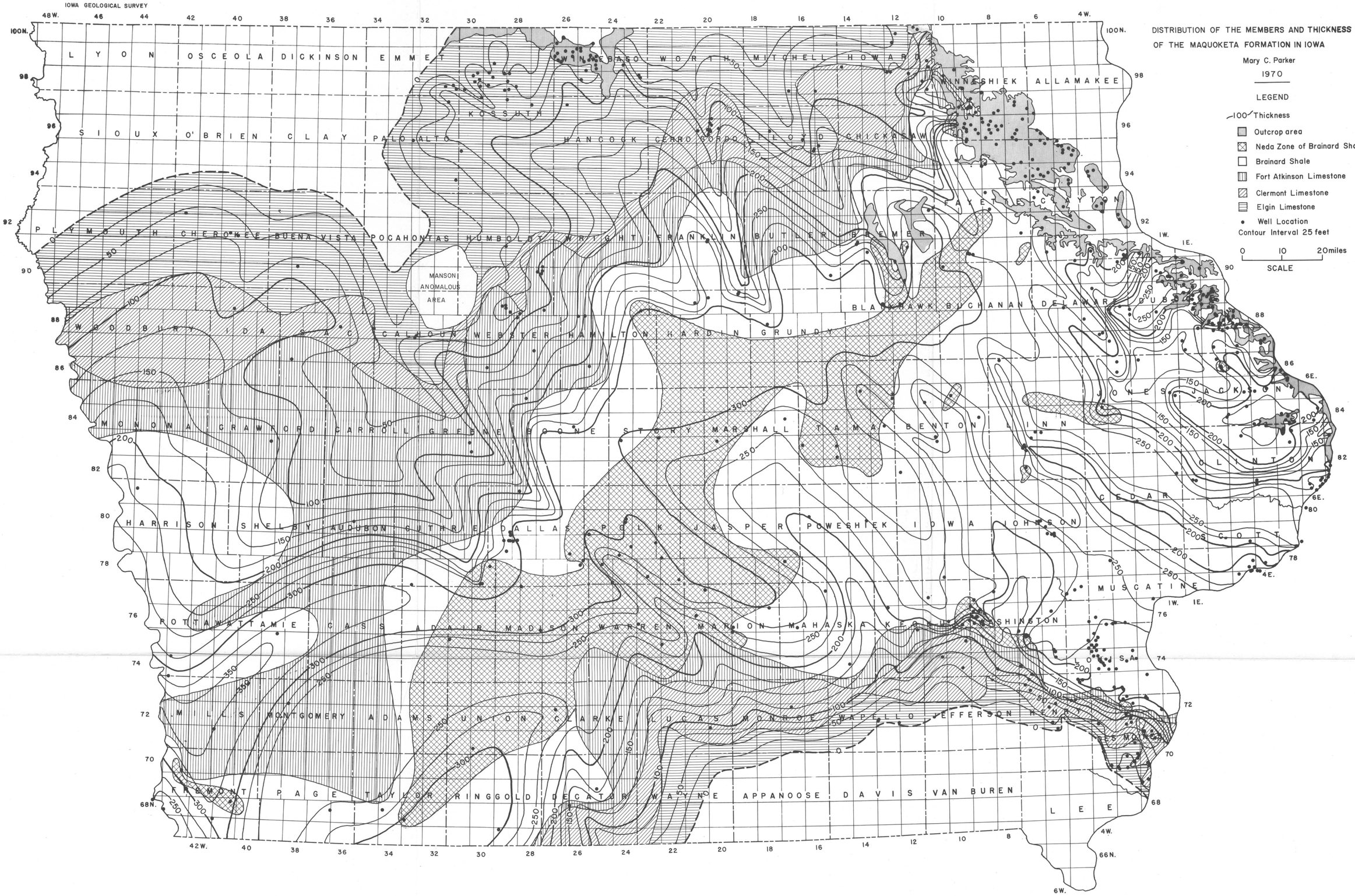


THE MAQUOKETA FORMATION (UPPER ORDOVICIAN) IN IOWA

by

Mary Combs Parker

INTRODUCTION

This report is a summary of the regional variations in lithology and thickness and distinguishing criteria of the Maquoketa Formation (Upper Ordovician) in Iowa.

A description of the extent, structural features, and composition of the Maquoketa Formation is desirable for the resolution of many economic and engineering problems. Completion of water wells within or below the Maquoketa requires information on availability of ground water from the Maquoketa and zones that might cave and therefore require casing. Excavation of caverns for the storage of liquid petroleum products requires information on depth below land surface and thickness of potential reservoir beds and caprock. In underground storage of natural gas, the Maquoketa rocks may be used either as reservoir or cap depending upon the lithologic characteristics, attitude and elevation of the beds. Oil has been produced from equivalent rocks in portions of the Forest City Basin in Kansas and Missouri.

The change in facies from predominantly shale in the east to carbonate towards the west may play a part in the deterioration in water quality in the Jordan Sandstone (Cambrian) in the western one-quarter of the state. The absence of shale in the Maquoketa may permit an exchange of water throughout the carbonate section from the Devonian rocks above, down through the Jordan Sandstone below. The area in which the poorer quality water is obtained from the Jordan aquifer roughly coincides with the area in western Iowa where the Maquoketa is a carbonate.

MAQUOKETA FORMATION

General Statement

The Maquoketa Formation is composed dominantly of bluish-green and brown, dolomitic shale and greenish-gray or brown, argillaceous dolomite which locally is cherty. The Maquoketa Formation was named by White (1870) for exposures along the Little Maquoketa River, Dubuque County, Iowa. Calvin (1906) named and described four formations in the Maquoketa Shale Group, the type sections of which are located in northeast Fayette County and southwest Winneshiek County, Iowa. Ladd (1929) reported that from the type locality of the formation, carbonate rock increases to the northwest and argillaceous material to the southeast. He recognized the units described by Calvin but called them members and called the Maquoketa Shale a formation instead of a group. The Iowa Geological Survey recognizes the divisions of Calvin and the ranks given them by Ladd. The members are: Elgin Limestone, Clermont Shale, Fort Atkinson Limestone, and Brainard Shale.

The Maquoketa occurs throughout most of Iowa except where it has been removed by erosion in the extreme southeast, northeast, north-central, and northwest portions of the state (map 1). The Manson Anomalous Area is located within the area of occurrence of the Maquoketa Formation. A mass of brecciated Precambrian rocks lies directly beneath the drift near Manson, Iowa. Surrounding the crystalline mass is a depressed zone about 280 square miles in area, consisting of a thick section of severely disturbed Lower Cretaceous sedimentary rocks (Hoppin and Dryden 1958). No wells within this area have reached any sedimentary rocks definitely known to be Paleozoic in age. This anomalous area is delineated on all of the maps in this report.

Maximum thickness of the Maquoketa Formation occurs in a band from southwest to northeast Iowa where the Maquoketa is overlain by Silurian rocks. Thicknesses of 275 to 300 feet are common in this area. The maximum recorded thickness is 350 feet in a well in Mills County (southwest Iowa). The Maquoketa strata thin to the north and northwest and to the southeast. Another band of thick Maquoketa rocks extends southeasterly from Fayette County through Buchanan, Linn, Cedar, and Scott Counties.

In three problem areas in eastern Iowa (maps 3, 4, 5) where the Maquoketa is predominantly shale with minor interbedded carbonate, only the Elgin Member with its dark brown shales and dolomites is recognized. The remaining section of the Maquoketa above the Elgin consists of greenish-gray, dolomitic shale with a few discontinuous beds of argillaceous limestone or dolomite. Consequently, it is impossible to differentiate the Clermont, Fort Atkinson, and Brainard Members on the basis of lithology. A study of the microfauna might provide data by which the upper three members can be separated.

The Maquoketa Formation is underlain by the Galena Formation (Middle Ordovician). In eastern Iowa the contact between the two formations is relatively sharp where the very slightly argillaceous, light-colored carbonates of the Galena are overlain by dark brown shales and brown, argillaceous dolomites of the Elgin Member. In western and southwestern Iowa, however, the contact is less sharp and lithologic similarities between the Galena and Maquoketa suggest continuous deposition. It is in this area that the Clermont and Elgin Members of the Maquoketa and the underlying Galena Formation are thought to be correlative with the Viola, Fernvale-Viola, or Fernvale-Kimmswick of Oklahoma and Kansas. Regardless of the terminology the lithologies are the same—porous dolomites which locally are cherty.

The depauperate zone is a thin zone near the base of the Maquoketa that contains minute black phosphatic fossils and phosphatic nodules and pellets. The zone apparently has a sporadic distribution throughout the state. The fact that the depauperate zone has not been observed in all wells that reach the lower Maquoketa may be the result of different drilling and sampling techniques rather than local non-deposition.

The Neda is a zone at or near the top of the Maquoketa that is characterized by red or maroon shales that locally contain discoidal concretions of hematite and limonite. It occurs in a sinuous band from southwest to northeast Iowa (map 1) where the Maquoketa is thickest and is overlain by rocks of Silurian age. In addition, occurrences of the Neda have been recorded from drill cuttings in southeast and east-central Iowa where the Maquoketa is thinner and is overlain by rocks of Middle Devonian age. Where Silurian strata are superjacent, the Neda Zone is interpreted to be the result of a period of weathering prior to Silurian deposition. The presence of a similar, erratically distributed, weathered zone where Siluran rocks are absent may be the result of continued weathering and erosion of the Maquoketa through Silurian and possibly Lower Devonian time. The Neda generally is 5 to 20 feet in thickness and occurs not only on the Brainard Member but also on the Fort Atkinson and Clermont Members.

The Maquoketa is overlain by rocks of Silurian age, and where these have been removed by erosion, by rocks of Devonian, Cretaceous, or Pleistocene age. The contact of the Maquoketa with these rocks generally is sharp. Some difficulty in separation of the units is encountered in western Iowa where the Ordovician and post-Ordovician strata have been completely dolomitized. However, certain characteristics persist that permit correlations to be made with some degree of certainty. Black "bars and specks" that occur in Maquoketa strata in the outcrop area continue into western Iowa and persist where the rocks have been dolomitized. In addition, where Devonian strata overlie the Maquoketa, the basal beds of the Devonian usually contain embedded grains of quartz sand. Cretaceous rocks that are superjacent are readily separable from the Maquoketa.

Lithofacies Maps

The lithofacies maps (maps 2, 3, 4, 5) show the lithologies present in the members of the Maquoketa as they are today.

Three lithologies dominate the Maquoketa Formation: carbonate, shale, and chert. Some limestone does occur in eastern Iowa, but the percentage is low and most of the limestone is dolomitic. For practical purposes the carbonate may be considered a dolomite.

The percentages of each end-member lithology were computed for rock cuttings from available well data and plotted on triangle coordinate paper which was sub-divided into fields as shown in figures 1, 2, 3, 4. The numbers on the graphs indicate the number of computations which fell on a given point. For simplicity of illustration only the three major divisions are shown on the maps. Included in the carbonate field, for example, are argillaceous carbonate and cherty carbonate as well as those points that fall within the carbonate triangle. Similarly the chert field contains dolomitic and argillaceous chert; the shale field contains dolomitic and cherty shale. The distribution of points makes it clear that the divisions are less sharp than the lithologic terminology suggests because the boundary between argillaceous carbonate and cherty carbonate, for example, is gradational.

The Fort Atkinson shows the broadest scattering of points and the Elgin shows a broader scatter than do the Brainard or Clermont. The Brainard and Clermont are composed dominantly of varying percentages of dolomite and shale whereas the Fort Atkinson and Elgin contain varying percentages of chert, dolomite, and shale.

THICKNESS AND FACIES MAP OF THE ELGIN LIMESTONE MEMBER, MAQUOKETA FORMATION, IN IOWA

Mary C. Parker

1970

LEGEND

20 Thickness

Outcrop area

Carbonate

Shale

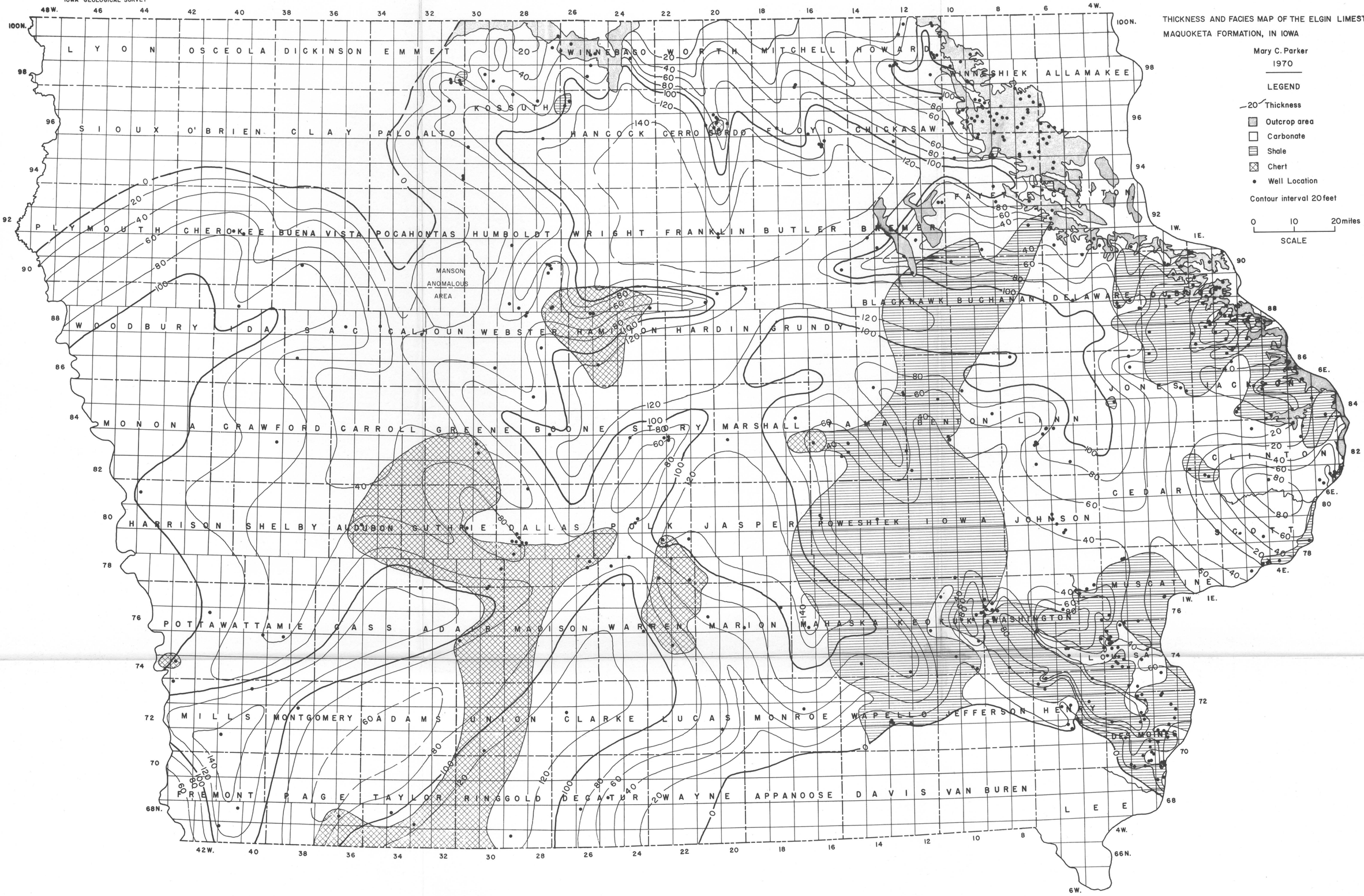
Chert

Well Location

Contour interval 20 feet

0 10 20 miles

SCALE



ELGIN LIMESTONE MEMBER

The Elgin Limestone Member was named by Calvin (1906) for exposures near Elgin, Fayette County, Iowa. It overlies the Galena Formation and underlies the Clermont Shale Member.

The Elgin is the most widespread member of the Maquoketa in Iowa and is present throughout the area of occurrence of the formation. It attains its maximum thickness of 150 feet in southwestern Iowa and thicknesses of 100 to 120 feet are common in a band from southwest to northeast Iowa. In north-central Iowa thicknesses of 145 feet have been recorded in wells in Franklin County. From the northeast trending band the Elgin thins in all directions to the limit of the member.

The Elgin Member consists predominantly of grayish-brown to brown, dolomitic shale and brown, argillaceous dolomite which locally is cherty. It grades from dominantly shale in eastern Iowa to a carbonate and chert facies in western Iowa.

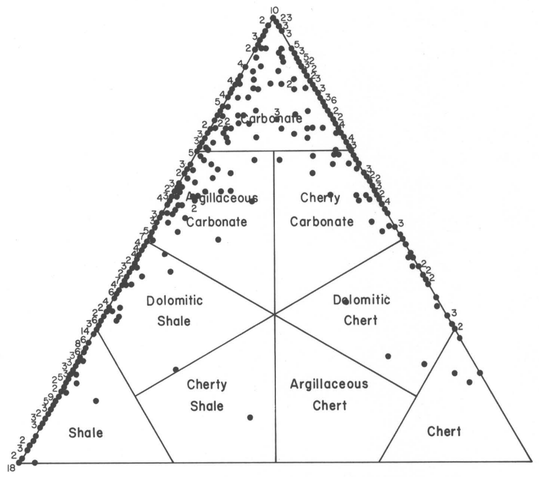


Figure 1. End-member plots of the Elgin Limestone Member lithologies from well sections in Iowa.

THE MAQUOKETA FORMATION (UPPER ORDOVICIAN) IN IOWA

THICKNESS AND FACIES MAP OF THE CLERMONT SHALE MEMBER, MAQUOKETA FORMATION, IN IOWA

Mary C. Parker

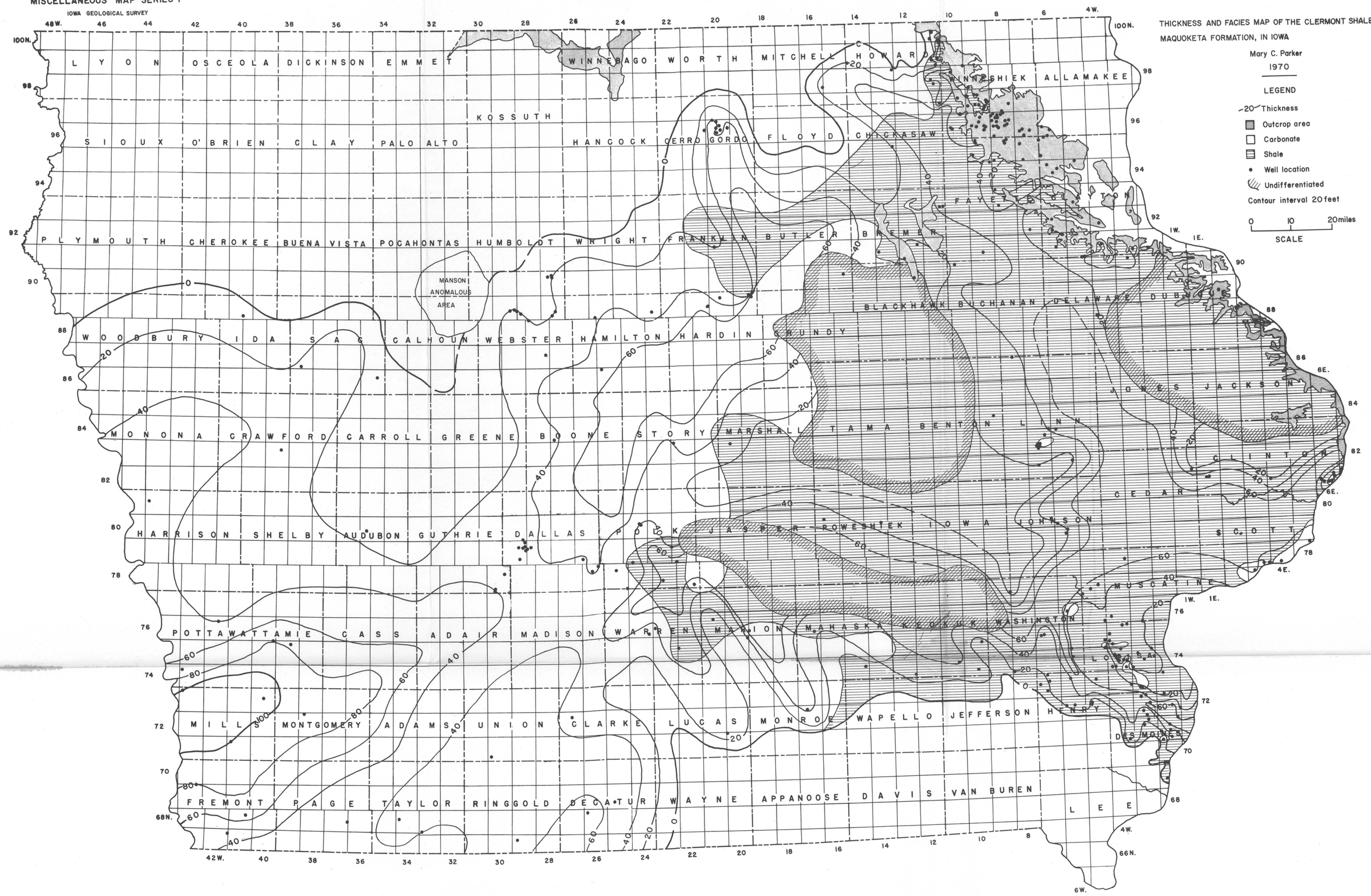
1970

LEGEND

- 20 Thickness
- Outcrop area
- Carbonate
- Shale
- Well location
- Undifferentiated

Contour interval 20 feet

0 10 20 miles
SCALE



CLERMONT SHALE MEMBER

The Clermont Shale Member was named by Calvin (1906) for exposures at Clermont, Fayette County, Iowa. The Clermont Member overlies the Elgin and underlies the Fort Atkinson. It is not as widespread as the Elgin because of post-Ordovician erosion. In eastern Iowa, in the three areas delineated on maps 3, 4, and 5, the Clermont probably is present, but data is lacking to differentiate it.

The Clermont attains its maximum thickness of 105 feet in southwest Iowa. The greater thicknesses occur in a southwest-northeast band through the central part of the state and in a northwest-southeast band in eastern Iowa where thicknesses of 60 feet are common.

The Clermont has two distinct facies. In eastern Iowa the Clermont consists predominantly of greenish-gray shale which often is slightly dolomitic. Toward central and southwestern Iowa the shales grade into greenish-gray, fine to medium crystalline dolomite that lacks chert. This non-cherty interval separates the cherty beds of the Fort Atkinson above and the Elgin below.

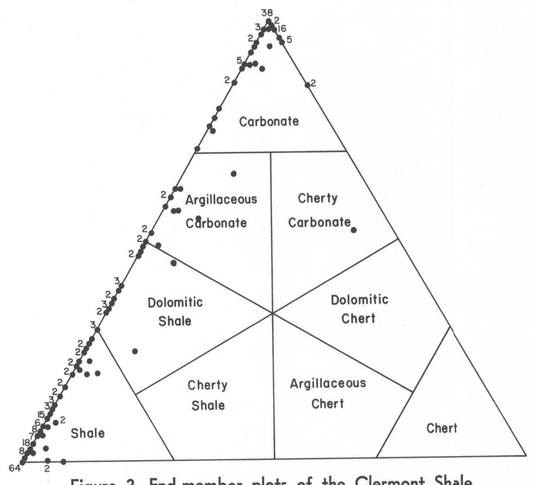


Figure 2. End-member plots of the Clermont Shale Member lithologies from well sections in Iowa.

THICKNESS AND FACIES MAP OF THE FORT ATKINSON LIMESTONE MEMBER, MAQUOKETA FORMATION, IN IOWA

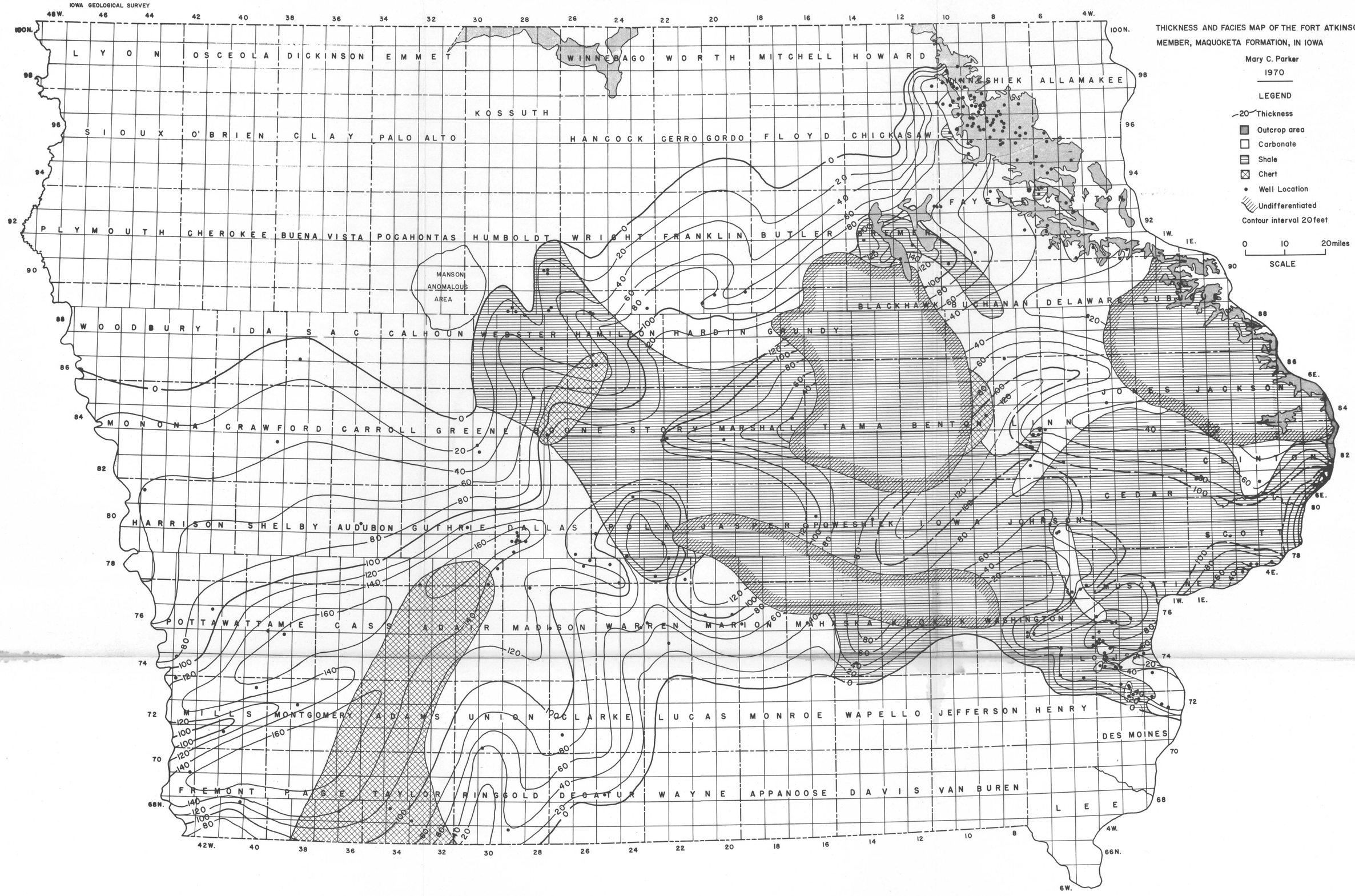
Mary C. Parker
1970

LEGEND

- 20 Thickness
- Outcrop area
- Carbonate
- Shale
- Chert
- Well Location
- Undifferentiated

Contour interval 20 feet

0 10 20 miles
SCALE



FORT ATKINSON LIMESTONE MEMBER

The Fort Atkinson Limestone Member was named by Calvin (1906) for 40 feet of dolomite and limestone exposed in a quarry at Fort Atkinson, Winneshiek County, Iowa. It is underlain by the Clermont Member and overlain by the Brainard Member except where the Brainard has been removed by erosion. It is not as widespread as the Clermont and Elgin Members.

The Fort Atkinson attains its greatest thickness in a broad band from southwest to northeast Iowa where thicknesses of 100 to 150 feet are common. In a northwest-southeast band in eastern Iowa thicknesses of 80 to 100 feet are not unusual. It probably is present in the undifferentiated areas.

The Fort Atkinson has three distinct facies. The dominantly carbonate facies in northeastern and southwestern Iowa are separated by a broad area in central and east-central Iowa where the Fort Atkinson is dominantly a dolomitic shale. Chert is the dominant lithology in a band through Page, Taylor, Adams and Adair Counties; in a smaller area in Boone and Hamilton Counties; and in an isolated occurrence in eastern Benton County.

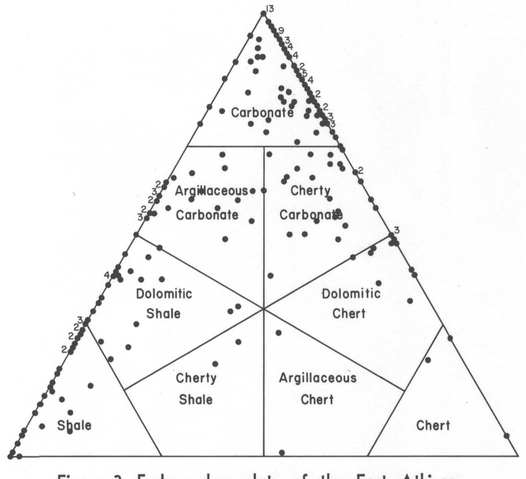


Figure 3. End-member plots of the Fort Atkinson Limestone Member lithologies from well sections in Iowa.

IOWA GEOLOGICAL SURVEY

THICKNESS AND FACIES MAP OF THE BRAINARD SHALE MEMBER, MAQUOKETA FORMATION, IN IOWA

Mary C. Parker

1970

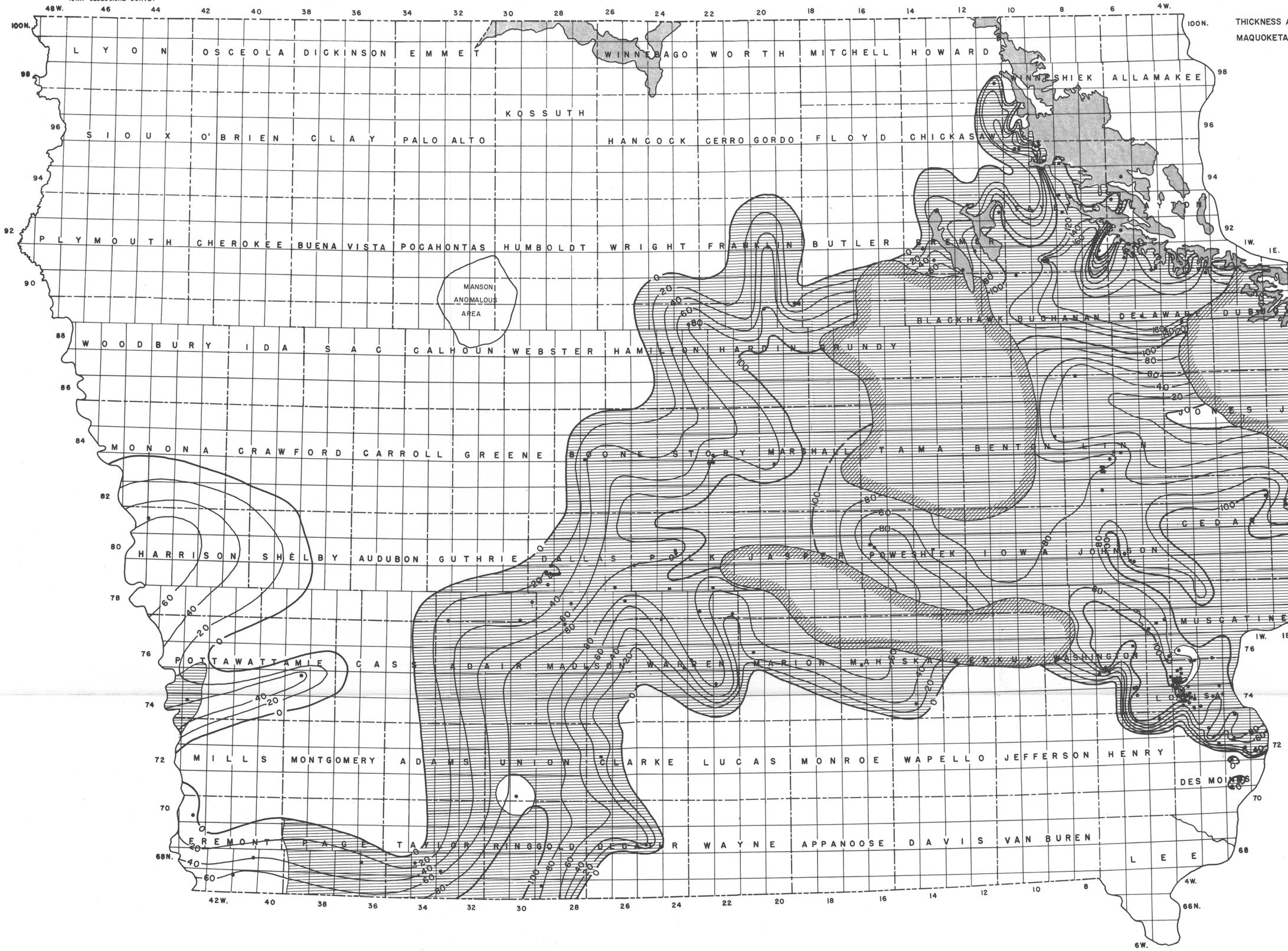
LEGEND

- 20 Thickness
- Outcrop area
- Carbonate
- Shale
- Chert
- Well Location
- Undifferentiated

Contour interval 20 feet

0 10 20 miles

SCALE



BRAINARD SHALE MEMBER

Calvin (1906) proposed the name Brainard Shale for 120 feet of bluish-gray shale and associated beds of limestone exposed near the Brainard railway station, Fayette County, Iowa. The Brainard overlies the Fort Atkinson and underlies the Silurian or Devonian.

The Brainard is absent or thin in much of southwest Iowa because of erosion prior to deposition of Silurian beds. It attains its greatest thickness of 165 feet and 185 feet in Delaware and Clayton Counties. In a narrow band from southwest to northeast Iowa thicknesses of 80 to 100 feet are common.

The Brainard consists predominantly of grayish-green, plastic shale which contains a variable amount of dolomite rhombs that give it a distinctly granular character. Minor thin beds of limestone or dolomite occur near the top and bottom of the member. In extreme western Iowa and locally throughout the rest of the state the Brainard is dominantly argillaceous dolomite.

Neda Zone

The Neda Formation, here considered a zone within the upper portion of the Maquoketa Formation, was named by Savage and Ross (1916) for exposures near Neda in eastern Wisconsin.

The Neda is most commonly found in a band from southwest to northwest Iowa where the Maquoketa is the thickest (map 1). It generally overlies the Brainard Member, although a similar zone has been recorded overlying both the Fort Atkinson and Clermont where these members are the uppermost units of the Maquoketa in southeastern Iowa. The Neda ranges from a few feet to 20 feet in thickness and has been included in the isopach of the Brainard.

The Neda consists chiefly of red to maroon shales that locally contain hematitic or limonitic, concentrically laminated pellets. It is overlain by Silurian rocks throughout the area of its occurrence except in southeast Iowa where it is overlain by beds of the Wapsipinicon (Middle Devonian).

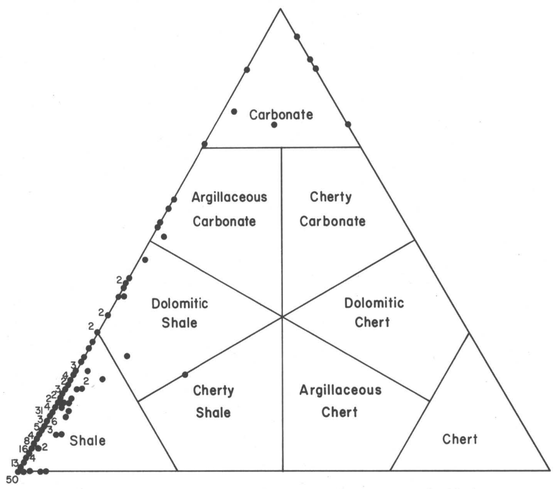


Figure 4. End-member plots of the Brainard Shale Member from well sections in Iowa.

TOPOGRAPHIC MAP OF THE MAQUOKETA FORMATION IN IOWA

Mary C. Parker

1970

LEGEND

Outcrop area

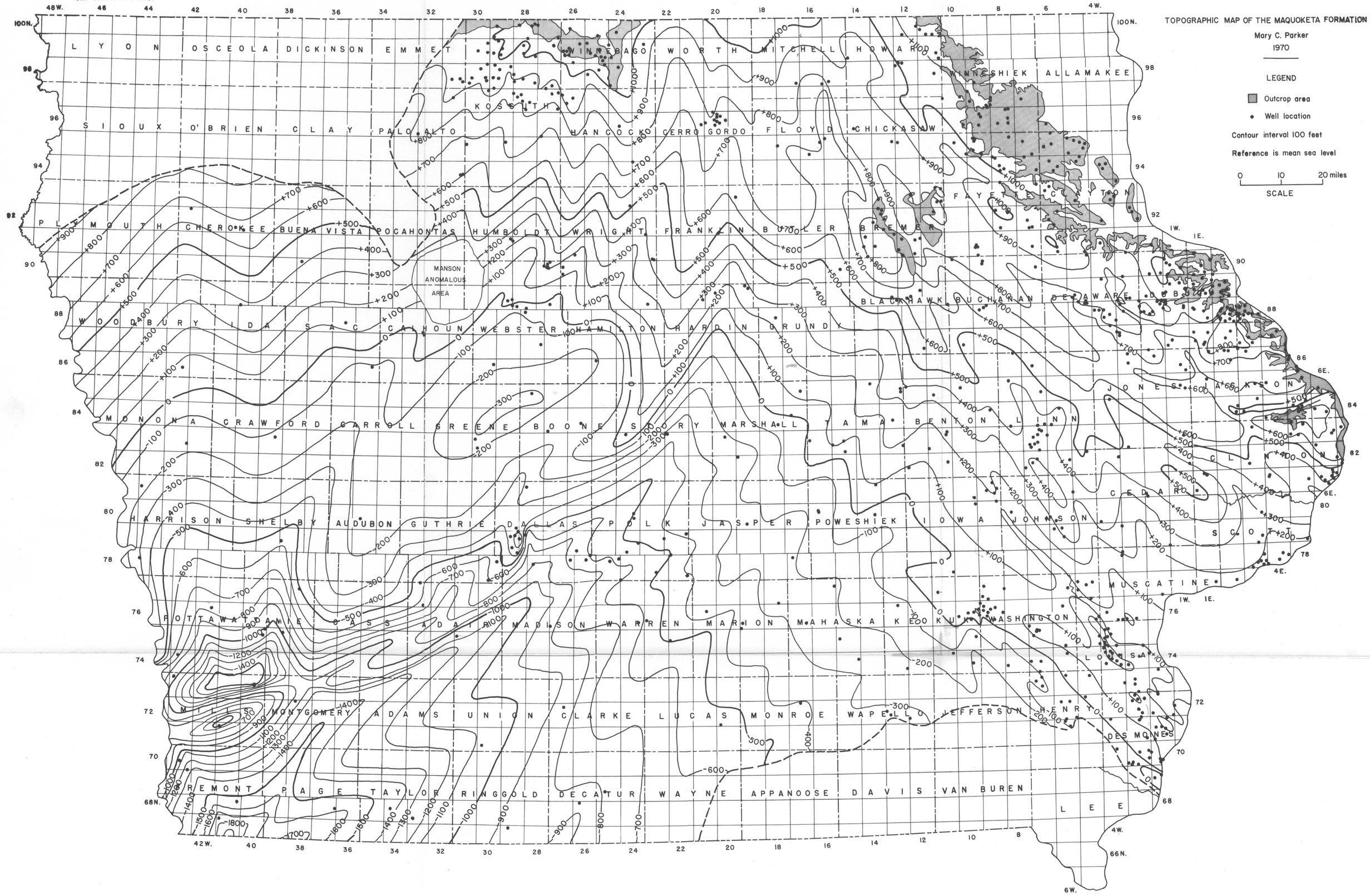
Well location

Contour interval 100 feet

Reference is mean sea level

0 10 20 miles

SCALE



STRUCTURE AND TOPOGRAPHY

The present attitude of the rocks in Iowa is a result of structural movements which occurred several times during geologic history. The topographic map of the Maquoketa Formation reflects the effect of these structural movements and shows where erosion occurred on the surface of the Maquoketa prior to deposition of Silurian rocks.

The regional dip toward the southwest is apparent from the outcrop pattern. In eastern Iowa the parallel anticlines, with their axes trending northwest-southeast parallel to the regional strike, have been mapped in younger rocks both on the surface and in the subsurface (McGee 1891, Keyes 1893, Gordon 1895, Norton 1911, Harris and Parker 1964).

One of the most prominent structural features is the series of domes and anticlines termed the Thurman-Redfield Structural Zone (Hershey and others 1960) which extends from Fremont County northeasterly to Hardin County. A possible extension of this zone trends north to the Iowa-Minnesota line through Franklin, Cerro Gordo, and Worth Counties. This Structural Zone and its possible extension either coincides with, or closely parallels the postulated eastern boundary of the Midcontinent Geophysical High (Henderson and others 1963).

Three basins in western Iowa are shown on the map. The northern periphery of the Forest City Basin is bounded approximately by the —1200-foot contour line. A basin in Mills and Pottawattamie Counties on the northwest side of the Structural Zone is also bounded by the —1200-foot contour line. A broad, shallow basin is indicated in parts of Greene, Webster, Hamilton, and Boone Counties.

ECONOMIC USES

In northeastern and northern Iowa where the Fort Atkinson and Elgin Members are dominantly carbonate, wells have been completed which yield water of sufficient quantity and acceptable quality for domestic use.

In Clayton, Fayette, and Winneshiek Counties the Fort Atkinson and Elgin Members are utilized for road aggregate for general surfacing and rolled stone base. They also are a source of agricultural lime.

Three caverns for the storage of liquified petroleum gas have been constructed in the Maquoketa Formation. These are: (1) the West Branch facility, located in east-central Johnson County, approximately two miles west of West Branch. The roof of the cavern is at a depth of 470 feet in the Brainard Member. (2) the Iowa City facility, located in eastern Johnson County, approximately seven miles southeast of Iowa City. The roof of the cavern is at a depth of 750 feet in the Fort Atkinson Member. (3) the Des Moines facility located in eastern Polk County at the southeast edge of Des Moines. The roof of the cavern is at a depth of 1395 feet in the Clermont Member.

The rock for excavated caverns must meet four requirements: (1) the rock must be impervious; (2) it must be massive to allow excavation of the cavity; (3) it must be structurally sound; and (4) it must be inert so that there is no reaction with the stored product. The cavern must be located at a sufficient depth to cause a hydrostatic pressure at cavern level that will be greater than the pressure of the product being stored so that if leakage occurs it will be into rather than out of the cavern. Because of the character and thickness of the shale members and the distance below the surface that they occur, the Maquoketa Formation is the most promising formation in eastern and central Iowa for the excavation of future caverns.

In natural gas storage facilities in Iowa the Maquoketa members, where composed primarily of shale, act as a secondary or even tertiary impervious cap above the cap rock immediately overlying the reservoir beds. Observation wells completed in the Maquoketa Formation are used to keep a constant watch for any gas which might escape.

Strata equivalent to the Clermont and Elgin Members of the Maquoketa Formation (the Viola) in Kansas have produced over 180 million barrels of oil. Lesser amounts have been produced in Oklahoma with minor production in Nebraska and Missouri. Most of the production has been from accumulations in small structural highs or in facies changes and truncation of porosity zones in stratigraphic traps. Similar structural or stratigraphic traps may have resulted in the accumulation of petroleum in the Maquoketa of Iowa.

ACKNOWLEDGMENTS

These maps have been prepared as part of the subsurface mapping program of the Iowa Geological Survey. Records of well sections prepared by many Survey staff members have been used in constructing the maps. Robin Russell, University of Iowa, recorded and reduced the data. D. L. Koch and O. J Van Eck, Iowa Geological Survey, critically read the manuscript.

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