maps and cross-sections. He correlated the sandstones and shales of this interval and applied the stratigraphic nomenclature used in the Black Hills area to the subsurface units. The stratigraphic interval consisted in ascending order of the: Lakota, Fuson, Fall River, Skull Creek, Newcastle, Mowry, Belle Fourche and Greenhorn formations. Hansen (1955, p. 5) proposed that the term Dakota be used as a Group term consisting of the Lakota, Fuson, Fall River, Skull Creek, Newcastle and Mowry formations. He concluded that the Newcastle Formation was possibly deposited in North Dakota as irregular channel deposits with deltaic type deposition in the southeastern part of the state.

Skolnick (1958, p. 798), in a study of the Lower Cretaceous rocks of the Black Hills, concluded that the occurrence of only the most persistent mineral species, the presence of quartz grains with partly abraded secondarily enlarged rims, and a feldspar content of less than half that of the average sandstone indicated that the Newcastle was derived from weathering of a former sedimentary unit. This, rather than low stream competency, would account for the fine particle size of the Newcastle. He further concluded that the conformable relationship between the Newcastle and the underlying Skull Creek Shale indicated that the source area was stable during deposition. Skolnick, like Collier, Dobbin, and Summerford, considered the Newcastle to be a nearshore deposit of shifting longshore currents near a forested land area.

Baker (1962, p. 161), from a study of the Newcastle outcrops, concluded that the sandstone was a non-marine, alluvial plain deposit. He listed the following as evidence: 1) the sharp erosional contact with the underlying Skull Creek Shale, 2) a typical non-marine facies with carbonaceous mudstones, sandstones, coal beds and channel-fill sandstones, 3) abundance of terrestrial plant remains, 4) the almost complete absence of marine fossils, and 5) evidence of truncation and channeling.

Wulf (1962) studied the Lower Cretaceous Albian rocks of the northern great plains in the subsurface from well logs and at the outcrops near the type areas. He compared the overall size and distribution of the Newcastle Formation in the Black Hills area with the present day Mississippi delta complex. He stated (1962, p. 1394) that, "the lower two-thirds of the type section of the Newcastle Sandstone resembles the deposits formed along the major distributaries of the Mississippi delta," with more massive sandstones occurring higher in the section. Further, he stated that this section is capped by a layer of bone coal with fossil roots, above which is found a second delta cycle superimposed on the lower delta. Wulf also found the thicker sections of Skull Creek Shale coinciding with the thick trends of Newcastle.

Wulf (1962, fig. 8) traced the Newcastle Formation northward with a cross section from Crook County, Wyoming, to Carter County, Montana. He found that the sandstone in the well to the north was at a higher stratigraphic position in the Mowry-Skull Creek shale interval, and he named this sandstone Dynneson after a test hole in Richland County, Montana, which he designated as the type section. He stated that a regional disconformity exists between the Newcastle of Wyoming

and the Dynneson of the Williston basin. He based this on the different origins; ascribing a deltaic origin to the Newcastle and a blanket-type origin for the Dynneson.

Little is known about the paleontology of the Newcastle and related Cretaceous formations, because the rocks in general are very poorly fossiliferous. Limited macrofossil studies have been made by Cobban (1951, p. 2179) and Cobban and Reeside (1951, p. 1892-1893). Cobban mentioned the occurrence of Inoceramus cadottensis in the rocks that are equivalent to the Newcastle Formation in western Montana. It is a guide to the Gastroplites zones of late Middle Albian age. Cobban and Reeside listed several ammonites from the Lower Cretaceous genera, Neogastiophites and Metengonoceras, from the Mowry Shale and believed it to be Upper Albian in age.

A brief report on microfossils was published by Crowley (1951) who studied cores from the Newcastle Formation in the oil fields of eastern Wyoming. He found the following genera: Verneuilina, Ammobaculites, Haplophragmoidea, Ammomarginulina, Haplositche, Spiroplectammina, Textularia, Quinqueloculina, Robulus, Tzehakina and Cornuspira. He found the same fauna present in the Skull Creek Formation, but absent in the Mowry Formation. He concluded that the Newcastle and Skull Creek are Early Cretaceous in age.

Skolnick (1958, p. 791) reported arenaceous Foraminifera from the Skull Creek Shale, the basal part of the Newcastle Formation and the lower part of the Mowry Shale. They included the following genera: Ammobaculites, Ammobaculoides, Haplophragmoides, and Trochammina. He compared these genera to similar near-shore, brackish, shallow water, lagoonal assemblages of the Kiowa, Walnut and Kiamichi formations of Kansas, Oklahoma and Texas. He assigned an age of Fredericksburg, middle Early Cretaceous or Lower and Middle Albian of Europe to the Skull Creek, Newcastle and the lower part of the Mowry.

## STRATIGRAPHY

### Newcastle Formation

The Newcastle Formation is present in the subsurface of the Williston basin in the eastern, western and south-central parts of North

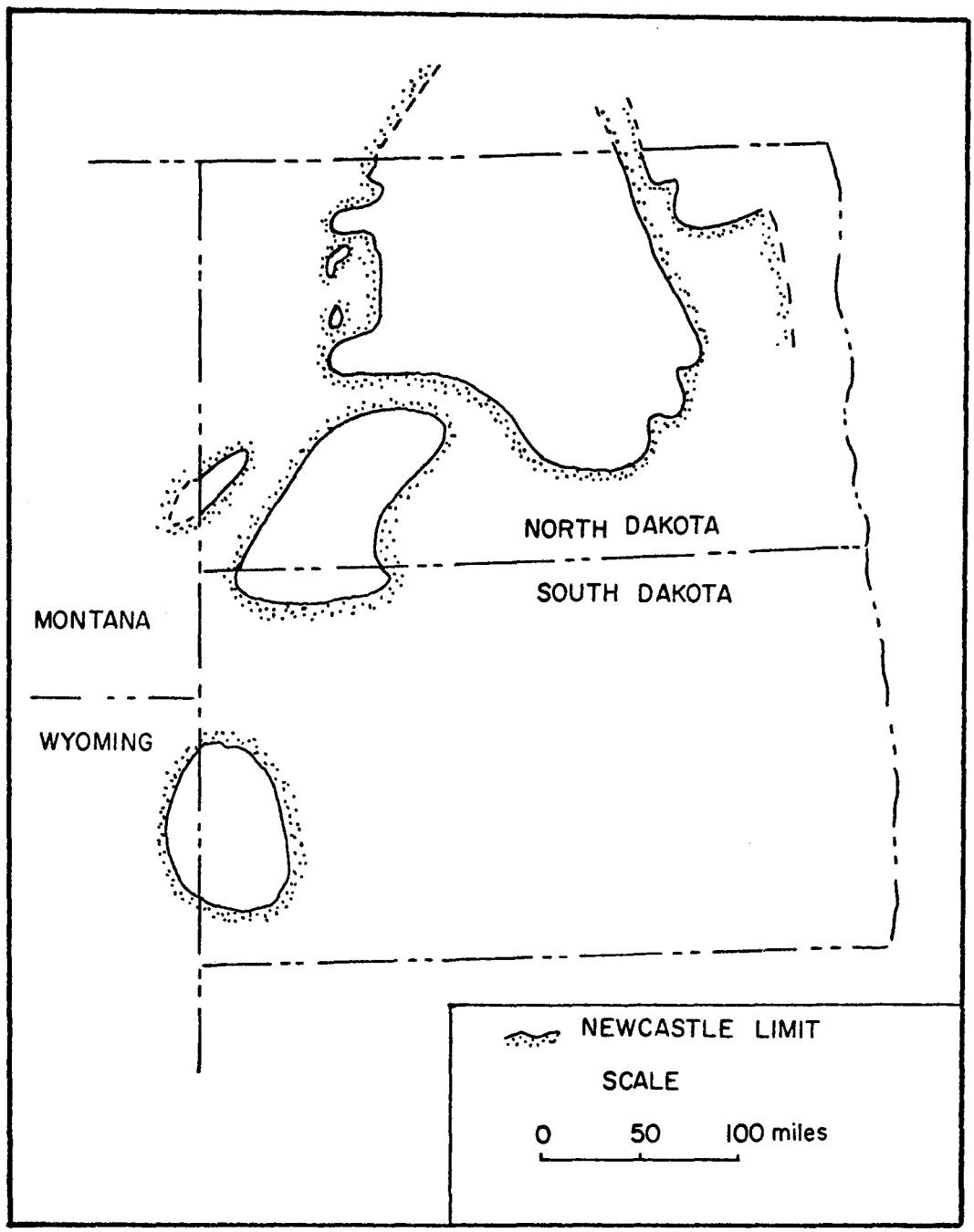


Figure 1. - Index map showing approximate limits of the Newcastle Formation in the area of study.

Dakota. It is absent in central and north-central North Dakota. There are also areas of no Newcastle along the axis of the Nesson anticline and in the southwestern part of the state (fig. 1).

The Newcastle Formation generally consists of medium and fine to very fine grained sandstone and siltstone. It becomes coarser grained in the areas of greatest thickness; one of which is in Dickey County in southeastern North Dakota where it is 280 feet thick; another is in Golden Valley County where it is as much as 142 feet thick. These two areas are connected by a 100-mile long, 25 mile wide area in which the Newcastle Formation is composed mainly of siltstone and very fine grained sandstone (pl. 2).

In western North Dakota, samples of the Newcastle Formation from the Atlantic Refining Company, Anton Eberts No. 1 well, located in the SE 1/4 SE 1/4 sec. 18, T. 138 N., R. 97 W., Stark County, were studied. The following sample descriptions were lagged to Schlumberger log depths. Samples:

5530 - 40, Shale, medium to dark gray, soft, flaky to blocky
5536 - Log top of the Newcastle Formation
5540 - 5610, Shale as above, with sandstone, light gray to white, very fine to fine grained, subrounded quartz with fair to good visible porosity
5606 - Log top of the Skull Creek Formation
5610 - 20, Medium to dark gray shale, as before

In eastern North Dakota samples of the Newcastle Formation from the S. D. Johnson, No. 1 Willis A. Lawston well located in the SW 1/4 SW 1/4 sec. 16, T. 163 N., R. 69 W., Rolette County were studied. The following sample descriptions were also lagged to Schlumberger log depths. Samples:

1710 - Log top of the Newcastle Formation
1709 - 39 Sandstone, white, fine to medium grained, friable, subangular to subrounded quartz with excellent visible porosity and permeability
1738 - Log top of the Skull Creek Formation

## Units Adjacent to the Newcastle Formation

In the subsurface of the North Dakota portion of the Williston basin, the Newcastle Formation rests on and is conformable with the Skull

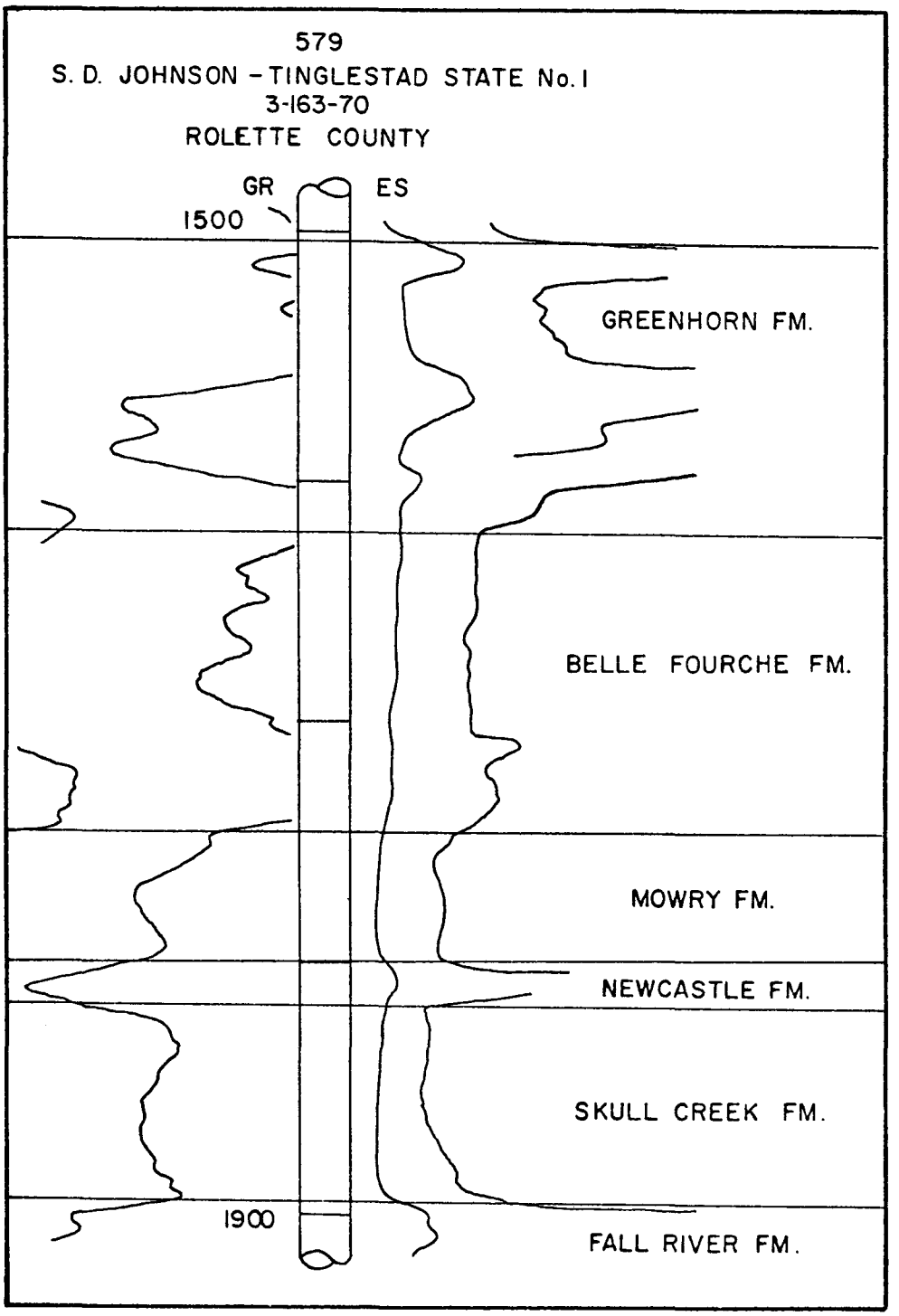


Figure 2. - Typical gamma ray and resistivity curves of the Greenhorn-Skull Creek interval.

Creek Formation. The Newcastle Formation is conformably overlain by the Mowry Formation. Both of these formations are composed of medium to dark gray, flaky to blocky shale.

The cross-sections illustrate the occurrence of the Lower Cretaceous Formations in North Dakota and their relationship to adjacent formations (pl. 6-10). In areas where the Newcastle is absent, the shale sections of the Mowry and Skull Creek formations appear very similar on logs and the top of the Skull Creek Formation could not be determined. This section is then referred to as "undifferentiated Mowry-Skull Creek.

From a maximum thickness of 532 feet in southwestern Bowman County, near the Montana and South Dakota borders this interval thins to 28 feet in Cavalier County in northeastern North Dakota (pl. 4). A study of this map and the isopachous map of the Newcastle Sandstone (pl. 1) indicates that the total thickness of the three formations is not affected by the presence or absence of the Newcastle Formation, except in the southeastern part of the state. In this area, a thickening extends into the state from South Dakota which coincides with a thickening of the Newcastle Formation. In areas where there was no deposition of Newcastle, an equivalent section of shale was deposited.

In northeastern North Dakota, within Cavalier, Walsh, Nelson and Grand Forks Counties, several other sandstones have been developed within the Mowry Formation and the overlying Belle Fourche Shale. In this area, the Newcastle and the 10-50 foot thick underlying shale, which may or may not be part of the Skull Creek Formation, appear to overlap successively lower units of the Fall River-Lakota interval. This indicates an erosional unconformity at the base of the shale under the Newcastle Formation. This relationship was not found elsewhere in the study area.

## STRATIGRAPHIC RELATIONSHIPS AND CORRELATIONS

Two cross-sections (pls. 11 and 12) were prepared to trace the Newcastle Formation from the subsurface of the Williston basin of North Dakota to a shallow well approximately one mile from the type section near Newcastle, Wyoming. The first section originated in Slope County in southwestern North Dakota, extended through Fallon and Carter Counties, Montana, and Crook County, Wyoming, to the type area in Weston

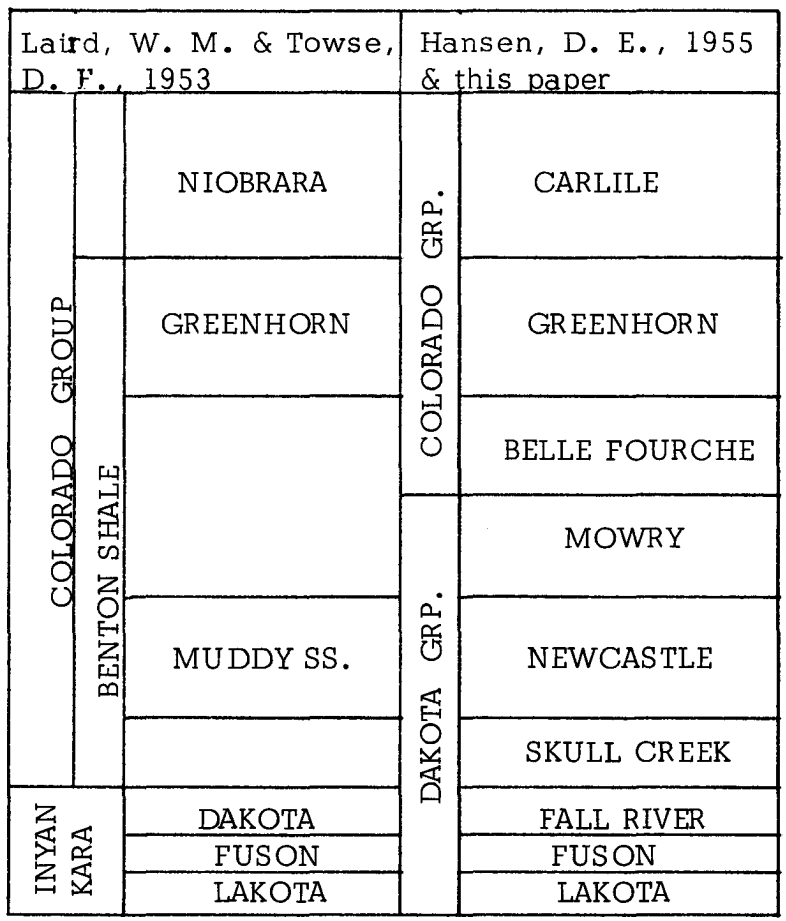


Figure 3. - Previous and present stratigraphic nomenclature for the Greenhorn-Fall River interval in North Dakota. Modified after Hansen, 1955.

County, Wyoming. The second section originated in Dickey County in southeastern North Dakota and extended through northern South Dakota to tie into the third well of the first section, in Carter County, Montana. In this manner, the Newcastle Formation of eastern and western North Dakota was traced to the type area.

The top of the Greenhorn Formation was used as a datum for the cross-sections. Where it was not possible to trace the Greenhorn south from southern Montana into Wyoming, the datum was lowered to the top of the Mowry Formation. The distinctive gamma ray kick at the top of the Mowry Formation in the Williston basin is probably a reflection of a bentonite bed equivalent to the Clay Spur bentonite of Wyoming (Wulf, 1962, p. 1402).

Present and previous stratigraphic nomenclature for the Greenhorn-Fall River interval in North Dakota is shown in figure 3. This interval may be easily traced through the subsurface from North Dakota into the Black Hills area of Wyoming and South Dakota, near the type area of the Newcastle Formation. There is some disagreement in the Black Hills area as to whether the Newcastle Sandstone should be assigned formation or member rank, but most workers have regarded it as a member of the Graneros Shale.

Skolnick (1958, p. 805) considered the Newcastle a member of the Skull Creek Shale. He based the conclusion on the fact that in the type area, the Newcastle is in many places absent from the section. Also, that it contains neither lithologic nor fossil evidence which accurately marks the regional stratigraphic relationships of the sandstone. He also considered the basal part of the Mowry Shale to be more closely related to the underlying Skull Creek Shale than to the typical, siliceous, upper Mowry Shale, and thought that it should also be considered a member of the Skull Creek Formation.

Wulf (1962, p. 1377) also considered the Newcastle to be a member of the Skull Creek Formation, but, he placed a regional disconformity at the top of the Newcastle. This disconformity was based on an erosional surface that has not been found by other workers. He regarded the Dyneson sandstone of the Williston basin as a member of the Mowry Formation.

In this study of Williston basin logs and samples, it appears that the contacts between the Mowry, Newcastle and Skull Creek are conformable. A study of the cross-sections (pl. 6-12) shows that in areas where

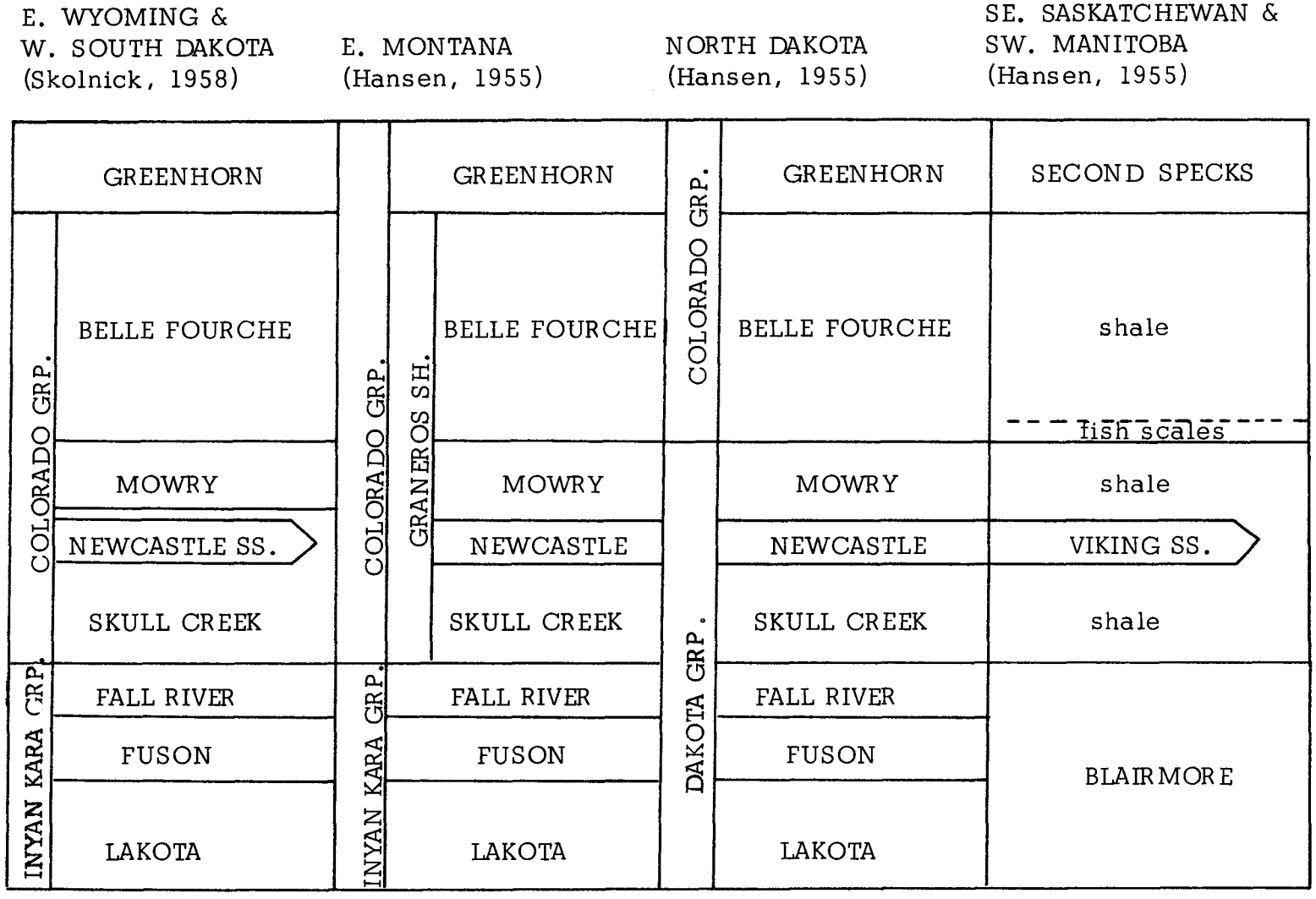


Figure 4. - Correlation of the Newcastle Formation of North Dakota with laterally equivalent rocks in Canada, Montana, South Dakota and Wyoming.

the Newcastle thickens, both the Mowry and Skull Creek shales thin. This and the compensating increase in shale thickness in areas where the Newcastle is missing, indicate that the Newcastle Sandstone is a coarse clastic facies of portions of the Mowry Shale and the Skull Creek Shale.

The American Commission on Stratigraphic Nomenclature (1961, p. 650) stated that "a formation is a body of rock characterized by lithologic homogeneity, it is prevailingly but not necessarily tabular and is mappable at the earth's surface or traceable in the subsurface." The Newcastle Formation in the Williston basin fits the above requirements and should be classified as a formation. This follows the usage of Hansen (1955, p. 24) in his study in North Dakota.

Gries (1962, p. 165) indicated that the thick sandstone present in eastern South Dakota approximately 200 feet below the top of the Greenhorn Formation is the Dakota Formation. He shows the Newcastle, Fall River, and Lakota formations as westward-extending tongues of the Dakota. Wulf (1962, p. 1376) extended this concept into eastern North Dakota. Plate 12 shows this thick sandstone, herein interpreted as Newcastle extending from South Dakota into southeastern North Dakota.

In eastern North Dakota, no well log was found in which a section of sandstone contained a combined section of Newcastle and Fall River sandstones. In all the wells studied, a shale body separates the Newcastle and Fall River formations in eastern and southeastern North Dakota where the Newcastle has an overlapping relationship with the Fall River and successively older units of the Dakota Group from west to east. A study of the cross sections of Gries (1962, p. 165, 169) indicates that, contrary to his conclusions, in eastern South Dakota the Fall River Formation pinches out, and the thick sandstone lying on the Precambrian is Newcastle rather than combined Newcastle and Fall River comprising the Dakota.

The Newcastle Formation extends into central Montana where it is called the Bow Island Formation, and it can be traced farther as the Viking Sandstone of Alberta and southwestern Saskatchewan. A check of representative logs and well information cards in southeastern Saskatchewan and southwestern Manitoba indicates that the Newcastle of northwestern North Dakota extends to the northeast and the Newcastle of northeastern North Dakota extends to the northwest. These sandstones appear to join in T. 9 N., R. 30 W., W.P.M. in Saskatchewan

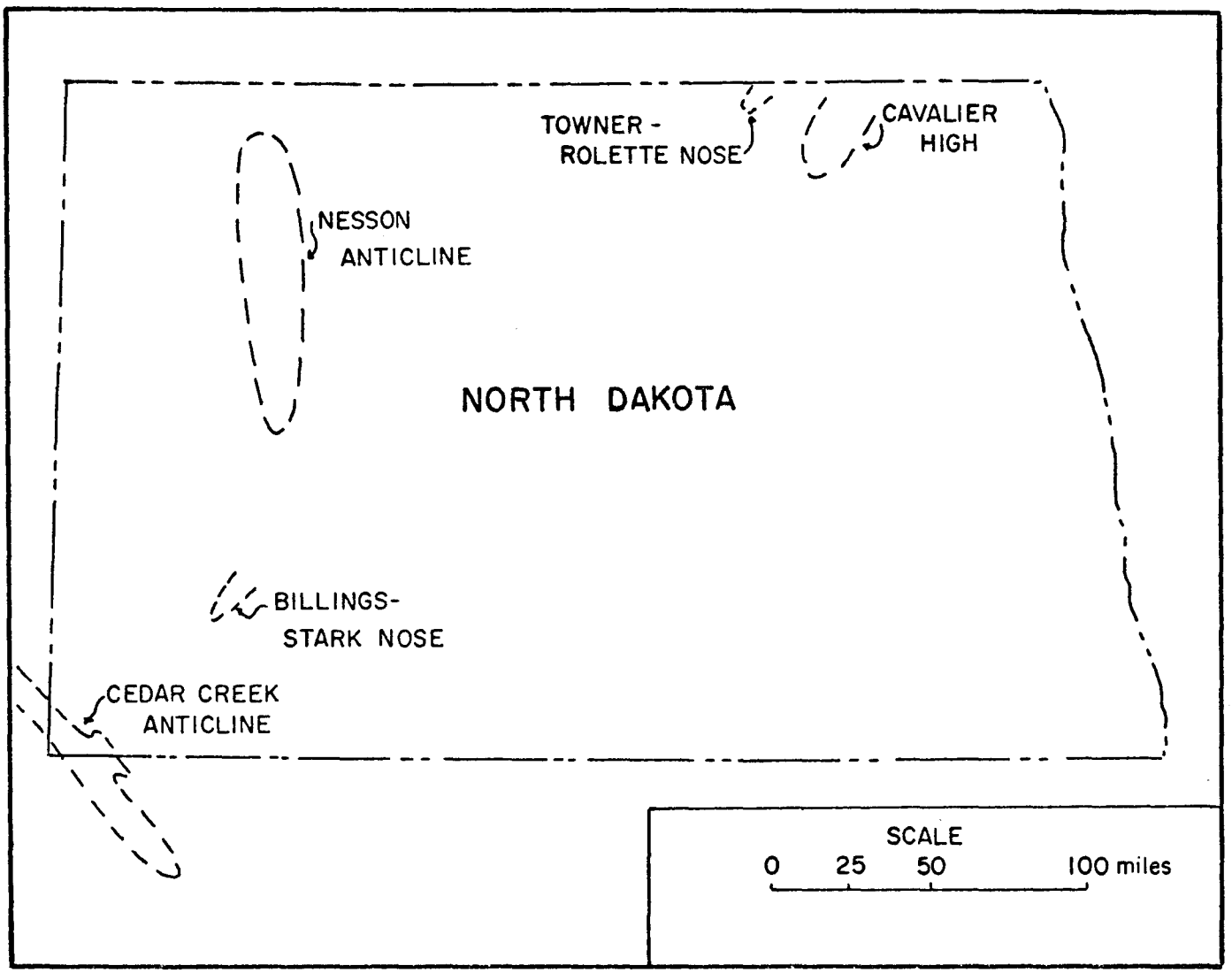


Figure 5. - Location map showing structural elements that affected Newcastle sedimentation in North Dakota.

along the Manitoba border, 50 miles north of the U. S. - Canada border. Thus, a complete circular occurrence of sandstone surrounds an area of shale in central North Dakota, southeastern Saskatchewan and southwestern Manitoba. In this area of Canada, the Newcastle is called the Viking Sandstone.

## STRUCTURAL ELEMENTS

### General

The Newcastle Formation was deposited in the Williston basin as part of the Zuni Sequence (Carlson and Anderson, 1965, p. 1844). This is a predominantly clastic sequence deposited in the widespread Jurassic and Cretaceous seas of the western interior. The Williston structural basin had little effect on this sedimentation, and the Newcastle and related formations are eastward extensions of the predominantly fine-grained clastics deposited in the seas of the Rocky Mountain area.

During deposition of the Newcastle Formation, there may have been minor uplift of positive areas such as that of the Black Hills (Crowley, 1951). Crowley based this uplift on the occurrence of small amounts of gold in the Newcastle Formation that is identical to gold from the Precambrian of the Harney Peak area of the Black Hills.

Two major structural elements affected Cretaceous deposition in North Dakota, the Cedar Creek anticline and the Nesson anticline, both in the western part of the state. Three minor structural elements also affected deposition, the Cavalier high (Ballard, 1963, p. 32) in northeastern North Dakota, and two structural noses, one in the Billings County-Stark County area, and the other in the Rolette County-Towner County area (fig. 5).

### Cedar Creek Anticline

The Cedar Creek anticline appears to have had very little effect on deposition of the Newcastle Formation. A thick Newcastle section and also a Newcastle "zero" area (pl. 2) extend across the anticline without interruption or deflection. However, the anticline appears to have had some effect on the deposition of the Skull Creek Shale and the Mowry Shale

as both of these formations rapidly thicken along the southwest side of the crest of the structure (pl. 3).

## Nesson Anticline

A thick section (up to 132 feet) of Newcastle extends from southwestern North Dakota to the southern end of the Nesson anticline where it rapidly thins and pinches out (fig. 1). Newcastle extends from west to east across the anticline, ranging in thickness from 5 feet to 42 feet along the crest. The average thickness along the crest is about 15 feet with three circular areas of non-deposition located at structurally high areas. The Newcastle extends 15 to 20 miles down the east flank of the anticline where it pinches out into the undifferentiated Mowry-Skull Creek shale interval. The Newcastle along the crest and on the east flank of the anticline is silty except at the north end, where it develops fair to good porosity and permeability. It appears that the Nesson anticline acted as a partial barrier to currents carrying sand.

## Billings-Stark Structural Nose

A northeast-trending structural nose (pl. 3) is present in Billings and Stark Counties in southwestern North Dakota. The Newcastle Formation is very thin along this nose and thickens rapidly to the northwest and the southeast. This nose does not appear to have had any effect on Skull Creek or Mowry deposition.

## Cavalier High

The Cavalier high was active throughout the Paleozoic (Ballard, 1963, p. 32), and is shown on the structural map of the Mowry Formation as a northeast trending nose within Cavalier County in northeastern North Dakota. The high was an area of non-deposition of Newcastle Sandstone although the sandstone extends from the front of the nose around the northwest and southeast sides.

## Rolette-Towner Nose

Thirty-five miles northwest of the Cavalier high a 4 to 5 mile-wide southwest-trending nose occurs along the Canadian border in Rolette and

Towner Counties. This nose has approximately 100 feet of relief on both flanks. It was not mapped into Manitoba to determine if there is closure on the up-dip side, but such closure is doubtful. The Newcastle Formation extends westward from the Cavalier high area as a narrow band along the crest of the nose; it is absent on both flanks (pl. 6). The absence of Newcastle on the flanks may be due to post-Cretaceous uplift and erosion or perhaps due to the nose acting as a shoal area during Newcastle deposition. If the latter is true, the absence of Newcastle on the Cavalier high could also be due to it being a small shoal or land area at the time of Newcastle deposition.

## ENVIRONMENTS OF DEPOSITION

Previous authors have indicated that the Newcastle Formation of the Williston basin of North Dakota was probably deposited as a marine sand under near-shore conditions, with the distribution of the sand controlled by waves and currents. The isopachous map of the sandstone (pl. 2) indicates that it had source areas to the northwest, west, southwest and southeast.

In southeastern North Dakota, the sandstone thickness may indicate a deltaic type of deposition in that area (Hansen, 1955, p. 370). In eastern North Dakota, the Newcastle occurs as a blanket sand that thickens to the east. Although there is insufficient control in this area to determine what happened, the eastern edge of the sand was probably an erosional limit later covered by Pleistocene glacial deposits. In northeastern North Dakota, the Newcastle was deposited around the sides of the Cavalier high, which may have been a minor land area, and on the Towner-Rolette structural nose, which was probably a shoal area.

In the western part of the state, the Newcastle was deposited by currents which were influenced by the position of the Nesson anticline. The rapid thickening and thinning of the sandstone, the presence of many areas of non-deposition of sandstone, and the pinching out of many individual sandstone lenses within the Newcastle suggest that this area was a shelf area possibly combined with one or more delta complexes.

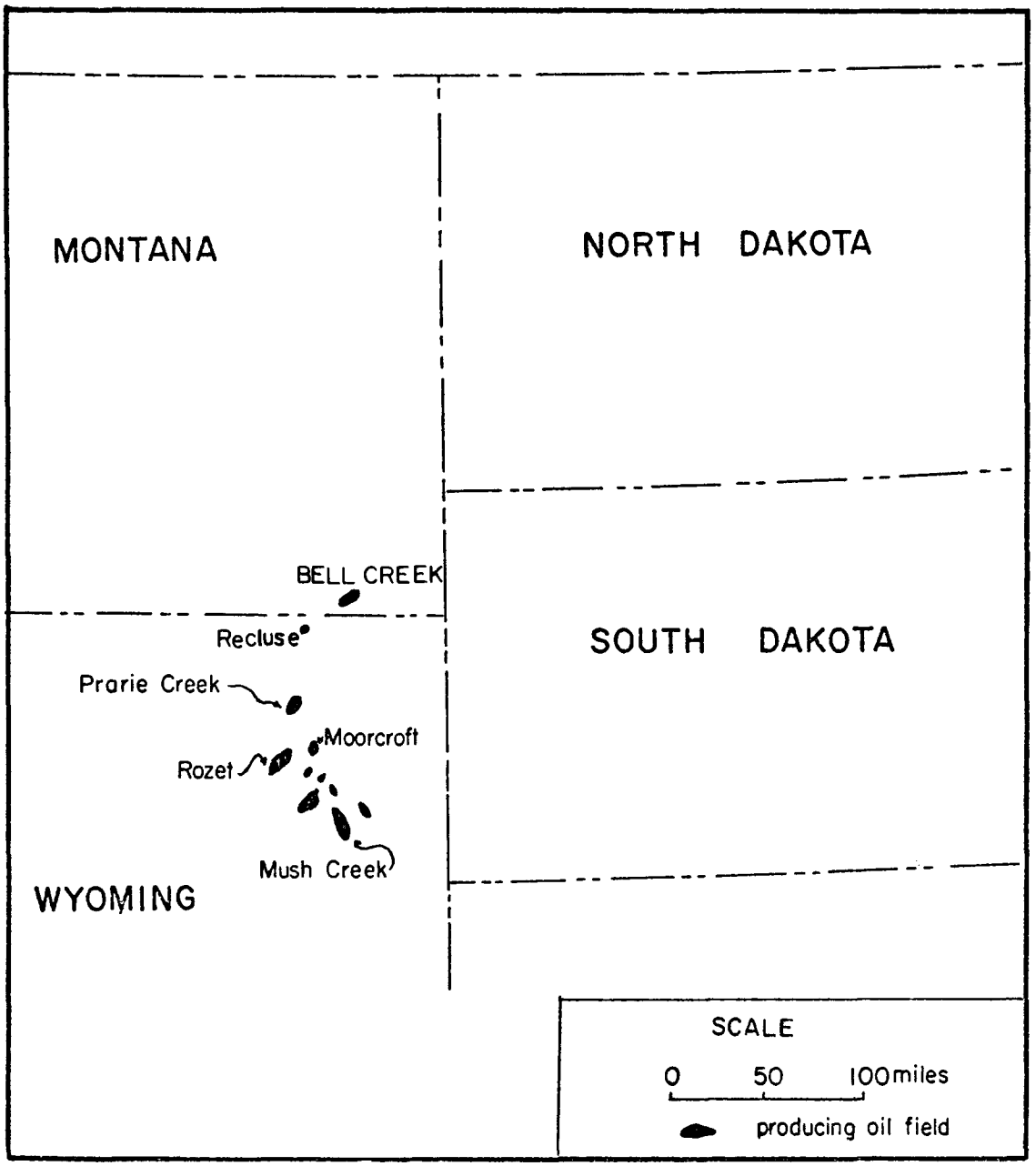


Figure 6. - Location map showing oil fields in southeastern Montana and eastern Wyoming that produce from the Newcastle Formation.

## ECONOMIC GEOLOGY

### Known Oil Fields

Several fields in northeastern Wyoming produce oil from the Newcastle Formation (fig. 6). Although most of these fields have been found during the past thirty years, the Moorcroft field was discovered in 1887 (Enyert and Madsen, 1962, p. 306). Many of these fields have rewarded their developers with very prolific production such as the oil discovered in the Mush Creek area in the Western Oil and Gas Co., Milhouse No. 1, which was completed for an initial potential of 1,747 barrels of oil per day, in 1944. Five years later, in 1949, this field had produced 1,472,509 barrels of oil from 133 wells. This production was from a depth of between 3800 and 3900 feet (Summerford, et al., 1950, p. 1851-1854).

The Wyoming-North Dakota cross section (pl. 11, well F-5) passes through a producing well in the Prairie Creek Field, in Wyoming which was discovered in 1963. The Recluse field in Wyoming and the Bell Creek field in Montana (fig. 6), both of which were discovered in 1967, have extended the Newcastle producing trend closer to North Dakota.

All the fields that produce from the Newcastle Formation in Wyoming appear to be similar to the Rozet Field, located on the east flank of the Powder River basin 18 miles west of the Black Hills monocline in Crook County (Waterman, 1962, p. 2930). Production is from a stratigraphic trap in which the Newcastle Formation thins and becomes impermeable on the north, east and southeast sides of the field whereas the down dip edge of the field is limited by the water table.

## PETROLEUM POSSIBILITIES IN NORTH DAKOTA

The Newcastle Formation should have excellent possibilities for future petroleum production in North Dakota. The Newcastle Formation in most areas is a clean sandstone with good porosity and permeability. The overlying Mowry Shale should form an effective reservoir cap rock. This is usually the case in Wyoming, although Wulf (1964, p. 55) reported that in some areas where dry wells have been drilled, the Mowry was fractured and oil bearing, the Mowry seal apparently having ruptured, allowing

the oil to escape from the Newcastle. The Newcastle appears to have been deposited during a time of relatively rapid marine deposition, providing the environment to trap suitable organic material for the formation of petroleum.

Numerous oil shows within the central South Dakota sandstone interval that correlate with the Newcastle have been reported by Wulf and Gries (1963, p. 194). Two Newcastle shows in northwestern South Dakota, five in southeastern Montana and two in southwestern North Dakota were plotted and mapped by Wulf (1964, p. 55). The present author was not able to locate the two North Dakota shows in the data on file with the North Dakota Geological Survey.

Several areas of interest within North Dakota were discovered in this study. The area of rapid thickening and thinning of the Newcastle in southwestern North Dakota should be an excellent area to prospect, as should an area in Dunn County where a north trending thick sandstone section pinches out into shale to the east in the up-dip direction. Another area of interest is in Slope, Billings and Stark Counties where the sandstone becomes very thin along the Billings-Stark structural nose. The sandstone from the northwest lies against this nose in an up-dip position. The facies changes of separate sandstone lenses to shale within the Newcastle Formation are possible traps. The Newcastle in this area is between 4,000 and 5,000 feet in depth.

The Newcastle Formation along the crest of the Nesson anticline is probably too silty to be an effective reservoir rock, but there are two thick areas (pl. 1) on the east flank that have possibilities.

In eastern North Dakota, the sandstone tongue around the northwest side of the Cavalier high is an excellent prospect. It is similar in size and shape to the trap at the Rozet Field in Crook County, Wyoming. The location of an up-dip pinchout of the sandstone on the Towner-Rolette structural nose should provide another prospect, although it may be located in Manitoba. The Newcastle in this area is between 1,000 and 2,000 feet in depth.

The excellent Newcastle reserves in Montana and Wyoming, and the possibilities of many promising stratigraphic traps in North Dakota, plus the easy and fast drilling in penetrating the shale sections above the Newcastle, should do much to promote Newcastle exploration in North Dakota.

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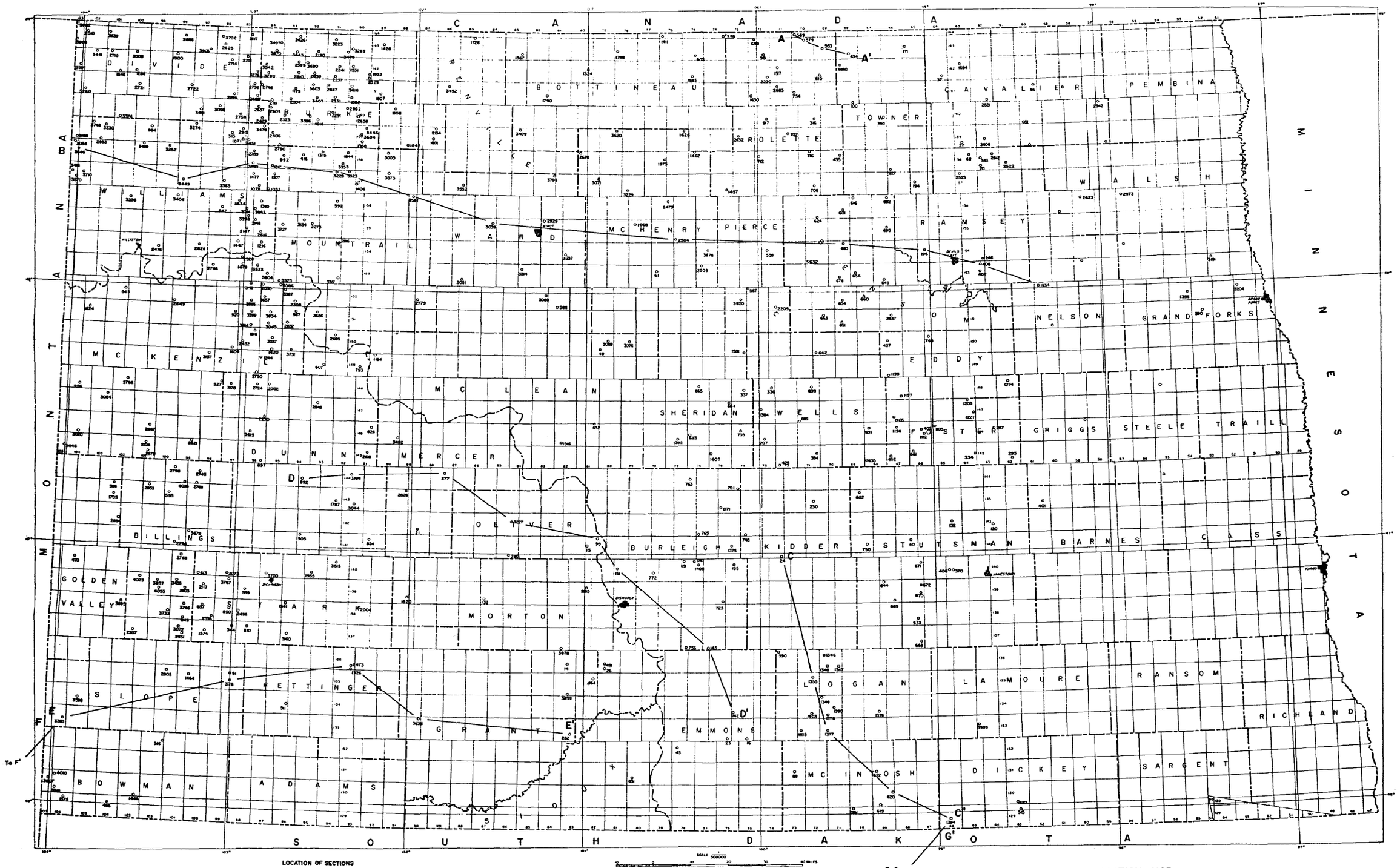



LOCATION OF SECTIONS

A-A'—PLATE 6
B-B'—PLATE 7
C-C'—PLATE 8
D-D'—PLATE 9
E-E'—PLATE 10
F-F'—PLATE 11
G-G'—PLATE 12

SCALE 1:500000

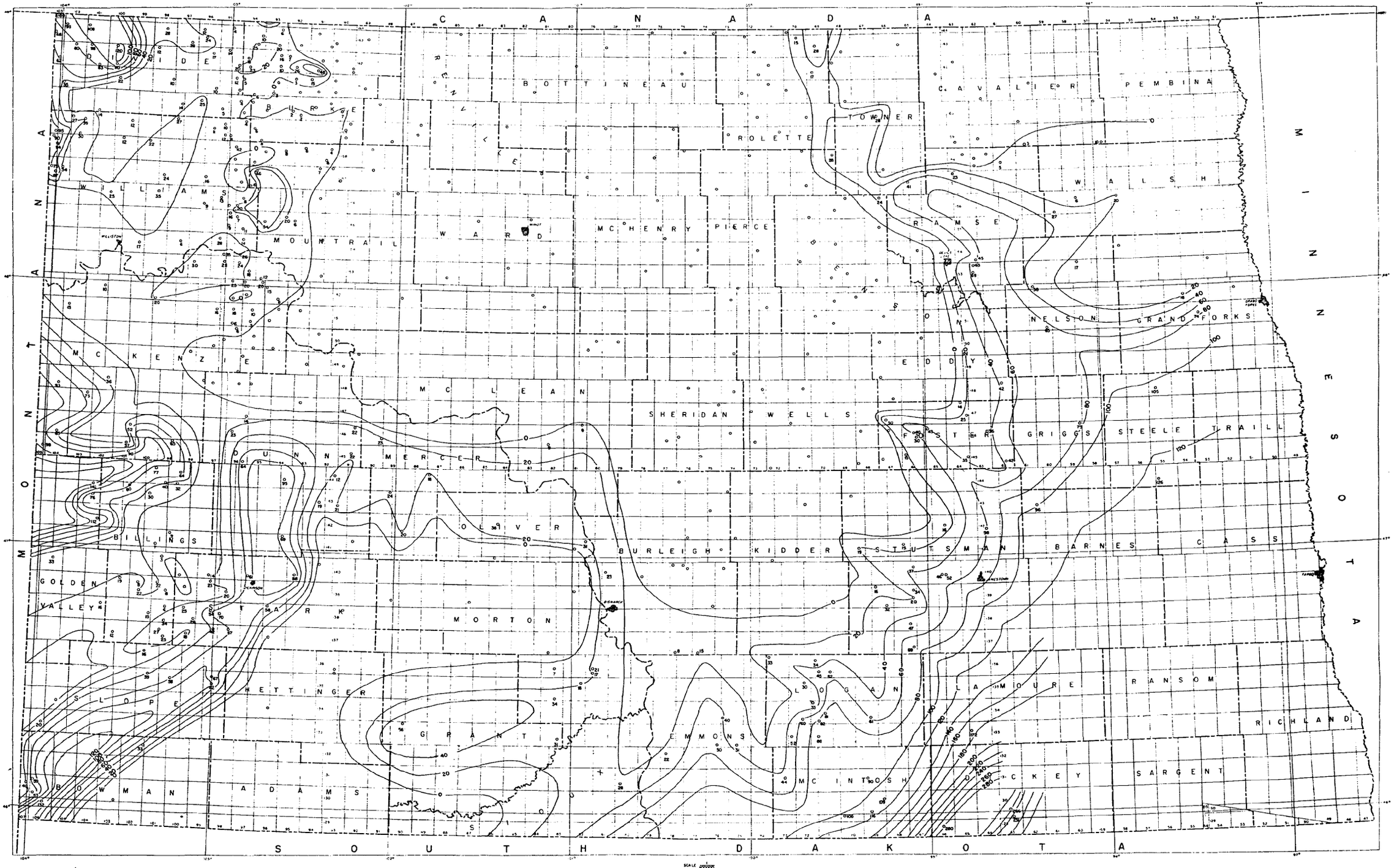
0 10 20 30 40 MILES

• CONTROL WELL

437 NORTH DAKOTA GEOLOGICAL SURVEY WELL NUMBER

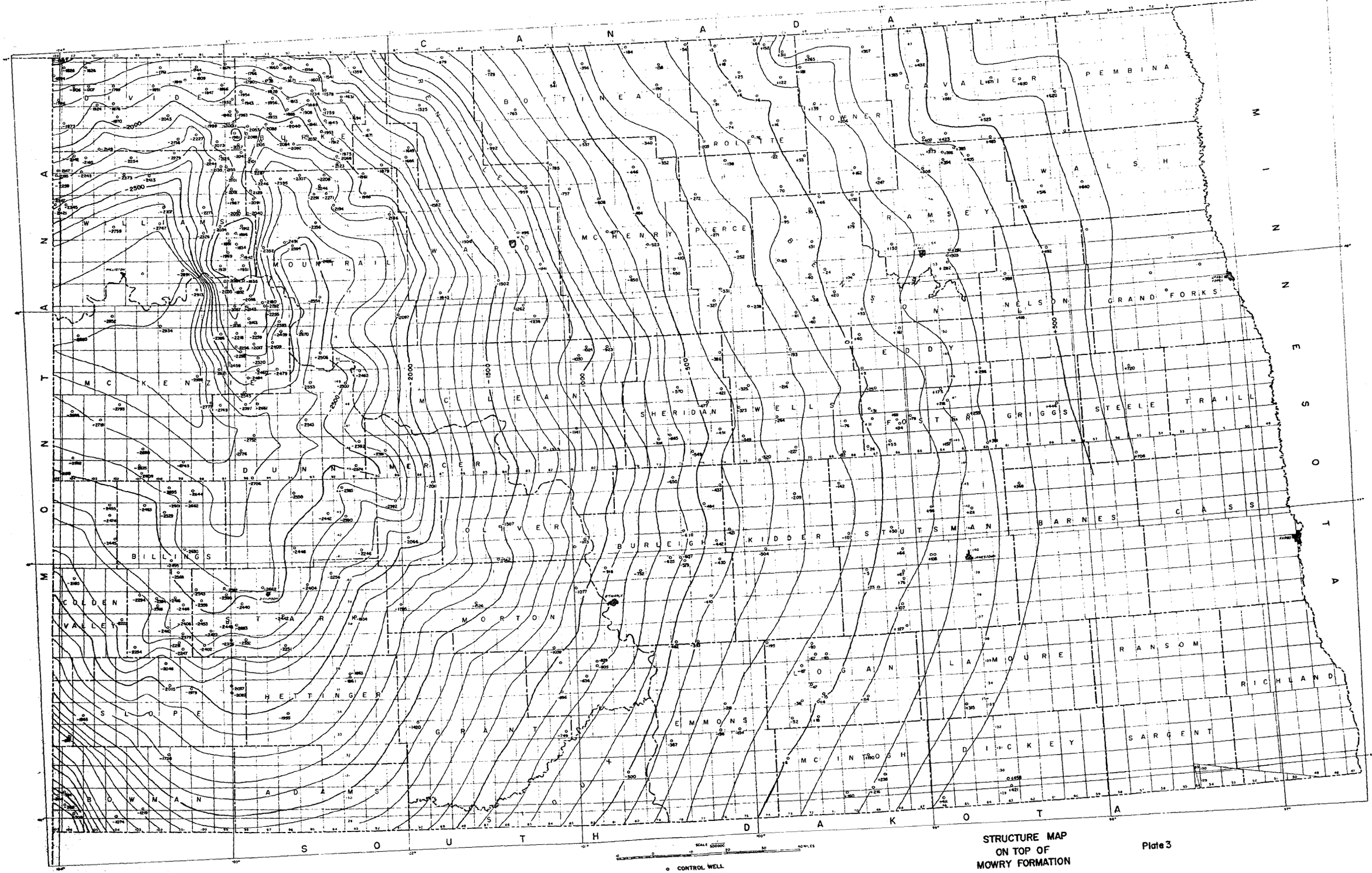
# LOCATION MAP SHOWING WELL CONTROL USED

Plate I



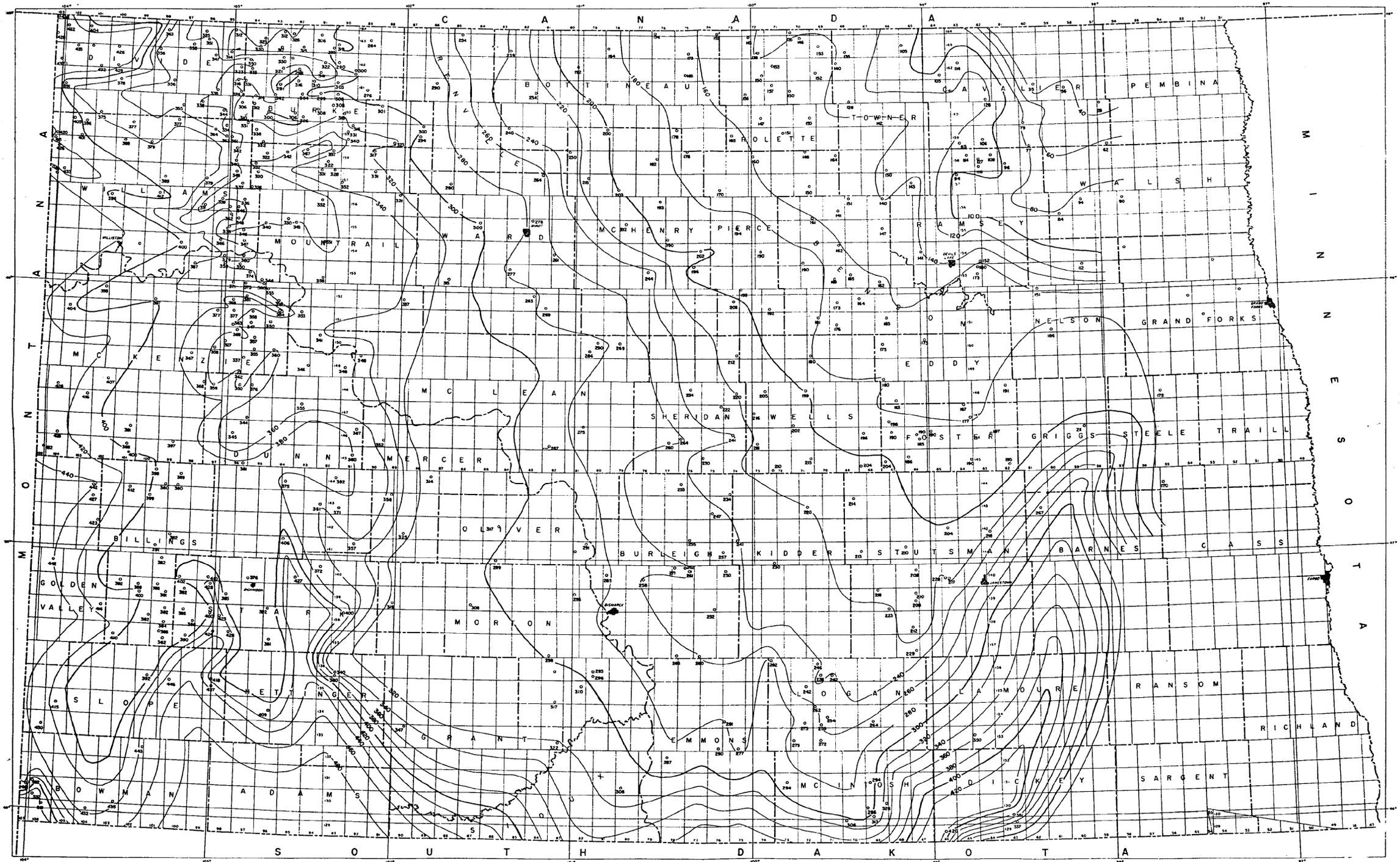

# ISOPACHOUS MAP OF THE NEWCASTLE SANDSTONE

Plate 2



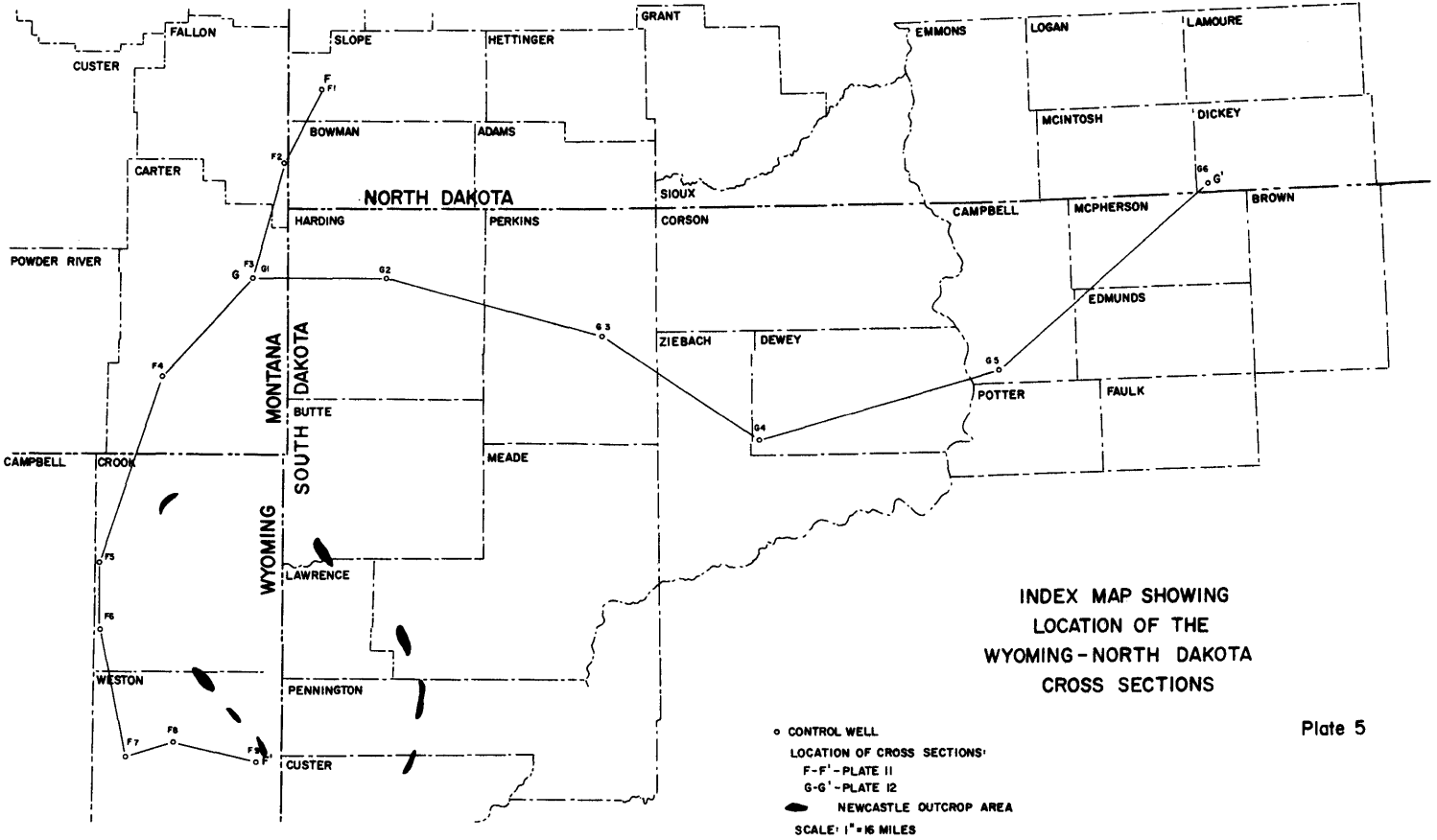

STRUCTURE MAP
ON TOP OF
MOWRY FORMATION

Plate 3




# ISOPACHOUS MAP OF THE MOWRY, NEWCASTLE & SKULL CREEK FORMATIONS

Plate 4




INDEX MAP SHOWING
LOCATION OF THE
WYOMING - NORTH DAKOTA
CROSS SECTIONS

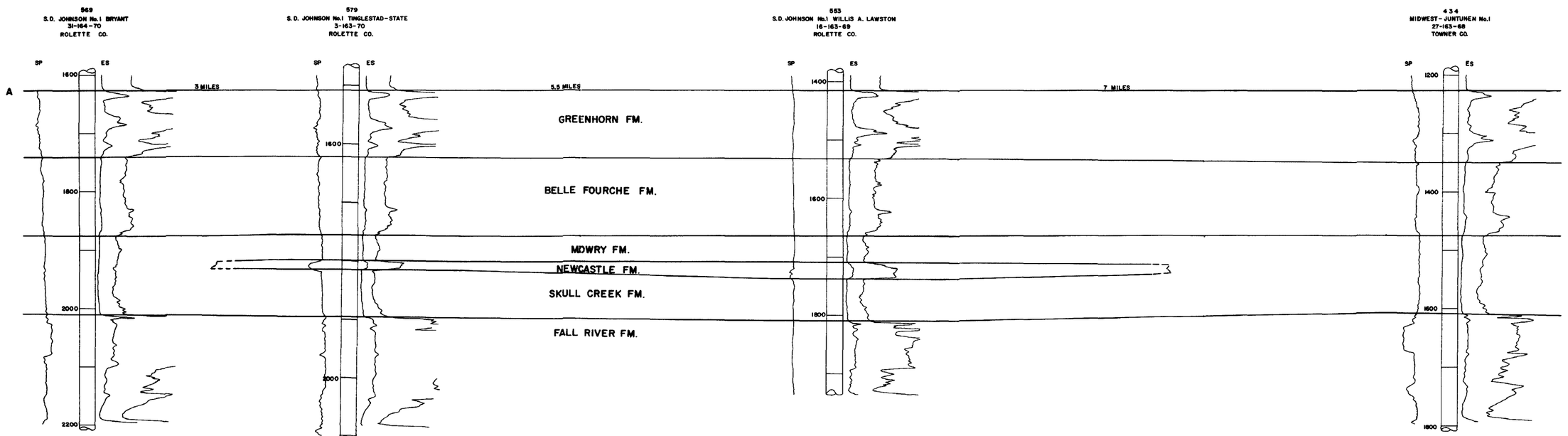
Plate 5

o CONTROL WELL

LOCATION OF CROSS SECTIONS:
F-F' - PLATE II
G-G' - PLATE 12

NEWCASTLE OUTCROP AREA

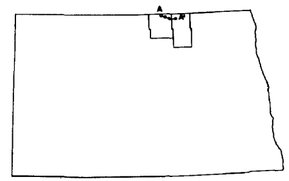
SCALE: 1" = 16 MILES



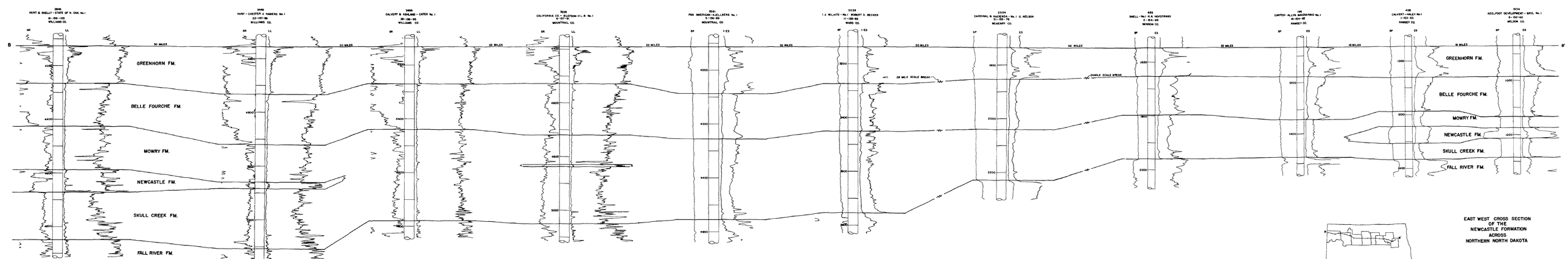

EAST-WEST CROSS SECTION
OF THE
NEWCASTLE FORMATION
IN
NORTHEASTERN NORTH DAKOTA

Plate 6

SCALE: 1"=50', vert.
3"=1mile, horiz.



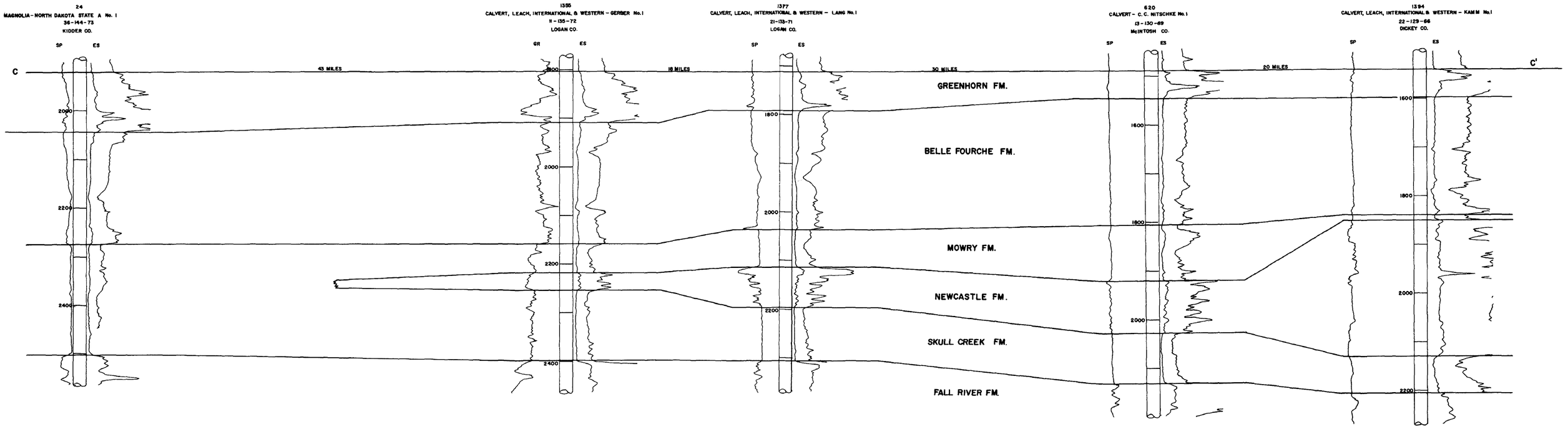

INDEX MAP

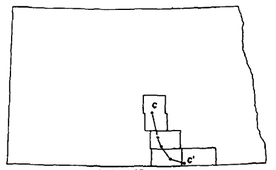



EAST WEST CROSS SECTION
OF THE
NEWCASTLE FORMATION
ACROSS
NORTHERN NORTH DAKOTA

Plate 7

SCALE- 1"=1 SHOWN, MAPS
1"=50', VERT.



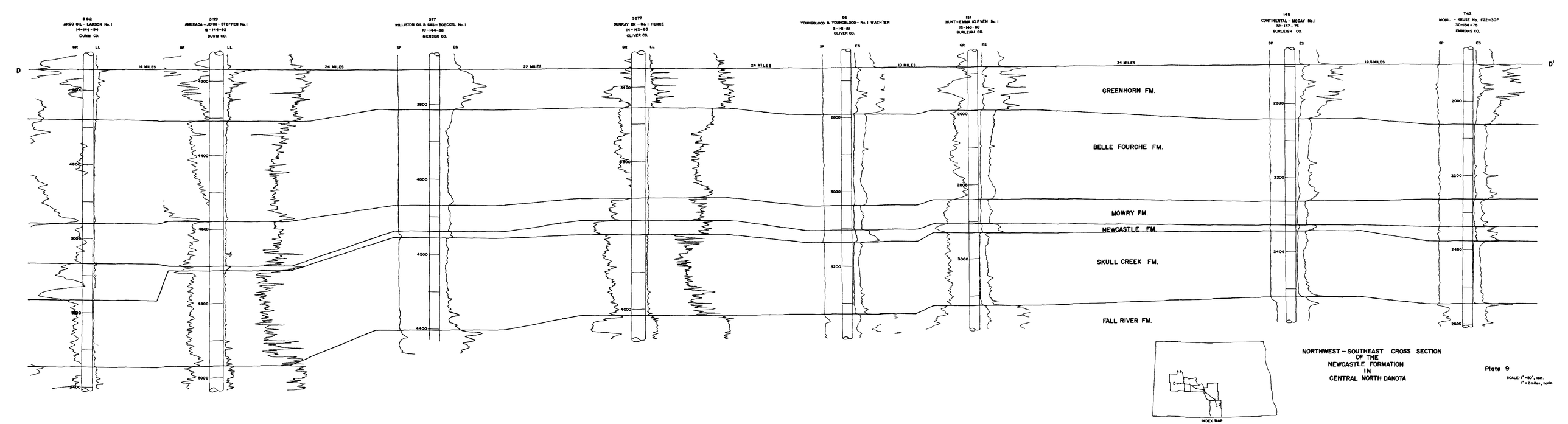




INDEX MAP

# NORTH-SOUTH CROSS SECTION OF THE NEWCASTLE FORMATION IN SOUTHEASTERN NORTH DAKOTA

Plate 8

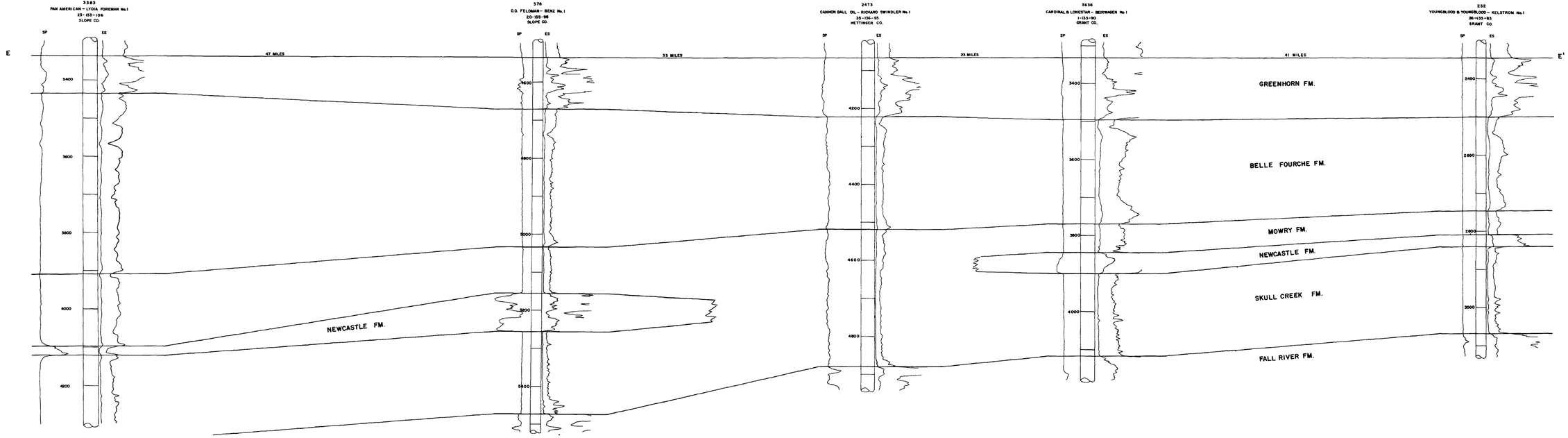
SCALE: 1" = 50' vert.
1" = 2 miles horiz.




NORTHWEST – SOUTHEAST CROSS SECTION
OF THE
NEWCASTLE FORMATION
IN
CENTRAL NORTH DAKOTA

Plate 9

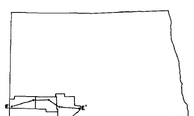
SCALE: 1" = 50', vert.
1" = 2 miles, horiz.



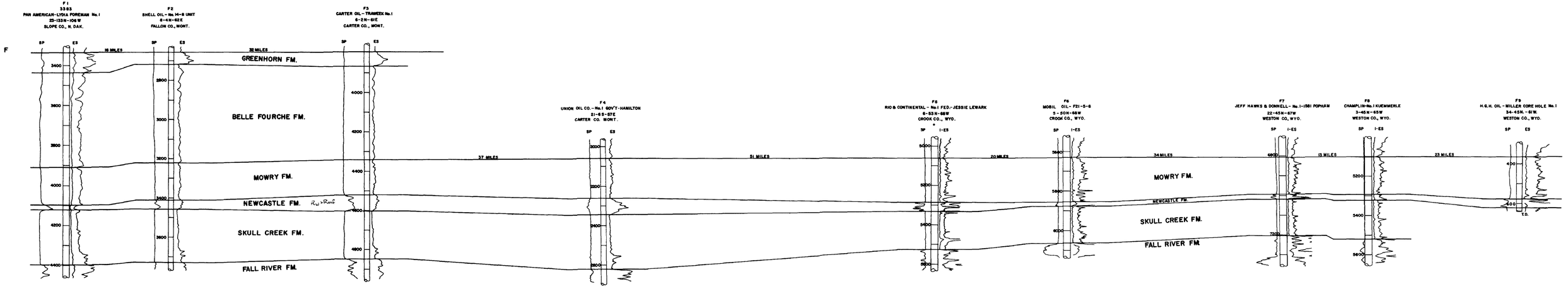

# EAST-WEST CROSS SECTION OF THE NEWCASTLE FORMATION IN SOUTHWESTERN NORTH DAKOTA

Plate 10

SCALE: 1" = 50', vert.
1" = 2miles, horiz.



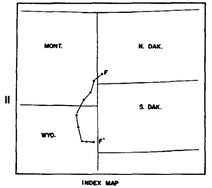

INDEX MAP



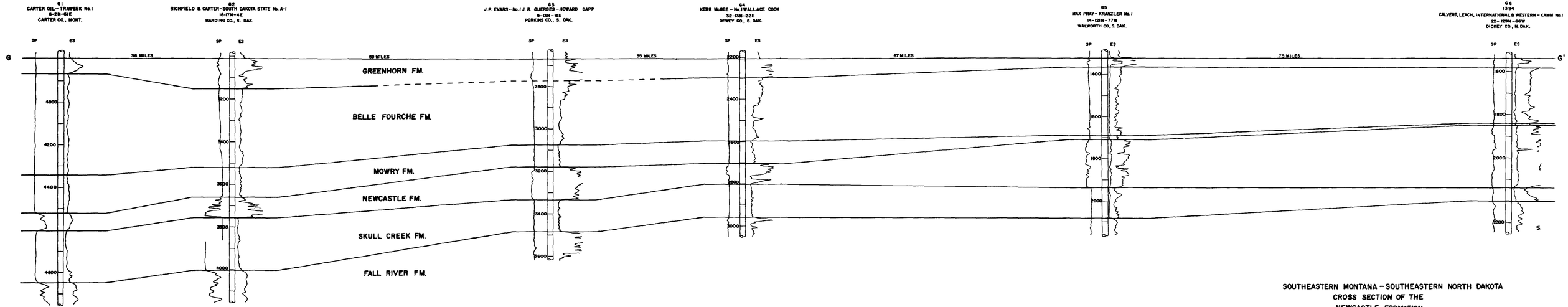

**WYOMING – NORTH DAKOTA**
**CROSS SECTION OF THE**
**NEWCASTLE FORMATION**

SCALE: 1"=100', vert.
1"=3 miles, horiz.

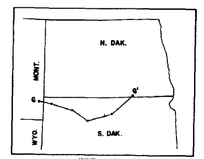
Plate II




INDEX MAP




SOUTHEASTERN MONTANA – SOUTHEASTERN NORTH DAKOTA
CROSS SECTION OF THE
NEWCASTLE FORMATION
THROUGH SOUTH DAKOTA



INDEX MAP

Plate 12

SCALE: 1" = 100', vert.
1" = 4 miles, horiz.