Bulletin No. 15
IOWA HIGHWAY RESEARCH BOARD

Highway Construction Materials from the Consolidated Rocks of Southwestern Iowa

by

H. Garland Hershey, C. N. Brown,
Orville Van Eck, and R. C. Northup

Prepared by
IOWA GEOLOGICAL SURVEY
IOWA CITY, IOWA
in cooperation with
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CONTENTS

ILLUSTRATIONS

HIGHWAY CONSTRUCTION MATERIALS FROM THE CONSOLIDATED ROCKS OF SOUTHWESTERN IOWA

H. Garland Hershey, C. N. Brown
Orville Van Eck and R. C. Northup

INTRODUCTION

PURPOSE AND SCOPE OF REPORT

Southwestern Iowa, unlike other parts of the State, does not have plentiful near-surface supplies of stone available for highway construction purposes. The long and intensive search for such road material by quarrymen, highway engineers, geologists, and others interested in all phases of stone use resulted in a growing conviction that the only hope of locating new and significant deposits lay in a regional geological survey. Further, such a survey would result in the delineation of areas where exploration should be economically feasible as well as those areas where exploration would have little or no chance of success. These views formed the foundation for developing the project covered by this report under a cooperative agreement with the Iowa Highway Research Board of the Iowa State Highway Commission.

The aims of the project were (1) to locate and describe all consolidated rocks found in place at the surface, or penetrated by drilling or other means; (2) to correlate these rocks geologically; (3) to assemble this information and the valid geological inferences from it into cross sections and maps showing the type of bedrock, thickness of overburden and rock structure; and (4) to write appropriate comments so that the potential usefulness and the most promising sites for future exploration or expansion for stone quarries can be readily seen and be of maximum value.

The report was prepared with the knowledge that its chief immediate use would be by highway engineers and geologists, county engineers, materials producers, and prospectors. To facilitate their use of the report, certain phases were stressed and some standard methods of presentation and arrangement were not rigidly followed. The scientific integrity of the report is not compromised by these deviations from the formal scientific writing practices, nor is the value of the report for other uses thereby lessened.

PROGRAM OF INVESTIGATION

The methods used in the compilation of this report were those regularly used by the Geological Survey. All of the published and unpublished material in the files was reviewed and preliminary maps made for guidance in the field. The field work consisted of locating and describing all consolidated rock exposures in the area of interest; the preliminary office work consisted of critically re-examining all pertinent data in the files. Every effort was expended to obtain those additional data from drillers, oil companies, and other individuals or agencies that were not in the Survey's files or in its past publications.

Upon completion of these preliminary operations, geological correlation of all known rock strata in the area was re-examined, reviewed, and, where necessary, changed. This part of the project was considered to be most vital because upon it depended the correct prediction of sources of limestone not physically known. The paleontological, lithological, and structural studies employed in this phase of the investigation led to new maps and to another cycle of field and office checks. The corrections made necessary by these advanced studies were incorporated into the report as it appears here.

We believe the method of presentation chosen, one largely of graphical methods, will be the most valuable to those who will use this report as a guide for future exploration and development.

AREA OF REPORT

This report covers an area of about 6,200 square miles and includes the 11 southwestern counties of Iowa (fig. 1). The area is bounded on the west by the Missouri River and on the south by the Iowa-Missouri state line. The economy of the area is based primarily on agriculture and its related industries.

ACKNOWLEDGEMENTS AND PERSONNEL

Numerous members of the Iowa Geological Survey staff worked on this project. During the early years, R. M. Jeffords of the U. S. Geological Survey did considerable work in connection with his ground-water studies and was in direct charge of the project insofar as subsurface work was concerned. His earlier experience in working with Pennsylvanian rocks added importantly to the program and completeness of the study. However, he resigned in November, 1953, to enter the oil business. Since early 1954, Charles N. Brown has supervised the project.

At the inception Louis F. Jenkinson, Gunnar A. Norgaard and George J. Degenfelder were assigned the major responsibility for the field and office work on the surface rocks. Norgaard left the Survey in November, 1952, Jenkinson and Degenfelder in May, 1953, all to enter the petroleum industry. Charles E. Graham was employed on the project during the summers of 1952 and 1953 but was not thereafter available. Orville Van Eck began work on the project during the summer of 1953 and continued part time until completion. He is responsible for assembling most of the data and for completing the columnar sections started by Jeffords. He prepared

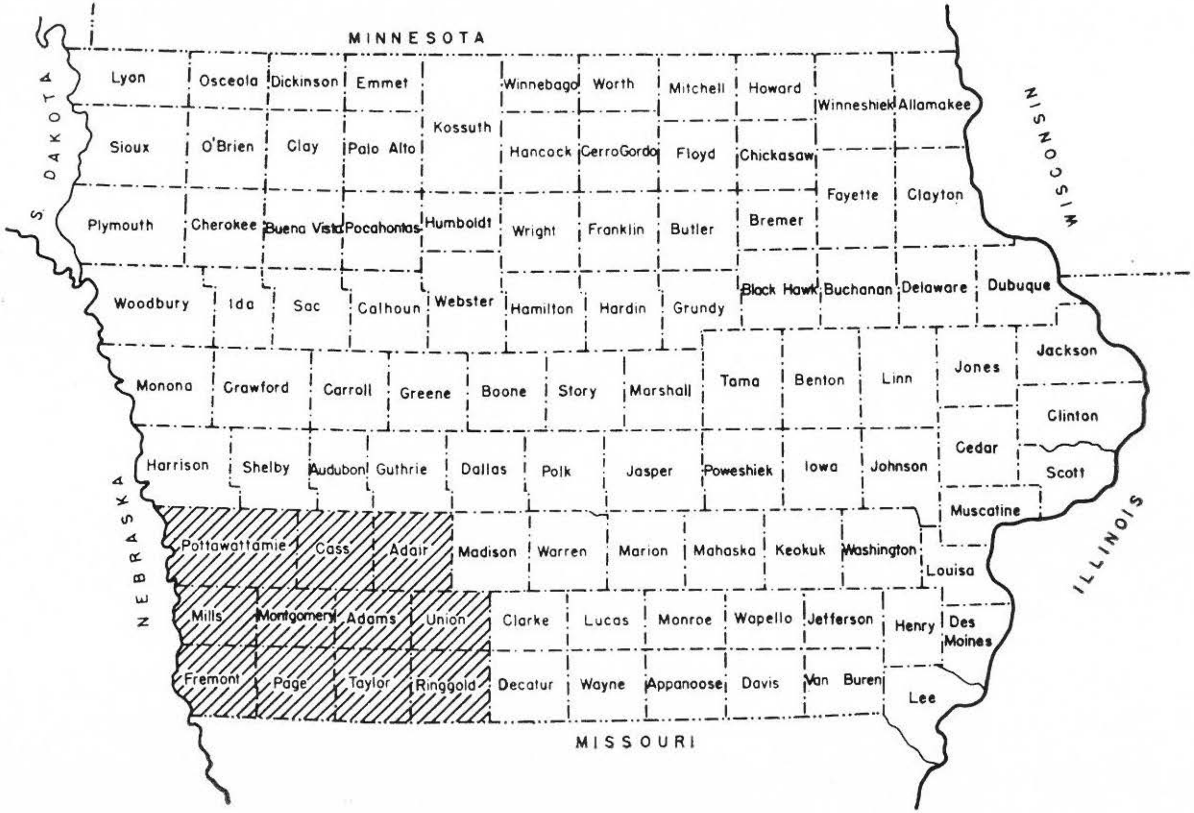


Figure 1. Area of report.

most of the areal and structural maps, the geologic cross sections, and much of the text. Fred H. Dorheim and Russell B. Campbell have been associated with the project part time since 1956, principally in connection with field checking and the preparation of overburden and location maps. The illustrations were drafted by Charles C. Cashmark, Charles M. Fouts, and Donald E. Poline. The typists, to whom the authors owe special gratitude, were Olatha M. Tweedy, Marilyn Carstens, Mary Goss, and Janet E. Jaeger.

Well and core drillers, county engineers, rock producers, staff members of the Highway Commission and other state departments, as well as other groups and individuals have contributed information and assistance which is gratefully acknowledged.

Much work has been done in the past on rocks pertinent to this report. Our study is based upon the results of studies by earlier workers. No attempt is made here to review fully the earlier reports, but a selected bibliography is appended and we have drawn freely from the older records.

PROBLEMS OF CORRELATION

The rocks of southwestern Iowa from the surface down consist of Pleistocene loess and drift over discontinuous patches of Dakota sandstone of Cretaceous age which in turn overlie the Pennsylvanian rocks, commonly known as the "Coal Measures" (fig. 2). Where Cretaceous rocks are absent, the glacial drift lies directly upon rocks of Pennsylvanian age. Beneath the Pennsylvanian rocks and buried at great depth are the massive pre-Pennsylvanian limestones and dolomites with intercalated shales and sandstones. By far the greatest potential source of crushed rock acceptable for highway aggregate in the area is from the Pennsylvanian system; consequently a major space allotment is given to the discussion of these rocks.

Surface exposures of consolidated rocks suitable for highway construction are relatively few in southwestern Iowa as they are mostly hidden beneath glacial drift. Moreover, the Cretaceous blankets the Pennsylvanian rocks over large areas. Thus, much reliance must be placed upon subsurface data obtained chiefly as a result of water well drilling. However, the Pennsylvanian strata are notoriously poor aquifers and few water wells are drilled below the glacial drift or Cretaceous rocks; consequently, subsurface information is not abundant in this region of the State. Fortunately, the possibility of oil discovery is considered to be greater in southwestern Iowa than elsewhere in the State and data obtained from test drilling for petroleum have been helpful toward the solution of the general geology of the area.

The characteristics of the rocks themselves pose difficulties, particularly in the Pennsylvanian section. Upon exposure they weather quickly, slump, and commonly become rapidly overgrown. Weathering characteristics, of course, often aid the geologist, but more often valuable diagnostic features are lost as a result of weathering. The cyclical deposition of the Pennsylvanian adds complications in an area where the rocks are poorly exposed, such as southwestern Iowa. For example, a limestone member of one cyclothem or formation may not be distinguishable from limestone members of several other cyclothems. Diagnostic fossils are not always found and commonly do not occur. Furthermore, thickness and other characteristics change laterally, thus compounding the problems of specific recognition.

One of the most useful methods for identifying Pennsylvanian strata is by the sequence of rock units involved; i.e., the superposition of beds. Thus the more beds that are available for examination in an exposure or from cuttings or cores from a drill hole, the more precise and the more reliable is the determination in the absence of fossils or other specifically diagnostic features. Well cuttings and cores are also of great value in that they commonly yield a greater sequence of rock than can be found at the surface in southwestern Iowa. Although well cuttings and cores do not reveal certain weathering characteristics, do not permit identification of large fossils, and do not show some detailed cyclical attributes which aid in the distinguishing of formations in outcrops, every effort should be made to save as complete a record as possible of any drillings done in the area.

The following sections of this report will describe the Pleistocene, Cretaceous, and Pennsylvanian rocks but no descriptions will be made of the pre-Pennsylvanian systems. The pre-Pennsylvanian rocks which furnish so much road material in other parts of the State could be similarly used in southern Iowa, but they are so deeply buried that they have not been exploited up to the present time. The older and therefore lower groups of Pennsylvanian rocks occurring in Iowa are not exposed in the area of this report, but they are present beneath the younger strata. Descriptions of them from nearby areas where they are characteristically exposed are included in this discussion because a knowledge of them will be useful in the future development of the rock resources of southwestern Iowa.

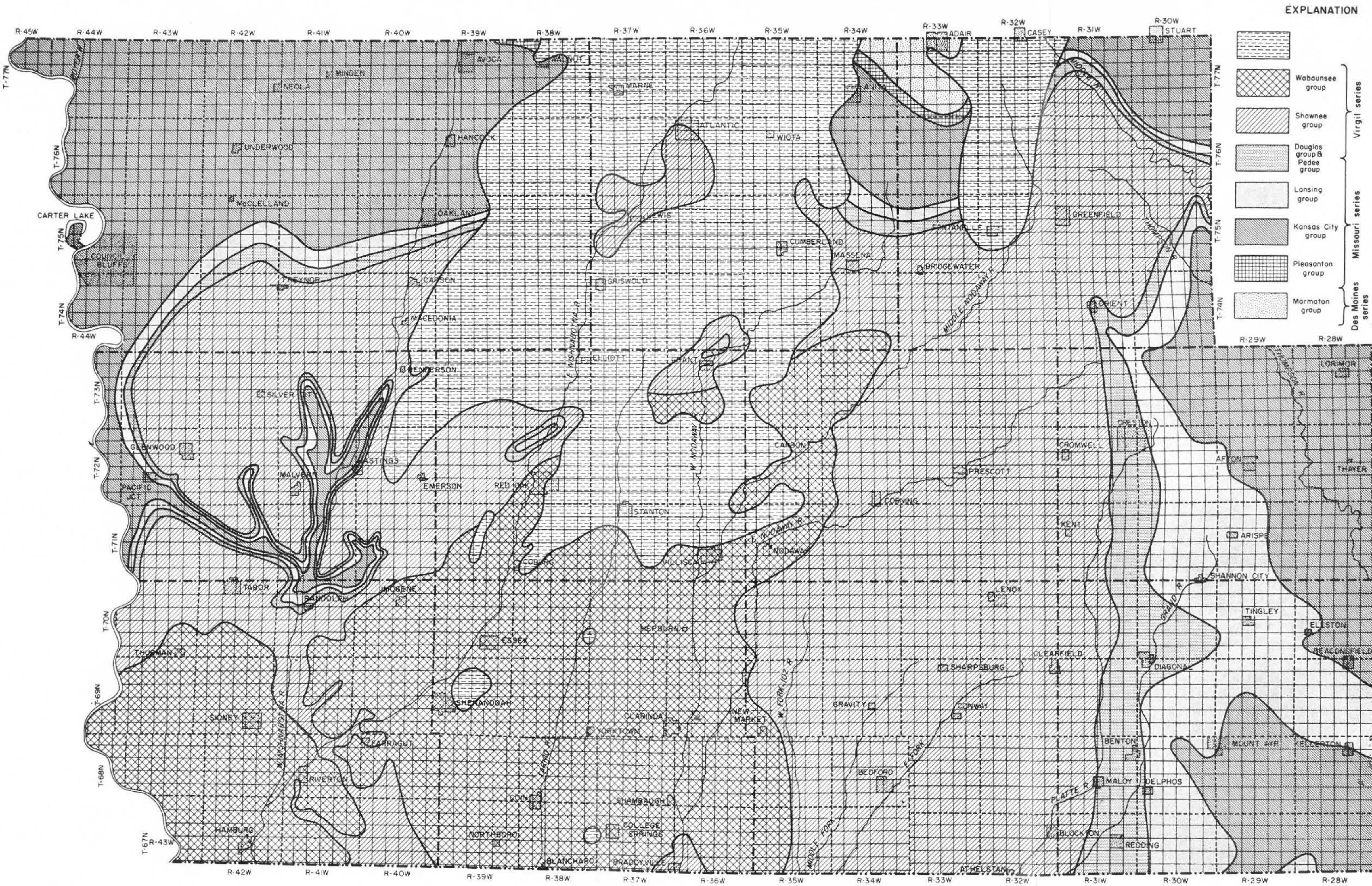


Figure 2
Geologic map of southwestern Iowa

Iowa Geological Survey, 1960

POST-PENNSYLVANIAN STRATIGRAPHY OF THE AREA

PLEISTOCENE SERIES

The Quaternary system in Iowa is represented by Pleistocene and minor Recent deposits. In southwestern Iowa, the Pleistocene is dominantly a loess-covered complex of glacial till; lesser amounts of Recent and Pleistocene alluvium occur chiefly in the terraces and flood plains of streams dissecting the area. These deposits (fig. 3) mantle an eroded bedrock surface of relatively high relief (fig. 4), and for the purpose of this report may be considered as overburden, along with the Cretaceous materials discussed in the following section. With the exception of the deeply buried ancient valleys, which may have as much as 500 feet of fill, the glacial deposits average about 200 feet and range in thickness from 300 feet on the primary divides to zero where erosion has exposed the consolidated rocks.

The wind-blown silts and sands composing the loess are easily excavated. They are subject to rapid erosion, especially where they occur in their maximum thickness of approximately 100 feet in the bluffs near the Missouri River.

Eastward from the river the loess diminishes in thickness to approximately 12 feet in Ringgold and Union counties, but it mantles the topography everywhere except where erosion has removed it. The main body of the loess is of Wisconsin age, but near the Missouri River the basal portion is called the Loveland loess and is of Illinoian age. Locally, where late Sangamon erosion was moderate, the Loveland loess is overlain by the late Sangamon paleosol.

The predominant Pleistocene deposit, the glacial drift, is usually a complex of tills and interbedded sands separated in some places by buried soils. The oldest drift is the Nebraskan. Where uneroded, it is separated from the overlying Kansan till by a thick soil profile, the Aftonian gumbotil, and where eroded it may be the site of large gravel deposits such as that at Afton Junction. The Kansan overlies the Nebraskan and is indistinguishable from it except perhaps that it is less compacted. This uppermost till, like the one it covers, may contain stringers of sand. Where uneroded, the uppermost till is separated from the overlying loess by a massive buried soil profile, the Yarmouth gumbotil.

Although the tills themselves are not now used in highway surfacing, a knowledge of them is important. Their buried soils are potential causes of landslides in quarries and road cuts; and their associated sands and gravels are useful for highway purposes as well as for sources of water.

The terrace and flood-plain deposits vary in age from early Pleistocene to Recent and may be as thick as 400 feet or more. They occur in most of the drainage ways and are quite noticeable in the major valleys. They are composed mostly of silts, clays, and sands, but where they were deposited during floods, such as those caused by glacial melting, they contain extensive beds of sand and gravel. The flood plain and terraces of the Missouri River are especially noted for huge deposits of both fine and coarse materials.

Although not visible in the present landscape, the loess and glacial till lie over integrated drainage systems which they have buried. Some of these buried valleys are quite small and would serve to produce little water; but the ancient buried valley here named Fremont Channel, which passes through Mills and Fremont counties (fig. 4), has approximately 500 feet of glacial debris in it and may be a very valuable source of water. The courses of the bedrock valleys shown on Figure 4 are areas in which prospecting for quarry rock would be of little avail.

CRETACEOUS SYSTEM

Dakota Formation

Rocks of the Dakota formation are the only representatives of the Cretaceous system in southwestern Iowa and underlie the glacial drift in parts of six counties (fig. 2). The formation was originally extensive, but erosion prior to the glacial epoch has left only remnants of its once widespread occurrence. The Dakota remaining in the area is composed primarily of poorly cemented sandstone with minor amounts of clay shale and some conglomerate. The conglomerate most often is composed of siliceous pebbles lightly held in a ferruginous matrix, although locally it may be very tightly cemented or not cemented at all. The pebbles have a characteristic polish, a varying degree of roundness, and commonly are partly coated with iron and manganese. The conglomerate has been used as a road metal but is not suitable for concrete aggregate because it cannot satisfactorily withstand the freeze and thaw test and because of the ferruginous coating. It is not considered significant as a highway construction material except in small quantities locally. It is best exposed in an old borrow pit near Coburg, Montgomery County, cen. S. line, sec. 30, T. 71 N., R. 38 W., where it is tightly cemented chiefly by iron and manganese. Conglomerate and sandstone, both almost completely uncemented, have been exploited for road metal from a pit near Coburg in the S½ sec. 17, T. 71 N., R. 38 W.

Field recognition of the Dakota formation is often difficult for several reasons. Most commonly the sandstones and conglomerates are loosely cemented and have the appearance of sands and gravels; the shales are of the claystone and mudstone type, poorly compacted and with the appearance of clays. These characteristics make recognition of the Dakota units difficult because they resemble some basal glacial deposits so closely. This is particularly true in drilling operations. In many drillers' logs, sand, gravel, and clay are reported at the base of glacial drift sections. There is no doubt that many of these deposits have been considered glacial materials,

Figure 3
OVERBURDEN THICKNESS IN SOUTHWESTERN IOWA

whereas, in reality, they are Dakota. The greatest care must be exercised by the driller and the geologist because, even when samples are available from drill holes, it is often extremely difficult to distinguish the Dakota from glacial sands and gravels. Even the cementation of the Dakota does not necessarily ease the problem because occasionally glacial sands and gravels are so tightly cemented that they ring when struck with a hammer.

For these reasons the mapping of the limits of the Dakota in southwestern Iowa must be considered tentative because it is based heavily on drillers' logs. In all probability the Dakota in this area is more extensive than the map shows.

PENNSYLVANIAN ROCKS OF SOUTHWESTERN IOWA

GENERAL FEATURES

Rocks of the Pennsylvanian system form the bedrock of almost two-thirds of Iowa. The areal extent of this system was originally even greater as is shown by the outliers that are found at considerable distances from the main body of Pennsylvanian sediments. Despite their great areal extent, rocks of this system are not as well exposed as those of the other Paleozoic systems, which is primarily due to the nature of the Pennsylvanian sediments. In contrast to the older systems, which contain an abundance of massive resistant limestones and dolomites, the Pennsylvanian is composed largely of non-resistant shales, and subordinate limestones. As a result, exposures soon slump and become overgrown.

Throughout Pennsylvanian time there was a recurring succession of inundations by the seas which resulted in a cyclic deposition of marine and non-marine sediments. Deposits that represent a sedimentary cycle have been called cyclothems (Weller, 1932, p. 1,003). In the Eastern Interior Basin, a cyclothem is considered to be the equivalent of a formation, but in the Mid-Continent region, of which the area of this report is a part, it is not considered equivalent. In Iowa, boundaries between the cyclothems are not always well marked, whereas the boundaries between certain lithologic units are readily defined and mark the natural groupings that are called formations (fig. 5). However, the recognition of cyclothems greatly facilitates the correlation of formations in Iowa.

The ideal cyclothem, as described by Moore (1935, p. 24-25), is as follows:

12. Shale (and coal)
11. Shale, typically with molluscan fauna
10. Limestone, algal, molluscan, or with mixed molluscan and molluscoid fauna
9. Shale, molluscoids dominant
8. Limestone, contains fusulinids, associated commonly with molluscoids
7. Shale, molluscoids dominant
6. Limestone, molluscan, or with mixed molluscan and molluscoid fauna
5. Shale, typically with molluscan fauna
4. Coal
3. Underclay
2. Shale, may contain land plant fossils
1. Sandstone

Members 1-4 in the initial part of the cyclothem and 12 at the end are non-marine. The remaining members are marine. This simple type of cyclothem is found in the Wabaunsee group, but in the Shawnee group a more com-

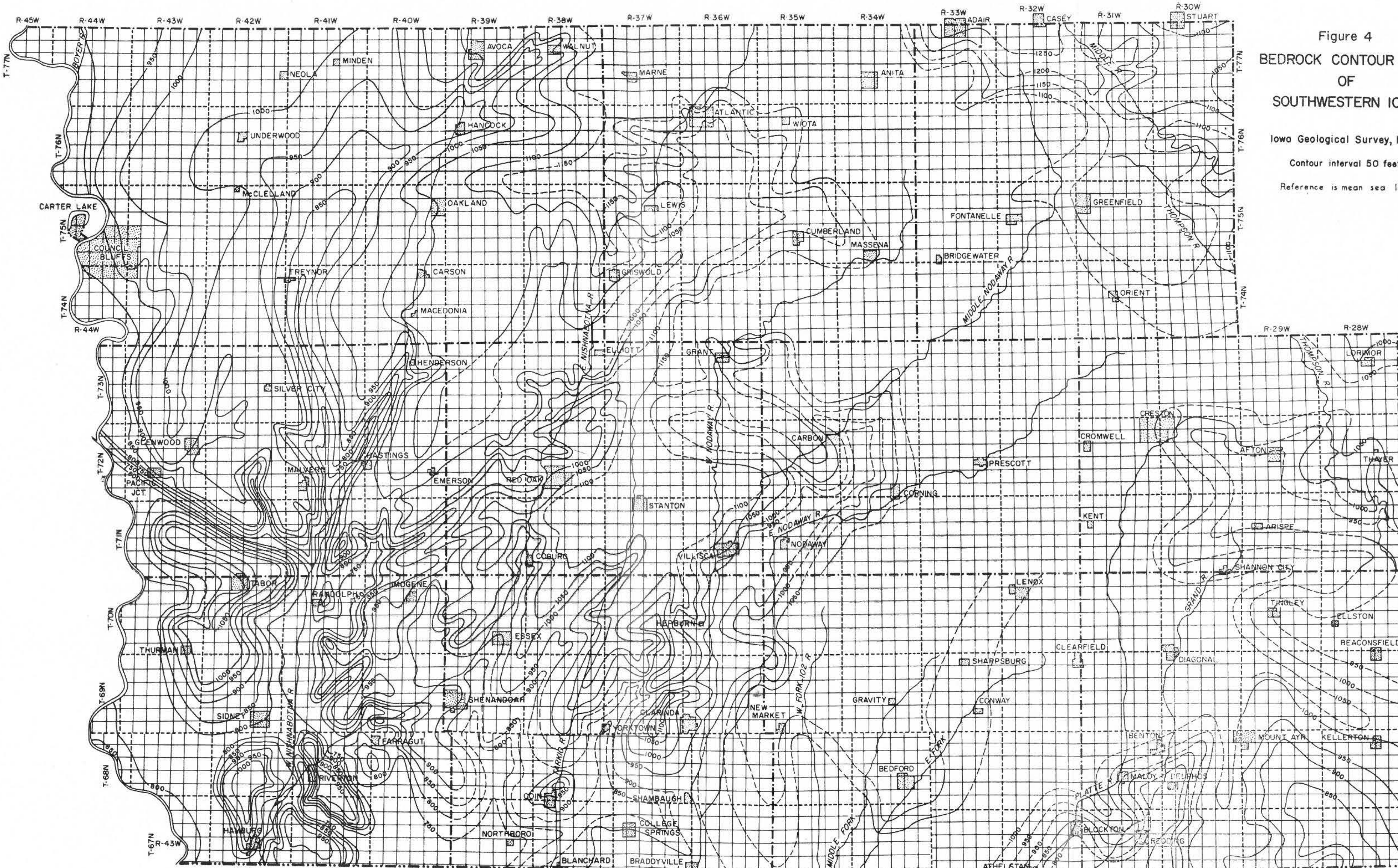


Figure 4
BEDROCK CONTOUR MAP
OF
SOUTHWESTERN IOWA

Iowa Geological Survey, 1960

Contour interval 50 feet

Reference is mean sea level

Series	Group	Formation	Members
Virgil Series	Wabaunsee Group	French Creek Sh. Jim Creek Ls. Friedrich Sh. Grandhaven Ls. Dry Sh. Dover Ls. Langdon Sh.(Nyman Coal) Maple Hill Ls. Wamego Sh.	
		Tarkio Ls. Willard Sh. Elmont Ls. Harveyville Sh. Reading Ls. Auburn Sh. Wakarusa Ls. Soldier Creek Sh. Burlingame Ls.	
		Silver Lake Sh. Rulo Ls.(generally missing in Iowa) Happy Hollow Ls. Cedar Vale Sh.(Elmo Coal) White Cloud Sh. Howard Ls. Severy Sh.(Nodaway Coal)	
	Shawnee Group	Topeka Fm.	Coal Creek Ls. Holt Sh. DuBois Ls. Turner Creek Sh. Sheldon Ls. Jones Point Sh. Curzon Ls. Iowa Point Sh. Hartford Ls.
		Calhoun Fm.	
		Deer Creek Fm.	Ervine Creek Ls. Burroak Sh. Haynies Ls. Larsh Sh. Rock Bluff Ls. Oskaloosa Sh. Ozawkie Ls.
		Tecumseh Fm.	Rakes Creek Sh. Ost Ls. Kenosha Sh.
		Lecompton Fm.	Avoca Ls. King Hill Sh. Beil Ls. Queen Hill Sh. Big Springs Ls. Doniphan Sh. Spring Branch Ls.
		Kanwaka Fm.	Stull Sh. Clay Creek Ls. Jackson Park Sh.
		Oread Fm.	Kereford Ls. Heumader Sh Plattsmouth Ls. Heebner Sh. Leavenworth Ls. Snyderville Sh. Toronto Ls.
	Douglas Group	Lawrence Fm. Stranger Fm.	

Series	Group	Formation	Members
Missouri Series	Pedee Group	Iatan Fm. Weston Sh.	
	Lansing Group	Stanton Fm.	
		Vilas Sh.	
		Plattsburg Ls.	
	Kansas City Group	Bonner Spring Sh.	
		Wyandotte Fm.	Farley Ls. Island Creek Sh. Argentine Ls. Quindaro Sh. Frisbie Ls.
		Lane Sh.	
		Iola Fm.	Raytown Ls. Muncie Creek Sh. Paola Ls.
		Chanute Sh.	
		Drum Ls.	Corbin City Ls. Cement City Ls.
		Quivira Sh.	
		Westerville Ls.	
		Cherryvale Fm.	Wea Sh. Block Ls. Fontana Sh.
		Dennis Fm.	Winterset Ls. Stark Sh. Canville Ls.(generally missing in Iowa)
		Galesburg Fm.	
		Swope Fm.	Bethany Falls Ls. Hushpuckney Sh. Middle Creek Ls.
		Ladore Sh.	
		Hertha Ls.	
	Pleasanton Group	Exline Ls. Ovid Coal	
Des Moines Series	Marmaton Group	Lenapah Fm.	Cooper Creek Ls.(Sni Mills of Missouri)
		Nowata Fm.	Sandstone(Madison County)
		Altamount Fm.	Worland Ls. Lake Neosho Sh. Amoret Ls.
		Bandera Fm.	
		Pawnee Fm.	Coal City Ls. Mine Creek Sh. Myrick Station Ls. Anna Sh.
		Labette Sh.	Mystic Coal Marshall Coal
		Fort Scott Ls.	Higginsville Ls. Houx Ls. Summit Coal Blackjack Creek Ls.
	Cherokee Group	Cherokee Sh.	Mulky Coal Bedford Coal Bevier Coal Ardmore Ls.(Verdigris) Whitebreast Coal

Figure 5. Sequence of Pennsylvanian rocks in southwestern Iowa.

Description	Persistent beds of cyclothems		Oread	Lecompton	Deer Creek	Topeka
		(The megacyclothems are designated by the name of the limestone formation that each contains)				
Shale, sandy, plant fossils, thick	E.9	Kanwaka shale	Stull shale	Tecumseh shale		Severy shale
Limestone, oölitic or pebbly, contains algae, few mollusks	E.7				Hartford limestone	
Shale, molluscan & molluscoid fossils	E.6				Calhoun shale	
Limestone, contains fusulinids & molluscoids	E.5		Clay Creek limestone			
Shale & sandstone, plant fossils	E.1-0		Jackson Park shale			
"Super" limestone Limestone, oölitic or floggy, molluscan fossils, locally prominent	D.7		Kereford limestone	Avoca limestone	"Upper" Ervine Creek limestone	
D.6 to C.6 inclusive			Heumader shale	King Hill shale		
"Upper" limestone Limestone, light gray, wavy-bedded, locally chert-bearing, contains fusulinids & molluscoids, generally thick	C.5		Plattsmouth limestone	Beil limestone	"Lower" Ervine Creek limestone	Coal Creek limestone
Shale, molluscan & molluscoid fossils	C.4-.2					
Shale, black, fissile, conodonts, scanty brackish-water molluscan fauna, locally insects, macerated plant fragments	C.1		Heebner shale	Queen Hill shale	Larsh-Burroak shale	Holt shale
"Middle" limestone Limestone, dark blue, single massive bed with vertical joints, contains fusulinids & molluscoids, generally 1 to 2 feet thick	B.5		Leavenworth limestone	Big Springs limestone	Rock Bluff limestone	Du Bois limestone
Shale, generally unfossiliferous	A.9-.8		Snyderville shale	Doniphan shale	Oskaloosa shale	Turner Creek shale
Limestone, oölitic or granular, locally 3 to 4 feet thick	A.7					Sheldon limestone
A.6 Shale, generally not differentiated						Jones Point shale
"Lower" limestone Limestone, blue-gray, weathers brown, ferruginous, impure, massive or uneven thick beds, contains fusulinids & molluscoids	A.5		Toronto limestone	Spring Branch limestone	Ozawkie limestone	Curzon limestone
Coal beds: Shale, marine, generally molluscan fossils	A.2		Lawrence formation	Kanwaka shale	Tecumseh shale	Iowa Point shale
Coal beds: Shale, sandy, plant fossils	A.1					
Coal beds: Sandstone, nonmarine, locally contains plant fragments, may be conglomerate at base	A.0					

Figure 6. Shawnee megacyclothems.

plex sequence of related cyclothems, called megacyclothems, is recognized. The nature of the megacyclothems is shown in Figure 6. Variations of these rhythmic cycles of deposition also occur within the other groups of the Pennsylvanian system. Cyclothemic sedimentation in the Mid-Continent area is discussed in detail by Moore (1935, p. 20-38).

In an area such as Iowa, where Pennsylvanian rocks generally are not well exposed, a knowledge of the cyclic sedimentation is essential in correlation. Examination of Figure 6 will show that certain types of rocks appear only at definite places within the cyclothem. Thus, the black fissile shale is present only between the "middle" and "upper" limestones, and the "middle" limestone is always dark blue, thin, massive, and commonly vertically jointed.

Probably the outstanding feature of the Pennsylvanian system in the Mid-Continent region is the great lateral persistence of many minor units, which has made possible the correlation of stratigraphic units over several hundreds of miles. To accomplish such correlations, extreme care is required in the examination of all available exposures and cores, and here also, the recognition of cyclic sedimentation is an important consideration. It is natural that certain units will be poorly developed in some areas and on casual examination will appear to be missing from the section where other members have been recognized. However, on closer examination, the missing member is generally found to be represented. For example, a coal smut or lignite zone commonly occurs at the horizon where a solid coal would normally be found; similarly, a limestone bed may be represented in places by limy nodules within a shale or perhaps by a very calcareous shale phase.

During Pennsylvanian time there was no great faunal change that is readily recognizable for use in correlation, but some minor changes and certain faunal groupings occurred that can be used. The most important fossil in this system is the fusulinid, the spindle-shaped foraminifera that persisted throughout Pennsylvanian time. Although many of the changes that occurred within this species are evident only by microscopic examination, certain changes are obvious. For example, fusulinids in the Drum limestone are typically very tiny, those in the Plattsmouth limestone are elongate and resemble grains of rice, and those in the Ervine Creek limestone are relatively large and obese. These differences are very distinctive. Also important are the algal fossil remains *(Ottonosia* and *Osagia)* that are indicative of a receding sea. Although not diagnostic, they are useful in determining the position of a unit within a cyclothem as they are more commonly associated with the "super" limestone. The "super" limestones also are usually somewhat oolitic.

From this discussion it is evident that the study of the Pennsylvanian rocks requires painstaking care and the use of all available criteria to arrive at acceptable correlations. This has been the goal throughout this program.

ROCK UNITS AND NOMENCLATURE

Rocks of the Pennsylvanian system of Iowa are divided into the Virgil series, Missouri series, and Des Moines series. The Virgil series is composed of the Wabaunsee, Shawnee, and Douglas groups. The Shawnee group contains several exploitable limestones that provide an important part of the highway construction materials of southwestern Iowa. The Wabaunsee and Douglas groups are composed predominantly of shales and contain no limestones of economic importance for highway construction under existing specifications.

The Missouri series in Iowa is classed in the Upper Pennsylvanian and includes the Pedee, Lansing, Kansas City, and Pleasanton groups. Of these, the Kansas City group contains the only limestones that are at present widely quarried in the area of this report, although the Stanton limestone of the Lansing group is quarried locally. The other groups are predominantly shale.

The Des Moines series of Middle Pennsylvanian age is composed of the Marmaton and Cherokee groups. In the Marmaton group shales and siltstones predominate, but limestones of commercial value do occur; whereas the Cherokee group is composed chiefly of sandstones and siltstones, with shales subordinate, and limestones lacking.

It is now believed that sandstones belonging to the Atoka or Morrow series also occur in Iowa beneath the rocks of the Des Moines series. They are not significant to this study and will not be further discussed.

Detailed descriptions of the various rock strata in sequence and the major structural features of the area are presented in the remainder of this chapter of the report. It is followed by a chapter describing the character and thickness of the rock sequences as they occur in each county as shown by Figure 7. Figure 8 shows the location of several detailed cross sections (figs. 9-16) which present stratigraphic relations within the area of investigation.

Virgil Series

Wabaunsee Group

Rocks of the Wabaunsee group are found only in Adams, Montgomery, Taylor, Page, and Fremont counties. This group is predominantly shale with limestone, siltstone, minor sandstone units, and thin coal seams. No limestone member of this unit is thick enough to be of economic interest in connection with highway construction; consequently, these rocks have not been quarried. Nonetheless, all known exposures have been carefully measured and in almost all instances correlations have been made. A few correlations

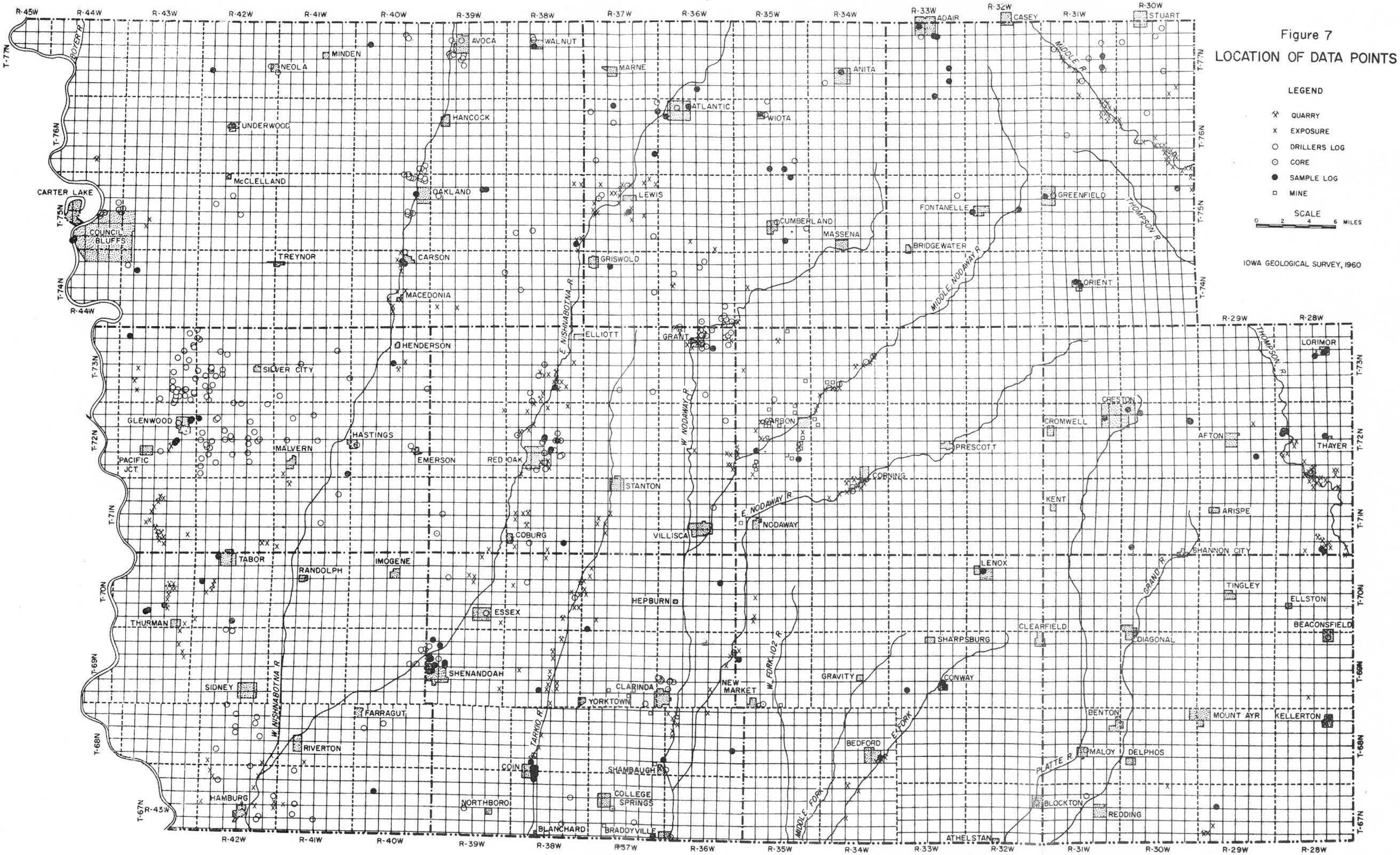


Figure 7
LOCATION OF DATA POINTS

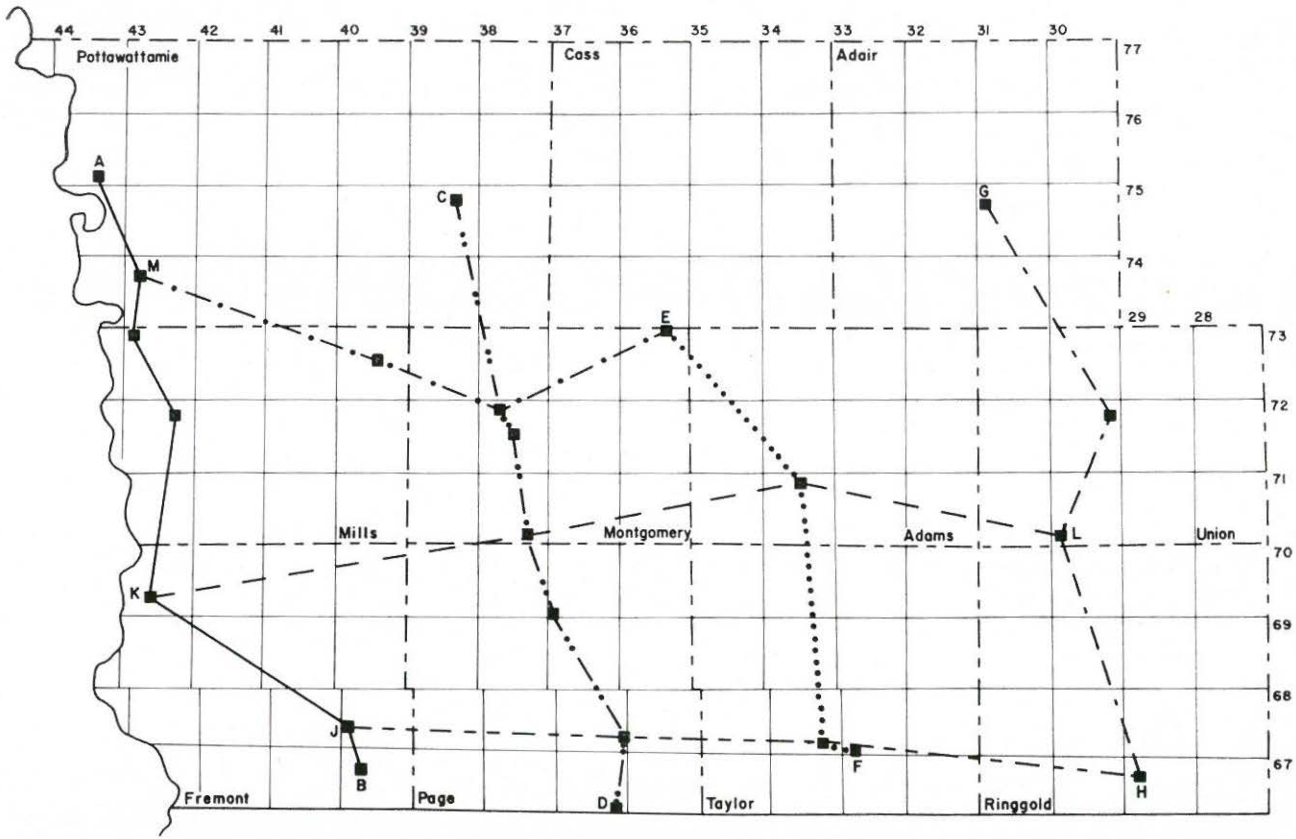


Figure 8. Location of cross sections.

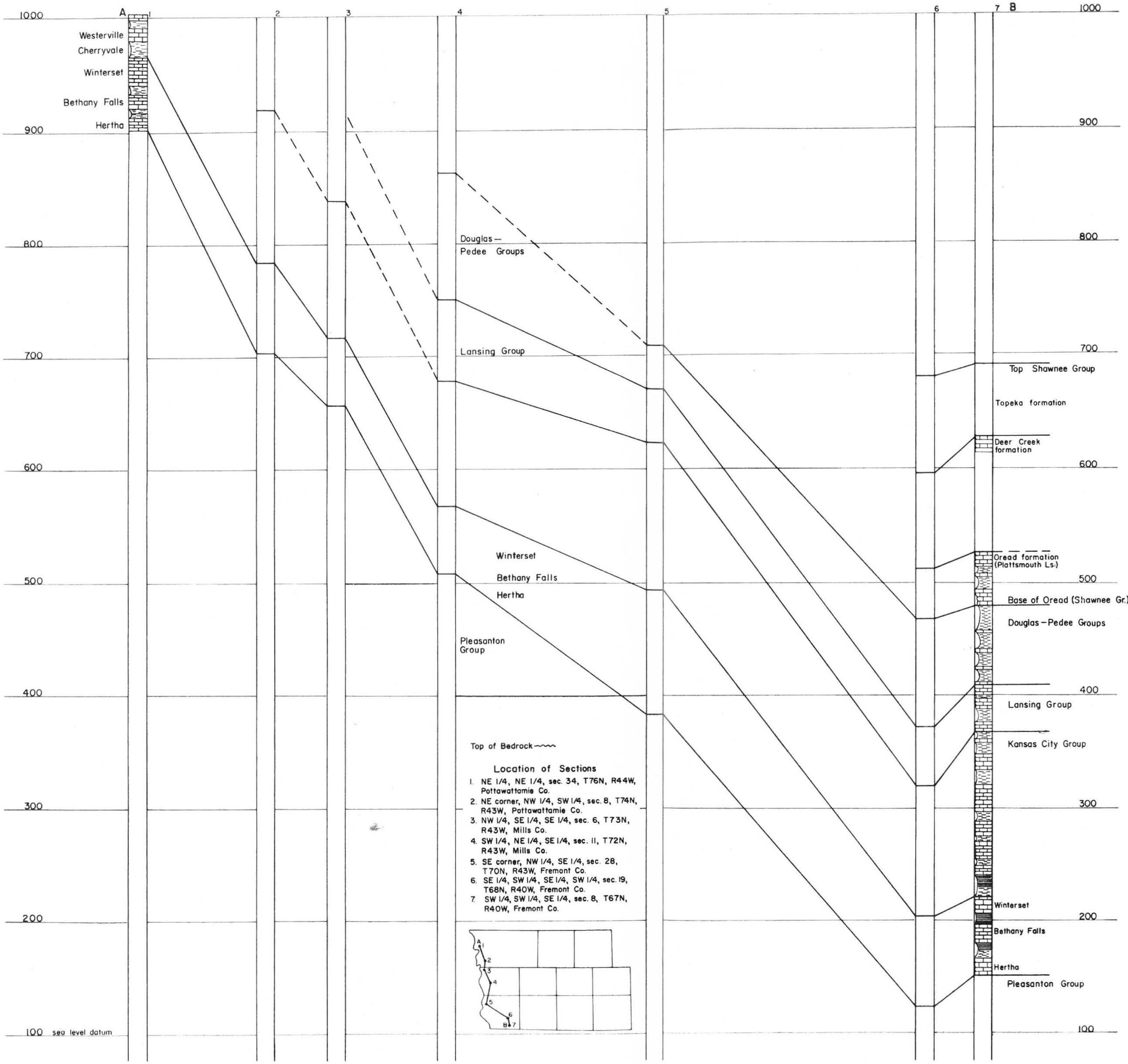


Figure 9. Cross section A-B, Crescent City to Hamburg.

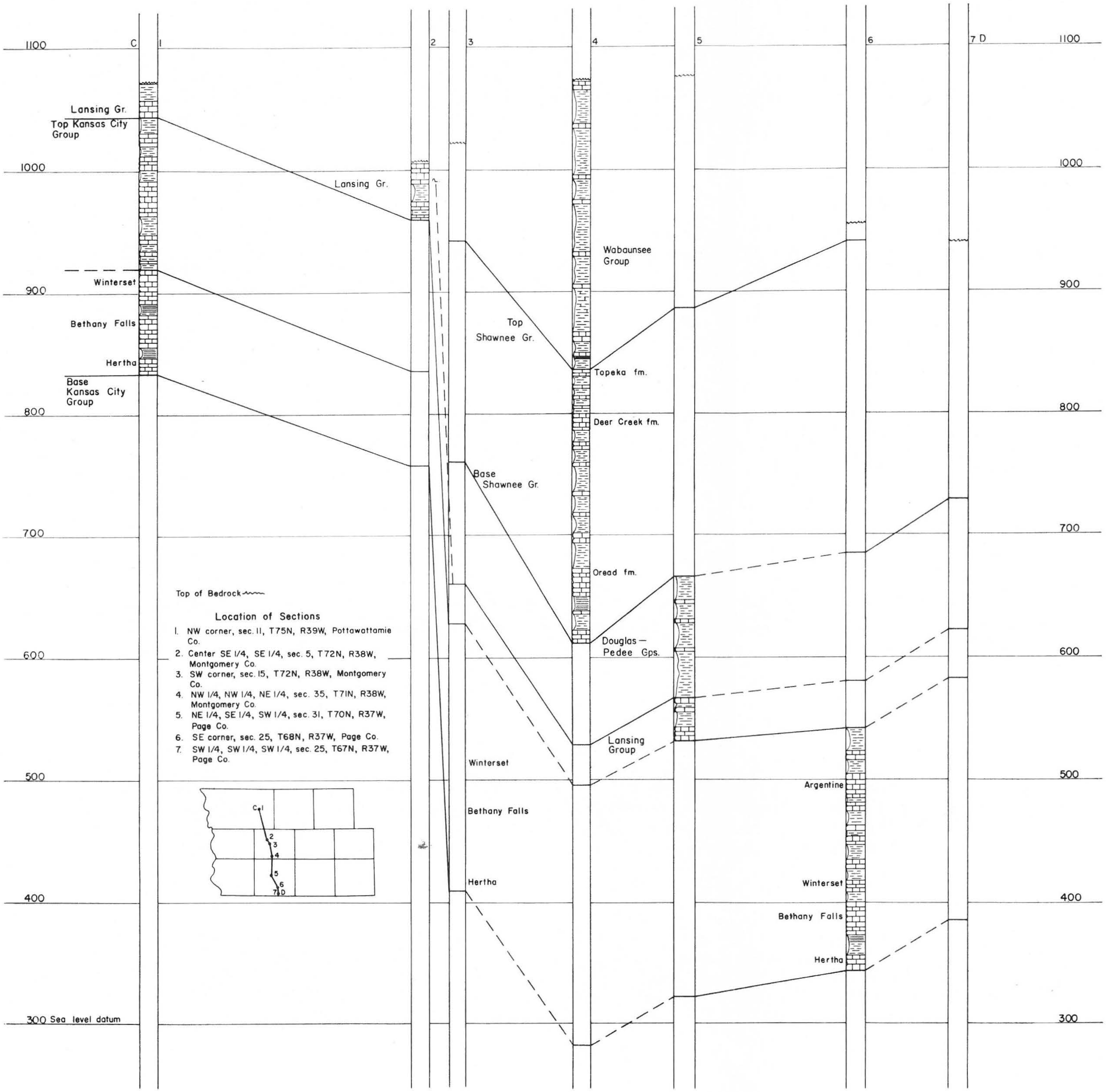


Figure 10. Cross section C-D, Oakland to Braddyville.

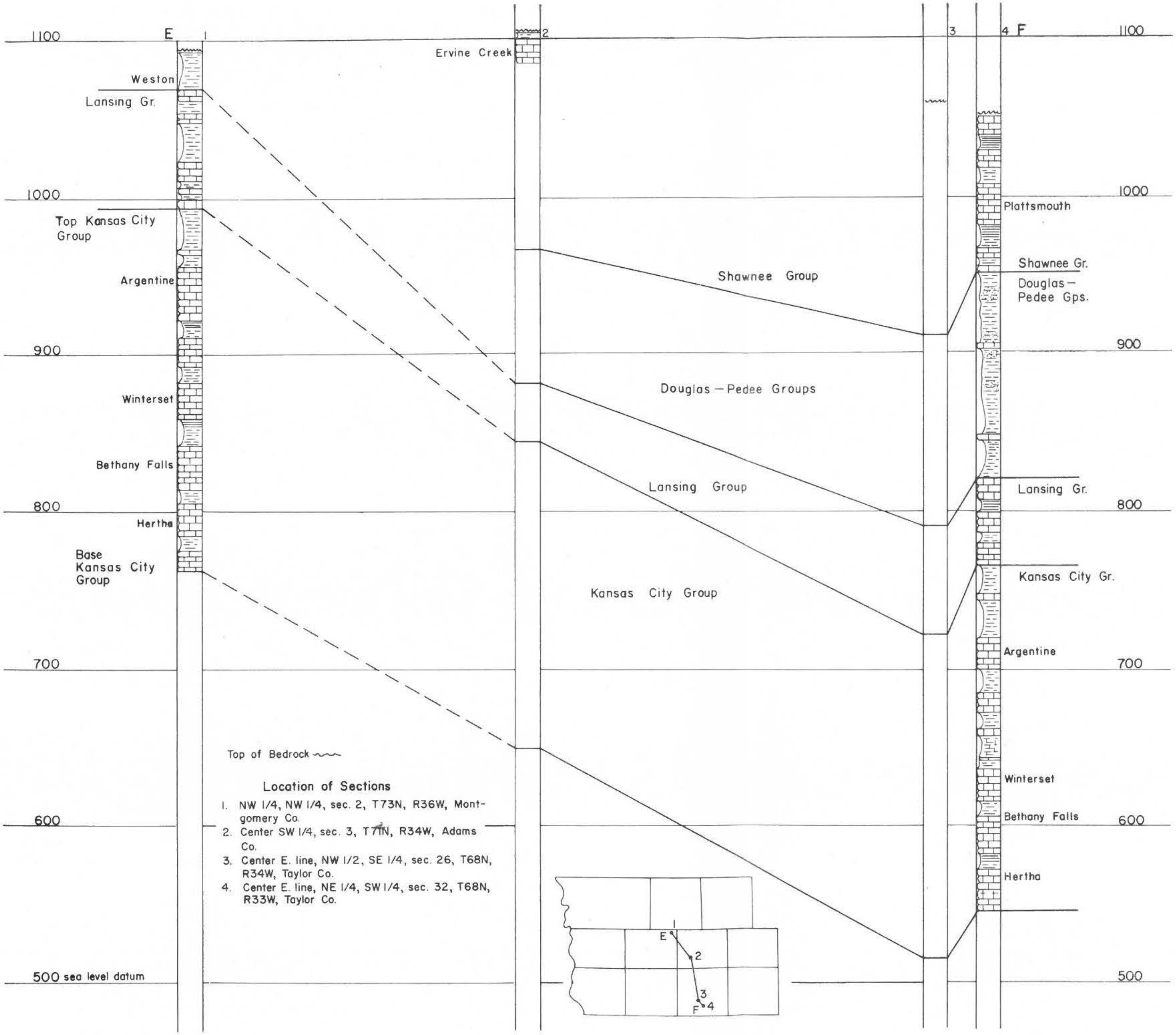


Figure 11. Cross section E-F, Grant to Bedford.

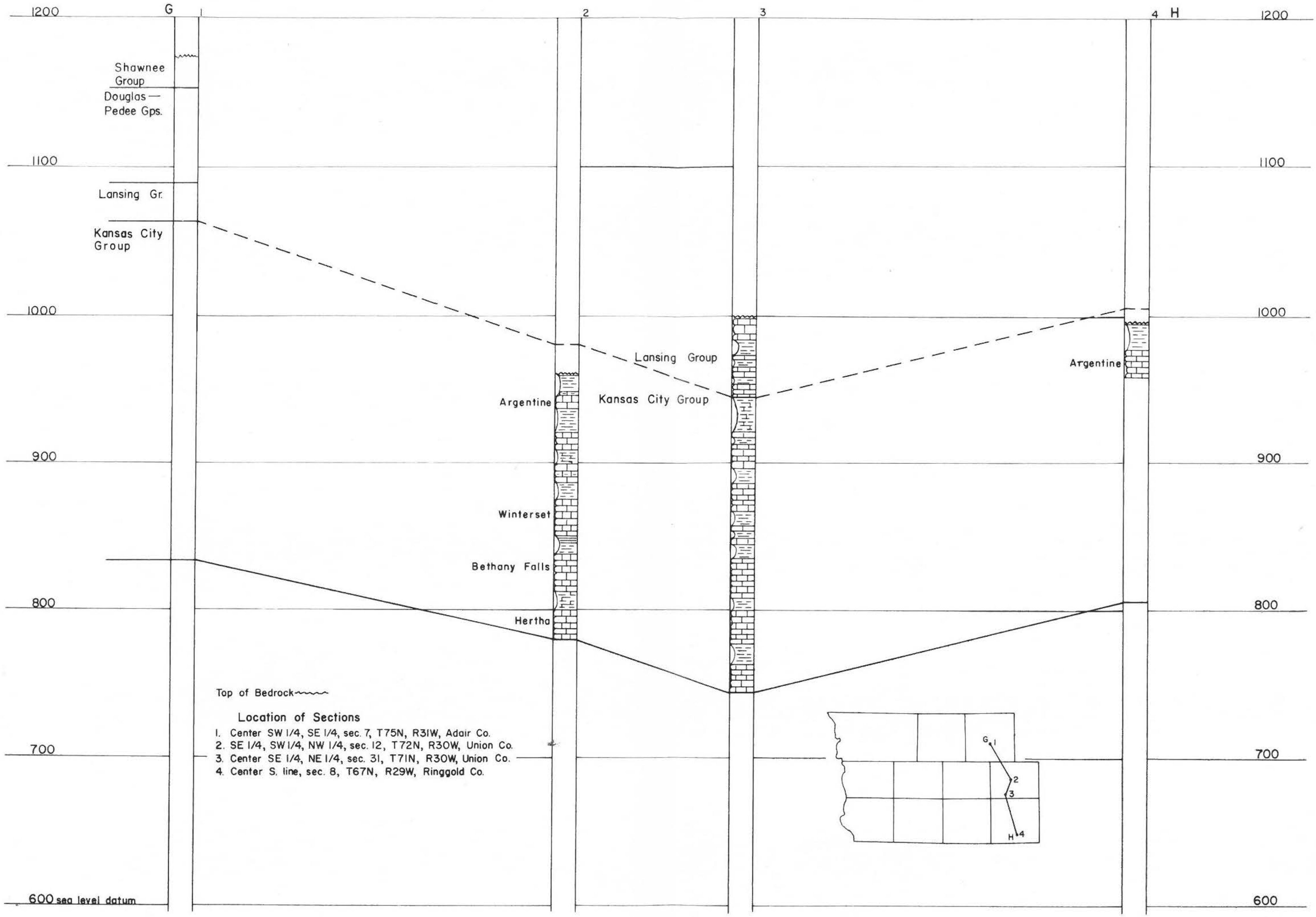


Figure 12. Cross section G-H, Greenfield to Mt. Ayr.

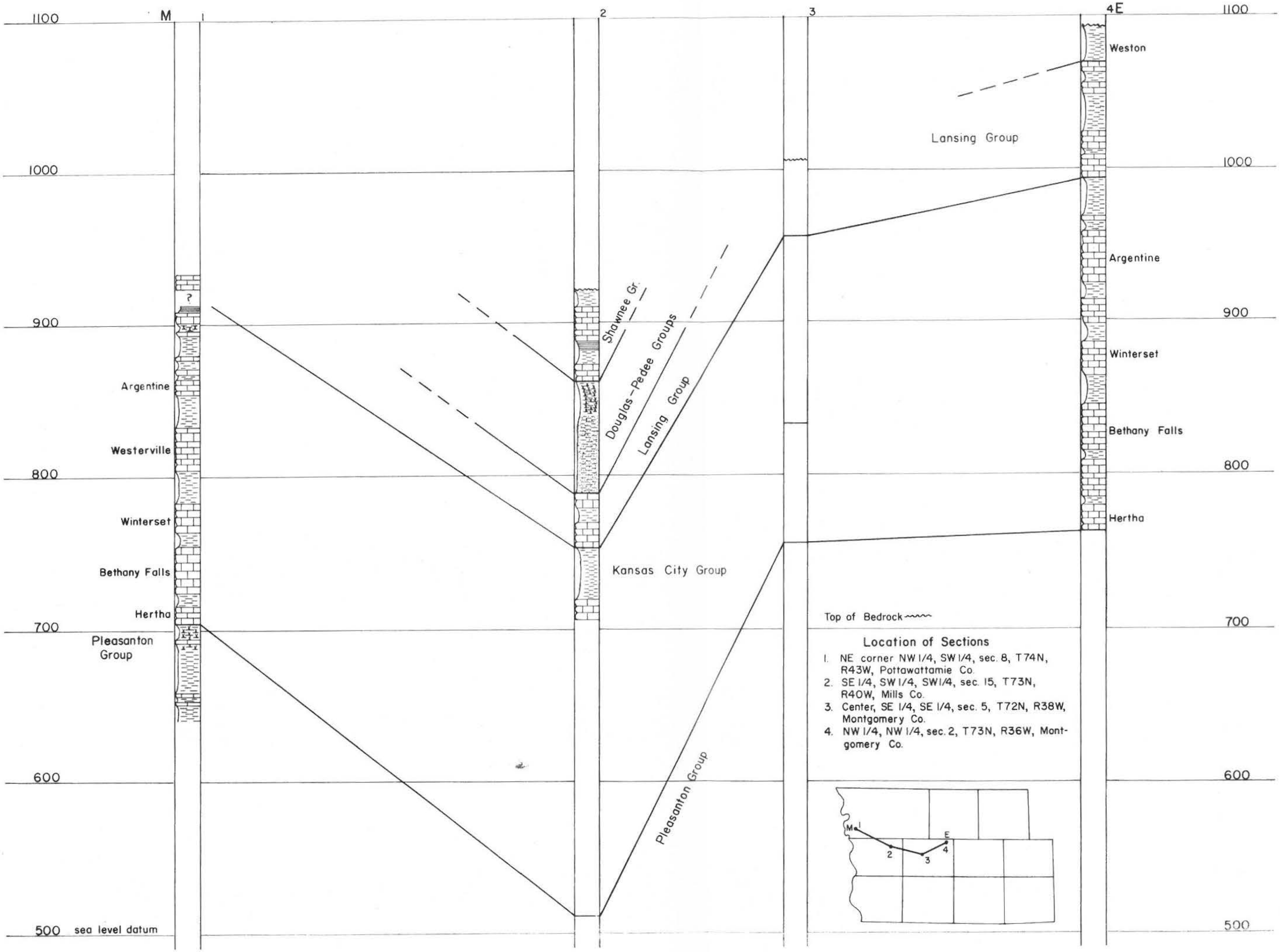


Figure 13. Cross section M-E, Council Bluffs to Grant.

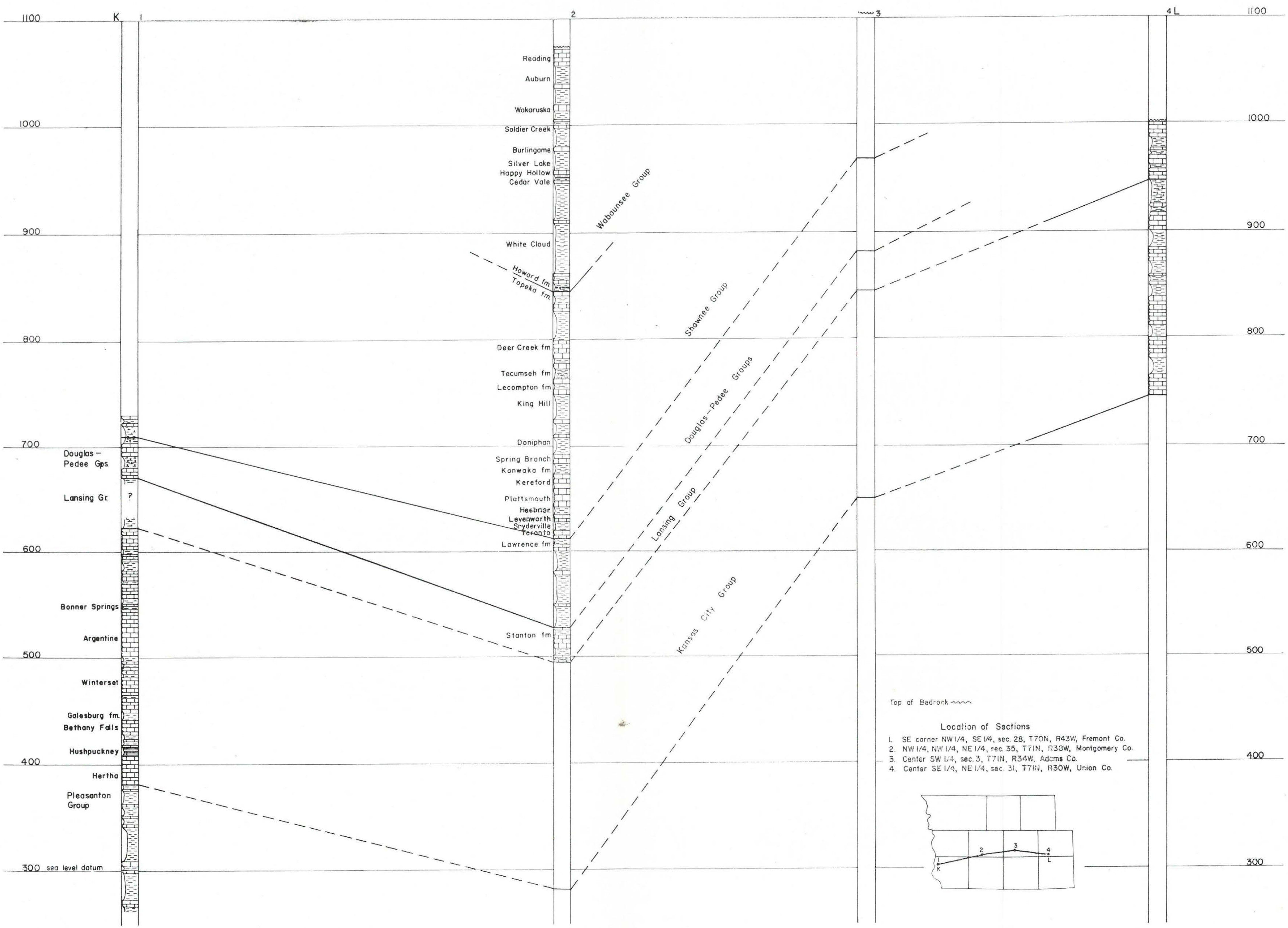


Figure 14. Cross section K-L, Thurman to Creston.

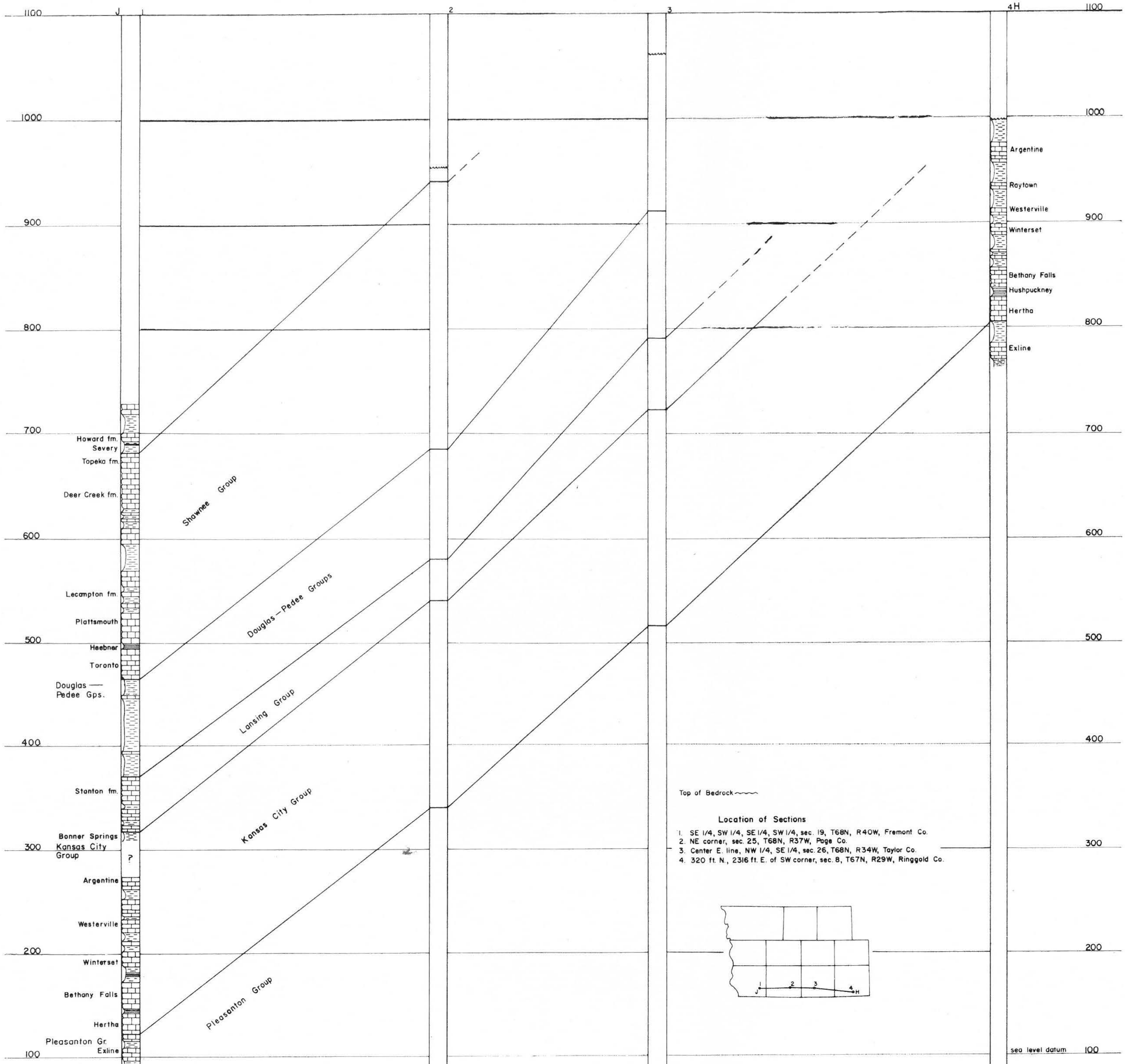
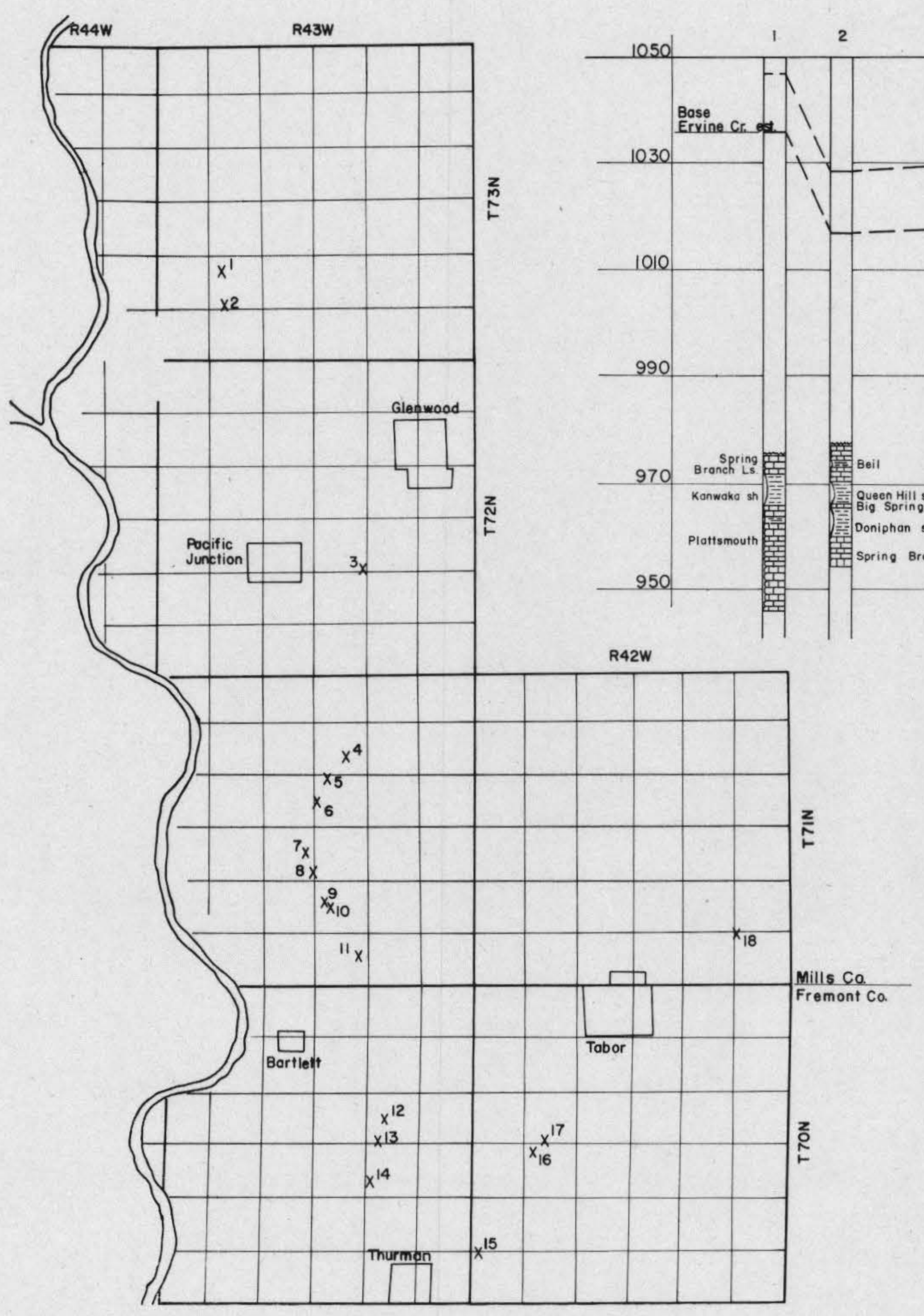
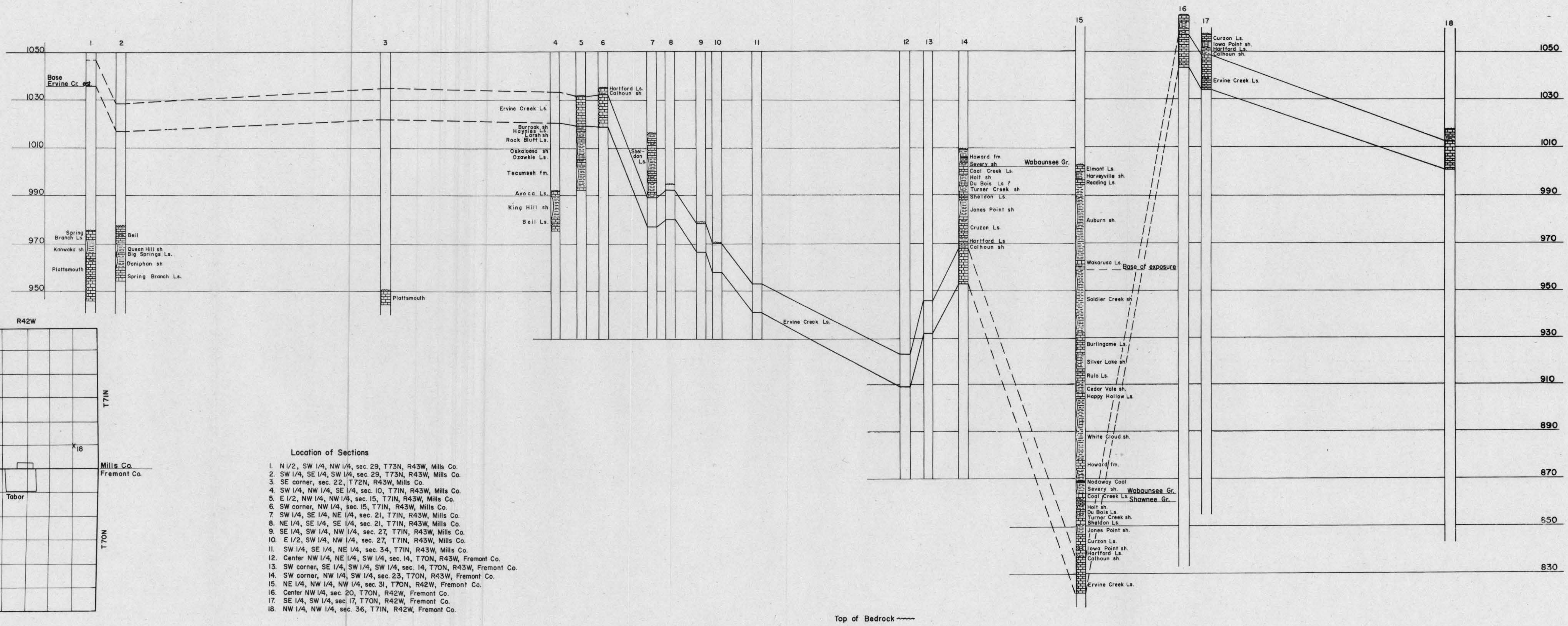


Figure 15. Cross section J-H, Farragut to Mt. Ayr.



Location of Cross Section



Location of Sections

1. N 1/2., SW 1/4, NW 1/4, sec. 29, T73N, R43W, Mills Co.
2. SW 1/4, SE 1/4, SW 1/4, sec. 29, T73N, R43W, Mills Co.
3. SE corner, sec. 22, T72N, R43W, Mills Co.
4. SW 1/4, NW 1/4, SE 1/4, sec. 10, T71N, R43W, Mills Co.
5. E 1/2, NW 1/4, NW 1/4, sec. 15, T71N, R43W, Mills Co.
6. SW corner, NW 1/4, sec. 15, T71N, R43W, Mills Co.
7. SW 1/4, SE 1/4, NE 1/4, sec. 21, T71N, R43W, Mills Co.
8. NE 1/4, SE 1/4, SE 1/4, sec. 21, T71N, R43W, Mills Co.
9. SE 1/4, SW 1/4, NW 1/4, sec. 27, T71N, R43W, Mills Co.
10. E 1/2, SW 1/4, NW 1/4, sec. 27, T71N, R43W, Mills Co.
11. SW 1/4, SE 1/4, NE 1/4, sec. 34, T71N, R43W, Mills Co.
12. Center NW 1/4, NE 1/4, SW 1/4, sec. 14, T70N, R43W, Fremont Co.
13. SW corner, SE 1/4, SW 1/4, SW 1/4, sec. 14, T70N, R43W, Fremont Co.
14. SW corner, NW 1/4, SW 1/4, sec. 23, T70N, R43W, Fremont Co.
15. NE 1/4, NW 1/4, NW 1/4, sec. 31, T70N, R42W, Fremont Co.
16. Center NW 1/4, sec. 20, T70N, R42W, Fremont Co.
17. SE 1/4, SW 1/4, sec. 17, T70N, R42W, Fremont Co.
18. NW 1/4, NW 1/4, sec. 36, T71N, R42W, Fremont Co.

Figure 16. Cross section showing structural detail, Pacific Junction to Thurman.

are tentative, however, because the outcrops are small and distances between exposures are great.

The Wabaunsee group may be divided into subgroups called Richardson, Nemaha, and Sac-Fox (Condra and Bengston, 1915, p. 14; Condra, 1935, p. 4, and 1949, p. 12-20; Condra and Reed, 1959, p. 41). These subgroups are not well defined in Iowa and are not identified in this report, nor are the major units broken down into members as they are in the other groups of the Pennsylvanian.

Because of the great predominance of shale within the Wabaunsee group, exposures soon become slumped and overgrown, and for this reason some of the sections described by early workers have since become obscured. For example, the youngest Pennsylvanian rock to be described in Iowa was from an exposure on Mill Creek, south of Riverton (Smith, 1908, p. 638). Here the French Creek shale, the Jim Creek limestone, and the Friedrich-Dry shale were exposed but are no longer visible. Younger rocks may also be present beneath the drift between Thurman and Hamburg and east of Hamburg but they are not exposed and have not been reported in drilling records.

Following is a very brief description of the members of the Wabaunsee group, discussed in descending order. There is little to distinguish the units as seen and many of the correlations are necessarily on the basis of sequence and not lithologic or paleontologic distinction. The strata are believed to thin considerably to the northeast and therefore the sections measured in the southwest will show the greatest thickness.

The *French Creek shale*, as described by Smith (1909) is gray, blocky, thin bedded, and very calcareous. The exposed thickness was 10 feet.

The *Jim Creek limestone* is dark blue to black, weathers red or brown, and is argillaceous. The upper portion is usually thin bedded and the lower portion massive. The fossils include *Chonetes* and *Myalina*. Thickness seldom exceeds one foot.

The *Friedrich shale* is bluish gray to light gray, micaceous, and silty in the upper part. This shale is poorly exposed now, but a thickness of 10 feet has been measured. The interval from the lower part of Friedrich shale through the Grandhaven limestone is exposed along the bluffs of the Missouri River and major tributaries in Fremont County extending from the NW¼ sec. 1, to the NW¼ sec. 13, T. 69 N., R. 43 W. Condra and Reed (1959, p. 43) suggest that their Otoe shale, Palmyra limestone, and Minersville shale may occupy the horizon of the Friedrich shale and their Morton limestone that of the Grandhaven limestone.

The *Grandhaven limestone* is bluish gray, and weathers to a buff brown. It is usually micaceous and argillaceous, and the upper part tends to be slabby and contains many limonite nodules. The thickness is about 2 feet.

At the well-known McKissick Grove exposure (SE½ sec. 13, NE¼ sec. 24,

T. 67 N., R. 42 W.), the section from the lower Friedrich shale to the Table Creek shale has been exposed. A dam across the creek at the section line of secs. 13 and 24 has obscured most of this exposure.

The *Dry shale*, as seen at the foregoing location, is a bluish-gray, silty shale with thin, interbedded, gray limestone and siltstone. Ferruginous concretions are common in the siltstone. The thickness is approximately 20 feet.

The *Dover limestone*, which is consistently about 3 feet thick, is made up of two limestone beds separated by a thin bed of gray shale. The upper limestone is dense, gray, unfossiliferous, and weathers to a buff color. The lower limestone is dark gray to black, weathering in a nodular form with many white fragments of *Derbyia, Chonetes,* and *Crurithyris.*

The *Table Creek shale* is composed of gray sandstone at the top, a reddish calcareous shale near the center, and a sandy shale near the base. The distinctive *Nyman coal* occurs near the top of this formation and serves as an aid in correlation. At the SW cor. SE¼SE¼ sec. 13, T. 67 N., R. 42 W., this formation has an exposed thickness of 3.75 feet. Condra and Reed (1959, p. 42), proposed the term "Langdon" for this interval.

The three formations immediately below the Table Creek shale are not generally recognized in the area of this report. However, in the N½SE¼ SW¼ sec. 36, T. 70 N., R. 43 W., Fremont County, beds are exposed which are here tentatively correlated with a part of the Table Creek shale—Willard shale interval.

At the top of the foregoing section, 3.5 feet of blocky green and gray shale is identified as the basal part of the *Pierson Point shale.* The interval between the Maple Hill limestone and the Tarkio limestone has been named Wamego by Condra and Reed (1959, p. 42) for clarification purposes.

Below this is the *Tarkio limestone*[1], recognized as two limestone beds with an intervening fossiliferous gray shale. The upper limestone is nodular and argillaceous and the lower one is blocky and very limonitic. The total thickness of this unit is 6.8 feet.

Underlying the Tarkio limestone is the *Willard shale.* This shale is gray at the top, maroon near the center, and black at the base. A thin argillaceous limestone occurs about 3 feet below the top. The total thickness is 9:5 feet.

Beneath the Willard shale is the *Elmont limestone*, made up of two limestone beds separated by a fossiliferous gray shale. The upper bed is nodular and argillaceous, and the lower is dark blue gray, sublithographic, and

[1] The Tarkio limestone described here, in accordance with the Kansas usage, is not the Tarkio limestone first described by Calvin (1901, p. 429-435). Subsequent to the description of the type section by Calvin, other workers erroneously applied the name to the "Chocolate limestone" in Kansas (Swallow, 1867, p. 67). Continued misuse of the term was recognized by Moore (1935, p. 229), who urged the formal approval of the misusage. The Tarkio limestone of Calvin is probably the Reading limestone of Kansas usage.

tends to break into massive rectangular blocks. This unit is commonly about 2 feet thick.

Just northeast of Thurman in the NE¼NW¼NW¼ sec. 31, T. 70 N., R. 42 W., an exposure in the bank of Plum Creek shows the interval from the Elmont limestone downward to the Wakarusa limestone. Underlying the Elmont limestone, the *Harveyville shale* as seen here is composed of gray shale in the lower part, limy nodules near the center, and brown shale in the upper part. The thickness of this unit is 3 feet.

Beneath the Harveyville shale the *Reading limestone* is made up of two beds of gray, crinoidal limestone which characteristically weather to a deep brown as a result of the high limonite content. It is usually very fossiliferous with many crinoid and brachiopod fragments, and the fossils stand out in relief against the weathered stone. The thickness is about 3 feet.

Underlying the Reading limestone is the *Auburn shale* which is noted for its many distinct phases. The upper part is a greenish-gray, clayey shale. In the center the shale is deep red to maroon, silty, and micaceous. This middle portion commonly contains many leaf imprints and carbonaceous films. The lower part is very silty, dark gray to black and in places carbonaceous. The total thickness is about 35 feet.

The *Wakarusa limestone* underlies the Auburn shale and is made up of two blocky bluish-gray, fine-grained limestone beds separated by a thin gray crinoidal shale.

Farther to the northeast in the SW¼SE¼ sec. 25, and the NW¼NE¼ sec. 36, T. 72 N., R. 36 W., Montgomery County, the interval extending from the Soldier Creek shale to the Cedar Vale shale is exposed.

The *Soldier Creek shale* is gray at top and bottom, with a maroon shale zone near the top. Near the center is a micaceous, gray sandstone and siltstone. The thickness here is about 30 feet.

Underlying the Soldier Creek shale is the *Burlingame limestone*, which consists of three limestone beds separated by shale. The upper limestone is dark gray, finely crystalline, and contains a great many fossil fragments. This bed is about 6 inches thick, and is underlain by a very dark-gray, soft, clayey shale that is about 1.5 feet thick. The lower two limestone beds are separated by a very calcareous, laminated, gray shale that is about 5 feet thick. The upper limestone of the pair is gray, argillaceous, and blocky, and the lower is concretionary, sandy, and fragmental. The total thickness of the Burlingame limestone here is 12 feet.

The *Silver Lake shale* is next below the Burlingame limestone. It is a bright-gray shale, well-bedded, with a few limonitic bands at the base. The thickness is about 11 feet.

The *Rulo limestone*, which underlies the Silver Lake shale in some areas, has not been identified in this section or elsewhere in Iowa. In Nebraska it is dark gray and earthy.

The *Cedar Vale shale* is marked by the Elmo coal at the top. The shale is gray and blocky and contains a nodular limestone near the top and near the center. The *Elmo coal* has at times been confused with the Nodaway coal, but the Elmo coal is much more lignitic and lacks the caprock, the missing Rulo limestone, such as the Nodaway coal has in the persistent Howard limestone. The total thickness of the Cedar Vale was found to be 18 feet in a drill hole near Coin.

The *Happy Hollow limestone*, which underlies the Cedar Vale shale, is poorly exposed in Iowa. In a very limited exposure in the SE¼NE¼ sec. 19, T. 73 N., R. 35 W., Adams County, a fine-grained, sandy limestone that weathers yellowish is tentatively identified here as the Happy Hollow limestone. In the drill hole near Coin this unit was about 2 feet thick.

The thickest formation in the Wabaunsee group is the *White Cloud shale*. It is gray and green and usually the upper half contains many limestone nodules, some of which show septarian structure and are filled with veins of light and dark calcite. Quite commonly a massive sandstone is found at the base. The full thickness of this formation has not been found at the surface, but it was measured at 100 feet in coal mines in Adams County.

The *Howard limestone* forms the caprock for the persistent *Nodaway coal* and can be identified on this basis. In the eastern part of the area of this report the Howard is a dark-gray to black, coarsely crystalline limestone. To the west a fine-grained gray limestone occurs above this bed and in some places a dark shale is present separating the limestone beds. The thickness is seldom more than 1.5 feet. In areas where the development of the Howard limestone is complete, it is composed of three limestones and two shale units. The lowermost limestone is missing in the Iowa section, and the lower shale unit and the included Nodaway coal are considered to be a part of the underlying Severy shale because it is not practicable to draw a boundary between two shale bodies.

The Nodaway coal has been mined rather extensively in the past in Adams, Taylor, and Page counties. This coal ranges in thickness from a minimum of 6 inches to a maximum of 3 feet and the average is about 16 inches. Because it is rarely altogether absent, this coal is a valuable stratigraphic marker.

The *Severy shale* forms the base of the Wabaunsee group. In places an underclay is present beneath the Nodaway coal. Black, slaty shale or gray, fossiliferous shale overlies the coal and gray shale with a few limestone nodules forms the base of the formation. The thickness averages about 7 feet.

Shawnee Group

The Shawnee group of Iowa includes, from top to base, the Topeka, Calhoun, Deer Creek, Tecumseh, Lecompton, Kanwaka, and Oread formations. These formations are persistent in the area of this report, although some of the members are not everywhere recognized. Where the members are not definitely recognized, it is very possible they are represented by inconspicuous zones the lithology of which suggests that of the missing member.

Unlike the overlying Wabaunsee and underlying Douglas-Pedee groups, the Shawnee is made up of relatively thick limestones and thinner shale members, which makes this group an important source of highway construction material. The formations are also much better exposed, and the repetition of beds, owing to cyclic sedimentation, is quite evident. The repetition of beds may lead to erroneous correlation. Therefore, each exposure has been studied with precise care in an attempt to find the distinguishing characteristics of the members of each formation.

Topeka Limestone Formation

The Topeka formation, as classified by Condra (1949, p. 20), consists of five limestone members and four shale members, which, from top to base, are the Coal Creek limestone, Holt shale, DuBois limestone, Turner Creek shale, Sheldon limestone, Jones Point shale, Curzon limestone, Iowa Point shale, and Hartford limestone.

The Topeka limestone is variable in thickness, largely as a result of the thinning and thickening of the shale members. It is 31 feet thick north of Thurman, and 29 feet at Red Oak, but thins northward to about 13 feet at Macedonia. Northeast of Greenfield the Topeka limestone reaches a thickness of about 35 feet, although the shale thicknesses vary considerably over short distances.

The *Coal Creek limestone*, the upper unit of the Topeka, is very persistent in lithologic and faunal characteristics. In thickness it generally ranges between 5 and 6 feet. The unit consists of medium- to dark-gray, dense limestones interbedded with thin fossiliferous shales and, in a few localities, contains some dark chert. It is very fossiliferous, containing bryozoans, fusulinids, and many brachiopods, including *Marginifera* and *Composita*.

The *Holt shale* consists of an upper fossiliferous, dark- to light-gray shale with an underlying black fissile shale that changes little in character throughout the area of occurrence. It ranges in thickness from 2 to 3 feet.

The *DuBois limestone*, is generally a single bluish-gray bed, but may be divided into two limestone beds separated by shale. It is very fossiliferous, containing pelecypods, gastropods, brachiopods, and in some cases, *Osagia*. The edges of the fossils weather in relief on the surfaces of joint planes. The thickness seldom exceeds 1 foot. Where present this limestone is distinctive but in some localities it appears to lens out, as in sec. 12, T. 76 N., R. 31 W., Adair County, and in sec. 23, T. 70 N., R. 43 W., Fremont County, where the underlying Turner Creek and overlying Holt shale are in recognizable contact.

The *Turner Creek shale* consists largely of light- to bluish-gray, massive shale that is in part calcareous with some interbedded lime nodules. The lime nodules are generally thin but locally are a foot or more in thickness, as in a quarry in sec. 23, T. 70 N., R. 43 W., Fremont County, and in sec. 12, T. 76 N., R. 31 W., Adair County. This shale ranges in thickness from 3.7 feet in sec. 23, T. 70 N., R. 43 W., Fremont County, to 6.1 feet west of Macedonia in Pottawattamie County. Green dendrites are found in the lower parts of this unit in some localities.

The *Sheldon limestone* is a light-gray, fossiliferous, generally fine-grained complex of two or three beds depending upon the presence of shale separations. Usually at least one of the beds is a massive unit containing brachiopods, pelecypods, and, an important factor in the correlation of the whole unit, abundant *Osagia*. The thickness is 3.2 feet about a mile north of Thurman, Fremont County, 2.1 feet west of Macedonia, Pottawattamie County, and 5.0 feet near Howe, Adair County.

The *Jones Point shale* is a light- to dark-gray, argillaceous to calcareous, fossiliferous shale with some beds of thin fossiliferous limestone. This shale diminishes rapidly in thickness from 7.0 feet near Thurman, to 2.3 feet west of Macedonia, to 0.7 foot near Howe.

The *Curzon limestone* is variable in texture and is often divided into two or three units by thin shale partings. Near Thurman, a fine-grained to sublithographic, brecciated bed that contains soft green shale within the fractures is quite common near the top of this member. North of Thurman, in Mills County, the upper beds are thicker and contain dark-brown chert. Near Howe, it is made up of a light-gray *Osagia*-bearing bed overlying a fine-grained, massive, fossil-bearing limestone. West of Macedonia it is composed of alternating shales and limestones. The thickness varies from about 9 feet near Thurman, to 6 feet near Macedonia, and to about 3 feet near Howe.

The *Iowa Point shale* is generally olive to dark brown in the upper part, grading to greenish gray below. It varies locally from a calcareous shale to a complex of thin limestone beds. The thickness varies greatly within small distances, perhaps because of nearby structures. In sec. 20, T. 70 N., R. 42 W., it is 3.5 feet thick and in sec. 23, T. 70 N., R. 43 W., it is only 1.3 feet thick. West of Macedonia in sec. 21, T. 74 N., R. 40 W., it is about 3 feet and near Howe it is 1.8 feet in a quarry in the SW cor. sec. 1, T. 76 N., R. 31 W., but it is only 0.4 foot thick in another quarry in the center NW¼ sec. 12, T. 76 N., R. 31 W.

The *Hartford limestone* is usually found as one bed of light- to blue-gray, massive limestone, although locally it contains a thin shale bed. The upper portion generally is *Osagia*-bearing, while the sponge *Amblysiphonella* is quite persistent throughout. The Hartford limestone ranges in thickness from 1.0 foot near Thurman, to slightly more than 0.5 foot in a quarry near Howe, to 1.2 feet in another quarry not far distant. The locations of these measurements are the same as those given for the Iowa Point shale. The Hartford limestone is called Wolf River in Nebraska.

Calhoun Shale Formation

The *Calhoun shale* is dark gray to bluish green and is usually quite fossiliferous. Near Thurman the thickness is about 1.5 feet, west of Macedonia, about 3 feet, near Howe about 1 foot, and south of Corning, somewhat more than 3 feet. Although comparatively thin and seemingly insignificant in the area of this report, this shale bears formation rank because it is persistent and everywhere occupies the same position above the algal and oolitic upper beds of the Ervine Creek limestone.

Deer Creek Limestone Formation

The Deer Creek formation is made up of four limestone and three shale members. They are, from top to bottom, the Ervine Creek limestone, the Burroak shale, the Haynies limestone, the Larsh shale, the Rock Bluff limestone, the Oskaloosa shale, and the Ozawkie limestone.

The *Ervine Creek limestone* consists of massive to wavy-bedded, fossiliferous, light-gray limestone, often chert bearing. In almost all exposures, algal and oolitic limestone beds are found near the top. Obese fusulinids are common in the middle parts and sponges, brachiopods (*Composita, Marginifera*, etc.), and corals are common in the lowermost beds. The obese fusulinids, which have been identified as *Triticites beedei*, are, so far as is known, limited to the Ervine Creek, and are very diagnostic. A thickness of 14.7 feet was measured northeast of Thurman, 13 feet in sec. 15, T. 71 N., R. 43 W., Mills County, about 14 feet at Macedonia, 10 feet northeast of Greenfield, and about 14 feet southwest of Corning.

The Ervine Creek is one of the most economically important limestones in the Virgil series and it is quarried rather extensively in Adair, Adams, Fremont, Mills, eastern Pottawattamie, and Taylor counties.

The *Burroak shale* is not everywhere differentiated because of the absence in some areas of the Haynies limestone, which results in the coalescing of the Burroak and Larsh shales. Where the Haynies limestone is present, as near Thurman, the Burroak shale is bluish-gray, argillaceous, and fossiliferous, often containing one or two dark streaks. Near Thurman it is somewhat more than 1 foot thick, while at Macedonia it is very thin. It is not differentiated near Howe.

Haynies limestone is best exposed in outcrops and quarries south of Pacific Junction, where it is a single massive bed, dark gray, argillaceous, and fossiliferous, containing *Ottonosia*, various gastropods, *Juresania*, *Marginifera*, and *Amblysiphonella*. It seldom attains a thickness of more than 1 foot and is generally less. Although the Haynies limestone was not recognized in the old quarries at Macedonia, a more recent opening west of town shows a thin shale section that could be Burroak underlain by a 1-foot bed of limestone that resembles the Haynies. The Haynies is not known in the quarries near Howe.

Condra and Reed (1937, p. 54) state that where the Burroak is thin or absent the Haynies cannot be differentiated from the Ervine Creek. However, the shale that is persistent at the base of the Ervine Creek in Iowa appears to be typical of the Burroak shale. Also, in places where the Burroak and Larsh shales have not been differentiated, the basal limestone of the Ervine Creek does not resemble the Haynies, as Condra and Reed (1937, p. 54) suggest by stating that it is not clearly separated from the Ervine Creek limestone in areas where the Burroak shale is either thin or absent. In the view of the Iowa Geological Survey, it is the Haynies limestone that is not always represented.

The *Larsh shale* in its upper part is gray to olive green, argillaceous, and blocky to thin bedded, while in the lower portion it is black and fissile. No fossils have been reported from this shale. The thickness is approximately 2 feet throughout the entire area where the Burroak and Larsh shales are differentiated.

The *Rock Bluff limestone* is dark blue to gray, dense, and is generally found in one massive bed, but in places weathers into two layers. It is very persistent and ranges from 1.6 feet to slightly more than 2 feet in thickness in most of its occurrences but is slightly thinner near Howe and Macedonia.

Although the *Oskaloosa shale* has not been recognized in the greater part of this area, the greenish-gray, blocky, 6-foot interval in an old quarry south of Pacific Junction (E½NW¼NW¼ sec. 15, T. 71 N., R. 43 W.) is here identified as this member.

Similarly, the *Ozawkie limestone* has been identified only in the quarry mentioned above. Here it is 0.4 foot of light-gray, fine-grained limestone overlying 1.5 feet of dark-gray arenaceous shale which in turn overlies a buff, sandy limestone bed about 1 foot thick. Where not recognized the two members mentioned above may be included in the upper part of the Tecumseh shale formation.

Tecumseh Shale Formation

The Tecumseh shale formation is made up of two shale members and a limestone member in some places, but they are not differentiated at all exposures. Where the two lower members of the Deer Creek cannot be differentiated they are often included in the Tecumseh. The Tecumseh consists, from top to bottom, of the Rakes Creek shale, the Ost limestone, and the Kenosha shale.

The *Rakes Creek shale* has been identified in an old quarry in sec. 15, T. 71 N., R. 43 W., Mills County. Here it consists of a greenish-gray, sandy shale with a thin limestone stringer near the base. The thickness is somewhat more than 7 feet.

The *Ost limestone* was also recognized near Thurman by Condra and Reed (1937, p. 21). They describe it as being in two limestone beds separated by a greenish-gray, argillaceous shale that is about 1.5 feet thick. The upper limestone bed is light gray, with many fossil fragments and *Osagia*, and is little more than 1 foot thick. The lowermost bed is brownish gray and massive, with a thickness of about 2.5 feet.

The *Kenosha shale* was described as being bluish and argillaceous, with *Crurithyris* near the base. The thickness was given as 6.5 feet at the foregoing location.

Northeast of Greenfield the members of the Tecumseh shale have not been differentiated. It is bluish gray, argillaceous, and usually has a nodular limestone near the middle. This limestone may be the equivalent of the Ost but no definite correlation has been made. The thickness of the Tecumseh is slightly more than 10 feet, which is less than that near Thurman.

Lecompton Limestone Formation

The Lecompton limestone formation consists of four limestone and three shale members, which are, from the top down, the Avoca limestone, the King Hill shale, the Beil limestone, the Queen Hill shale, the Big Springs limestone, the Doniphan shale, and at the bottom, the Spring Branch limestone. The thickness varies from about 34 feet north of Thurman, to about 30 feet at Stennett, to 11 feet north and east of Greenfield.

The *Avoca limestone* consists of two thin, fossiliferous, dark- to bluish-gray limestones separated by a dark-gray, fossiliferous shale. South of Pacific Junction it is about 2 feet thick, but it could not be differentiated northeast and east of Greenfield.

The *King Hill shale* is dark to greenish gray and massive, and contains seams of nodular limestone. It is about 7.5 feet thick south of Pacific Junction and about 6 feet thick northeast of Stennett.

The *Beil limestone* is one of the most readily identifiable members of the Pennsylvanian. It consists of two limestones separated by shale. The upper limestone is light gray, dense, massive, and often contains abundant *Osagia*. The shale is buff and very calcareous, grading into the limestones above and below, and carries a profusion of the coral *Campophyllum torquium*, which is very typical of this member. The lower limestone varies from gray to green in color and in some exposures occurs as two beds, the lowermost being somewhat nodular. The entire lower limestone is very fossiliferous and argillaceous. In the Missouri River bluff exposures north and south of Pacific Junction, the Beil is almost 6 feet thick, while near Stennett the thickness is about 3 feet. It has not been recognized farther to the northeast.

The *Queen Hill shale* is dark to greenish gray and argillaceous in the upper part and black and fissile below. In sec. 29, T. 73 N., R. 43 W., Mills County, the thickness is about 4.5 feet, and about 4 feet near Stennett. It has not been identified farther to the northeast.

The *Big Springs limestone* is generally in one massive, light- to dark-gray, argillaceous bed. In some exposures it is very fossiliferous, while at others it is quite barren, containing only *Osagia*. Near Folsom, in the SW¼ sec. 29, T. 73 N., R. 43 W., the Big Springs is about 1 foot thick, and near Lewis and Stennett it is about 1.5 feet thick, although this thickness is not consistent.

The *Doniphan shale* is dark gray to buff in color and is very calcareous, with beds of fossiliferous, nodular limestone common. The brachiopod *Linoproductus* is generally very abundant within this shale. The thickness is variable, being 5 to 6 feet at Folsom, and 3 to 4 feet at Stennett and in the area between Lewis and Griswold.

The *Spring Branch limestone* is made up of massive, gray, cherty limestone separated into two or three beds by thin shales. Near the top a well-developed algal zone containing *Osagia* is quite persistent, while in some exposures, many fusulinids are found in the middle and lower parts. The chert in the Spring Branch is usually very dark gray to rusty brown, in contrast to the black chert found in the Plattsmouth limestone of the Oread formation. Also, the characteristic "rice grain" fusulinid that is so profuse in the Plattsmouth chert is much less common in the chert of the Spring Branch. The thickness of this member varies considerably, being about 5 feet thick at Folsom, about 10 feet at Lewis, and 7 feet north of Griswold and at Stennett.

Kanwaka Shale Formation

At the type locality in Kansas, the Kanwaka consists of two shale members separated by a limestone member. In Iowa, where it is thin, the limestone member is not well defined and is undifferentiated. Between Lewis and Griswold the Kanwaka is a gray to buff, fossiliferous shale commonly containing nodular limestone beds. The *Clay Creek limestone*, the middle member of the Kanwaka, is not recognized, and the Kereford limestone, upper member of the Oread, does not appear to be present; therefore, this shale interval probably includes equivalents of the Kereford and Heumader intervals of the Oread. The thickness assigned to the Kanwaka here is somewhat more than 10 feet.

Near Stennett the Kereford limstone has been recognized so it is possible here to distinguish between the Kanwaka and upper Oread formations, although the Kanwaka members remain undifferentiated. The Kanwaka consists of gray to brown shale with calcareous nodules and is very fossiliferous. The thickness varies from 6.5 to 7 feet. East of Greenfield the Kereford member appears to be missing, as near Lewis, so the Kanwaka at these localities probably includes the equivalents of the Kereford-Heumader intervals. A thin coal smut is commonly found near the top of the Kanwaka in this area. The thickness assigned to the Kanwaka here is about 10 feet.

Oread Limestone Formation

The Oread formation consists of four limestone and three shale members. In descending order they are the Kereford limestone, Heumader shale, Plattsmouth limestone, Heebner shale, Leavenworth limestone, Snyderville shale, and Toronto limestone. As previously stated, the Kereford limestone is missing in some localities; consequently, the Kanwaka and Heumader shales are in contact. Where the Toronto limestone is missing the base of the Oread is indeterminate and the Snyderville shale cannot be separated from the underlying Douglas group. As a result of these conditions the thicknesses that can be definitely assigned to the Oread formation are variable. Near Folsom and Stennett thicknesses of 42 and 52 feet, respectively, have been measured.

The *Kereford limestone* is generally light to medium gray, fine grained and dense, and occurs as one massive bed. In a quarry just north of Red Oak it is a 2-foot massive, finely oolitic bed with *Osagia* in the upper part and fusulinids throughout. Near Grant, where the thickness is only 1.4 feet, the oolitic characteristic is missing but *Osagia* are present. Fossils are not generally abundant but in some places brachiopods, gastropods, and crinoid fragments are common.

Next, beneath the Kereford limestone, is the *Heumader shale.* The character and thickness change considerably over short distances. The color ranges from olive green to brown and black. At some places there are black carbonaceous zones and black subfissile beds, although in general the shale structure tends to be blocky. The fossil content is also variable with many brachiopods and bryozoans at some exposures while others are almost barren. The average thickness is about 3 feet.

The *Plattsmouth limestone,* the main ledge of the Oread, includes somewhat argillaceous limestone beds that, in part, grade northward and eastward to a very calcareous shale. This member is typically light gray in color and occurs in thin, wavy, irregular beds of finely crystalline to sublithographic limestone separated by thin shale partings. Black chert, locally containing white fusulinids, occurs at practically all localities as an outstanding characteristic of this member. As exposed at quarries in Montgomery County, the Plattsmouth includes a thin upper cherty limestone, a thick section of shaly limestone containing very abundant fusulinids, and a lower unit having less shale and fewer fusulinids. The thickness is about 20 feet. In Cass County the thickness is about 13 feet and includes, in descending order, about 2 feet of thin-bedded limestone; 3 to 4 feet of fusulinid-bearing argillaceous limestone; 4 feet of very calcareous olive shale weathering buff and containing very abundant *Chonetes, Echinoconchus,* *Juresania, Neospirifer, Composita,* large crinoid columnals, and large ramose bryozoans; and 3 feet of argillaceous to sublithographic cherty fossiliferous limestone. In Madison and Adair counties the member includes 4 feet of *Osagia*-bearing, wavy-bedded, sublithographic limestone, 2 to 3 feet of argillaceous fusulinid limestone, 7 to 8 feet of very fossiliferous calcareous shale, 3 to 4 feet of alternating, dark-blue, cherty limestone and platy shale, and 1.5 feet of massive limestone containing *Ottonosia* at the base.

The upper fusulinid zone is characteristic of the Plattsmouth throughout these counties and together with the distinctive lithology of the underlying Heebner and Leavenworth members permits identification of the Plattsmouth even where the middle portion is largely argillaceous. In subsurface studies the member is recognized by the abundance of the fusulinids and its position just above the thick shaly and silty Lawrence-Weston interval. At isolated exposures the member is distinguished from generally similar limestone members of other formations by the great abundance of fusulinids in the upper part, the distinctive black chert containing white fusulinids, a very fossiliferous middle shale containing large ramose bryozoans, and the characteristic sequence of beds. The abundant fusulinid is of the *Triticites secalicus* type that can be distinguished from other abundant fusulinids in the Shawnee group of Iowa and adjacent Nebraska by its long moderately slender form. The caninoid coral, *Pseudozophrentoides verticellatum,* that occurs abundantly in the middle of this member in southeastern Nebraska has not been observed in Iowa.

The *Heebner shale* characteristically is composed of olive clay shale split near the base by a black fissile shale. The thickness ranges from about 2.5 feet in Cass County to 3 feet in Adair County to about 5 feet in Montgomery County. Fossils are observed rarely, although conodonts occur in the black shale and, locally, brachiopods occur at the top. The Heebner shale persists wherever this interval is exposed or penetrated by wells. It is identified by the occurrence of black shale and by the association in the stratigraphic section.

The *Leavenworth limestone* is a single massive bed of limestone and occurs beneath the Heebner shale at practically all localities where this section is observed. The limestone is dark to medium bluish gray, weathering to light gray, dense to finely fragmental in texture, and breaks into rectangular fragments. The thickness is very constant, varying between 1.1 to 1.3 feet at exposures in Madison, Adair, and Cass counties. The Leavenworth limestone has been encountered in cores in Montgomery County, and commonly can be identified in samples from wells in areas where this interval occurs. The limestone contains embedded brachiopods and crinoidal fragments, but is chiefly characterized by abundant large *Ottonosia.* This unit is practically identical in lithology, thickness, and organic remains to the

Hartford limestone member of the Topeka limestone formation, but the nature of the adjacent strata permits reliable differentiation.

The *Snyderville shale*, lying below the Leavenworth member, is poorly exposed and the thin limestone bed occurring at the base is difficult to recognize in well cuttings. In Adair County about 8 feet of shale, slightly silty and red at the base, occurs between the Leavenworth limestone and a limestone tentatively called the Toronto. This shale is gray to black in the upper portion and contains *Derbyia, Chonetes,* and productids near the top. About 8.5 feet of Snyderville shale seems to be present in Montgomery County although it is not exposed. Where the underlying limestone is lacking, the base of this member is indeterminate.

Nodular sandy limestone occurring about 8 feet beneath the Leavenworth limestone in Adair County is tentatively identified as the *Toronto limestone*. A similar limestone bed in Cass and Montgomery counties is known from well records. Data are not available, however, to preclude the possibility that this bed represents the Amazonia, Haskell, or Iatan limestones of the Lawrence-Stranger formations.

The bed called Toronto in Kansas is the same as that known as Weepingwater in Nebraska (Condra, 1948, p. 26). Although Weepingwater is a prior term, brief examination of the section at the type locality suggests that the limestone there may not be the same as that called Weepingwater elsewhere.

The Douglas group includes the lowermost rocks of the Virgil series. Because the boundary marking the base of this group and the top of the Pedee group of the Missouri series is very obscure in Iowa, the association of these two groups is discussed in the following paragraphs pertaining to the Missouri series.

Missouri Series

Douglas-Pedee Groups

In Iowa it is not possible to locate accurately the unconformity separating the Pedee group of the Missouri series from the Douglas group of the Virgil series. If a break in sedimentation does exist it may be above, within, or below the sediments lying between the Oread limestone of the Shawnee group and the Stanton limestone of the Lansing group. The individual units in this interval are poorly defined and for this reason the entire interval is considered as a unit and is referred to the Douglas-Pedee group. In the western part of the area under discussion it has been possible to recognize locally in subsurface the Iatan limestone, which is the uppermost formation of the Pedee group, and the Stranger shale, the lowermost formation of the Douglas group. However, it is rarely possible to differentiate these formations in Iowa and the entire interval is called the Lawrence-Weston shale.

The Douglas-Pedee group in Iowa is exposed only in western Madison and eastern Adair counties. It is composed of gray silty shales and siltstone with a calcareous zone near the center, and a maroon shale near the top. The shales are usually micaceous and thinly platy. The total thickness of this group is about 18 feet where seen in outcrop but in subsurface thicknesses up to 80 feet have been assigned to it.

Lansing Group

The Lansing group as it exists in the area of this report is composed of two argillaceous, thin-bedded limestones and an intervening red and gray shale which are, in descending order, the Stanton limestone, the Vilas shale, and the Plattsburg limestone.

Stanton Limestone Formation

Exposures of the Stanton limestone are found only in western Madison, eastern Adair, and southern Ringgold counties. In Ringgold County the Stanton consists of 13 feet of light- to dark-gray, thinly bedded, argillaceous limestone containing shale partings and many white brachiopod and gastropod sections. In Adair and Madison counties this unit is only 8 feet thick and commonly is a sequence of three gray and black nodular limestones separated by shales. The upper shale is gray and fossiliferous with brachiopod and crinoid fragments. The lower shale is black and carbonaceous.

Vilas Shale Formation

The Vilas shale is seen at the surface only in western Madison and eastern Adair counties, where it is a 12-foot sequence of gray, unfossiliferous shale overlying a maroon shale. It closely resembles the Bonner Springs shale of the Kansas City group in consisting of a red unit and a gray unit, but the order of the colors is reversed.

Plattsburg Limestone Formation

The Plattsburg limestone is exposed only in western Madison County where it is a highly fossiliferous, gray to maroon, nodular, fine-grained, algal limestone with interbedded red and green shale. At the outcrop it has a thickness of about 4 feet.

Kansas City Group

This group of rocks consists of limestones and shales extending from the top of the Bonner Springs shale to the base of the Hertha limestone. An offshore fauna persists throughout this group with little change and the various limestones must be recognized in the field largely by the sequence of their beds and by their relation to the shales above and below.

Bonner Springs Shale Formation

The Bonner Springs is the uppermost formation of the Kansas City group and consists of a gray to black shale overlain by a maroon shale that very often contains limestone nodules. It resembles the Vilas shale of the Lansing group in most respects but the order of color is reversed. The thickness in most exposures is about 10 feet.

Wyandotte Limestone Formation

The formation is made up, from top to bottom, of the Farley limestone, the Island Creek shale, the Argentine limestone, the Quindaro shale, and the Frisbie limestone.

The *Farley limestone* is comprised of two or three gray, argillaceous limestone beds separated by thin shales and varies in thickness considerably. In a quarry in sec. 5, T. 75 N., R. 29 W., Madison County, the thickness is only slightly more than 2 feet; whereas in a quarry in sec. 4, T. 71 N., R. 28 W., Union County, it is more than 7 feet thick.

Although usually poorly exposed, the *Island Creek shale* at the quarry in sec. 5, T. 75 N., R. 29 W., Madison County, is a gray, platy shale with limestone nodules near the top. Here it is fossiliferous with abundant *Chonetes, Crurithyris, Derbyia,* and other brachiopods, and has a typical thickness of 4.5 feet.

The *Argentine limestone* in Madison County is an 18-foot sequence of two or three massive limestones separated by dark-gray to buff, calcareous shales. It is fossiliferous throughout with *Osagia* and brachiopods; chert nodules are abundant in the upper and lower beds. In Union County it is not fully exposed but, where seen, it has a thickness of about 12 feet and closely resembles the Argentine in Madison County except that the shale partings are more numerous.

The top of the *Quindaro shale* is poorly defined. The Argentine-Quindaro contact is arbitrarily placed where the limestone is subordinate and shale dominates the section. As seen in Madison and Union counties, the Quindaro shale consists of a black, fissile shale overlain by a gray to olive-gray, fossiliferous shale, and underlain by a gray shale. This member is about 3.7 feet thick. Although Condra and Upp (1933, p. 31) did not recognize the Quindaro in their Middle River traverse in Iowa it is recognized here.

The *Frisbie limestone* is a blue, dense, locally fossiliferous limestone in an exposure in the NE¼SE¼NE¼ sec. 9, T. 75 N., R. 28 W., Madison County. Its thickness is only 0.5 foot.

Lane Shale Formation

The Lane shale is recognized in Madison County as an olive to dark-gray, fossiliferous shale containing limestone lenses and at some localities has a thin bed of maroon and green shale at the base. In Union County the Lane is poorly exposed, but where seen it is a greenish-gray to yellow, calcareous shale with lenses of gray fossiliferous shale. In Madison County the thickness is about 7 feet. In Union County the Lane is not fully exposed at any one location but the total thickness is probably about 10 feet.

Iola Limestone Formation

This formation is made up of two limestones and one shale. In descending order they are the Raytown limestone, the Muncie Creek shale, and the Paola limestone.

The *Raytown limestone*, as recognized in the Middle River section in Madison County, is composed of a 9-foot sequence of light-gray, wavy-bedded, fossiliferous limestones separated into two or three units by thin shales. This unit differs from the Raytown of Condra and Reed (1933, p. 10). They describe it as several thin limestone beds, all of which are quite fossiliferous, and report a thickness of about 3 feet.

The *Muncie Creek shale*, as found in Madison and Union counties, is composed of two contrasting shale beds. The upper bed is dark gray to green and has a thickness of about 1 foot. The lower bed is a hard, platy, black shale containing conodonts. The thickness of this bed is 1.7 feet.

The *Paola limestone* is a light-gray, sublithographic, massive limestone with shale partings. It is fossiliferous containing *Dictyoclostus, Composita*, and *Marginifera*, and is about 1 foot thick.

Chanute Shale Formation

The Chanute formation is made up of a greenish-gray, fossiliferous upper shale bed of varying thickness separated from a lower greenish-gray shale by a thin coal smut. The total thickness is about 5 feet.

Drum Limestone Formation

The Drum formation of Iowa is a single conglomeratic, oolitic limestone bed characterized by tiny *Triticites*. It has the same lithologic and fossiliferous characteristics throughout the area of this report, but it ranges in thickness from 6 feet in Madison County to 14 feet in Pottawattamie County.

Quivira Shale Formation

As recognized in a quarry near Crescent, Pottawattamie County, the Quivira formation is a brownish, calcareous, fossiliferous shale containing thin coquina limestone seams. The fossils are *Linoproductus, Derbyia, Juresania*, and *Neospirifer*, along with ramose bryozoans. The thickness here is about 6 feet. In Madison County the Quivira has a thickness of slightly more than 1 foot and is a dark-gray slaty shale containing *Lingula*.

Westerville Limestone Formation

The Westerville limestone in Madison County is a light-gray, massive limestone containing *Osagia* and is about 2 feet thick. In Pottawattamie County the thickness is about 10 feet, and the unit is made up of several beds separated by thin shale partings. The upper part is generally oolitic and contains small fusulinids and the lower part is argillaceous and sparsely fossiliferous.

Cherryvale Shale Formation

The Cherryvale formation contains in descending order the Wea shale, the Block limestone, and the Fontana shale. These members have not been differentiated in Madison County, but they have been tentatively identified at the Crescent quarry where they have the following characteristics.

The *Wea shale* consists of two dark-gray shale units that are separated by hard, black fissile shale that contains gray laminations. The total thickness is about 3 feet.

The *Block limestone* is made up of gray limestone nodules enclosed in a gray shale matrix. The thickness of this unit is only 0.5 foot.

The *Fontana shale* is gray, calcareous, silty, and somewhat micaceous. The entire unit is 10 feet thick; the lower 9-foot interval is massive and blocky and the upper 1 foot is thin bedded.

The Cherryvale formation in Madison County is comprised of thinly bedded dark-gray shale with several thin beds of dense dark blue-gray fossiliferous limestone. *Derbyia* and *Chonetes* are very abundant, the latter occurring in such large numbers as to form thin coquina-like zones at certain horizons. The thickness is about 9 feet.

Dennis Limestone Formation

The Dennis is made up of the Winterset limestone, the Stark shale, and the Canville limestone. The Canville is usually missing in the Iowa section.

The *Winterset limestone*, at the type section, is composed of a massive upper unit commonly containing brown chert nodules changing to an easily quarried, thin-bedded basal section. A shaly zone 4 feet from the top has an abundance of the fusulinid *Triticites irregularis* which serves to distinguish this member from the lower lying, largely fusulinid-free, Bethany Falls limestone. The entire unit is about 12 feet thick.

The *Stark shale*, which underlies the Winterset limestone, is dark gray and fossiliferous at the top changing to a black fissile shale at the base. It varies in thickness both locally and regionally; sections in Madison County have a thickness from 1.8 to 2.9 feet and in cores from Pottawattamie County it is 5.0 feet thick.

The *Canville limestone*, where it is present in the area of this report, is a dark-gray argillaceous, fine-grained limestone containing *Dictyoclostus*. In a quarry just east of Logan this member has a thickness slightly in excess of 2 feet.

Galesburg Shale Formation

The Galesburg thins greatly from Madison County to Pottawattamie and Harrison counties. A good exposure of the Galesburg may be seen in the NE¼ sec. 5, T. 75 N., R. 27 W., Madison County, where it is a light-gray to buff shale containing lime concretions and is about 9 feet thick. At Logan the Galesburg is a dark olive green and is only slightly more than 1 foot thick.

Swope Limestone Formation

The Swope formation consists of the following three members discussed in descending order: the Bethany Falls limestone, the Hushpuckney shale, and the Middle Creek limestone.

The *Bethany Falls limestone* is composed of thick limestone beds containing thin shale partings which are usually quite calcareous and fossiliferous. The uppermost beds are generally algal and occasionally oolitic, but have a fine-grained texture in the basal sections. The entire member has an average thickness of approximately 16 feet.

The *Hushpuckney shale* closely resembles the Stark shale of the Dennis formation in being gray and fossiliferous above and black and fissile at the base. However, it is possible to differentiate these two members by the presence or absence of a limestone unit at their base. The Middle Creek limestone is persistent at the base of the Swope formation and has a distinctive lithology, whereas the Canville is very seldom present at the base of the Dennis formation.

The *Middle Creek limestone* is thin, blue gray to black, dense, and fine grained. It is generally well jointed, weathers into small rectangular blocks, and is not known to exceed 1 foot in thickness.

Ladore Shale Formation

The Ladore shale is not exposed in the area of this report but in Madison County near Winterset it is a 14.5-foot complex of shales separated by siltstones containing limestone nodules. The upper shales have a greenish cast and the basal unit is red and silty. Cores from Pottawattamie County show this shale to have the same lithology as in Madison County but to be only 8 feet thick.

Hertha Limestone Formation

The Hertha is the basal formation of the Kansas City Group. In an outcrop in Madison County it is typically composed of three limestones with one thin shale separating the lower two. The middle limestone bed is fragmental and fossiliferous, containing *Myalina*, *Osagia*, and *Composita*. The upper and lower limestone beds are argillaceous and lenticular.

The thickness in Madison County is only about 4 feet while cores from the Council Bluffs area show a thickness of about 9 feet.

Pleasanton Group

The Pleasanton group of Iowa is composed primarily of shales with some sandstone, thin limestones, and minor amounts of coal. The upper boundary of this group is at the base of the Hertha limestone and the lower boundary is the unconformity that marks the break in sedimentation between the Missouri and Des Moines series. The lower boundary is indefinite in the area of this report; but in Appanoose County, Iowa, Cline (1941, p. 70) places the unconformity at the base of the Chariton conglomerate which is described as a matrix of reddish ferruginous sandstone in which are embedded small waterworn pebbles and brecciated blocks of gray, drab, and white limestone. A conglomerate of almost identical lithology is exposed in the center SW¼ sec. 17, T. 74 N., R. 26 W., Madison County, but the associated overlying beds are not exposed here. Although Cline was in doubt as to the exact position of this conglomerate, he felt that it occurred somewhat above the Exline, a thin limestone recognized at several places in Madison County. However, there is no marked unconformity above the Exline and because the question of the exact location of the base of this group is one of academic importance only, the Pleasanton is here considered to extend to the top of the Cooper Creek limestone. This is made up of fragments of brecciated, white limestone in a grayish-green argillaceous matrix.

The Pleasanton group has not been subdivided into formations, although certain distinctive units such as the Exline limestone and Ovid coal are recognized. Because the top of the Des Moines series is an erosional surface, the thickness of the Pleasanton varies considerably. As exposed in a ravine in the N½SE¼ sec. 27, T. 76 N., R. 27 W., Madison County, a 19-foot section occurring between the base of the Hertha and the top of the Cooper Creek limestone makes up the Pleasanton. The upper 10.6 feet is a medium- to dark-gray, clayey shale that contains abundant *Chonetina*. Below this shale is a 0.5-foot bluish-gray limestone overlying 2.8 feet of olive to dark-gray shale that is platy and blocky, and contains many very thin beds of nodular, dense, argillaceous limestone. Next below is the Exline limestone, which is medium gray, dense and massive, contains *Marginifera, Composita,* and is 1.2 feet thick. The lower 3.7 feet are shales varying from black to grayish green. About 1 foot above the base is a thin-bedded, impure coal that is tentatively identified as the Ovid coal.

Drill cuttings from wells drilled in the area under discussion show a thick sequence of shales with some sandstones that usually cannot be differentiated beneath the Hertha limestone. For the purposes of this report they are of no economic interest.

Des Moines Series

Marmaton Group

The sequence of thick shales and sandstones with thin limestones and coals, extending from the base of the Blackjack Creek limestone to the top of the Cooper Creek limestone, is designated the Marmaton group of the Des Moines series. The classification used here is that agreed upon by the

State Geological Surveys in the northern Mid-Continent region (Moore, 1948, p. 2,027-2,028). Although the Iowa Survey is not entirely in agreement on this classification, it is used here for the convenience of those who may be familiar with the grouping as used in the other states of this region.

The Marmaton group includes in descending order the Lenapah formation, the Nowata formation, the Altamont formation, the Bandera formation, the Pawnee formation, the Labette formation, and the Fort Scott formation.

Lenapah Limestone Formation

This formation is represented in Iowa by the *Cooper Creek limestone* (Sni Mills of Missouri). It is characteristically white to light gray and has a brecciated appearance with dense limestone fragments in a light grayish-green, argillaceous matrix. In Madison County the Cooper Creek ranges from 3 to 5 feet in thickness, and in Appanoose County to the southeast it reaches a maximum thickness of about 7 feet. Cline (1941, p. 65) correlates this unit with the ledge known to the miners of Appanoose County as the "floating rock" (Bain, 1896, p. 382).

Nowata Shale Formation

The thick sequence of shales and sandstones beneath the Cooper Creek limestone and above the Worland limestone is here called the Nowata, although this may include part of the overlying Lenapah formation as recognized in Missouri. However, in Iowa there is no obvious break in sedimentation that would justify differentiation.

In the N½SE¼ sec. 27, T. 76 N., R. 27 W., Madison County, an 11-foot section immediately below the Cooper Creek is covered, but below the covered interval 33 feet of grayish-brown sandstone containing traces of purple lenticular beds is exposed. Another exposure of this interval in a road cut in the center of the N½NE¼ sec. 5, T. 75 N., R. 27 W., shows 25 feet of silty red shale with green zones. The underlying Worland is exposed in the NW¼NE¼ sec. 26, T. 75 N., R. 26 W., where it is overlain by about 20 feet of siltstone, sandstone, and shale. From this evidence it is assumed that the Nowata shale is about 50 feet thick in Madison County.

Altamont Limestone Formation

The Altamont is made up of the Worland limestone, the Lake Neosho shale and the Amoret limestone. This unit was not previously recognized as a formation in Iowa but as a result of studies made in Madison County it now appears to be a valid formation for this area.

The uppermost member, the *Worland limestone*, is composed of thin wavy beds separated by green-gray fossiliferous shale seams, and occasional pockets of green shale. In Madison County it is 2.5 feet thick, but it thickens to 6 feet in southern Appanoose County where it is quarried for road metal.

Below the Worland is the *Lake Neosho shale.* The upper part of the shale is dark gray and fossiliferous. In Madison County this horizon contains *Mesolobus,* stratigraphically the highest known occurrence in this part of Iowa. Beneath this shale is a persistent coal streak underlain by a clay that is gray above and red below. The total thickness is about 6 feet.

The basal member of the Altamont is the *Amoret limestone,* represented in Madison County by a thin layer of fresh-water limestone nodules in a matrix or red underclay that is continuous with the shale member above. The Amoret is not present farther south in Iowa, but as here described is almost identical to that described in northern Missouri. The maximum thickness exposed in Madison County is 10 inches.

Bandera Shale Formation

The Bandera formation comprises the rocks between the Altamont and the Pawnee formations. It has not been subdivided into members, and where the Amoret member of the overlying Altamont formation is missing it is not possible to differentiate these three formations.

The Bandera is well exposed below the Amoret and above the Coal City limestones in a ravine in the NW¼ sec. 26, T. 75 N., R. 26 W., Madison County. Here it consists of 10 feet of red and green mottled clay and shale at the top followed by 15 feet of green, micaceous, cross-bedded sandstone and siltstone below.

Pawnee Limestone Formation

The Pawnee is made up of the Coal City limestone, the Mine Creek shale, the Myrick Station limestone, and the Anna shale, in descending order.

The *Coal City limestone* is named for exposures in the bluff of the Chariton River near Coal City in southeastern Appanoose County (Cline, 1941, p. 64). There it is a light blue-gray, hard, finely crystalline limestone in two massive beds. It is fossiliferous with *Chaetetes,* fusulinids, and brachiopods abundant. Locally very large crinoid stems are so abundant as to form a coquinoid limestone. This member ranges from 2 to 2.5 feet in thickness in Appanoose County. In Madison County the Coal City is gray and fine-grained and contains many fusulinids in a thin slabby zone at the top. The thickness is only 1 foot.

Next below the Coal City member is the *Mine Creek shale.* In Appanoose County this member is composed of shale and clay that varies from light to dark blue-gray in color and has a persistent carbonaceous streak or coal smut about 3 feet from the top. In Madison County this coal smut is only about 4 inches from the top and underlies a gray, fossiliferous shale. Beneath the coal smut is a gray shale resting on a 2-foot bed of gray, sandy limestone that is locally conglomeratic. Underlying the limestone is a sequence of siltstone, sandstone, and shale. The aggregate thickness of this member is about 8 feet in Appanoose County while in Madison County it is 21 feet.

The *Myrick Station limestone* also changes considerably from Appanoose to Madison County. In Appanoose County it is made up of two limestone beds separated by a 1-foot bed of fossiliferous shale that is greenish gray above and brown to black below. The upper limestone is light gray, hard, nodular, and earthy. It varies from 1 to 9 inches in thickness. The lower bed is blue-gray, finely crystalline, and dense, and is about 2 feet thick. In Madison County this member has an upper bed of light-gray, dense, argillaceous limestone that grades laterally into the overlying shale and has a maximum thickness of 0.3 foot. The lower bed closely resembles the Myrick Station of Appanoose County in that it is bluish gray, dense, and massive. This bed is 0.8 foot thick.

The lower member of the Pawnee formation is the *Anna shale*. There is little change in character of this member in Iowa. As seen in a stream-cut exposure in the NW¼ sec. 13, T. 75 N., R. 26 W., Madison County, the upper bed is olive shale that weathers buff and contains a hash of fossil fragments. Below this is a dark-gray platy shale with light-gray fucoidal markings. The lower shales are dark gray to black, hard, and slaty with thin gray lime concretions and bands in the upper part, and are soft and clayey in the lower part. The total thickness of the Anna member is 2.2 feet at this location.

Labette Shale Formation

The Labette formation comprises the rocks between the Pawnee and Fort Scott formations. It has not been subdivided into members but two distinctive units have been named. These are the *Mystic coal*, which marks the top of the formation, and the *Marshall coal*.

The characteristics of the Labette change markedly from the southeast in Appanoose County to the northwest in Madison County. As seen in Appanoose County only the Mystic coal with a thin underclay is present. Here the coal is in three seams with a total thickness of 3 feet separated by very thin shales. The underclay is green gray above and rusty below, and contains abundant root marks. The total thickness of the Labette here is 6 feet. The Mystic coal has been extensively mined in this area.

In Madison County the Mystic coal occurs in one impure seam about 6 inches thick. This is underlain by a medium-gray, clayey shale that contains many fossil plant fragments and a very thin irregular coal seam which is probably the northward extension of a thicker coal seam in Appanoose County. The thickness of the shale is 2.9 feet.

In Madison, Dallas, and Guthrie counties the Labette contains a 1.4-foot bed of greenish-gray siltstone that is not present in Appanoose County.

Underlying the siltstone is a medium- to dark-gray, platy shale about 2 feet thick that overlies the Marshall coal. In Madison County this coal is impure with shale and pyrite partings, and is about 8 inches thick. Underlying the coal is about 7 feet of gray, clayey shale. The total thickness of the Labette in Madison County is 15 feet.

Fort Scott Limestone Formation

The Fort Scott is the lowermost formation of the Marmaton group, and it is made up of the rocks extending from the base of the Labette to the top of the Cherokee group. The Fort Scott has not been completely differentiated in Iowa but in descending order the following members have been identified: Higginsville limestone, Houx limestone, Summit coal, and Blackjack Creek limestone. The characteristics appear to change but little between Appanoose and Madison counties.

The *Higginsville limestone* is medium gray, finely crystalline, and massive. It is somewhat more fossiliferous to the southeast than in Madison County. It has a thickness of 2 feet in Appanoose County, and 1 foot in Madison County.

A shale section underlies the Higginsville, but in the exposures in Appanoose County a carbonaceous zone is found immediately below the limestone; whereas in Madison County this horizon is a reddish-brown shale containing large ostracods. The shale interval between the Higginsville and Houx limestones is about 15 feet thick in Appanoose and about 7 feet thick in Madison County.

The *Houx limestone* is persistent and maintains its position from Madison County southward into Missouri. It is light to dark gray, characteristically earthy, and very fossiliferous, with *Composita*, *Derbyia*, and *Chonetes*. The thickness varies from 8 inches in the south to 4 inches in Madison County. Underlying the Houx is a shale that varies greatly in thickness with the greater development in the south.

The *Summit coal* occurs in the shale underlying the Houx limestone. In Appanoose County this coal is represented by a black shale that is canneloid at the base, but in the Madison County sections the Summit is missing. The shale interval between the Houx and Blackjack Creek limestone is about 10 feet in Appanoose County but thins to about 2 feet in Madison County.

The *Blackjack Creek limestone* forms the base of the Fort Scott formation. It is one of the thickest and most persistent limestones in the Des Moines series in Iowa. It is light gray to light blue-gray, weathers brown to buff and varies from massive to slabby structure. In the south, where the overlying shale is more completely developed, this limestone is only 1 foot thick but to the north it increases to 4 feet.

It can readily be seen from the foregoing discussion that the Marmaton group contains no limestone of sufficient thickness to be of present-day economic importance.

Cherokee Group

The section from the base of the Marmaton group to the top of the Mississippian system is designated as the Cherokee group of the Des Moines series. Although this may include a part of either the Atoka or Morrow series, the Iowa Geological Survey has not differentiated them. Other states of the northern Mid-Continent region (Kansas, Missouri, and Oklahoma) have further divided the Cherokee group into the Cabaniss-Krebs subgroups.

Within the Cherokee group dark carbonaceous shales, clays, and siltstones predominate, with sandstones secondary in importance. This group also contains a number of economically important coal units. Limestone is not important, although there are minor amounts of thin fresh-water and marine limestone present. The rocks of this group were deposited in the cyclic sequence that is typical of the Pennsylvanian of this region. However, the sequence is much less complex than is found in the cyclothems of younger groups. In contrast to the other cyclothems, where marine deposits are predominant, cyclothems of the Cherokee group generally have equal or greater amounts of continental deposits, and the marine phase is comparatively less well developed.

The most readily traceable and continuous lithologic units of the Cherokee cyclothems are the coal beds and horizons. For this reason formations commonly include strata from the top of one coal bed to the top of the next higher coal bed, and the name of the coal is generally applied to the formation. Because coals are the most important units of this group, and also because the rocks are not exposed anywhere in the area of this report, it is sufficient here to name the major coals that have been recognized in southeastern Iowa, where rocks of the Cherokee group are well exposed. These units are, in descending order, the Mulky coal, Bedford coal, Bevier coal, Ardmore limestone, and Whitebreast coal. Other less important coal beds occur in the Cherokee group but are seldom differentiated. The Ardmore limestone is included in this list because it is an exceptionally widespread unit that maintains approximately the same characteristics over an area reaching from Oklahoma to southern Iowa. It consists of two thin gray limestones separated by a thinly laminated, dark-gray shale. The limestones contain an abundance of *Marginifera.* The Ardmore limestone of Iowa is the Verdigris limestone of Kansas, Missouri, and Oklahoma, and may be the equivalent of the lower Oak Grove of Illinois.

The other limestones of this group are thin and commonly discontinuous. This fact, combined with the great depth at which they underlie the area of this report, eliminates them from further consideration as a source of road material.

MAJOR STRUCTURAL FEATURES

The entire area discussed in this report is a part of the Forest City basin, a downwarped area including adjacent parts of Missouri, Nebraska, and Kansas. The axis of the basin trends northeast-southwest and in Iowa it plunges southwest. Numerous structural features of lesser areal extent occur within the basin, and they are of vital importance to the future development of rock and mineral resources. Principally, these features are anticlines, domes, and synclines and are the results of folding. Faulting, once believed by some workers to be one of the dominant features of the area, is now considered to have played a less important role. The present interpretation of structural data for southwestern Iowa is shown on Figure 17. The base of the Hertha limestone was chosen as a datum plane for the structure contour map (fig. 17) because it is persistent, underlies the entire area, and is generally recognizable in well cuttings and cores.

One of the most outstanding features of the basin in southwestern Iowa is a structural zone marked by a series of domes and anticlines with some faulting extending from north of Thurman and Red Oak, through Grant and continuing to the northeast. This zone extends southwestward into Nebraska and northeastward in Iowa through Redfield, Ames, and beyond. Some of the names applied to it in the past are the Thurman-Wilson fault, Thurman-Wilson deformation, and Redfield anticline (Condra, 1938). As a result of the additional information developed by this study, the term "structural zone" appears to describe this occurrence most accurately. The name Thurman-Redfield structural zone is here proposed for it.

Major known features comprising the Thurman-Redfield structural zone in southwestern Iowa (fig. 17) include anticlines south of Tabor (Tabor anticline), south of Malvern (Malvern anticline), north of Red Oak (Red Oak anticline), and at Grant (Grant dome). The axes (long directions) of the anticlines within the zone are aligned roughly northeast-southwest, but the Malvern anticline is elongated more nearly north-south, reminiscent of the Redfield gas storage structure in Dallas County, Iowa, which also has a north-south alignment.

A similar structural zone may be present in a narrow area extending north-northeastward from east of Hamburg, through Farragut and near Red Oak. The major features of this zone are the Hamburg anticline located east of Hamburg; the Farragut anticline, southwest of Farragut; and the Red Oak anticline which marks the intersection of this zone with the Thurman-Redfield zone. A third zone may be indicated trending almost north-south from south of New Market through Grant. The New Market anticline and the domed areas at Grant are the major known features of this possible zone at present.

In Mills County north of the Thurman-Redfield structural zone are three additional structural features—the Bartlett syncline, the anticline in Lyon

Township here named the Lyon anticline, and the previously unrecognized Glenwood syncline—all plunging to the southwest (fig. 17).

The only positive evidence of faulting in the area is in the vicinity of Thurman, Mills County. Many workers have discussed a fault 2 miles north of Thurman known as the Union fault and Condra (1938) has summarized their reports admirably. Condra (1938, p. 8) states, "There is some possibility that a second fault may occur in the south limb of the anticline at Jones Point and near Thurman." There have been wide differences of opinion concerning the displacement of the Union fault. Earlier workers following White favored a displacement of 300 or more feet, but Condra (1938, p. 8) concludes that the vertical movement was "8.8 feet at the crest of the structure on the Nebraska side of the river, where the downthrow is southwestward . . . ," and about 10 feet north of Thurman. In regard to possible faulting in the south limb of the anticline at Jones Point, Condra states that "the displacement is not greater than 30-40 feet on the Iowa side . . ." of the Missouri River. Observations made during this study confirm the existence of faults with small displacements in a quarry in the NW¼ sec. 20, T. 70 N., R. 42 W. Undoubtedly faulting occurs elsewhere in southwestern Iowa and will come to light as additional basic information becomes available as a result of new quarrying, mining, and drilling operations.

Other structural features of the area will be discussed in the individual county sections of this report.

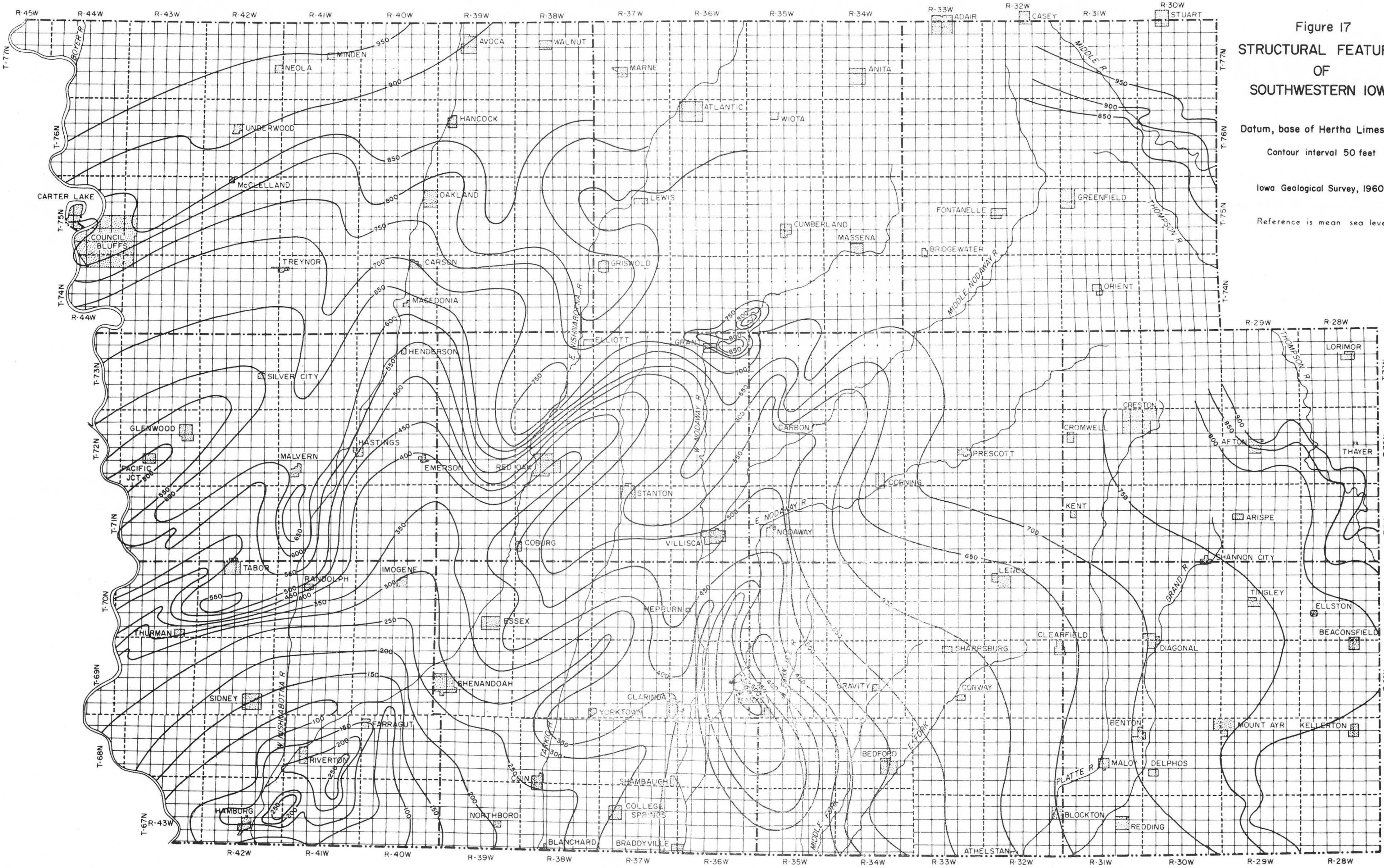


Figure 17
STRUCTURAL FEATURES
OF
SOUTHWESTERN IOWA

Datum, base of Hertha Limestone

Contour interval 50 feet

Iowa Geological Survey, 1960

Reference is mean sea level

BEDROCK GEOLOGY AND SOURCES OF ROCK IN THE COUNTIES

In the discussions by counties that follows, detailed descriptions of exposed rock, and in some instances core descriptions are included under the heading of stratigraphy. The decriptions are arranged to present as complete a geologic section as possible. All known exposures are listed in the appendix of this report, and correlations are given, except for those exposures of such minor extent that correlation is not possible. For each county a columnar section is presented to show the characteristic features, thickness, and sequence of the formations that are exposed, or expected to be reached by moderately deep drilling.

The physiography of each county has been adequately discussed by earlier workers and is not repeated here but special references are presented that cover this phase of the subject. These references, along with the others in the list of selected references, cover the pertinent work that has been done in the area of this report.

Included also is a discussion of the structural features that are known to exist within each county. They are shown on the structure map (fig. 17). Under the heading of rock sources, locations of potential quarry sites are pointed out, and areas where further exploration is advisable are also mentioned.

ADAIR COUNTY

Stratigraphy

The bedrock of Adair County consists of Pennsylvanian rocks (fig. 18) of the Shawnee, Douglas-Pedee, Lansing, Kansas City, and Marmaton groups overlain in the western part of the county by a tongue of Cretaceous sandstone and shale. The Cretaceous rocks do not crop out and are known only from scanty subsurface data. A few sets of samples from drilled wells exist and these, together with drillers' logs, indicate that characteristic Dakota sandstones, conglomerates, and shales are present as preglacially eroded remnants and outliers of deposits that were more extensive at an earlier time. Correlation of the Pennsylvanian rock units in Adair County is exemplified in the following detailed sections. Those sections subject to divergent interpretations are followed by discussion of the problems involved.

The following Pennsylvanian section occurs in the southeast part of the old workings in a quarry in the SE¼SW¼ sec. 12, T. 76 N., R. 31 W.

Virgil series	
Wabaunsee group	
Howard limestone	Feet
1. Shale, olive, flood of chonetids	0.3
2. Limestone, bluish-gray, argillaceous, nodular	0.2

3. Shale, olive, clayey, ramose bryozoans, crinoids	0.3
4. Limestone, bluish-gray, dense, brittle, massive, *Derbyia*	0.4
Severy shale	
5. Shale, olive, clayey, *Linoproductus*	2.6
6. Shale, bluish-gray, weathers light grayish green, hard, clayey	2.6
Shawnee group	
Topeka formation	
Coal Creek limestone	
7. Limestone, light-gray, weathers light gray, massive, rough texture, *Osagia*	2.5
8. Shale, gray	0.1
9. Limestone, light-gray, weathers white, shelly fracture, *Ottonosia, Composita, Juresania*	1.0
10. Covered interval, probably like below	2.2
11. Shale, buff, contains limestone nodules, *Enteletes, Composita*	1.2
12. Limestone, light brownish-gray, fine to sublithographic, large crinoids, fusulinids	5.2
13. Limestone, light-gray, weathers brown and banded, fine	1.0
Holt shale	
14. Shale, olive, weathers buff orange, *Lingula* near top, *Hustedia* and gastropods below	1.8
15. Shale, black, fissile, hard, top 0.1 foot soft	1.7
16. Shale, black, clayey, soft	0.3
Turner Creek shale	
17. Shale, bluish-gray, clayey, blocky, weathers chippy	2.0
18. Shale, olive, clayey	1.1
19. Limestone, light bluish-gray, weathers buff, nodular, argillaceous	1.5
20. Shale, light bluish-gray, weathers yellowish olive, thin-bedded, contains green dendrites	1.4
Sheldon limestone	
21. Limestone, light-gray, weathers buff, massive beds 0.8 foot thick, dense, local nests of *Composita*	1.5
22. Shale, olive, weathers buff	0.1
23. Limestone, bluish-gray, weathers gray brown, medium-crystalline, hard, brittle, *Osagia*	1.5
24. Limestone, brownish-gray, massive, conchoidal fractures	1.9

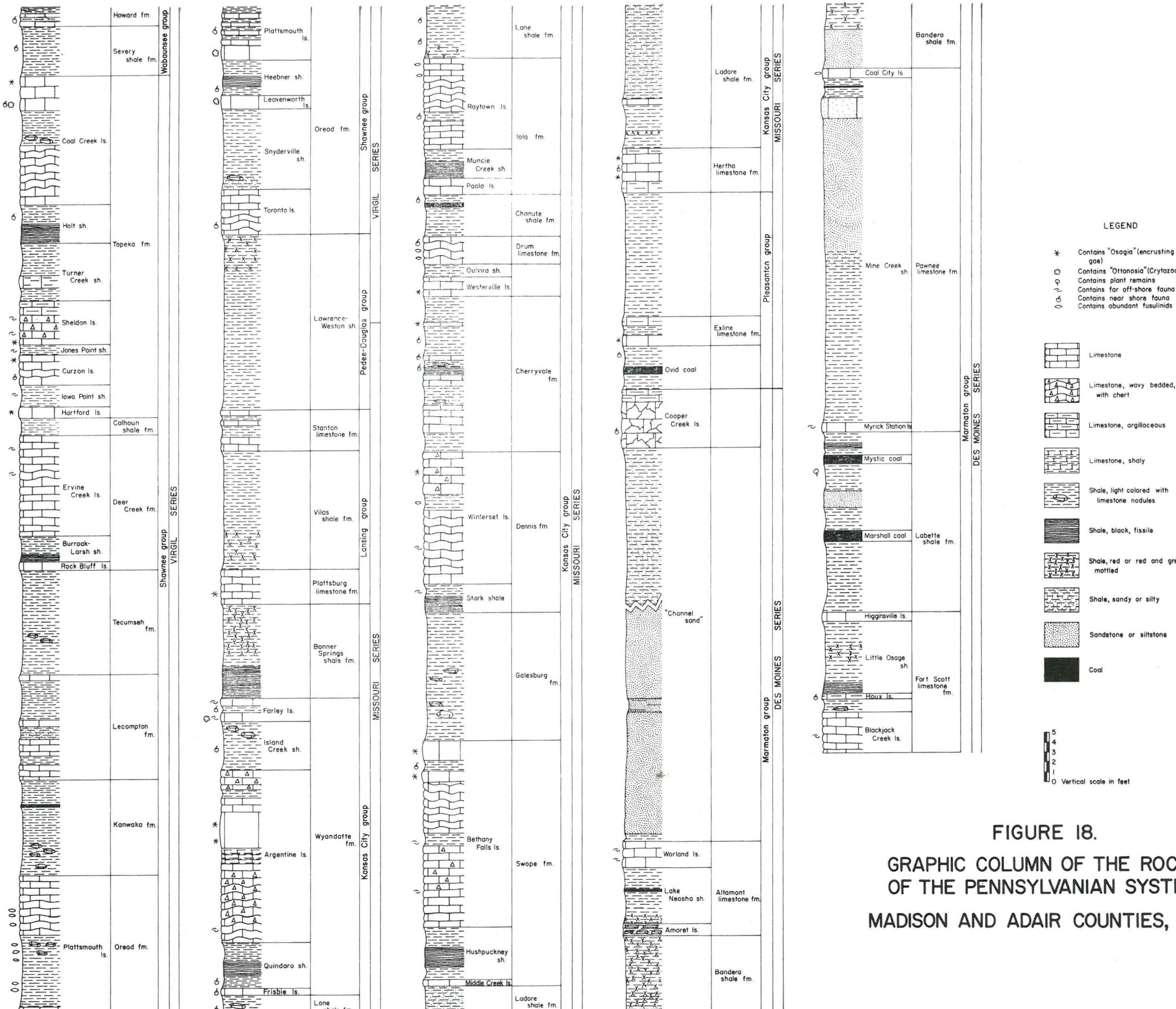


FIGURE 18.

GRAPHIC COLUMN OF THE ROCKS OF THE PENNSYLVANIAN SYSTEM

MADISON AND ADAIR COUNTIES, IOWA

Jones Point shale	
25. Shale, olive to brown, clayey	0.7
Curzon limestone	
26. Limestone, brownish-gray, weathers white, sublithographic, exposed	1.0

A quarry in the SW cor. sec. 1, T. 76 N., R. 31 W., permits the downward extension of the foregoing section.

Virgil series	
Shawnee group	
Topeka formation	
Turner Creek shale	Feet
1. Shale, bluish-gray, weathers blue, limy, thin bedded, green dendrites	2.6
Sheldon limestone	
2. Limestone, light-gray, weathers buff, argillaceous, shaly, nodular	1.3
3. Limestone, light-gray, dense, bluish-gray chert nodules, grades into bed above, brachiopods	1.1
4. Limestone, light-gray, fine, bluish-gray chert, clear calcite fillings, *Dictyoclostus*, gastropods	1.4
5. Limestone, bluish-gray, weathers white, argillaceous, *Osagia*	0.5–0.9
Jones Point shale	
6. Shale, olive, thin limestone lenses, *Neospirifer, Crurithyris, Rhombopora*	0.6–0.8
Curzon limestone	
7. Limestone, light-gray, massive, *Osagia*, crinoids	0.6
8. Limestone, light-gray, sublithographic, two massive beds, calcite veinlets, *Allorisma, Composita, Mooreoceras*	2.3
Iowa Point shale	
9. Shale, brownish-gray above, grading to bluish-gray below, hard, abundant dark fossil sections, *Osagia*	1.8
Hartford limestone	
10. Limestone, light-gray, sublithographic, massive, weathers slabby, dark brachiopod sections, crinoids, *Osagia*	0.6
Calhoun formation	
11. Shale, grayish-green, clayey	0.1
12. Shale, bluish-gray, weathers yellowish brown, crinoids	0.8
13. Shale, medium-gray, weathers blue, crumbly, *Neospirifer*, crinoids	0.6

Deer Creek formation

Ervine Creek limestone

14. Limestone, light-gray, weathers white, four massive beds, wavy argillaceous partings; dark-gray chert layer near middle with white fossil section, scattered chert nodules, *Marginifera, Neospirifer, Dictyoclostus,* many crinoids — 0.6
15. Limestone, brownish-gray, top 1 foot brittle, bluish gray and argillaceous below, base covered — 5.0

On the basis of cores, Welp, Thomas, and Dixon (1957, p. 423-428) have placed the sections described above in the Kansas City group, with the units assigned to the Ervine Creek limestone above being called the Bethany Falls limestone, and a corresponding change for the overlying beds. This divergent interpretation may have a possible faunal justification in that the cephalopod *Mooreoceras* has been found in unit 8 above and it has not been previously reported from beds higher than the Kereford limestone of Nebraska or the Weston shale of Kansas (Shimer and Shrock, 1944, p. 553).

The following composite Pennsylvanian section occurs in a series of north-side road cuts from the NW cor. SE¼SW¼ sec. 26 to the SE cor. NE¼SW¼ sec. 26, T. 76 N., R. 30 W.

Virgil series

Shawnee group

Lecompton formation

Spring Branch limestone — Feet

1. Limestone, bluish-gray, weathers light bluish gray, finely crystalline, brecciated appearance, traces of purple shale, *Composita, Osagia, Myalina,* chonetids, ramose bryozoans — 0.8
2. Shale, light greenish-gray, weathers with a purple cast, clayey — 2.3
3. Limestone, bluish-gray, weathers buff gray, thin-bedded with shaly partings; increasingly slabby and shaly to top; *Osagia, Allorisma,* bryozoans — 3.2
4. Limestone, medium-gray, weathers brown, fine, massive, pectens, chonetids, *Derbyia, Dictyoclostus, Neospirifer,* crinoids — 0.3

Kanwaka formation

5. Shale, olive, platy limestone seam near top; *Chonetes, Crurithyris, Juresania, Neospirifer,* bryozoans — 1.9
6. Coal — .05
7. Shale, greenish-gray, weathers chippy, numerous limy nodules and plates — 6.0

Oread formation	
Plattsmouth limestone	
8. Limestone, light-gray, weathers gray, thin bedded to nodular, sublithographic	3.9
9. Limestone, gray, weathers buff, argillaceous, rounded slabby beds, abundant *Triticites*	3.0
10. Shale, medium-gray, weathers light grayish buff, very fossiliferous with *Chonetes, Composita, Neospirifer*, bryozoans, crinoids, fusulinids	4.6
11. Limestone and shale; limestone, dark-blue, weathers buff, black chert nodules, *Dictyoclostus;* shale, gray, weathers buff, platy, hard, calcareous, *Chonetina*; thin limestone beds 0.2 to 0.5 foot thick	4.0
12. Limestone, upper part brown, fine, pyrite; lower half blue-gray, medium-crystalline, fossiliferous, small *Ottonosia*	1.4
Heebner shale	
13. Shale, olive, weathers buff, blocky	1.5
14. Shale, black, blocky and mottled brown below; black, hard, fissile above	1.1
15. Shale, olive, weathers light grayish brown, abundant *Crurithyris, Wellerella*	0.5
16. Shale, buff, clayey	0.2
Leavenworth limestone	
17. Limestone, medium bluish-gray, weathers white, single bed, crinoidal, *Ottonosia*	1.1
Snyderville shale	
18. Shale, buff, calcareous with thin calcareous plates, crinoid stems and plates	0.2
19. Shale, olive-gray, weathers light gray, black near top, platy with hard calcareous layers, *Derbyia*, productids	4.1
20. Shale, buff, blocky	2.0

This section could be correlated differently by calling the Kanwaka shale the Heumader shale and the Spring Branch limestone the Kereford limestone. The Survey's correlation is made because of the nature of the Kanwaka shale as defined by Moore (1935, p. 169-170). He describes it as including both marine and non-marine deposits, and it includes the terminal part of the Oread cyclothem, all of the Clay Creek cyclothem, and the initial part of the Lecompton cyclothem. Further, Moore described the Kanwaka as locally having a coal or coal smut as in the foregoing section. The units here called Kanwaka meet these requirements and these beds do not resemble the Heumader shale as seen where the Kereford limestone is present.

More of the Pennsylvanian stratigraphic section below the foregoing is exposed in a small Middle River tributary in the NE¼NE¼ sec. 1, T. 75 N., R. 30 W.

Virgil series	
Shawnee group	
Oread formation	
Plattsmouth limestone	Feet
1. Shale, light-gray, weathers buff, numerous white limestone nodules, very fossiliferous with *Dictyoclostus, Chonetes,* bryozoans, crinoids	4+
2. Limestone and shale; limestone, blue, weathers buff, dense, 0.1 to 0.7 foot nodules; shale, dark-gray, weathers buff, hard	2.9
3. Limestone, upper half brown, dense, fossil sections; lower half medium-gray, weathers brown, medium-crystalline	1.4
Heebner shale	
4. Shale, olive, clayey, blocky	1.3
5. Shale, black, fissile at top, brown and blue clayey and blocky below	1.3
6. Shale, olive, weathers buff, clayey, abundant *Crurithyris*	0.4
7. Limestone, medium blue-gray, weathers light gray, upper surface is brown, many crinoids, *Ottonosia, Neospirifer*	1.1
Snyderville shale	
8. Shale, dark blue-gray, weathers buff gray, abundant *Derbyia* in upper part	6.7
9. Shale, olive-buff, weathers buff, irregular white limestone masses	0.3
10. Shale, red-maroon, silty, blocky	1.1
Toronto limestone	
11. Limestone, light-gray, weathers light gray, nodular, sandy	1.3
12. Limestone, as above but more nodular, *Composita,* gastropods	2.9
13. Shale, light-green, silty	0.1
Douglas-Pedee group	
Weston-Stranger shales	
14. Shale, red with greenish mottling and slightly silty in top 0.5 foot; lower part brownish-red, clayey, platy, red and green concretions	3.3

15. Shale, light greenish-gray, thinly platy, silty, micaceous — 4.9
16. Shale, dark blue-gray, weathers light blue gray, silty, thin plates — 9.2

Missouri series
  Lansing group
    Stanton formation

17. Limestone, medium-gray, weathers light gray, argillaceous crinoidal band at top — 0.4
18. Shale, medium-gray, clayey, *Derbyia*, *Chonetina*, *Punctospirifer* — 0.6
19. Limestone, dark-gray, weathers light gray, dense, argillaceous, massive, conchoidal fracture, weathers rounded, *Juresania*, *Chonetes* — 0.6
20. Shale, dark-gray to black, very fossiliferous, *Derbyia*, *Juresania* — 1.4
21. Limestone, blue-gray, weathers light blue-gray, argillaceous, slabby, algal — 9.7

The disconformity between the Missouri and Virgil beds is not generally identifiable in Iowa but lies somewhere in the deposits that separate the Stanton and Oread formations, here called the Weston-Stranger shales of the Douglas-Pedee groups. This break is shown in the section above as being at the top of the Stanton formation for ease of illustration only.

The oldest Pennsylvanian rocks outcropping in Adair County are exposed beneath 2 feet of overburden in the south side of a cutbank of the Middle River in the NE¼NW¼SE¼ sec. 36, T. 76 N., R. 30 W.

Missouri series
  Lansing group
    Stanton formation — Feet

1. Shale, light greenish-gray, clayey, becomes more blocky downward, contact between shale and glacial material indistinct — 3.0
2. Shale, very dark-gray, blocky, becomes black and platy downward — 6.2
3. Limestone, medium dark-gray, shaly, chonetids, crinoid stems — 0.7
4. Shale, medium dark-gray, platy, many brachiopod fragments, crinoid stems, bryozoans — 1.3
5. Shale, black, somewhat lignitic — 0.9
6. Limestone, medium light-gray, weathers dark buff, very fine-grained, dense; upper 0.3 foot shaly, lower portion massive, large brachiopods — 1.7

Vilas formation		
7.	Shale, light-buff, many *Neospirifer*	0.1
8.	Shale, dark-gray, becoming black downward, blocky	2.8
9.	Shale, dark-brown, blocky, many thin limy plates	1.7
10.	Shale, maroon, to water	7.0

Physiography

The physiographic features of Adair County are discussed by J. E. Gow and J. F. Tilton in Iowa Geological Survey volume 27, pages 281-282.

Structure

Details of the structural pattern in Adair County remain largely unknown simply because there are not sufficient data points on which to base sound conclusions. However, certain generalizations are possible.

The Thurman-Redfield structural zone trends northeast-southwest. It is positively expressed by the domes near Grant in Montgomery, Adams, and Cass counties to the southwest of Adair County, and by structural features including those in the vicinity of Redfield in Dallas County to the northeast. This means that, by necessity, the structural zone crosses Adair County probably through or immediately north of Bridgewater and Fontanelle and through or south of Stuart.

Investigations in the vicinity of Howe by Welp, Thomas, and Dixon (1957, p. 426-427) have revealed the presence of considerable structural relief within relatively short horizontal distances. They postulate a major fold trending northeast-southwest in sec. 12, T. 76 N., R. 31 W., with a small narrow syncline and anticline occurring in the southeast limb. They believe that "this deformation is a part of the Redfield structural trend."

Available information indicates that the rocks dip generally to the south and west over the remainder of the county which is thickly mantled by glacial drift. Additional subsurface information will undoubtedly reveal a structural picture as complex as that shown by the counties to the southwest.

Rock Sources

Outside the area of Middle River, there apparently is little possibility of opening new quarries in Adair County. As in the other counties of southwestern Iowa, any drilling that goes into bedrock is of great importance, and even those wells that do not reach bedrock furnish some information, if only in a negative sense. With this thought in mind the Iowa Geological Survey continues to gather as much well data for Adair County as becomes available.

The Plattsmouth limestone, which in its outcrop areas through the remainder of southwestern Iowa is an important quarry stone, in Adair County is of very poor quality containing more shale than is normally seen elsewhere. This fact narrows the available usable rock to the members of either the upper part of the Shawnee group, or the lower part of the Kansas City group. Exploration should be carried on with this thought in mind.

ADAMS COUNTY

Stratigraphy

The bedrock of Adams County, as throughout most of southwestern Iowa, is covered by a heavy mantle of glacial drift (fig. 3). Much of the information about the stratigraphy (fig. 19) must come from wells drilled into the bedrock. Unfortunately, few well logs are available for this county. The area of outcrop is limited to the west half of the county, and the exposures that are present are generally of small vertical extent. On the basis of all information now available, it is believed that the bedrock of Adams County is made up of rock of the Shawnee and Wabaunsee groups, with the exception that the western edge of the county has a rather inconspicuous covering of Dakota sandstone and associated shales and clays.

Perhaps the best exposure of rocks of Cretaceous age in Adams County is in a ravine in the NW¼NW¼SW¼ sec. 19, T. 72 N., R. 35 W. At the top of the exposure is a brown, coarse-grained sandstone that is locally conglomeratic with quartz grains, iron oxide, and reddish-brown shale. The thickness varies from 0 to 8 feet. Beneath the sandstone is a light-gray to drab siltstone that contains plant fragments, brown iron concretions, and a few thin lenses of sandstone. The maximum thickness of this unit is 33 feet. At the base of the exposure is a 5-foot ledge of medium-grained, buff sandstone.

Because most of the rocks of the Cretaceous system in Adams County closely resemble those described above and are easily distinguished from rocks of Pennsylvanian age, no further discussion of their characteristics is needed.

An outcrop in the NW¼SW¼ sec. 31, T. 72 N., R. 35 W., shows what is believed to be the stratigraphically highest Pennsylvanian rock exposed in Adams County. The exact correlation is somewhat doubtful, but this is certainly part of the lower Wabaunsee group. A detailed section follows.

	Feet
Virgil series	
Wabaunsee group	
Silver Lake shale	
1. Shale, grayish-brown, finely laminated, locally silty	4.0
2. Shale, dark-gray, blocky, somewhat laminated	0.6
Rulo limestone	
3. Limestone, bluish-gray, weathers yellow, medium-grained, no fossils noted	2.8

Cedar Vale shale		
4. Shale, gray to buff		10.0
5. Shale, black, bituminous		1.5
6. Shale, yellow		0.3
7. Limestone, bluish-gray, hard		0.7
8. Shale, gray to buff	exposed	21.0

As already explained, the correlation of this exposure is doubtful, but for reference purposes the foregoing names have been assigned. The basis for this correlation is the black, bituminous shale (unit 5) which seemingly represents the Elmo coal phase of the Cedar Vale shale, and the overlying bluish-gray limestone that resembles the Rulo limestone as described by Moore (1935, p. 213).

Most of the intervening stratigraphic units from the foregoing section down to the Howard limestone are now concealed in Adams County. The Howard limestone, the lowermost limestone of the Wabaunsee group, forms the caprock for the persistent Nodaway coal that has been mined at many places in the western part of this county. The Howard outcrops at a number of places along Middle Nodaway River, but none of the exposures are very extensive. Where seen it is a medium dark-gray limestone that is finely crystalline, contains many calcite veinlets, and weathers light gray and somewhat slabby. The weathered surface usually has a covering of fossil hash made up of crinoid stems and brachiopods. The thicknesses vary considerably but a maximum thickness of 3 feet is common for the Howard limestone.

A limestone in the bed of Middle Nodaway River just south of the old Eureka bridge site in the SE¼NE¼ sec. 31, T. 73 N., R. 34 W., is here correlated as part of the Coal Creek limestone, the topmost member of the Topeka formation of the Shawnee group. The upper bed is dark gray, weathers light gray, is fine grained, slabby, and has a thin shale parting near the center. The lower bed is dark gray and shaly. At the time of measurement only 2.3 feet of rock was exposed.

Although no longer accessible, an old quarry in the center of the E½ sec. 4, T. 71 N., R. 34 W., showed (unpublished Survey notes) the lower part of the Topeka formation, the Calhoun shale, and the upper part of the Deer Creek formation. A detailed section follows:

Virgil series	
Shawnee group	
Topeka formation	
Iowa Point shale	Feet
1. Shale, buff, clayey	0.5
2. Shale, olive-gray, soft, fossiliferous	0.7
Hartford limestone	

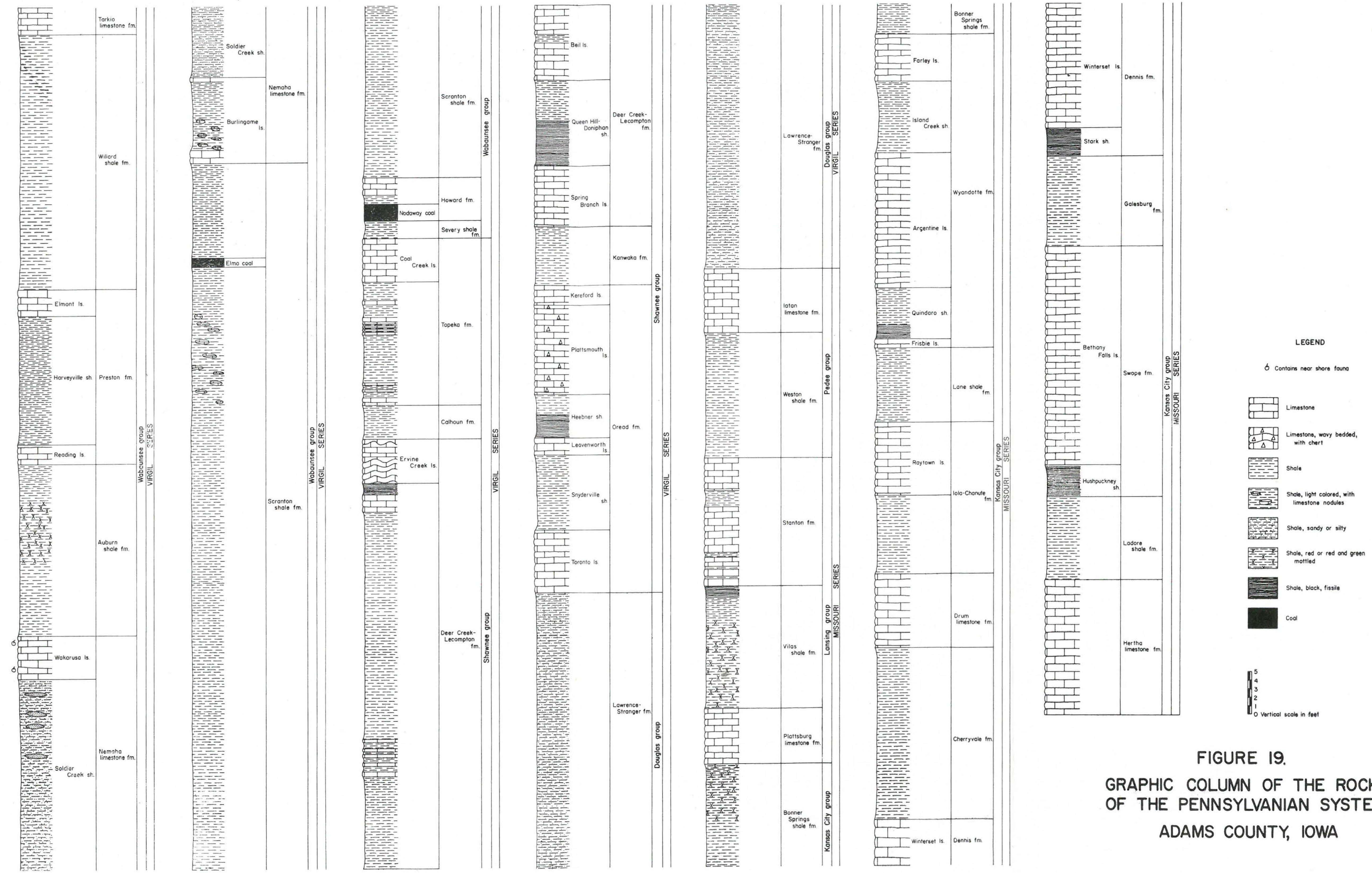


FIGURE 19.

GRAPHIC COLUMN OF THE ROCKS OF THE PENNSYLVANIAN SYSTEM ADAMS COUNTY, IOWA

3. Limestone, gray, blocky, fine-grained; lower part brown and argillaceous 1.8

Calhoun shale

4. Shale, buff, fossiliferous with crinoid segments, *Chonetes, Crurithyris* 0.6
5. Shale, dark-gray, thin-bedded to blocky; a 0.2-foot fossiliferous brown shale seam about 1 foot above the base 7.5

Deer Creek formation

Ervine Creek limestone

6. Limestone, gray, sublithographic, massive and thin-bedded; some shaly partings and wavy beds; about 8 feet below the top is a 0.5-foot shaly zone rich in *Triticites* 10.5

At a quarry in the center of the SW¼ sec. 3, T. 71 N., R. 34 W., not far from the foregoing location, only the Calhoun shale and the Ervine Creek limestone are exposed. For purposes of comparison a detailed section is given below.

Virgil series

Shawnee group

Calhoun formation — Feet

1. Shale, bluish-green, silty, moderately calcareous, some fossil fragments 1.0
2. Shale, dark-green, silty, calcareous, brownish near top 2.3

Deer Creek formation

Ervine Creek limestone

3. Limestone, light- to medium-gray, weathers bluish on bedding planes, argillaceous to dense, crystalline calcite common locally, fossiliferous. Appears as one or two massive beds, but is locally shattered, giving the upper part a slabby appearance. In the southeastern part of the quarry bed 4 seems to be a part of this massive ledge, making it proportionately thicker. Contains *Neospirifer, Linoproductus,* crinoid remains 3.3
4. Limestone, light-gray, sublithographic, abundant brachiopod sections, *Composita* 0.8
5. Shale, upper half blue-gray to olive, clayey, bedded, contains *Lingula;* lower half brown, clayey, crinoid stems 0.3
6. Limestone, light-gray, weathers medium gray, wavy bedding 0.3 to 2 foot thick; obese fusulinids in lower

1.5 foot, *Osagia* above; brownish shale partings conspicuous, abundant brachiopod sections, crinoid stems 3.5

7. Limestone, wavy-bedded and shale partings, few nodules of black to dark-gray chert, crinoid stems and fusulinids 1.6
8. Limestone, light-gray, massive, somewhat argillaceous, grading downward into grayish-brown calcareous shale; small *Composita*, *Osagia*, crinoid stems 3.7

Burroak-Larsh shale

9. Shale, olive, thin black zone at top, contains *Crurithyris*; lower portion contains dark-gray limestone concretions, *Linoproductus;* floor of quarry 1 ±

A core taken from the floor of the quarry was reported to have gone through 14 feet of shale underlain by 4 feet of limestone.

No older rock is known to be exposed in Adams County, although almost certainly rocks of the lower Shawnee group lie immediately beneath the drift on the eastern side of the county.

Physiography

The physiography of Adams County is discussed by L. W. Wood in Iowa Geological Survey volume 37, pages 271-290.

Structure

In the extreme northwest corner of Adams County, the strata rise steeply to the crest of the Grant Dome, which is named for the town of Grant in the northeast corner of Montgomery County. From this point, where the Plattsmouth limestone is at or near the surface, the strata dip rather steeply to the southeast into a small syncline where rocks of the Wabaunsee group form the bedrock. The trend of this syncline is south-southwest, and it probably extends to the southwest corner of the county. Over the remainder of the county the structure appears to be a large north-south trending monocline that rises gently to the east. It is this structural rise that has brought the Ervine Creek limestone close enough to the surface to be quarried in the Bedford area.

Rock Sources

Within the Wabaunsee group of rock there is not a limestone member of sufficient thickness to warrant the removal of glacial material and shales to recover the limestone for road building material. The same condition exists within the Topeka formation, the uppermost formation of the Shawnee group.

The Ervine Creek limestone, the highest member of the Deer Creek formation, is the rock now being quarried in Adams County, and will probably be the only source of rock in the county. With the present methods of quarrying there seem to be little possibility of opening any new quarry operations, although slight extensions of existing quarries are possible. Because of this, some thought should be given to mining for limestone.

The probability that rocks of lower Shawnee age will directly underlie the glacial material toward the eastern edge of the county is reason enough for prospecting in this area. Little information is now available to show what the drift thicknesses are, but it is assumed they are prohibitive to stripping for open-pit quarry operations. However, if it were found that the Plattsmouth-Spring Branch limestone interval was available by mining, an economically feasible operation may be possible. These two members should provide an aggregate thickness of about 25 feet of limestone.

In Adams County, where only a few quarries have been operated and few wells have been drilled that yield any stratigraphic information, any drilling or testing is of great interest and can be of great value.

CASS COUNTY

Stratigraphy

In Cass County the exposures of consolidated rock are limited to the Dakota sandstone of the Cretaceous system, the limestones and shales of the Shawnee group (fig. 20), and possibly the Douglas group of the Pennsylvanian system.

The Dakota sandstone, as seen in outcrops in Cass County, is usually highly ferruginous. Tester (1929, p. 255-256) described the following section as characteristic for the west central Iowa region. The location is one mile southwest of Lewis, in sec. 15, T. 75 N., R. 37 W.

Zone		Feet
6	Sandstone, white to buff and yellow, fine- to coarse-grained, friable. Appears to grade upward to finer sands; a layer of gray thinly laminated clay appears 18 to 20 feet from base but is not continuous. There are many very local and irregularly exposed clay conglomerate zones with boulders of clay up to 10 and 11 inches in diameter and 3 to 4 inches thick. These zones, though occurring at irregular horizons, are discontinuous and are nearly horizontal on wavy surfaces. The pebbles and boulders of clay have their longer axes parallel, or nearly so, to the surfaces on which they rest. The differences in amount of iron oxide cement give the sandstone a locally banded appearance. About 21 feet from the base of this zone a gray shale bed increases in thickness toward the east and southeast. Eastward the base of the shale zone contains a hard, red, finely sandy concretionary zone	28–32

5 Shale, green to gray, thinly laminated and resting on a wavy, hummocky surface, which is brown to red, owing to concentration of iron oxide. Much of the shale occurs as conglomerate pebbles. The zone is irregular and probably not continuous for a great distance. Average thickness ½
4 Sandstone, yellow to buff and white, friable, coarse-grained. Contains many irregular zones of poorly developed iron oxide concretions and clay conglomerate pebbles. Cross-bedding inclined to south-southeast 6½
3 Sandstone, generally covered except for very small exposures, where it appears to be similar to that above 7
2 Sandstone, and conglomerate shale, with much iron oxide and interfingering of thin lenses. Very poorly exposed 3
1 Limestone, upper Pennsylvanian. Exposed approximately 4

Because of their rather distinctive appearance, along with a lack of invertebrate fauna, there is seldom any difficulty in distinguishing the shales associated with the Dakota sandstone from those of the Pennsylvanian system. Occasionally the overlying glacial material resembles Dakota shales but close inspection usually permits differentiation. In outcrop, the Dakota appears to be quite localized but subsurface studies have shown it to be very extensive over the county (see fig. 2). For the most part, the sandstones are poorly cemented and slumping rapidly obscures exposures. The area of outcrop of the Shawnee group is very limited because Dakota sandstone and Pleistocene deposits cover it everywhere except at scattered localities in the valleys.

The youngest member of the Pennsylvanian system now exposed in Cass County is the Queen Hill shale member of the Lecompton formation. This can be seen, with some underlying members, in an abandoned quarry in the E½SW¼SE¼ sec. 8, T. 75 N., R. 37 W. A detailed section follows.

Virgil series
Shawnee group
Lecompton formation
Queen Hill shale — Feet
1. Shale, dark-green, contains brown and greenish-gray limestone nodules; lower 6 inches is a gray shale with limy nodules; contains *Derbyia, Neospirifer* 5.0

Big Springs limestone
2. Limestone, light-gray, weathers buff and gray, argillaceous, dense, medium-crystalline; contains large *Composita*, bellerophontid gastropods in upper part 0.9

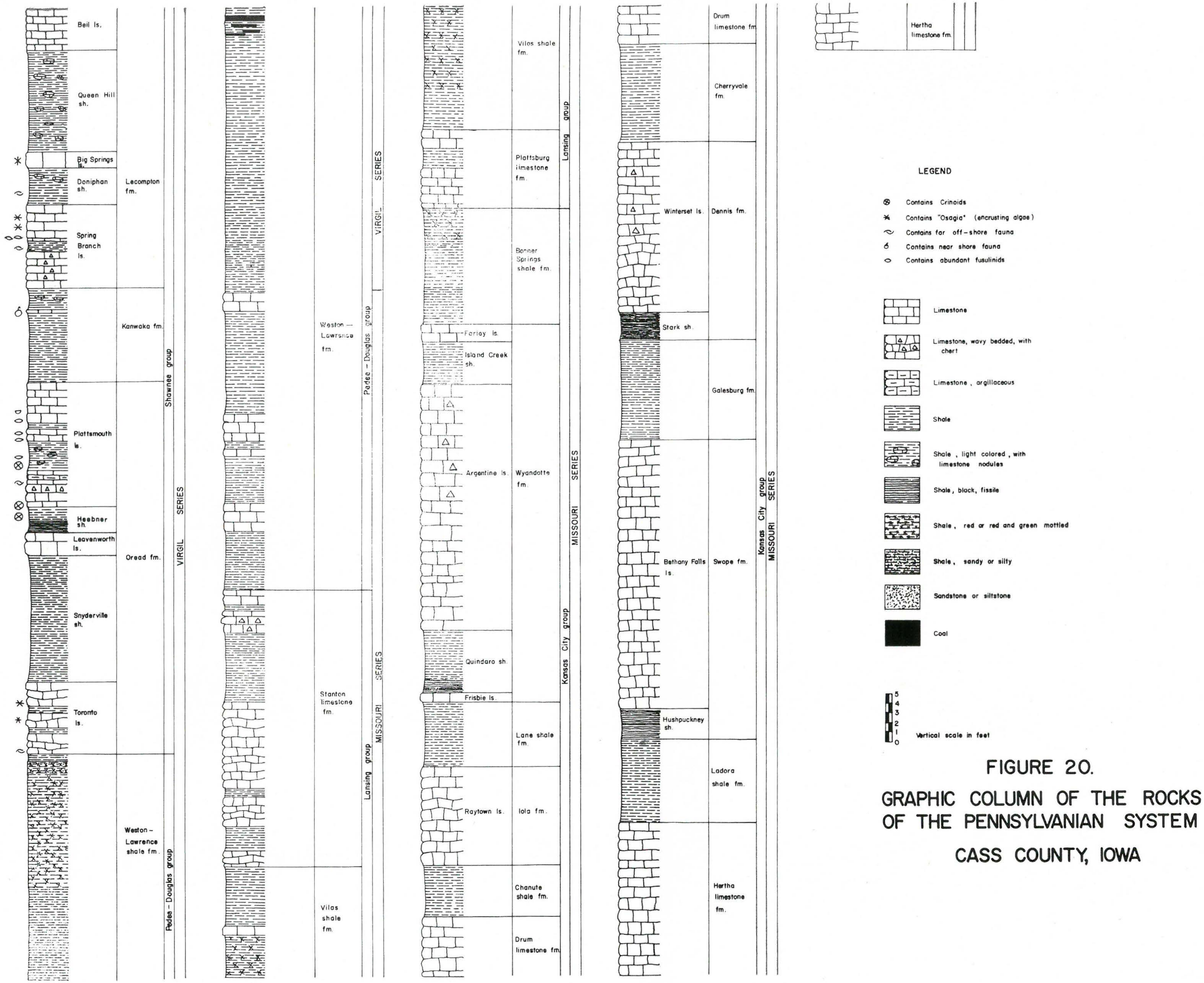


FIGURE 20.

GRAPHIC COLUMN OF THE ROCKS OF THE PENNSYLVANIAN SYSTEM CASS COUNTY, IOWA

Doniphan shale

3. Shale, gray, very calcareous, with limy nodules, blocky 1.4
4. Shale, dark-gray, weathers gray, chippy, hard; clams abundant in lower half; nodular at base 3.2

Spring Branch limestone

5. Limestone, light-gray, weathers gray and buff, sublithographic to finely granular; wavy-bedded, uneven pitted surface, pinkish-brown chert nodules at top; thin shale seam at base 1.6
6. Limestone, light-gray, weathers brown, sublithographic, massive, with gray and flesh-colored fusulinids 1.5
7. Shale, black, mottled gray, clayey, blocky 0.8
8. Limestone, very dark bluish-gray, weathers brown, dense, massive, contains brownish-black chert nodules in lower part; *Dictyoclostus* 2.7
9. Limestone, light-gray, weathers light gray and buff; middle portion weathers chippy causing a shalelike appearance; very argillaceous; fenestellid and ramose bryozoans, *Composita, Chonetes, Derbyia,* crinoid stems; lower 0.4 foot medium-gray, fine-grained, dense 2.1

Kanwaka formation

10. Shale, dark olive-green, weathers gray, has darker zones upper zone has flood of *Crurithyris, Stereostylus* 1.8+

An extension of the foregoing section may be seen in the bank of Indian Creek, north of Highway 6, in the SE¼SW¼ sec. 5, T. 75 N., R. 37 W. The Spring Branch-Plattsmouth interval is exposed at this location.

Virgil series
Shawnee group
Lecompton formation

Spring Branch limestone — Feet

1. Limestone, light-gray to buff, fine-grained, thin wavy beds 1 to 3 inches thick; few fossils 0.7
2. Limestone, buff to light-gray, much black chert spotted with white in center 0.7 foot; upper and lower 0.5 foot appear as individual beds locally; crinoids and brachiopods abundant in lower 1 foot 1.7

Kanwaka formation

3. Shale, buff to dark-brown, mottled at top, contains fragments of crinoidal limestone in upper 1 foot which may be intermittent bed 2.0

4. Limestone, buff, argillaceous; many small crinoid fragments, ramose bryozoans, *Crurithyris, Dictyoclostus, Derbyia* 0.3
5. Shale, grayish-green, weathers light grayish green, blocky, many small brachiopods in upper 0.3 foot 1.3
6. Shale, medium- to dark-brown, weathers buff, blocky 1.0
7. Shale, grayish-green, weathers light gray, some brown spotted areas; blocky, partly covered at base 5+

Oread formation

Plattsmouth limestone

8. Limestone, buff to yellow, weathers light yellow; many small calcite veins 0.8
9. Limestone, light grayish-green, weathers light gray and rounded, argillaceous, thin-bedded 1.4
10. Limestone, light grayish-green, argillaceous, many fossil fragments and fusulinids 1.3
11. Shale, brown 0.2
12. Limestone, grayish-green, very hard, flood of fusulinids, generally one massive bed 3+

Although units 3 through 7 are here assigned to the Kanwaka formation, the equivalent of the Heumader shale of the Oread formation is probably included. This is brought about by the fact that the Kereford limestone, which is the uppermost member of the Oread formation and immediately overlies the Heumader shale, is absent in this area. Under these conditions it is not possible to differentiate the Heumader from the Kanwaka.

At present a complete section of the Plattsmouth limestone is not exposed in Cass County. In the NE¼SE¼ sec. 1, T. 75 N., R. 37 W., beds that are believed to be the top of the Plattsmouth are exposed in a cutbank of a south tributary of Turkey Creek. A detailed section follows:

Virgil series

Shawnee group

Oread formation

Plattsmouth limestone — Feet

1. Limestone, light-gray, weathers buff, medium-crystalline, thick slabby beds, contains flood of fusulinids 2.0
2. Shale, buff, contains limestone nodules similar to the limestone above; flood of fusulinids and also some *Composita* 1.0+
3. Covered interval, probably shale 3.0
4. Limestone, medium-gray, weathers dark gray, with crinoid stems, fenestellid bryozoans, *Chonetes* 1.0

5. Limestone, medium-gray, fine-grained, dense, contains abundant brown to black chert nodules 0.5+

The middle zones of the Plattsmouth are now covered, but the lower Plattsmouth-Leavenworth interval is well exposed at a rock cut in the Nishnabotna River in the NE¼SE¼NE¼ sec. 16, T. 75 N., R. 37 W., where the following section was measured.

	Feet
Virgil series	
Shawnee group	
Oread formation	
Plattsmouth limestone	
1. Limestone, rusty-yellow, weathers light brownish gray, some crinoids, bryozoans, brachiopods and a flood of fusulinids	3.0
2. Shale, light-gray, dense, limy and resistant, crinoids and bryozoans	2.4
3. Shale, light- to olive-gray, very fossiliferous with crinoids, bryozoans and brachiopods	1.1
4. Limestone, light- to medium-gray, weathers buff, argillaceous, less resistant than unit below; contains crinoids, bryozoans, brachiopods	1.0
5. Limestone, light- to medium-gray, dense, hard; abundant brown to black chert nodules in lower 0.5 foot; argillaceous seams and nodules in upper part; many crinoids, bryozoans, brachiopods; thin shale parting at base	1.5
6. Limestone, light- to medium-gray, hard, sublithographic above, lower part transitional to shale below; very fossiliferous with small horn corals, crinoids, bryozoans, *Wellerella*	1.5
Heebner shale	
7. Shale, olive-gray, weathers light grayish brown on top, pyrite veins and nodules; fossiliferous in upper 0.5 foot with crinoids, bryozoans, brachiopods	1.6
8. Shale, black, fissile, hard	0.8
Leavenworth limestone	
9. Limestone, light- to medium-gray, weathers buff, with 0.2 foot buff shale at top	0.8
10. Limestone, light-gray to tan, dense, locally sublithographic, hard, splintery, trace of chert; many fossil fragments; crystalline calcite, pyrite and marcasite in clusters and veins; forms ledge and rapids in river; one massive bed	2.2

The Heebner and Leavenworth here show their typical lithologic peculiarities. The Heebner is characteristically light to bluish gray above, and black, fissile, and hard below. The typical abundance of vertical joints in the Leavenworth is strikingly apparent here, along with the dense, fine-grained character of the rock. The prevalence of joints eventually results in the weathering of the joint blocks into rounded boulders.

Another exposure of the lower Plattsmouth-Leavenworth interval may be seen in Turkey Creek in the SE¼NW¼ sec. 1, T. 75 N., R. 37 W., which is almost identical with the foregoing detailed section. About 500 yards downstream in Turkey Creek from the exposure mentioned above is the oldest exposed rock in Cass County. In the NE¼SE¼ sec. 2, T. 75 N., R. 37 W., the following exposure may be seen.

Virgil series
Douglas group
Lawrence-Stranger formations

		Feet
1. Limestone, medium dark-gray, weathers yellow to buff, slabby	exposed	0.8
2. Shale, dark-gray to black, well-bedded		6.0
3. Shale, dark-gray to black, lower 0.3 foot contains abundant ramose bryozoans, *Derbyia*		1.0
4. Limestone, dark-gray, fine-grained, in lenses, contains crinoids, bryozoans, and brachiopods		0.3
5. Shale, dark-gray at top and becoming lighter at base; basal 0.3 foot very lumpy		1.0
6. Limestone, dark-gray, weathers light gray, dense; two beds forming resistant ledge		0.7
7. Shale, dark-gray, weathers light gray, very blocky; contains *Lingula* and thin-shelled clams		1.2
8. Shale, black, limy and flaky		0.5
9. Shale, medium-blue to gray, blocky	exposed	3.0

The exact stratigraphic position of the individual beds is not certain. On the basis of elevation in comparison to the exposure only 500 yards away, in which the Plattsmouth-Leavenworth interval is definitely recognized, it seems plausible to assign this to the Lawrence-Stranger formations of the Douglas group. The topmost bed in this exposure is 1,116 feet above sea level while in the adjacent exposure the top of the Leavenworth limestone is 1,120 feet above sea level. To assign the beds in question to a lower stratigraphic position would require considerable structural rise in some 500 yards.

Physiography

The physiographic features of Cass County are discussed by J. L. Tilton in Iowa Geological Survey volume 27, pages 179-184.

Structure

Because of the lack of control, little can be said at this time about the structure in Cass County. The area of most control is in the vicinity of Grant, Montgomery County, where natural exposures, quarry operations, and exploratory drilling for petroleum have revealed the presence of a rather well delineated dome.

From the southwest corner of the county there is a gentle anticlinal nose that extends northeast to the vicinity of Lewis. To the north of this point there appears to be a very shallow, narrow syncline from which the strata rise gently to the north.

Evidence of at least moderate local structure is shown at two outcrops in T. 75 N., R. 37 W. At one outcrop in the SE¼NW¼ sec. 1 of this township, the top of the Leavenworth limestone is 1,120 feet above sea level. At another outcrop in the NE¼SE¼ sec. 2 of this township, shales tentatively assigned to the Lawrence-Stranger formation are 1,116 feet above sea level. Here, in a horizontal distance of about 1,500 feet, there is a structural rise of at least 25 feet toward the west.

Future drilling undoubtedly will show the structure to be much more complex than is now shown on the structure map that accompanies this report (fig. 17).

Rock Sources

Present data indicate the area about Lewis to be the most promising site for prospecting. The structural nose described above and the relatively thin overburden may combine to make available the Plattsmouth limestone, or perhaps the Argentine limestone.

An interesting locality that should be drilled in an effort to determine the structural details is in secs. 1 and 2, T. 75 N., R. 37 W., which was described under the section on structure. In sec. 1 of this township, the entire Plattsmouth limestone possibly may be found by drilling somewhat east of the outcrop of the lower part of this member on Turkey Creek in the SE¼NW¼ of this section. Drilling in the vicinity of the outcrop of the Lawrence-Stranger shale on Turkey Creek in the NE¼SE¼ sec. 2, T. 75 N., R. 37 W., may be advisable on the premise that the structure here is rising toward the west and that the underlying Argentine limestone may be found close enough to the surface to be quarried.

In the NE¼NE¼ sec. 16, T. 75 N., R. 37 W., exposures of the Plattsmouth limestone are to be seen at a number of points in the bluffs of the Nishnabotna River and, in the NE¼SE¼NE¼ of the same section, the lower part of the Plattsmouth and underlying Heebner shale and the Leavenworth limestone are exposed in the river. At this latter point the rocks appear to have a slight dip to the southwest. Farther to the southwest at the SW cor. sec. 17 of this township, the Kanwaka shale, which directly overlies the

Plattsmouth limestone, is exposed in a cutbank. Perhaps between the river cut in sec. 16 and the exposure in sec. 17 a full thickness of the Plattsmouth can be found with an economically favorable amount of overburden.

Over the remainder of the county the available logs of water wells indicate that the thickness of Pleistocene drift and Cretaceous shales and sandstones is too great to permit economical stripping for quarrying.

FREMONT COUNTY

Stratigraphy

With the exception of a very limited area near the north-central edge of the county (fig. 2) all of the bedrock of Fremont County is referred to the upper portion (Wabaunsee and Shawnee groups) of the Virgil series (fig. 21). These strata also constitute the uppermost members of the Pennsylvanian system in Iowa. Near the north edge of the county drilling has encountered bedrock of the Douglas-Pedee, Lansing, and Kansas City groups. It is possible that small patches of sandstone or conglomerate of Cretaceous age are present in the uplands, as in the neighboring counties of Mills, Montgomery, and Page, but these materials are not well enough exposed to allow their sure identification.

The mantle of glacial drift is extremely variable in thickness as a result of filling of the deep bedrock channels. The greatest recorded drift thickness in the county is near the southwest corner, where 390 feet of drift overlies bedrock. Nebraskan and Kansan drift sheets are present in Fremont County, but a thick mantle of post-Kansan loess covers the drifts except in the deeper valleys where erosion is relatively active. The loess at present offers no material for road construction, but further research in the burning characteristics of this material may reveal a use for it.

The oldest rocks exposed in Fremont County are units of the Shawnee group and only the uppermost formations of this group are visible in quarries and infrequent outcrops. The following detailed section shows the characteristics of the rocks of the upper Shawnee group, along with the lowest part of the Wabaunsee group. This section was taken from two quarries in sec. 23, T. 70 N., R. 43 W.

Virgil series	
Wabaunsee group	
Severy shale	Feet
1. Shale, olive-green, platy to blocky, with *Crurithyris*; upper 0.2 foot dark-gray, thin-bedded	2.0
2. Coal, soft, powdery (Nodaway)	0.5
3. Shale, upper 0.3 foot orange-brown, weathers medium gray, clayey; shale with plant fossils 1 foot below top	3.0–4.0

Shawnee group

Topeka formation

Coal Creek limestone

4.	Limestone, bluish-gray, dense, massive, finely banded	0.5
5.	Shale, olive, mottled dark, clayey, hard, thin-bedded; lower 0.8 foot bleached, soft, blocky	2.2
6.	Limestone, dark-blue, weathers blue, argillaceous	0.4
7.	Limestone, dense, 0.4-0.8-foot beds, contains black chert in lower 1 foot; *Marginifera, Ottonosia,* crinoid stems, high-spired gastropods	2.0
8.	Shale, black, weathers bluish gray, abundant *Crurithyris*	0.4
9.	Limestone, light bluish-gray, dense, contains pyrite	0.8
10.	Shale, dark-gray, clayey, contains *Crurithyris*	0.3
11.	Limestone, light bluish-gray as above, with *Marginifera*	0.5

Holt shale

12.	Shale, black, more blocky in lower portion, abundant *Crurithyris* above	1.0
13.	Shale, black, platy, fissile, hard; coaly streak 0.15 foot below base of fissile shale	0.4

DuBois limestone

14.	Limestone, bluish-gray, dense, abundant gastropods, occurs locally	0–0.6

Turner Creek shale

15.	Shale, dark-gray, clayey, with abundant *Marginifera, Derbyia,* pyrite nodules	1.0
16.	Limestone, light-gray with green mottling, weathers light gray and rounded, very argillaceous and blocky	1.6
17.	Shale, medium-gray, clayey, blocky	1.1

Sheldon limestone

18.	Limestone, white, oolitic, weathers slabby, abundant bellerophontid and high-spired gastropods	0.8
19.	Limestone, weathers light gray, massive, sublithographic, oolitic, with pyrite nodules, abundant *Osagia,* increasingly algal near the top	2.4

Jones Point shale

20.	Shale, dark-gray to black, clayey, upper portion quite limy; clams in lower part; productids and other brachiopods in middle and upper part; contains nodular and lenticular beds of bluish-gray, dense limestone	6.9

Curzon limestone

21.	Limestone, light-gray, weathers white, fine-grained with pseudo-oolitic texture, massive single bed;	

Myalina on upper surface, large bellerophontid and high-spired gastropods 1.0

22. Shale, brownish-gray, soft, platy, some fossil hash 0.8
23. Limestone, chalky looking, weathers white and blocky, very argillaceous, dense 3.5
24. Shale, dark olive-gray, clayey, platy 0.5
25. Limestone, light-gray, weathers gray to buff, dense, with black to brown chert lenses in the middle part 3.0

Iowa Point shale

26. Shale, upper 0.1 foot black, contains *Crurithyris*, lower part gray 0.3
27. Limestone, light-gray, dense, nodular, argillaceous, with *Osagia* and crinoid stems 0.3
28. Shale, upper part olive, clayey, weathers gray, platy, with *Crurithyris;* lower part black, platy, with *Lingula* 0.7

Hartford limestone

29. Limestone, light-gray, fine-grained, massive, single bed, with abundant *Ottonosia*, some gastropods 1.2

Calhoun formation

30. Shale, upper part dark-gray, with fossil hash; lower part dark-gray, weathers blue; clayey, blocky 1.2

Deer Creek formation

Ervine Creek limestone

31. Limestone, light-gray, weathers light gray, wavy-bedded, abundant *Osagia* and brachiopod sections; pyrite in lower part 2.8
32. Shale, gray, limy, with fusulinids 0.2
33. Limestone, brownish-gray, weathers light gray, argillaceous; obese fusulinids concentrated along shale partings in upper 3 feet; fine-grained and bedded in lower 3 feet 7.0

Units 1-12 of this section were described from a quarry in the NW¼SW¼ sec. 23, T. 70 N., R. 43 W., and units 13-33 from a quarry in the SW¼NW¼ of the same section. Along the bluff to the north into section 14 of this township these beds can be traced as they dip into the Bartlett syncline.

In the SE¼SW¼, sec. 17, and the center of the NW¼ sec. 20, T. 70 N., R. 42 W., two quarries have been opened that expose the Curzon-Ervine Creek interval. The members exposed here are essentially the same as their equivalents in the section given above. Outcrops of the Coal Creek limestone, Sheldon limestone, and the Iowa Point shale may be seen along Plum Creek in the NE¼ sec. 17 of this township.

Elsewhere in the county members of the Wabaunsee group make up the outcrops. The Wabaunsee group in Iowa is composed of thick shale sections

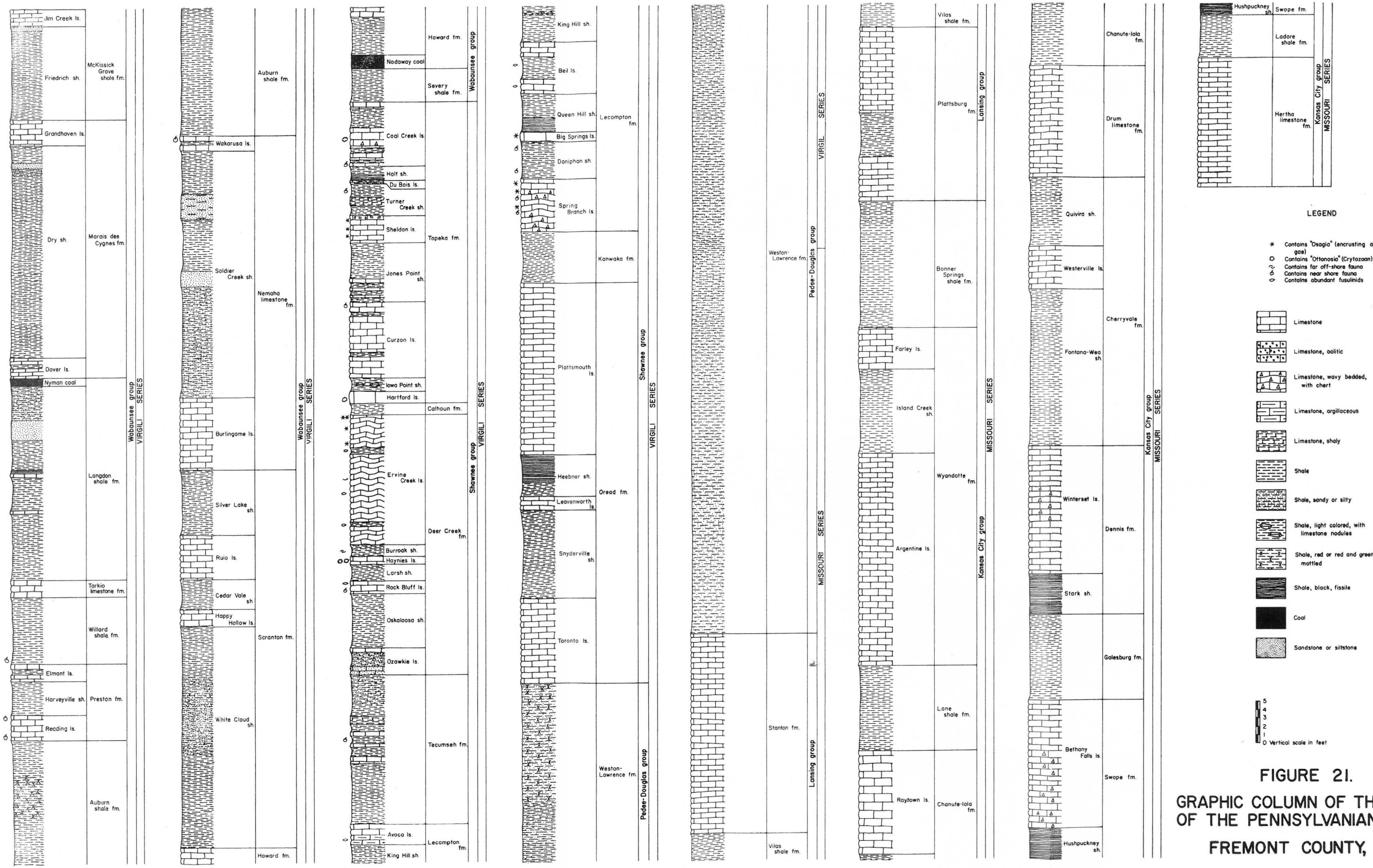


FIGURE 21.
GRAPHIC COLUMN OF THE ROCKS OF THE PENNSYLVANIAN SYSTEM
FREMONT COUNTY, IOWA

separated by thin beds of limestone that seldom exceed 2 feet in thickness. Outcrops are quite numerous near Hamburg, and in the area around Thurman. The following is a composite section modified after Condra and Reed (1938, p. 12-13). From this it may be seen that there is little possibility for large-scale quarrying operations within this group, although numerous small quarries have been operated for immediate local use.

Virgil series	
Wabaunsee group	
Friedrich shale	Feet
1. Shale, bluish-gray, with 6-inch sandstone bed at top, top eroded	10.5
Grandhaven limestone	
2. Limestone, dark blue-gray, argillaceous to pebbly, with pelecypods, gastropods, fragmentary fossils, crinoid joints, bryozoans, *Osagia*, etc.	1.5–3.0
Dry shale	
3. Shale, bluish-gray; upper part sandy with some sandstone; argillaceous below, about	25.0
Dover limestone	
4. Limestone, earthy, blue-gray, argillaceous, weathers brownish; tends to separate in two beds	2.8
Table Creek-Willard shale	
5. Shale, largely bluish-gray; Nyman coal near top, with 3-foot sandstone 4 feet below top; some thin limestones in lower part; reddish and fossiliferous at base	33.0–36.0
Elmont limestone	
6. Limestone, in two beds separated by shale; upper bed argillaceous; lower bed blue-gray and dense	2.0
Harveyville shale	
7. Shale, covered, probably	3.0–4.0
Reading limestone	
8. Limestone, blue-gray, dense, jointed, crinoidal; weathers yellowish; poorly exposed, probably about	3.0
Auburn shale	
9. Shale, bluish-gray in upper and lower part; maroon in middle part; fossiliferous at base; poorly exposed	30.0–35.0
Wakarusa limestone	
10. Limestone, in two fossiliferous beds separated by shale	1.8
Soldier Creek shale	
11. Shale, bluish-gray, with 3-foot red sandy zone 5 feet below top; lower 14.5 feet largely sandstone; 21 feet exposed; thickness determined by drilling on Theis farm, north of Nebraska City	29.0

Burlingame limestone

12. Limestone, not exposed, probably about	8.5

Silver Lake-White Cloud shale

13. Shale, not exposed, probably about	90.0

Howard limestone

14. Limestone; upper part light-gray, with bryozoans, brachiopods, etc., weathering yellowish; lower part blue-gray, slightly sandy, with gastropods and small pelecypods; about	4.5

Severy shale

15. Shale, bluish-gray and black; with Nodaway coal 2 feet above base; about	10.0

Location of measurements: Beds 1-2, W½ sec. 1 and W½ sec. 12, T. 69 N., R. 43 W.; beds 3-5, S½ sec. 13 and NE¼ sec. 24, T. 67 N., R. 42 W.; beds 5-6, SW¼ sec. 36, T. 70 N., R. 43 W.; beds 8-11, NE¼ sec. 35 and SW¼ sec. 26, T. 70 N., R. 43 W.; beds 12-13, test holes in Nebraska; beds 14-15, S½ sec. 14, T. 70 N., R. 43 W.

Physiography

The physiographic features of Fremont County are discussed by J. A. Udden in Iowa Geological Survey volume 13, pages 127-131.

Structure

The structure map (fig. 17) indicates an asymmetrical anticline in the northwest corner of Fremont County with one flank dipping steeply to the southeast at the rate of about 350 feet in 3 miles, and the other flank dipping more gently to the northwest at about 60 feet in 3 miles. The axis of the anticline trends approximately southwest-northeast and the stone quarries previously mentioned are on, or very near, the crest of the anticline. This structure has been described as a fault, an anticline, and an anticline with faulting. The latter is probably correct, although the faulting must be of very minor extent. In a quarry in the center of NW¼ sec. 20, T. 70 N., R. 42 W., small faults trending northeast to north-northeast were observed. From the quarry entrance the northwest side is downthrown, with displacements of about 4 to 6 inches. Farther east in the quarry, the southeast side is downthrown, with one observed displacement of at least 12 inches. These small faults, scattered throughout the flanks of the anticline, could very well account for the situation near Thurman where dip measured on the outcrop is not enough to account for the structure that is known to exist.

From a point in sec. 13, T. 69 N., R. 43 W., the strata dip into a syncline where they pass entirely below the bottomland level, to rise again in the vicinity of Waubonsie State Park (secs. 29, 32, T. 67 N., R. 42 W.). A small anticline trending southwest-northeast, whose axis passes approximately through Hamburg, has brought members of the Wabaunsee group to the surface in the vicinity of Hamburg and Riverton. The crest of this anticline is made up of two domes separated by a shallow saddle. The smaller dome lies just northeast of Hamburg and the larger dome lies southeast of Riverton. The term Riverton-Hamburg domes is convenient when referring to this structure.

Rock Sources

In the past some quarries have been opened in the rocks of the Wabaunsee group but these have been strictly for local use, because the amount of limestone in comparison to shale is much too small to warrant a large scale operation.

The geologic column (fig. 21) for Fremont County shows that the uppermost rock in the Shawnee group that is thick enough to be quarried economically is the Ervine Creek limestone of the Deer Creek formation. The only quarries operating at the present time are those utilizing the Ervine Creek as the main source in conjunction with the much thinner overlying limestones.

At the present time there seems little possibility of any new localities for quarry operations within the county. The heavy drift cover, coupled with the fact that the Wabaunsee group constitutes the bedrock over the greater part of the county, makes open-pit quarrying practical only where erosion has been vigorous enough to expose the upper rock of the Shawnee group.

The amount of overburden is considerable and is a limiting factor in the life of the operation at all quarry sites in this county. However, there is stone available at most of these places and it is an economic problem as to whether it can be removed.

The possibilities of underground mining should be seriously considered. This would permit the use of not only the Ervine Creek member but would probably make it economically feasible to mine some of the underlying members in the Shawnee group such as the Plattsmouth, for example. The governing factor would probably be the initial cost of shafting, which would in part be balanced by the steadier production of a cleaner stone and protection from inclement weather. Much more extensive prospecting should be done, with the possibility of mining being kept in mind. The most reliable method of subsurface prospecting in the rocks of the Wabaunsee and Shawnee groups is with the core drill. Many of the correlations in these groups depend upon the interpretation of the sequence of shales and limestones, and this sequence cannot be properly determined with any other method of drilling except under very special conditions.

MILLS COUNTY

Stratigraphy

All of the known exposures of indurated rock in Mills County are referred to the Shawnee group of the Pennsylvanian system (fig. 22), except for a few scattered remnants of sandstone of Cretaceous age. With the exception of a few minor exposures, the glacial mantle effectively conceals the bedrock in the eastern part of the county. As in Fremont County, the only exposures of any consequence are along the bluff line of the Missouri River valley and major tributaries. Starting at the southern edge of the county in sec. 34, T. 71 N., R. 43 W., the Ervine Creek limestone of the Deer Creek formation is seen in the bluff, rising to the north to section 21 of the same township where members of the Topeka formation have been quarried.

A detailed description taken from two quarries in sec. 21, T. 71 N., R. 43 W., follows:

	Feet
Virgil series	
Shawnee group	
Topeka formation	
Turner Creek shale	
1. Limestone, medium-gray, fine-grained, hard, calcite-lined vugs, some iron staining, contains *Ottonosia*	0.2
2. Shale, buff to gray, fossiliferous, becoming limy toward base, grading into unit 3. Abundant *Derbyia*, etc., fossil hash in upper 0.4 foot	2.0
3. Limestone, light-gray to buff, weathers very light buff, calcite veins, very argillaceous, almost a shale in places	1.5
4. Shale, buff to gray, blocky	2.0
Sheldon limestone	
5. Limestone, light- to medium-gray, weathers white to yellow, locally black on joint planes, becoming shaly near base; brown to black chert nodules near top; upper 3 feet forms one massive bed; contains *Osagia* and brachiopods	4.0
Jones Point shale	
6. Shale, medium- to dark-gray, massive and blocky above; two or three limestones in the lower half of the shale interval which are medium gray, fine grained, argillaceous, and contain large *Chonetes*, *Derbyia*, *Rhombopora*, other fossil fragments	6.0
Curzon limestone	
7. Limestone, light-gray, fine-grained to dense and earthy, brown chert nodules in upper part, lower part shaly, grades to next lower unit	2.0
8. Shale, dark-gray, weathers light gray, well-bedded	1.0
9. Limestone, light-gray to buff, much brown to black chert in bed 1.0 foot from top; very fossiliferous in lower 0.5 foot below chert	2.8

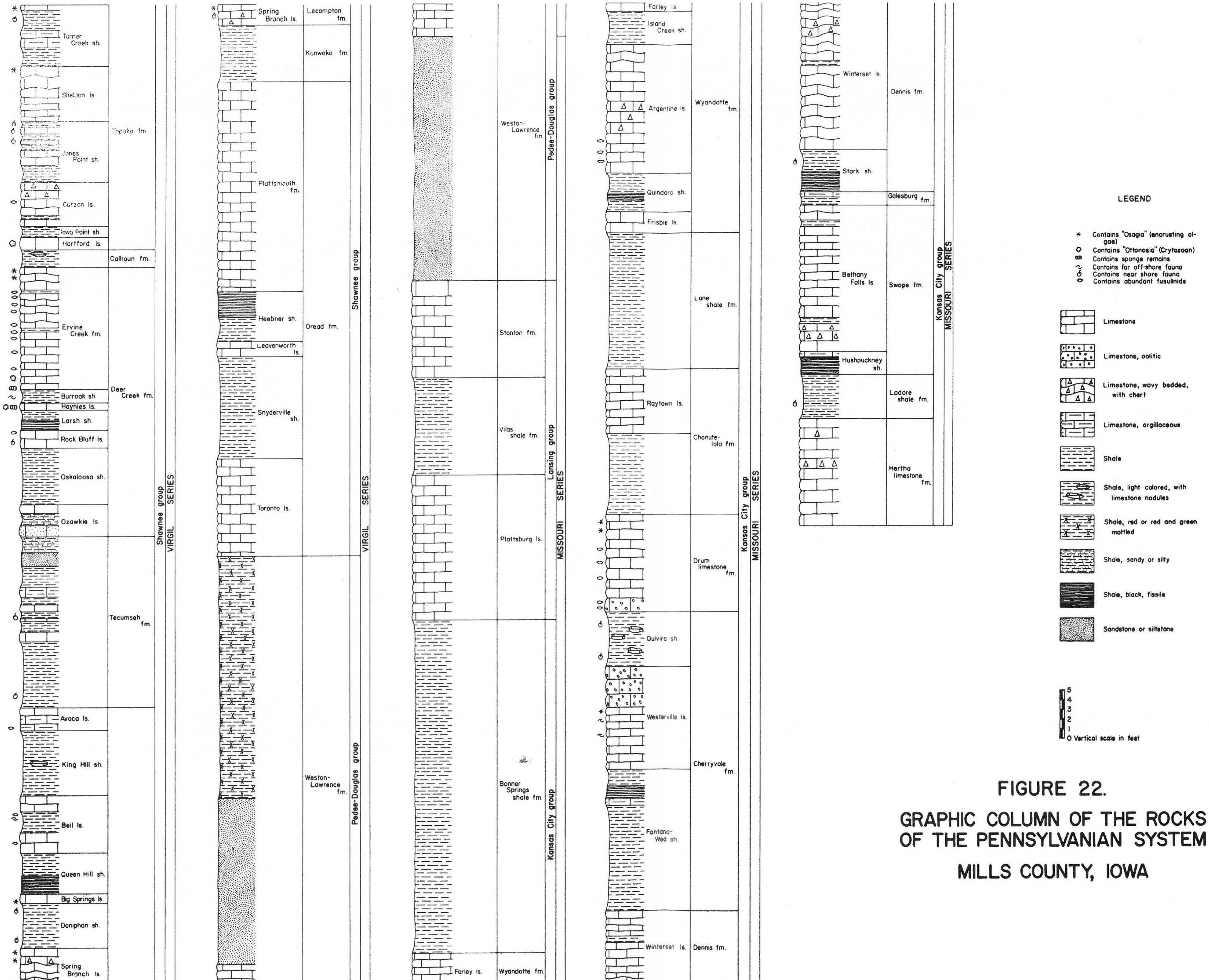


FIGURE 22.

GRAPHIC COLUMN OF THE ROCKS OF THE PENNSYLVANIAN SYSTEM

MILLS COUNTY, IOWA

Iowa Point shale

10. Limestone, medium- to dark-gray, fine-grained, massive, hard, contains crinoid stems — 0.5
11. Shale, light-gray, black at base and top, a 0.2-foot argillaceous limestone bed near top — 1.5

Hartford limestone

12. Limestone, light bluish-gray, dense, hard, one massive bed, *Ottonosia* abundant, crinoid fragments, bryozoans, gastropods — 1.3

Calhoun formation

13. Shale, dark-gray, locally iron-stained — 0.3
14. Shale, olive, blocky, some dark-gray mottling — 0.9

Deer Creek formation

Ervine Creek limestone

15. Limestone, light-gray, dense, hard, generally two beds of almost equal thickness, calcite-lined vugs, gastropods, many *Osagia* — 3.2
16. Shale, buff above and light bluish-gray below, marcasite nodules, crinoid stems, spirifers. A short distance north (0.4 mile) this bed is very thin and brown and black chert nodules are present — 0.8
17. Limestone, medium-gray, dense, hard, many *Osagia* — 1.1
18. Limestone, dark- to pinkish-gray, weathers light gray, hard, dense, in beds 5 to 8 inches thick; thin shale partings, fusulinids in limestone, crinoids — 1.8
19. Shale, medium- to dark-gray, weathers light blue gray, locally well indurated, many fusulinids — 0.2
20. Limestone, light brownish-gray, hard, massive, in beds 5 to 8 inches thick, thin shale partings; 0.3-foot shale zone 1 foot from top, fusulinids in shaly part — 4.0

Units 1-11 were described from a quarry in the SW¼SE¼NE¼ sec. 21, T. 71 N., R. 43 W., and units 12-20 from a quarry in the NE¼SE¼SE¼ of the same section.

In the E½NW¼NW¼ sec. 15, T. 71 N., R. 43 W., in an old quarry the following section may be seen.

Virgil series

Shawnee group

Deer Creek formation

Ervine Creek limestone — Feet

1. Limestone, light-gray, weathers grayish buff, finely crystalline, abundant small *Osagia*, weathers slabby, hard — 2.2

2. Shale, light-gray, weathers buff, very calcareous, gradational to limestones above and below, large fusulinids	0.5
3. Limestone, light-gray, weathers grayish buff and slabby, finely granular, limy shale partings, large fusulinids, *Stereostylus*	3.4
4. Shale, buff, weathers brown, very calcareous, abundant large fusulinids	0.3
5. Limestone, light-gray, weathers buff, finely crystalline, thin calcareous shale partings, wavy-bedded, fossil hash, *Ottonosia*; shaly at base with large fusulinids	4.0
6. Limestone, medium bluish-gray, weathers light bluish gray, finely crystalline, massive single bed, abundant *Ottonosia, Composita, Marginifera,* fistuliporoid bryozoans	1.9
Burroak shale	
7. Shale, medium olive-gray, clayey, dark-gray layer 0.3 foot from top, very fossiliferous	1.2
Haynies limestone	
8. Limestone, dark-gray, weathers grayish buff, hard, single massive bed, fine-grained, crinoids, *Ottonosia, Amblysiphonella, Juresania,* gastropods	0.8
Larsh shale	
9. Shale, medium grayish-brown, dark mottled gray near top, lower half is darker gray to nearly black at base	2.0
Rock Bluff limestone	
10. Limestone, medium- to dark bluish-gray, massive single bed, very fossiliferous, wavy-lined fossil section in middle, obese fusulinids and small gastropods in lower part	1.6
Oskaloosa shale	
11. Shale, dark grayish-brown, blocky, pyrite on joints	6.0
Ozawkie limestone	
12. Limestone, light-gray, fine-grained, hard	0.4
13. Shale, dark-gray, arenaceous	1.5
14. Limestone, yellowish-buff, sandy	1.1
Tecumseh formation	
Rakes Creek shale	
15. Shale, greenish-gray, sandy near base, grades to siltstone below	2.0
16. Siltstone, light grayish-green, weathers buff	1.5
17. Shale, grayish-green	1.5

18.	Limestone, light-gray, weathers buff, thin stringers of green shale, argillaceous, blocky	1.0
19.	Shale, greenish-gray, clayey	0.8
Ost limestone		
20.	Limestone, light buff-gray, shaly	0.5
21.	Shale, olive above, grades to dark-gray near base, abundant gastropods	0.5
22.	Limestone, medium-gray, hard	0.2
23.	Shale, dark-gray	1.0
24.	Limestone, yellow, impure, thin shale stringers	1.0

North of the above section in the SW¼NW¼SE¼ sec. 10, T. 71 N. R. 43 W., the following detailed Pennsylvanian section may be seen at a waterfall and above.

Virgil series
Shawnee group
Lecompton formation

		Feet
Avoca limestone		
1.	Shale, dark-gray to bluish-black, weathers light gray, more calcareous and indurated below. *Crurithyris, Chonetes, Composita, Derbyia, Punctospirifer,* ramose bryozoans	2.0+
2.	Limestone, dark-gray to black, weathers brownish gray, massive, fusulinids, bryozoans, brachiopods in lower 0.6 foot	1.8
King Hill shale		
3.	Shale, dark grayish-green, clayey, blocky	4.0
4.	Limestone, light grayish-green to almost maroon, weathers buff, very nodular, a resistant layer	1.5
5.	Shale, medium- to dark-gray, mottled at base, clayey, blocky	1.5
6.	Same as unit 4 with green clayey shale	0.7
Beil limestone		
7.	Limestone, light-gray, fine-grained, dense, hard, one massive bed, *Osagia*	2.0
8.	Shale, buff to olive-gray, very fossiliferous with bryozoans, fusulinids, large *Campophyllum torquium* (type fossil), *Composita*	2.0
9.	Limestone, gray, argillaceous, massive, corals, crinoid stems	0.9
Queen Hill shale		
10.	Shale, grayish-green, with limestone nodules	1.0
11.	Shale, grayish-green, blocky, clayey, dark streak 0.6 foot below top	2.3

12. Shale, black, fissile, hard	exposed	0.4

The above section is on the south edge of a southeast trending preglacial channel and no indurated rock is now exposed to the north until the following section may be seen in the SW¼SE¼SW¼ sec. 29, T. 73 N., R. 43 W., about half a mile south of Gowin school.

Virgil series

Shawnee group

Lecompton formation

Beil limestone	Feet
1. Limestone, upper two-thirds light- to medium-gray, dense, hard; lower one-third rusty-brown and not as resistant as upper part, *Campophyllum torquium*	1.8
2. Shale, yellow to buff, well indurated, typical Beil fossils, *Campophyllum torquium*, *Cladochonus*, fusulinids; grading into limestone above and below	2.1
3. Limestone, buff, earthy, locally well indurated, *Syringopora;* argillaceous and nodular in lower part	1.9
Queen Hill shale	
4. Shale, olive, clayey, blocky	1.3
5. Shale, black, clayey	0.2
6. Shale, olive-brown, blocky	1.0
7. Shale, black in middle, brownish-black at top and bottom, fissile	1.9
Big Springs limestone	
8. Limestone, light- to medium-gray, hard, argillaceous, one massive ledge, contains *Osagia*	0.9
Doniphan shale	
9. Shale, olive, blocky, locally well indurated; lenses of limestone, abundant *Linoproductus*, *Chonetes;* very typical of the Doniphan shale	2.5+

The Spring Branch limestone is exposed north from the foregoing location, at an old quarry just east of the road at Folsom in the N½SW¼NW¼ sec. 29 in the same township. Still farther north, in the SE¼NW¼ sec. 20 in the same township at a cut along the bluff road, the following section may be seen, although it is poorly exposed. Overlying the Pennsylvanian rocks at this exposure are 21 feet of white sandstone and ferruginous peanut conglomerate that closely resemble Cretaceous sandstone, but because of evidence found at another location it is known to be of Pleistocene age. This will be discussed later.

Virgil series
Shawnee group
Lecompton formation

Big Springs limestone	Feet
1. Limestone, brownish-gray, fine-grained, blocky	0.5
Doniphan shale	
2. Shale, olive-brown; limestone lenses in the upper part	4.6
Spring Branch limestone	
3. Limestone, weathers brown, impure, nodular	1.5
4. Limestone, gray, weathers brown, especially near top; massive, dense, pyrite crystals and calcite-filled vugs throughout; brown and black chert throughout but more common near the top	4.5
5. Limestone, bluish-gray, dense, massive, some black chert	1.2
Kanwaka formation	
Stull shale	
6. Shale, bluish-gray, well indurated and massive, grading into limestone, a few black slaty seams, very fossiliferous at certain horizons, few pyrite nodules	4.8

Exposures are rare throughout the remainder of the county because the thickness of glacial deposits increases greatly to the east. Near Malvern in the N½SE¼SE¼ sec. 31, T. 72 N., R. 41 W., about 1,500 feet downstream from the bridge located at the E¼ cor. sec. 31, a ledge of limestone forms a small waterfall. A detailed section follows.

Virgil series
Shawnee group
Lecompton formation

Spring Branch limestone	Feet
1. Limestone, dark bluish-gray, fine-grained, dense, massive; black chert layer at top and bottom; fossiliferous with productids, small clams, crinoid stems (this ledge is not found in place but as large blocks of float above falls)	1.0+
2. Limestone, buff-gray, weathers dark gray, medium-crystalline, massive, dense, fossiliferous with *Ottonosia*, large productids, *Wellerella*, crinoids. Forms falls	1.2+

It is likely that a shale bed separates the two limestones, but this could not be established because unit 1 was not found in place. Identification is not certain; but on the basis of appearance, elevation, and a slight northerly dip, these beds are assigned to the Spring Branch limestone.

At the site of an old quarry in the banks of Silver Creek, near Malvern, the following Pennsylvanian section was measured. The location is in the NW¼SW¼ sec. 5, T. 71 N., R. 41 W.

Virgil series
  Shawnee group
    Oread formation

Plattsmouth limestone	Feet
1. Limestone, light-gray, weathers light buff-gray, massive, finely crystalline, dense, small pockets with calcite, fossils not abundant, few *Osagia*, brachiopods, and crinoid stems	1.0
2. Limestone, light-buff, medium-crystalline, fusulinids abundant	4.0

In the banks of Spring Valley Creek in the center of the N½ sec. 36, T. 71 N., R. 42 W., intermittent exposures which appeared to dip to the west at about 3 degrees could formerly be seen along meanders where the creek cuts into the valley wall. A quarry has since been opened, using the Ervine Creek limestone as the working ledge. The following section was exposed.

Virgil series
  Shawnee group
    Topeka formation

Hartford limestone	Feet
1. Limestone, light-gray, very dense, few fossils, *Ottonosia*, *Chonetes*, gastropods, bryozoans	1.0
Calhoun shale	
2. Shale, bottom 1 inch is yellow-brown grading upward to grayish-green and back to yellow-brown; top portion is gray to light gray; fossil hash in upper 2 inches	2.0
Deer Creek formation	
Ervine Creek limestone	
3. Limestone, light-gray, finely crystalline, one massive bed, many *Osagia*, few fusulinids, crystalline calcite veins	1.0
4. Limestone, light-brown	0.2
5. Limestone, buff- to medium-gray, weathers light gray, finely crystalline, calcite veins abundant, one massive bed, fusulinids abundant	1.0
6. Shale, light-gray to green, very calcareous with some crystalline calcite, contains some silt and iron oxide, many fusulinids	0.3
7. Shale, light-gray, silty, containing light-gray, finely crystalline limestone	0.4
8. Limestone, light-gray, finely crystalline; calcite-lined vugs near middle and base; *Osagia*, obese fusulinids	

	near top; interbedded shale and limestone beds 0.3 to 1.0 foot thick	6.0
9.	Shale, light- to dark-brown, very calcareous, slightly silty, crinoid fragments, fusulinids, corals	0.5
10.	Limestone, light-gray, finely crystalline, massive, scattered fossil fragments, *Osagia*	2.0
Burroak shale		
11.	Shale, black, buff near upper contact, calcareous, silty	0.4
12.	Shale, light-gray to olive, calcareous with elongated limestone concretions, some silt and iron stains	0.8
13.	Shale, mottled, light-green to gray, calcareous	0.1
14.	Shale, black, calcareous, silty	0.2
15.	Shale, yellow to buff, calcareous	0.2
Haynies limestone		
16.	Limestone, light-gray, massive, finely crystalline, contains *Osagia*, and calcite veinlets	0.8
Larsh shale		
17.	Shale, yellowish-brown, becoming darker towards base, calcareous and silty, iron stains	1.3
Rock Bluff limestone		
18.	Limestone, dark to bluish-gray, weathers light gray, finely crystalline	1.5

In the northeast part of this county are small exposures of sandstone of Cretaceous (?) age. One such exposure is in the SW cor. sec. 14 and another in the NW cor. SW¼NE¼ sec. 22, T. 73 N., R. 40 W. Both are poorly exposed but in all probability are rather extensive.

An interesting outcrop that in many ways resembles the Cretaceous sandstones is to be seen along the bluffs in the SE¼NW¼ sec. 32, T. 73 N., R. 43 W. A well-cemented sandstone and peanut conglomerate is found high in the bluff. However, digging in the covered interval below the exposed rock has revealed till and "loess" which definitely makes the exposed rock Pleistocene in age.

Physiography

The physiographic features of Mills County are discussed by J. A. Udden in Iowa Geological Survey volume 13, pages 127-131.

Structure

Owing to sparsity of outcrops and deep-well records, it is not possible to get a detailed picture of the structure in Mills County. However, some conclusions can be drawn on the basis of what is known of the area.

At the southwestern edge of the county the rocks continue lowering for a short distance into the syncline which lies north of the anticline in northwest Fremont County. North from a point in the NE¼ sec. 34, T. 71 N.,

R. 43 W., the rocks again rise, which accounts for the succession of progressively older rocks that are exposed northward along the bluff line. A structural rise of about 80 feet occurs from the NE¼ sec. 34, T. 71 N., R. 43 W., to the NW¼SE¼ sec. 10, of the same township, a distance of about 3.5 miles. No rock is exposed between the latter point and an exposure in sec. 29, T. 73 N., R. 43 W. A deep-well record at Glenwood indicates that between these points there has been a lowering of 65 feet from the highest known point on the anticline in sec. 10, T. 71 N., R. 43 W., although this does not necessarily mean that Glenwood is situated over the deepest part of the syncline. Northward from Glenwood there is again a structural rise. The anticline rises about 60 feet in a distance of about 4 miles from sec. 29, T. 73 N., R. 43 W., to the SE¼ sec. 6, of the same township.

Across the remainder of the county it is impossible to make any definite statement about the structure. From the present data it appears probable that the small syncline at the southwest corner of Mills County plunges to the southwest and the two anticlines coalesce to form a single anticline trending northeast. On the basis of a single well near Henderson, it is believed that the syncline underlying Glenwood extends across the entire county.

Rock Sources

In Mills County there appears to be little chance of opening quarries at any new locations other than along the bluff line, with perhaps one exception described below. As in Fremont County, the overburden rapidly becomes excessive eastward from the face of the bluff. In the past many quarries have been opened along this line and were worked back into the bluff only a relatively short distance before the amount of stripping became prohibitive. There is still rock available at most of the abandoned locations. Modern earth-handling equipment has made it economically possible to strip a greater amount of overburden than was possible in the past, but even this is not sufficient to permit large-scale operations. In view of this, the possibilities of mining should be thoroughly investigated, keeping in mind the structure that is present in this county.

At locations where the Ervine Creek has been utilized in open-pit quarrying, the underground operations could be started by driving tunnels into the face of the quarry if a satisfactory roof is present. Presumably then it would be best to mine up-dip to facilitate drainage. Farther north along the bluff line where the structure rises to expose the Beil limestone and underlying formations, it is expected the Plattsmouth limestone would be found at depths that would not be too great. At an old quarry in the N½SW¼NW¼ sec. 29, T. 73 N., R. 43 W., the Spring Branch limestone is exposed. At this point the top of the Plattsmouth limestone should not be more than 15 feet below the top of the exposed rock. The thickness of the Plattsmouth here should be about 20 feet. Intense core drilling along the bluff in this area would seem to be justified.

The only location away from the bluff line that appears to hold promise for development is at a very old quarry site in the NW¼SW¼ sec. 5, T. 71 N., R. 41 W. At this place there is a small exposure of rock that has been correlated with the Plattsmouth limestone. The quarry was probably abandoned because of excessive overburden. Efficient stripping methods may make this a worthwhile prospect.

MONTGOMERY COUNTY

Stratigraphy

The exposures in Montgomery County are of the Shawnee and Wabaunsee groups (fig. 23), with the exception of some rather extensive exposures of the Cretaceous system. The Cretaceous in this county is comprised of sandstones and conglomerates with some shales, all of which are quite ferruginous. Tester (1931, p. 257-258) calls the exposures near Coburg typical of the Dakota sandstone and conglomerate. He gives the following detailed section for an exposure in the S½ sec. 30, T. 71 N., R. 38 W., just east of Coburg.

Zone		Feet
6	Silt to clay, gray to buff, contains much fragmented plant material and carbonized wood. Exposed	8–10
5	Sandstone and conglomerate, dark brown, red and yellow. Very irregularly bedded with particles ranging from sand to cobble grades; cement very unevenly distributed with some concentrations as concretions surrounding yellow friable masses. The pebble zones are irregularly distributed, though in detail they appear to be concentrated as foreset beds or small depression fills. The pebbles and cobbles are principally a brown cherty and gray vein quartz. The cross-bedding is normally constant for single zones, but the variety includes inclinations of foresets to the southwest, west and south. Figure 27 shows one of the upper hard ferruginous cross-bedded zones of the coarse sand and peanut gravel. Zone 5 overlies Zone 4 unconformably	12–25
4	Sandstone, yellow, buff and gray; wide variety of sizes of grains, ranging from cobbles to medium-grained sands. Cementation differs, controlling color and friability of rocks; not generally as well cemented as Zone 5. Color bands follow cross-lamination directions. Throughout exposure practically every pos-	

sible direction of cross-bedding may be noted; in the upper part the directions of foresets are dominantly in the north-northwest quadrant; in the central and lower parts of the foresets range from southwest, south, southeast, to east. In several zones there are definite 2- to 3-inch bands of pebbles which are usually nearly horizontal or inclined at very low angles; the less sand contained in the pebble zone the more horizontal is the position. Figures 29 and 30 show two views of the pebble bands and cross-bedded zones of this part of the exposure 12–15

3 Conglomerate, pebbles up to three-fourths inch in diameter. Makes a definite band in nearly horizontal position 2–3

2 Sandstone, medium- to coarse-grained at base grading to finer sands at top. Foresets inclined to south-southwest. At base is a single layer of pebbles lying on irregular contact of Zone 1 1–2

1 Sandstone, yellow to buff, medium- to coarse-grained with conglomerate in some of the foreset zones. Cross-bedding inclined to the north-northwest. Exposed 2–3

Most of the other Cretaceous exposures in Montgomery County show some if not all of the above zones. The rock is distinctive when seen at the surface and can usually be differentiated from the older rock of the area without difficulty. However, some of the contacts of the Cretaceous clay and sands with those of the overlying Pleistocene are very indefinite. This fact makes the subsurface interpretation of the Cretaceous rather difficult. On the basis of samples taken from well drillings the Cretaceous is seen to be quite extensive, although apparently missing in some areas. This may be due to the fact that it was deposited in lenses or that post-Cretaceous erosion removed the formation. Subsurface studies also show a far greater thickness of shale than is ordinarily seen in outcrop. The shales are soft and especially subject to erosion and slumping which results in the removal or overgrowth of the less resistant materials.

The exposures of the Wabaunsee group of the Pennsylvanian system are small and for the most part have not been differentiated. One exposure of this group is in the center of the south line NW¼ sec. 20, T. 71 N., R. 37 W., and at this locality only about 15 feet of rock is visible. This is typical Wabaunsee in that within the 15 feet there are six limestone beds with a total thickness of 4 feet. The exact stratigraphic position of these beds is not known but they are tentatively assigned to the Auburn-Elmont interval, which would place them about 200 feet above the top of the Shawnee group. A detailed description of the section follows.

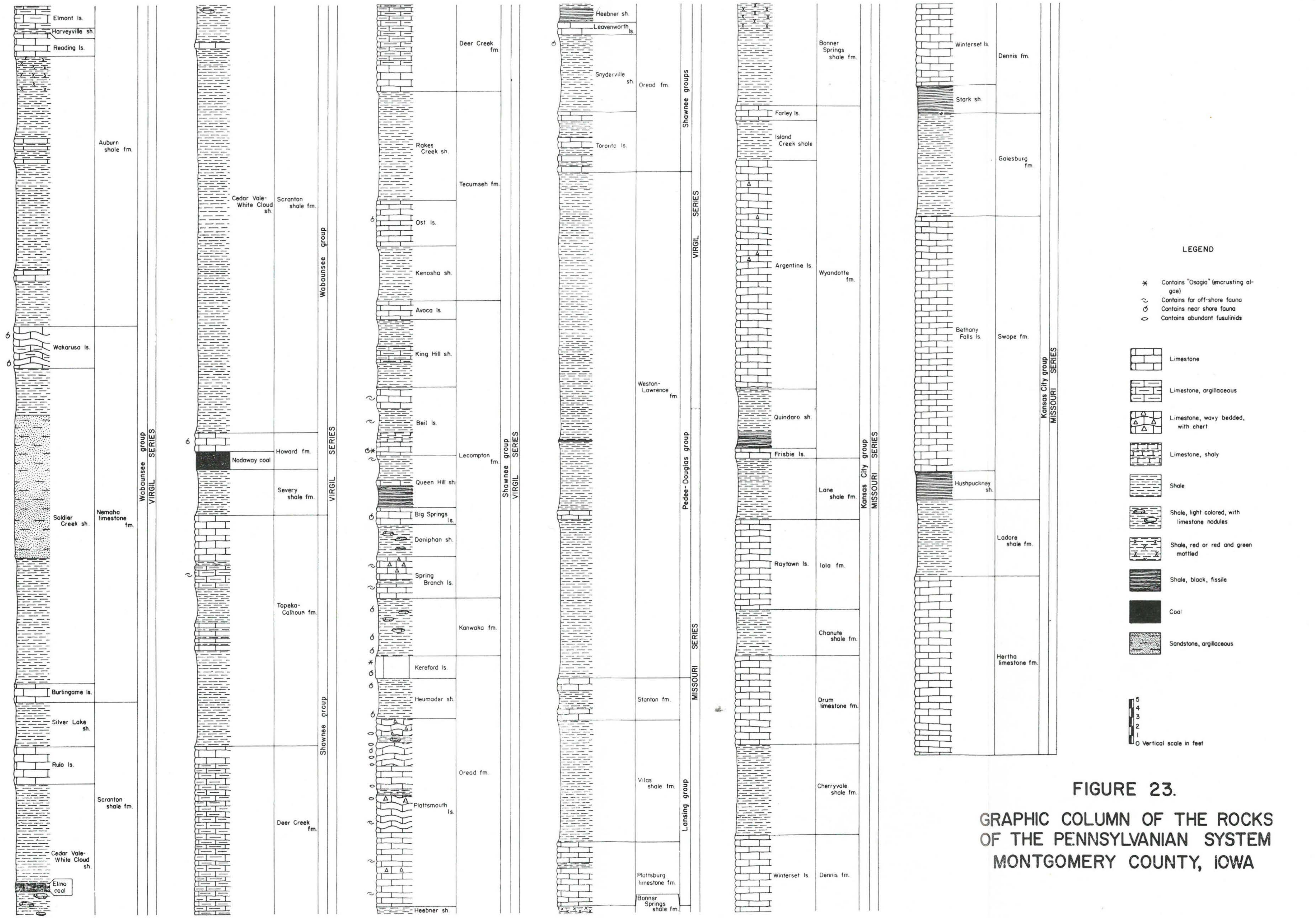


FIGURE 23.

GRAPHIC COLUMN OF THE ROCKS OF THE PENNSYLVANIAN SYSTEM MONTGOMERY COUNTY, IOWA

Virgil series
Wabaunsee group
Elmont limestone

1.	Limestone, light-gray, hard, fine-grained, dense, fossiliferous, almost covered in hillside	0.5
	Harveyville shale	
2.	Covered interval	3.0–5.0
	Reading limestone	
3.	Limestone, buff to brown, impure, porous; top 1 inch is reddish brown, hard, laminated, sandy	0.4
4.	Shale, buff to brown, calcareous	0.3
5.	Limestone, light-gray, hard, laminated, sandy	0.3
6.	Limestone, gray to buff, impure boulders in a yellowish-brown, clayey shale matrix	1.5
7.	Limestone, gray to brown, dense, medium-grained	0.5
8.	Shale, light-gray, silty, calcareous	1.0
9.	Limestone, light-gray, hard, fine-grained, dense, crystalline calcite, fossil fragments, one massive bed	1.0
	Auburn shale	
10.	Shale, rusty-brown, small veins of calcite, calcareous clay masses	0.8
11.	Shale, light-gray, slightly calcareous	1.0
12.	Shale, rusty-brown	0.6
13.	Shale, greenish-gray, calcareous	2.0
14.	Shale, dark reddish-brown, slightly calcareous, small masses of greenish-gray shale	1.0+

In T. 72 N., R. 36 W., a lower part of the Wabaunsee group may be seen exhibiting the very thin limestone and thick shale sections so characteristic of the group. Following is a composite of two exposures.

Virgil series
Wabaunsee group

	Soldier Creek shale	Feet
1.	Sandstone and siltstone, gray, micaceous; a gray shale in the upper few feet	16.0
2.	Shale, gray and buff, thin-bedded	14.0
	Burlingame limestone	
3.	Limestone, dark-gray, filled with broken fossil fragments	0.6
4.	Shale, dark-gray, soft, clayey	1.6
5.	Limestone, gray, medium-grained, argillaceous, blocky	1.3
	Silver Lake shale	
6.	Shale, gray, calcareous, laminated	5.3

Rulo limestone	
7. Limestone, gray, weathers reddish brown, dense, fine-grained, concretionary and sandy above, fragmental in part and pyritic below	1.6
Cedar Vale shale	
8. Shale, bright-gray	10.0
9. Shale, dark-gray, some limonitic bands in weathered portions	1.0
10. Lignitic coal, brown and black, soft, impure	1.0
11. Shale, gray, weathers buff, blocky, much nodular limestone	5.0
12. Shale, bright-gray, blocky	3.0
13. Limestone, dark-gray, highly weathered on surface, thin-bedded, fragmental	0.5
14. Shale, dark-brown, silty, fissile on top, dark-gray below	0.5

Units 1-10 were measured in the SW¼SE¼ sec. 25, and the remainder of the section in the NW¼NE¼ sec. 36, T. 72 N., R. 36 W. These correlations are not positive and are made on the premise that the lignitic bed, unit 10, represents the Elmo coal of the Cedar Vale shale.

Other exposures of the Wabaunsee group in this county may be located on the outcrop map (fig. 7). The exposures are of such small extent and so scattered as to make correlations extremely doubtful. However, it is very probable that the exposed rocks of this group belong to the Elmont or lower formations.

In Montgomery County only the lower portions of the Shawnee group are exposed. The exposures are localized, mostly in T. 73 N., R. 36 and 38 W., although there are a few in T. 72 N., R. 38 W.

The highest member of the Shawnee exposed in the county may be seen at an outcrop in the SW¼NE¼ sec. 26, T. 73 N., R. 38 W. A detailed description follows.

Virgil series	
Shawnee group	
Lecompton formation	
King Hill shale	Feet
1. Shale, light-brown, clayey, with small nodular limy masses	0.5
2. Shale, greenish-gray, blocky	0.2
Beil limestone	
3. Limestone, light-gray, weathers medium gray, dense, very fossiliferous with crinoid fragments, large clams, gastropods, spirifers, *Syringopora,* abundant *Osagia;* weathers irregularly at base	1.5

4. Shale, light-brown, clayey, contains nodular limy masses, very fossiliferous with crinoid stems, *Crurithyris Chonetes, Campophyllum*	0.8
5. Limestone, dark greenish-gray, argillaceous, contains many crinoid fragments, few fusulinids, bryozoans, brachiopods, partially covered	0.3+
Queen Hill shale	
6. Covered interval	2.0
7. Shale, lower 0.5 foot dark-gray, clayey; followed upward by 0.2 soft black coal. Upper 2.3 feet brownish-black, very fissile and platy, forms large sheets	3.0
Big Springs limestone	
8. Limestone, dark-gray, blocky, argillaceous, weathers chalky, very fossiliferous with crinoid stems, brachiopods, bryozoans, and burrowing clams	1.4
Doniphan shale	
9. Shale, drab to brown, platy to blocky, soft, contains two or three very fossiliferous nodular limestone beds, 0.1 to 0.2 foot thick. Increasingly calcareous near top and contains burrowing clams, abundant *Linoproductus, Chonetes*	3.3+

A lower section of the Shawnee may be seen in a quarry about a mile from the above location in the center of the NE¼ sec. 27, T. 73 N., R. 38 W. The top member here exposed is the Doniphan shale, which is at the base of the preceding section. A detailed description follows.

Virgil series
Shawnee group
Lecompton formation

Doniphan shale	Feet
1. Shale, yellow	3.0
Spring Branch limestone	
2. Limestone, light-gray to olive-gray, weathers buff, fine-grained to sublithographic, one massive ledge, very fossiliferous with crinoid fragments, ramose bryozoans, brachiopods; dark-gray chert masses in upper part	0.8
3. Limestone, light-brown to olive-drab, weathers brown, shaly, contains crinoids, bryozoans, brachiopods	0.2
4. Same as unit 2	1.0
5. Shale, olive-drab, blocky, very soft with hash of thin-shelled brachiopods, crinoid fragments, bryozoans; contains irregular limy nodular layer	1.0

6. Limestone, dark bluish-gray, weathers buff-gray, fine-grained, dense, contains thin-shelled brachiopods, bryozoans, crinoids, horn corals; weathers into rounded blocks 0.5
7. Limestone, gray- to dark-gray, fine-grained, dense, contains *Crurithyris, Juresania, Chonetes* 0.8

Kanwaka formation

8. Shale, greenish-gray, weathers gray, clayey, blocky 0.5
9. Shale, black, weathers mottled black and olive, weathers platy 0.7
10. Shale, grayish-brown, upper portion calcareous with calcareous nodules; very fossiliferous with *Crurithyris* predominating in upper part, lower part also contains *Composita, Marginifera, Wellerella,* crinoid plates and stems; middle portion contains *Chonetes, Derbyia, Juresania* 4.3
11. Shale, greenish-brown, with maroon streaks, blocky, soft, contains many thin brachiopod fragments, *Chonetes, Crurithyris* 1.0

Oread formation

Kereford limestone

12. Limestone, tan, weathers buff gray, nodular *Osagia* at top with *Osagia* throughout, sparsely fossiliferous 1.8

Heumader shale

13. Shale, chocolate-brown grading downward to maroon, blocky 2.0
14. Shale, dark greenish-gray to black in upper part, dark green in middle part, grades downward to deep maroon at bottom, soft, clayey and blocky 2.0

Plattsmouth limestone

15. Limestone, light-gray, sublithographic, massive, dark-gray to brown chert, contains many *Triticites* 2.0
16. Shale, buff, flood of *Triticites* 0.2
17. Limestone, buff, some dark chert with *Triticites* 1.0
18. Shale, olive-brown, clayey, unfossiliferous 0.5
19. Limestone, light-gray, weathers light gray, argillaceous slabby, some *Triticites* 1.3
20. Shale, olive-brown, becoming dark olive brown downward 1.4
21, Limestone, very light bluish-gray, fine-grained, dense, with *Osagia* 0.7
22. Limestone, pinkish-buff, argillaceous, black chert masses with white *Triticites* very persistent 0.4–0.6

23. Limestone, light bluish-gray, argillaceous, fine-grained, massive, contains *Triticites*, crinoids — 5.5
24. Shale, dark-brown, weathers light brown, clayey, platy when dry — 0.3
25. Limestone, dark-gray, weathers light gray, argillaceous, contains crinoids, *Triticites*, black chert nodules with white *Triticites*, generally about 2 feet from the top — 6.6

A short distance south of the foregoing section, in the SE¼SW¼ NE¼ sec. 27, T. 73 N., R. 38 W., an exposure in the road ditch shows the lower part of the Plattsmouth limestone and some of the underlying members of the Oread formation. A detailed section follows:

Virgil series	
Shawnee group	
Oread formation	
Plattsmouth limestone	Feet
1. Limestone, light-gray, weathers gray buff and into rounded blocks, many *Triticites* on weathered surface, a few brachiopods and *Osagia* at the top	0.5–0.8
2. Covered interval (probably as below)	0.5
3. Limestone, light-gray, weathers buff, shale partings, becomes very shaly toward top	3.3
4. Limestone, light-gray, weathers yellowish gray, massive, dense, very fine-grained, *Triticites*, gray chert nodules	1.6
5. Covered interval, (probably a shaly limestone)	1.0
6. Limestone, light-gray, nodular and shaly at base	2.0
Heebner shale	
7. Shale, gray to olive, blocky, contains *Crurithyris*	2.8
8. Shale, brownish-black and black, platy, hard, base approaches a shaly lignite	2.2
Leavenworth limestone	
9. Shale, light-gray, very limy with pellets of limestone, very fossiliferous with *Chonetes*, *Stereostylus*, ramose bryozoans, *Composita*, *Marginifera*	0.5
Snyderville shale	
10. Shale, light olive-gray, blocky, contains small coarsely crystalline limestone lenses, flood of large *Chonetes*. Exposed	2.0

The Leavenworth limestone as seen at this outcrop does not appear to be characteristic. However, Moore (1935, p. 165) states that this member has a tendency to weather into bouldery remnants, much as seen here.

The foregoing section contains the oldest exposed rock in this county.

Elsewhere, the Plattsmouth limestone and overlying rocks are exposed in quarries and outcrops, and except for minor detail, there is little difference from the sections already described (see fig. 7). Near Grant a few quarries have been opened in the Plattsmouth limestone which maintains the same characteristics as at Stennett.

In the NW¼SW¼ sec. 17, T. 72 N., R. 38 W., northwest of Red Oak, a quarry has been opened that allows a very good comparison of the Spring Branch-Plattsmouth interval. A detailed section follows.

Virgil series	
Shawnee group	
Lecompton formation	
Spring Branch limestone	Feet
1. Shale, light-gray, contains lime nodules, *Rhombopora*, *Crurithyris*	1.5
2. Limestone, dove-gray, weathers into nodules, massive, argillaceous, some black chert, contains *Crurithyris*, crinoids, gastropods	0.8
Kanwaka formation	
3. Shale, olive, clayey	0.8
4. Shale, light-gray, clayey, with lime nodules, many *Crurithyris*, *Rhombopora*, crinoid stems, more fossiliferous downward	3.2
5. Shale, olive, weathers brown, clayey, with pectens	1.5
Oread formation	
Kereford limestone	
6. Limestone, light-gray, weathers buff, finely crystalline, single massive layer, finely oolitic near top. *Osagia* in upper half, *Bellerophon*, fusulinids, crinoids and echinoids	2.0
Heumader shale	
7. Shale, greenish-gray, brownish-gray near center, thin-bedded, some iron staining locally, slightly calcareous	1.0
8. Shale, brown to buff, some bluish-gray streaks, non-calcareous, more massive near base	1.2
9. Shale, rusty with black mottled layer near center, some small white to greenish layers, very calcareous	0.5
10. Shale, light greenish-gray, slightly calcareous, limy concretionary layer near base, *Chonetes*. (Beds 7-10 contain clams, bryozoans, *Lingula*)	1.5
Plattsmouth limestone	
11. Limestone, upper 1.5 feet rusty, argillaceous, contains small light- to dark-brown chert nodules near the top; less resistant, very argillaceous 0.5 foot layer at base	2.0

12.	Limestone, gray to buff, dense, hard, one massive bed, contains fusulinids and brachiopods	1.0
13.	Limestone, shaly, abundant large black chert nodules	0.4–0.6
14.	Limestone, light-gray, dense, hard, one massive ledge, crowded with fusulinids, some crinoid fragments, gastropods, and burrowing clams	3.5
15.	Shale, light greenish-gray, with fusulinids, crinoid fragments	0.2
16.	Limestone, light-gray, weathers rusty, shaly, argillaceous, fusulinids	1.0
17.	Shale, gray to greenish-gray, contains limy nodules, very fossiliferous with fusulinids, crinoids	0.9
18.	Limestone, light bluish-gray, very persistent, dense, hard, fusulinids and brachiopods, shale parting at base	0.6
19.	Limestone, light-gray, weathers buff, massive 0.3-foot bed of chert nodules near top, locally argillaceous, some thin shale seams; contains fusulinids	3.6
20.	Limestone, gray to brownish-gray, argillaceous, in beds 0.4 to 0.8 foot thick, more shaly and thin-bedded near base, with fusulinids and brachiopods	3.4
21.	Limestone, light-gray, dense, massive, hard, black chert nodules in basal part, with crinoids, fusulinids	2.3
22.	Limestone, light-gray, argillaceous, locally shaly; this bed forms floor of the quarry	2.0+

Physiography

The physiographic features of Montgomery County are discussed by E. H. Lonsdale in Iowa Geological Survey volume 4, pages 386-387.

Structure

In Montgomery County, as in all of the counties of southwestern Iowa, the overburden is generally very thick and the information from wells is limited, which makes it extremely difficult to present any definite statements about the structure. At first glance it would seem that the anticline recognized in Mills County continues northeasterly across Montgomery County and that outcrops are found only along the streams whose cutting action has been vigorous enough to erode through the drift mantle overlying bedrock. However, some streams are barren of rock although erosion has proceeded as far as in other streams which do show outcrops. This is believed to result from some streams cutting into areas of local doming rather than into a simple elongate anticline. The outcrops found along the streams are usually of such limited extent and have dips of such small magnitude that doming is not readily apparent. However, in quarries where stripping has exposed a greater horizontal section of rocks, the dip becomes very apparent and is an important factor in the manner in which the quarry is worked.

Near Grant, in the northeast corner of the county, observed dips in quarries and structural evidence from outcrops and core holes show that this is an area of doming, with perhaps several lobes extending outward from the main structure. In a quarry in the NW¼NE¼ sec. 5, T. 73 N., R. 36 W., the dip is to the south-southeast, while slightly to the southeast in a quarry in the center of the N½SW¼ sec. 3, T. 73 N., R. 36 W., the dip is to the southwest. A reversal of dip is found in a quarry located in the SW¼NW¼ sec. 10, of the same township, where the dip is observed to be northeast. The high point on this dome is apparently east of Grant with a small synclinal fold extending north-south just east of Grant. The structure map (fig. 17) shows the remainder of the structural picture as it is now interpreted.

The structure at Stennett appears to be oriented north-south with quite a strong easterly dip. Elevations taken in quarries show a drop of about 40 feet in somewhat less than a mile from sec. 26 to sec. 25, T. 73 N., R. 38 W. Farther south in sec. 17 and 18, T. 72 N., R. 38 W., the dip, as measured in a quarry, has changed to the southwest at the rate of 3 feet in 100 feet. This may indicate that a dome structure also occurs here. Southward the structure rapidly drops off into a syncline and only rocks of Wabaunsee and Cretaceous age can be found in outcrops.

Rock Sources

The Plattsmouth limestone is the primary rock quarried in Montgomery County with perhaps the overlying Kereford and Spring Branch limestones furnishing a small part of total production. The Wabaunsee group offers nothing of value for quarrying. Considering these factors it seems that the most logical places for future explorations would be near the structural highs (see fig. 17) where beds below the Wabaunsee have been brought close to the surface.

A number of exposures, chiefly of Plattsmouth limestone in T. 73 N., R. 38 W., give promise of being potential sites for development. In the SE¼SE¼NE¼ sec. 33 a 10-foot section of the Plattsmouth is exposed in road ditches and at the SE cor. sec. 21 and SW cor. sec. 22 there is an extensive outcrop in which the Plattsmouth is well exposed. An exposure in the SE¼NE¼ sec. 26 has the Doniphan shale at the base, and the Plattsmouth will be about 15 feet below this member. A small but probably important outcrop in a road ditch in the SE¼SW¼SW¼ sec. 33 of this township is tentatively identified as the Spring Branch limestone. If this is the correct correlation, the Plattsmouth will be about 12 to 15 feet below this rock. All of these locations may be worthy of core drilling. In the center of the NW¼ sec. 3, T. 72 N., R. 38 W., a section from the Spring Branch limestone to the

Plattsmouth limestone is exposed in an old quarry. This quarry was probably not depleted and modern methods could possibly allow economically profitable operation at this site. A very obscure outcrop along Walnut Creek in the center of the NE¼SE¼ sec. 1, T. 72 N., R. 39 W., has been tentatively identified as Kanwaka shale. This is 5 to 10 feet above the top of the Plattsmouth limestone and drilling in this area might be worthwhile.

The possibilities in the Grant area have been quite well explored and exploited.

PAGE COUNTY

Stratigraphy

All of the indurated rocks exposed in Page County are in the Wabaunsee group (fig. 24), with the exception of three minor exposures of the Shawnee group and two of Cretaceous age. Although only two exposures of Cretaceous rocks are present in the county, drilling in the vicinity of Shenandoah has shown that Cretaceous sandstones underlie much of T. 68 and 69 N., R. 39 W. A very limited exposure in a ravine west of the center of the NE¼ sec. 25, T. 70 N., R. 38 W., shows about 8 feet of sandstone and conglomerate with the ironstone concretions and iron cementing so characteristic of the Cretaceous in Iowa. Another exposure of conglomerate that is almost certainly Cretaceous in age is located in the SW¼NE¼ sec. 13, T. 67 N., R. 38 W. The conglomerate here very closely resembles that seen near Coburg in Montgomery County, except that the cementing material here is calcium carbonate, and the characteristic iron staining is not as apparent.

The oldest rock exposed in Page County is at the SW¼SW¼SE¼ sec. 30, T. 67 N., R. 36 W., just south of the bridge at Braddyville on the west bank of the Nodaway River. A detailed description follows.

Virgil series
Shawnee group
Topeka formation

Coal Creek limestone	Feet
1. Limestone, dark bluish-gray, weathers light gray, nodular, fine-grained, two beds separated by thin shale, no fossils observed	0.5
2. Shale, brown	0.1
3. Limestone, bluish-gray; weathers light gray with a distinct line between weathered and fresh surface; fine-grained and dense	0.3
4. Shale, buff, contains limestone nodules, many fusulinids, crinoids, *Chonetes, Dictyoclostus*	4.0

5. Limestone, light bluish-gray, weathers light gray, fine-grained, massive, very fossiliferous with crinoid stems, *Rhombopora*, and *Fenestella*, *Worthenia*, *Marginifera*, *Juresania* 0.7

Holt shale

6. Shale, light buff-brown, calcareous	0.2
7. Shale, olive-brown, blocky, fossiliferous	1.0
8. Shale, black, blocky, clayey	0.8
9. Shale, black, fissile	0.7

DuBois limestone

10. Limestone, medium light-gray, fine-grained, dense, fossiliferous with *Osagia*, weathered surface a coquina of *Composita*, *Derbyia*, clams 0.9

Turner Creek shale

11. Shale, medium-gray, clayey and blocky, exposed 0.6

The DuBois limestone at this locality contains the fossils weathering in relief on the surface of joint planes, which is characteristic for this member. An aid in identifying the Coal Creek limestone is the sharp color distinction between the fresh and weathered surfaces, as described in unit 3 above. The chert commonly found associated with this member in Fremont County is absent here.

The Coal Creek limestone is better exposed just south of the bridge near Hawleyville in the NE¼SW¼ sec. 13, T. 69 N., R. 36 W. The section is as follows:

Virgil series

Shawnee group

Topeka formation

Coal Creek limestone	Feet
1. Limestone, dark-gray, weathers light gray and somewhat slabby, fine-grained, dense, fossiliferous with brachiopods and pelecypods, bottom very irregular	0.4
2. Shale, dark-gray, calcareous, platy, contains some shell fragments	0.3+
3. Limestone, medium dark-gray, weathers light gray, fine-grained, dense, massive, many brachiopods including *Marginifera*, *Juresania*	1.1
4. Shale, very dark-gray, blocky, clayey	1.1
5. Limestone, light-gray, weathers light gray, shaly, brachiopods, crinoid stems	1.2
6. Shale, dark olive-gray, blocky	0.6
7. Limestone, light-gray, weathers light gray, medium- to coarse-grained, somewhat soft	0.2

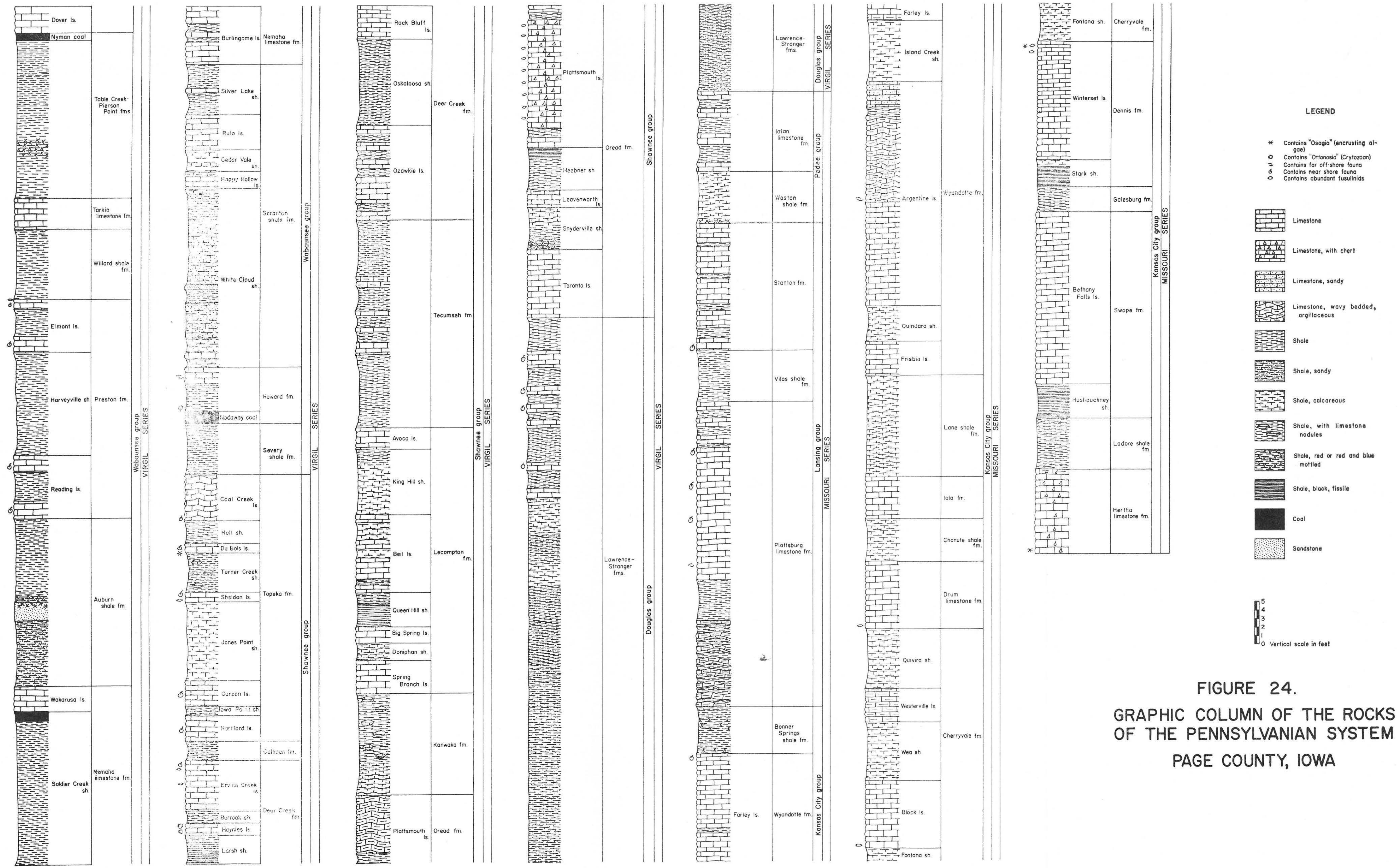


FIGURE 24.

GRAPHIC COLUMN OF THE ROCKS OF THE PENNSYLVANIAN SYSTEM

PAGE COUNTY, IOWA

Holt shale

8. Shale, dark-brown, blocky, hard, with limy intervals, exposed to water level — 1.0

The Coal Creek-DuBois interval is also exposed in the center SW¼ sec. 26, T. 69 N., R. 36 W. The exposure extends along the river for almost one-eighth mile, but it is slumped and almost completely overgrown.

Previous workers have described a section in the SE cor. sec. 12, T. 69 N., R. 36 W., from an abandoned quarry where lime was once burned. No rock is now exposed at that locality but from the descriptions probably the Severy shale, the lowest member of the Wabaunsee group, and the Coal Creek-DuBois interval were exposed.

There are numerous scattered exposures of the Wabaunsee group in Page County, but because they are of limited vertical and horizontal extent it is difficult to establish the stratigraphic relationships of the various sections. For this reason some of the correlations are tentative, and only the larger exposures will be described in detail. All exposures in the county have been measured in detail and are included in the list of exposures with this report.

The largest exposure in the county is found at the SE cor. SW¼ sec. 2, T. 69 N., R. 38 W., at the site of an old Civilian Conservation Camp quarry, which has become slumped and overgrown. The following section was measured.

	Feet
Virgil series	
Wabaunsee group	
Willard shale	
1. Limestone, light olive-brown, weathers buff, fine-grained, dense, very fossiliferous with crinoids, gastropods, small brachiopods	0.5
2. Covered interval, probably shale	4.0
Elmont limestone	
3. Limestone, light-gray, weathers buff, medium-crystalline, fossiliferous with *Triticites*, crinoid stems, bryozoans, small brachiopods, small horn corals	0.6
4. Shale	0.3
5. Limestone, medium-gray, fine-grained, dense, one massive ledge, very fossiliferous with *Crurithyris*, *Triticites*, crinoids small high-spired gastropods	1.0
Harveyville shale	
6. Covered interval, probably shale	8.5
Reading limestone	
7. Limestone, medium dark bluish-gray, weathers buff, fossiliferous with *Osagia*, brachiopod sections, crinoids, bryozoans, burrowing clams	1.5

8. Shale, dark-gray — 0.2
9. Limestone, highly weathered to brown, argillaceous, *Osagia*, burrowing clams, brachiopods, crinoids — 1.0

Auburn shale

10. Shale, dark olive-green, blocky; maroon layer about 2 feet thick starting about 8 inches from top; becomes sandy and micaceous near base — 9.0
11. Sandstone, greenish-brown, weathers maroon; top part more resistant than shale above; becomes finer downward — 1.0+
12. Sandstone, light-green becoming lighter in color toward the base of the exposure, weathers buff, micaceous, locally limy — exposed 8.0

Unit 12 is exposed across the road from the above location and about 3 feet below the base of unit 11.

Approximately the same interval as is shown by the foregoing section is represented in the west bank of a small creek in the NW¼NE¼SW¼ sec. 7, T. 70 N., R. 37 W. The detailed section is given below.

Virgil series

Wabaunsee group

Elmont limestone — Feet

1. Limestone, light-gray, weathers buff, fossiliferous with *Dibunophyllum*, *Ottonosia;* fossils are recrystallized and obscure — 0.5
2. Limestone, medium bluish-gray, weathers buff, fine-grained, dense, contains marcasite, fossiliferous with crinoids, fusulinids, fenestellid bryozoans — 0.7

Harveyville shale

3. Shale, gray, platy — 3.0
4. Limestone, highly weathered to a buff brown, very argillaceous, grades upward into a shale — 1.0
5. Concealed interval, probably shale — 1.0

Reading limestone

6. Limestone, light bluish-gray, fine-grained and dense, argillaceous at bottom, one massive bed very fossiliferous with *Osagia*, *Chonetes*, *Stereostylus*, thin brachiopod sections — 1.4
7. Shale, buff to brown, *Chonetes* — 0.3
8. Limestone, medium-gray, highly weathered to a buff brown, argillaceous, *Marginifera*, *Linoproductus* — 0.8

Auburn shale

9. Shale, dark chocolate-brown, grades into an indistinct

maroon zone, and finally to an olive green at base; lime-iron concretions; very fossiliferous at top 3.0

10. Shale, light olive-gray, micaceous and silty toward base 3.0
11. Siltstone, light olive-gray, micaceous, grades downward to a very fine sandstone and to silty sandstone at base of exposure exposed 5.0

The Elmont-Tarkio interval has been tentatively identified in a small exposure on the east bank of Middle Tarkio River in the SW¼SW¼SE¼ sec. 34, T. 69 N., R. 38 W. The section follows.

Virgil series
Wabaunsee group

Tarkio limestone	Feet
1. Limestone, medium light-gray, weathers light gray, very fine-grained, hard, massive	0.7
2. Limestone, weathers light brown, shaly in upper portion, silty texture in lower portion	0.6
3. Siltstone, light greenish-gray, micaceous	0.4
4. Shale, very light greenish-gray, silty, micaceous; lower 1 inch exceedingly fossiliferous with crinoid stems and plates	0.5
5. Limestone, medium light-gray, slabby with crinoids and thin brachiopod sections in upper 0.2 foot; lower portion dark-brown, dense, fine-grained, hard	1.1
6. Limestone, light-buff, shaly	0.8
Willard shale	
7. Shale, light greenish-gray, blocky	1.8
8. Shale, deep-maroon, blocky	8.0
9. Shale, medium dark-gray, silty	1.4
Elmont limestone	
10. Limestone, light-gray, weathers slabby, silty textured, interbedded with thin, platy, light-gray shales	2.9

Presumably the youngest rock exposed in Page County is found along a small stream in the NW¼NE¼NW¼ sec. 19, T. 70 N., R. 37 W. The detailed section follows.

Virgil series
Wabaunsee group

Dry shale	Feet
1. Shale, dark olive-green, contains an indistinct maroon zone, clayey; exposures are slumped, making it difficult to distinguish from glacial material	3.0+

Dover limestone

2. Limestone, light-gray, weathers gray buff, fine-grained, dense, fossiliferous with *Triticites*	0.7
3. Shale, dark olive-gray, *Crurithyris*, bryozoans	1.0
4. Limestone, light buff-gray, medium-grained, very fossiliferous with many *Triticites*, crinoids, brachiopod sections; base uneven; lower parts of thicker portions are coarsely crystalline and bluish gray	0.5–0.9
5. Shale, buff to light-brown, weathers gray, calcareous, has thin dark-brown to black lignitic zone at base that ranges from 0.1 to 0.3 foot in thickness, very lignitic where thinner; upper part of shale very calcareous and platy and contains *Marginifera*	0.1–0.4
6. Limestone, medium-gray, fine-grained, dense, very fossiliferous with *Triticites*, *Chonetes*, crinoids, gastropods, bryozoans, small pelecypods, one massive layer	1.0

Table Creek shale

7. Shale, light-gray to buff, upper portion calcareous and platy, becomes more blocky and gray downward	6.5
8. Shale, dark olive-green	0.5

Maple Hill limestone

9. Limestone, light greenish-gray at top, becoming dark greenish gray downward, slightly argillaceous, to creek level	1.0

Units 2 through 6 of the foregoing section are placed in the Dover limestone on the basis of the presence of numerous *Triticites*. The absence of the persistent Nyman coal in the shale, here called Table Creek, casts some doubt on the correlation. However, it is possible that unit 6 is actually a phase of the Table Creek shale and the lignite zone (unit 5) represents the Nyman coal.

A core taken in the NW cor. sec. 2, T. 70 N., R. 39 W., extends the section beneath the Reading limestone-Auburn shale interval previously described. This core was drilled by the Missouri Valley Limestone Company to a depth of 138 feet. The detailed log follows.

Virgil series

Wabaunsee group

Reading limestone

	Drilled	Recovered
	Feet	
1. Limestone, light bluish-gray, fine-grained, dense, *Ottonosia*, tiny *Triticites*, crinoid fragments, thin brachiopod sections	1.4	1.4

Auburn shale		
2. Shale, maroon, with yellow to green mottling, soft, earthy	11.0	1.6
3. Siltstone, greenish-gray, micaceous, slightly calcareous, grades into zones of silty limestone and very hard fine-grained dolomite appearing as nodules	10.0	2.0
4. Shale, light- to dark-gray, silty, micaceous, contains organic fragments and obscure pyrite nodules; platy at top, blocky at center, becoming subfissile near base; very fossiliferous in lower 0.5 foot with brachiopods, pelecypods, crinoids	14.4	14.4
Wakarusa limestone		
5. Limestone, medium-gray top and bottom; center portion dark-gray, coarse-grained, hard; crinoid stems in all parts; upper and lower portions argillaceous, fine-grained, soft	2.9	2.9
Soldier Creek shale		
6. Shale, light- to medium-gray; white calcareous zones near base; blocky, somewhat micaceous	1.7	1.7
7. Siltstone, light-gray, calcareous inclusions	2.4	2.4
8. Shale, light- to greenish-gray, platy, silty, very micaceous	3.4	3.4
9. Shale, mottled dark-gray and black; carbonaceous in upper 1.5 feet, medium gray below; very micaceous; small inclusions of quartz sand grains	3.5	3.5
10. Siltstone, gray, banded dark-gray to black, some pyritized plant remains, carbonaceous fragments, micaceous, argillaceous zones	16.0	16.0
11. Shale, medium-gray in upper part, somewhat silty; lower portion dark gray, has *Chonetes*, ostracodes, small pyrite inclusions, blocky above, platy toward base	12.5	11.5
Burlingame limestone		
12. Limestone, dark- to very dark-gray, brecciated, mass of fossil fragments, *Osagia*	0.9	0.9
13. Shale, light greenish-gray, very calcareous with numerous thin bands of light-brown limestone; less calcareous and somewhat silty and micaceous in lower portion	3.2	3.2

14. Shale, dark-gray, blocky, slightly silty	0.8	0.8
15. Limestone and shale; soft, pinkish limestone in very light-gray shale matrix; shale very calcareous; dark fossil fragments throughout	0.9	0.9
Silver Lake shale		
16. Shale, light-gray and somewhat silty above becoming dark-gray, platy below with some plant fragments; zone near middle is greenish-gray with brown laminations, silty, micaceous	10.0	10.0
17. Shale, black with white calcareous fossil fragments giving mottled effect, very carbonaceous, some pyritized plant fragments	0.5	0.5
18. Limestone, light-gray, fine-grained, dense with black to dark-gray shale inclusions	0.3	0.3
19. Limestone, light-gray, argillaceous, fine-grained	0.7	0.7
20. Shale, light greenish-gray, very calcareous, silty, and micaceous; with black shale inclusions in lower 1 foot	3.8	3.8
21. Shale, green to greenish-gray, calcareous with limestone zones; dark green toward base	8.5	8.5
22. Shale, dark- to medium-green with white to pinkish limestone inclusions	5.5	2.5
23. Shale, dark- and light-gray, finely banded, silty and micaceous, platy	0.5	0.5
24. Siltstone, dark-gray, micaceous, shaly, fossiliferous with small brachiopods	8.6	4.5
25. Shale, dark-gray, silty, very platy near base	15.6	15.6

The thickness assigned here to the Silver Lake shale seems extreme and suggests that perhaps units 17, 18, and 19 have been reversed in the core. If such is the case unit 17, the very carbonaceous shale, represents the Elmo coal commonly found at the top of the Cedar Vale shale. Units 18 and 19 are then the Rulo limestone, and units 20 through 25 are the Cedar Vale shale.

There are at present no exposures that show the interval below that described from the foregoing core. However, at the site of the old Shambaugh mill near Clarinda in the SE¼SW¼NE¼ sec. 7, T. 68 N., R. 36 W., the following detailed section was measured by Calvin (1900, p. 426).

	Feet	Inches
9. Yellow, weathered shale	4	
8. Black shale	1	

7. Yellow shale	1	3
6. Yellowish, impure limestone which at the north end of the exposure is in two layers—the upper 14, and the lower 18 inches in thickness. The lower bed thins and runs out in a few yards toward the south. Average thickness	2	
5. Yellowish shale, present in some parts of the exposure and not in others	0	6
4. Black slaty shale	0	6
3. Grayish, fossiliferous, non-laminated shale which disappears and reappears in distances of a few yards. Among the fossil species noted are: *Lophophyllum proliferum*, plates and spines of *Zeacrinus*, *Rhombopora lepidodendroides*, *Chonetes granulifera*, *Productus longispinus*, *Productus pertenuis*, *Derbya crassa* represented by numerous small, fragile individuals, *Spirifina kentuckiensis*, *Ambocoelia planoconvexa*, represented chiefly by detached valves, but very abundant, *Athyris subtilita*, *Straparollus catilloides*, *Bellorophon percarinatus*, *Bellerophon carbonarius* and a small *Pleurotomaria*	2	
2. Coal	1	6
1. Drab shale down to river	8	

Units 9, 8, 7 of this section are probably the base of the White Cloud shale. Unit 6 is the characteristic Howard limestone and the remaining units are in the Severy shale, which contains the persistent Nodaway coal. This is the base of the Wabaunsee group, and is the formation that stratigraphically overlies the Coal Creek limestone described earlier under the Shawnee group of the Pennsylvanian system.

Physiography

The physiographic features of Page County are discussed by Samuel Calvin in Iowa Geological Survey volume 11, pages 405-414.

Structure

The most striking structural feature in Page County is the pronounced anticlinal high that extends along the eastern edge of the county. The crest of the anticline is believed to extend between New Market in Taylor County and Hawleyville in Page County. This structure is here called the New Market anticline. This anticline as now drawn (fig. 17) is arcuate in shape with the north and south limbs bowed to the northeast and southeast, respectively. The dip on the west flank is relatively steep and lowers about 100 feet in 4 miles.

Closely adjacent to the New Market anticline, and perhaps a part of it, is a small structural rise near Braddyville. The trend of this small anticline, which was first mentioned by White (1870, p. 351), appears to be approximately north-south. The term Braddyville anticline is now applied to this structural feature.

An elongate shallow synclinal fold extends northeast from the vicinity of Shenandoah, on the western edge of the county, and reaches almost to the northern edge. This feature broadens to the southwest to form the syncline adjacent to the Riverton-Hamburg domes in Fremont County. From this low, the strata rise again to the northwest to form part of a long, broad structural high extending into Page County from Montgomery County

Undoubtedly the structure pattern is more complex than is shown on the structure contour map (fig. 17) and as more data become available these structural features will be refined; however, it is believed that they exist essentially as shown here.

Rock Sources

In the past small quarries have been opened in the rocks of the Wabaunsee group for local use. The minor amount of limestone available within this group does not warrant a large scale operation, and as the Wabaunsee constitutes the bedrock of almost the entire county there seems little possibility for major quarry operations at any location within the county, with perhaps two exceptions.

The most notable exception is the area near Braddyville where the section, as already described, shows the Coal Creek limestone, the top member of the Shawnee group, down to the Turner Creek shale. The top of the Ervine Creek, the highest major limestone in the Shawnee group, should be about 20 feet below the base of this exposure. The structure appears to rise somewhat to the west and this may bring the Ervine Creek above river level. Perhaps this fact, along with the possibility of using some of the limestones that overlie the Ervine Creek, namely the Sheldon, Curzon, and Hartford limestones, would make it worthwhile to test drill this site.

The area near Hawleyville may also be worthy of exploration. Here the upper members of the Shawnee are exposed and test drilling may locate the Ervine Creek member of the Deer Creek formation close enough to the surface for exploitation.

POTTAWATTAMIE COUNTY

Stratigraphy

The exposures of consolidated rock in Pottawattamie County are of the Shawnee and Kansas City groups of the Pennsylvanian system (fig. 25) with the exception of some limited exposures of the Cretaceous system, which covers the southeastern part of the county.

The principal exposures of the Cretaceous are in the west bluffs of the Nishnabotna River in the southeastern part of the county. The following Cretaceous section extends from the NW¼NE¼ sec. 1, T. 74 N., R. 38 W.,

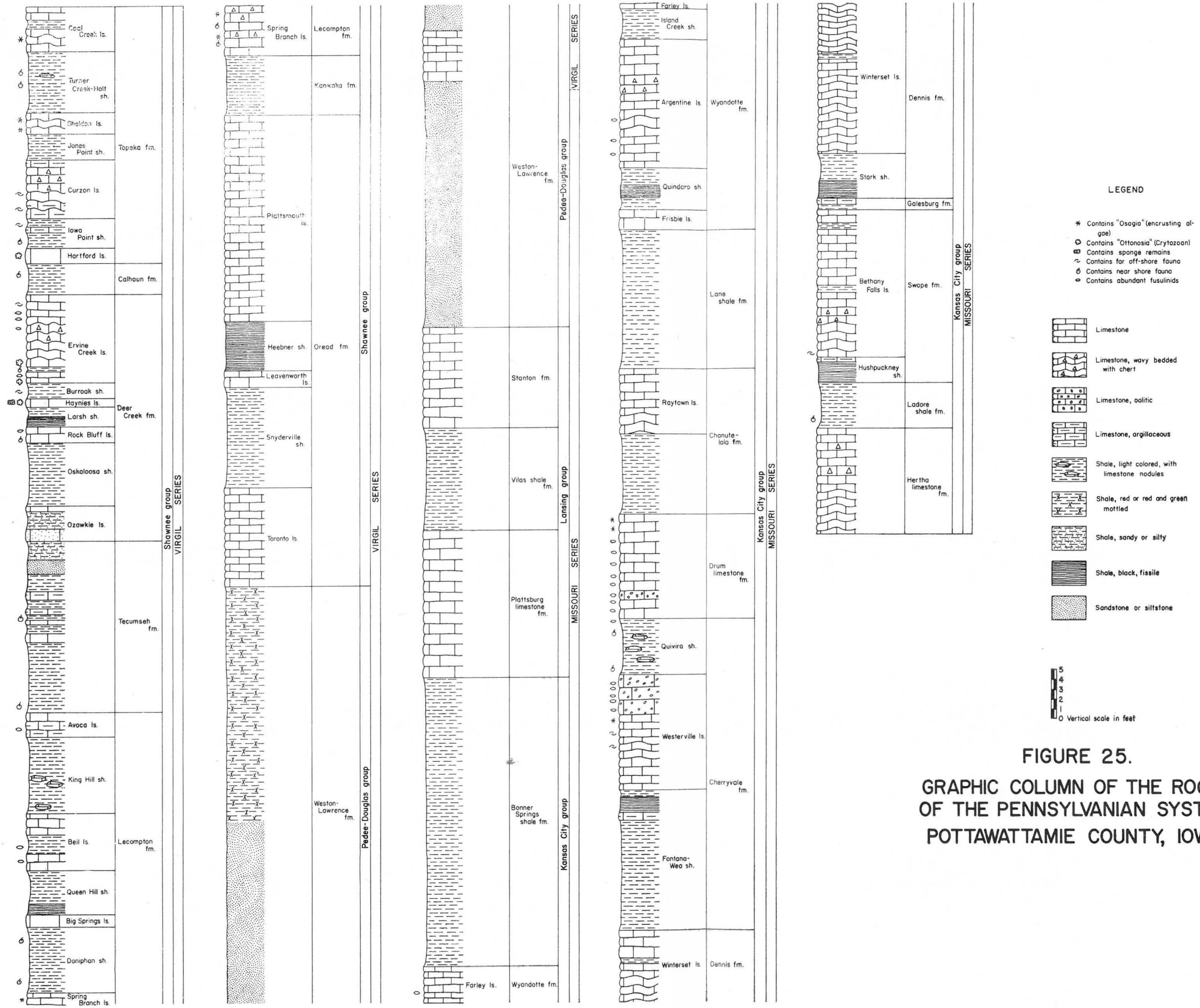


FIGURE 25.

GRAPHIC COLUMN OF THE ROCKS OF THE PENNSYLVANIAN SYSTEM POTTAWATTAMIE COUNTY, IOWA

northward along the base of the bluff through the E½ sec. 36, T. 75 N., R. 38 W., although the outcrop is not continuous.

	Feet
1. Clay, gray, silty, blocky	3.0
2. Siltstone, gray, weathers brown, contains clay lenses, ferruginous layers; these layers change laterally	1.5
3. Sandstone, white, weathers gray, fine-grained; exposed	14

There are numerous other small Cretaceous exposures in the county. They will not be discussed because they all resemble the section already described, are quite easily recognized as part of the Cretaceous system, and are of no immediate economic interest other than for their water-bearing properties.

The exposures of rocks of the Pennsylvanian system are very localized in this county, with rocks of the Shawnee group exposed in the southeastern part, and rocks of the Kansas City group exposed in the western part. Rocks of the intervening groups are not exposed within the county.

The youngest Pennsylvanian rocks are exposed in the Macedonia area. In a quarry in the SE cor., sec. 21, T. 74 N., R. 40 W., about half a mile west of Macedonia, the following section has been measured.

Virgil series
Shawnee group
Topeka formation

	Feet
Coal Creek limestone	
1. Limestone, light-gray, weathers white, two massive beds with shale parting, highly weathered, fossiliferous, with *Composita*, bryozoans, crinoid fragments, burrowing clams	1.5
Holt shale	
2. Shale, olive, bands of brownish-gray argillaceous limestone nodules	0.8
DuBois limestone	
3. Limestone, greenish- to brownish-gray, argillaceous, very nodular, *Myalina*	0.2–0.4
Turner Creek shale	
4. Shale, olive, blocky, bands of brownish-gray argillaceous limestone nodules, lower part poorly exposed, *Juresania*, bryozoans	6.1
Sheldon limestone	
5. Limestone, light-gray, weathers bluish to buff, lithographic, locally brecciated, nodular, wavy shaly partings, *Osagia* and fossil sections	2.1

Jones Point shale	
6. Shale, light-gray, upper 0.4 foot brown, blocky, hard, *Lingula*	2.3
Curzon limestone	
7. Limestone to calcareous shale, dark-blue to gray, quite hard, dense, brittle; bottom 0.2 foot black and contains black chert nodules; *Lingula*	1.0
8. Limestone, medium-gray, dense, hard, argillaceous; some crystalline calcite lining vugs and in veinlets; many brachiopods in broken cross section; black chert nodules throughout; abundant medium-sized *Dictyoclostus*	1.6
9. Limestone, light- to bluish-gray, argillaceous, crinoidal, almost shaly in places; locally a crinoidal shale about 1 foot above base; where shale separates the limestone into two beds, the lower limestone is about 0.6 foot thick, bluish gray, weathers buff, dense, massive, contains *Crurithyris*	3.3
Iowa Point shale	
10. Shale, green below, black above, calcareous, some calcite in veinlets, *Wellerella*	0.7
11. Limestone, light-gray, argillaceous, grades into shale above and below	0.5
12. Shale, lower part black, contains *Pecten;* upper part greenish-gray, calcareous, with *Crurithyris*, and abundant *Productus*	1.3
Hartford limestone	
13. Limestone, light-gray, very hard, one massive bed, some crystalline calcite, fossiliferous with abundant *Ottonosia* and crinoid joints	1.7
Calhoun formation	
14. Shale, dark-green to gray, calcareous, silty, fossil hash; tiny clam imprints 1 foot below top; upper 0.7 foot darker with crinoids, *Marginifera, Rhombopora*	2.3
15. Shale, black, calcareous, silty, many fossil fragments, *Lingula*; gradational to unit above	0.6
16. Shale, light-gray, calcareous, silty, some carbonaceous imprints, *Lingula*; locally an interbedded shale and limestone	0.2
Deer Creek formation	
Ervine Creek limestone	
17. Limestone, medium- to light-gray, dense, massive, hard, some crystalline calcite and fusulinids; black	

chert nodules near middle contain white circular blotches and lines; chert is fossiliferous with fusulinids, corals, brachiopods, and crinoids; some shale partings; fusulinid-rich, medium-gray shale about 1 foot from top; lower 1 foot has abundant *Ottonosia* and a few sponges 7.8

18. Shale, gray, blocky, white chonetids and fossil hash 0.4
19. Shale, black, mottled light-gray, fissile, silty, calcareous, many fossil fragments and imprints, *Leiorynchus* 0.2+
20. Limestone, light bluish-gray, argillaceous, *Marginifera, Ottonosia, Stereostylus,* crinoids, fusulinids 1.0

This section compares very closely with one exposed in a quarry in the SE¼SW¼ sec. 17, T. 70 N., R. 42 W., Fremont County. Unit 5, here called the Sheldon limestone, closely resembles the Sheldon limestone of other areas in that it is light gray and fine grained with the algal growth, *Osagia,* common. This, then, makes the overlying shale the Turner Creek, which has the color and nodular limestones characteristic of this member. Unit 3 is called the DuBois limestone on the basis of the nodular weathering characteristic and the presence of *Myalina.* The remainder of the correlations are quite obvious.

The upper part of the Ervine Creek is missing at this location. Also, there is the possibility that the lower units, 18, 19, 20, may not be properly assigned to the Ervine Creek. The black fissile shale, unit 19, is not generally found in the Ervine Creek, and, along with unit 18, may represent the Burroak shale. If such is the case, unit 20 then becomes the Haynies limestone. A core from the floor of the quarry would be necessary to clear up this stratigraphic detail.

For the sake of comparison, the following section, taken from quarries in the SW¼ sec. 14, and NW¼ sec. 23, T. 74 N., R. 40 W., is given in detail.

Virgil series
Shawnee group
Topeka formation
Curzon limestone — Feet

1. Limestone, gray, thin-bedded, interbedded with buff shale; fine grained and yellowish or bluish gray under the microscope; at the top is a *Marginifera* zone underlain by a zone of black chert 4.0

Iowa Point shale

2. Shale, olive-gray to buff, very fossiliferous above, black and fissile below; argillaceous limestone in middle 2.2

Hartford limestone	
3. Limestone, gray, weathers buff, blocky, lithographic, fossiliferous	1.9
Calhoun shale	
4. Shale, buff, fossiliferous above, blocky and gray below, weathers slate gray	3.4
Deer Creek formation	
Ervine Creek limestone	
5. Limestone, light-gray, finely granular, flaggy, interbedded with fossoliferous buff shale; rich in *Triticites beedei* near the top	3.0
6. Shale, buff, fossiliferous	0.2
7. Limestone, gray, weathers buff, fine-grained, massive, wavy bedding and a few shaly partings; dark chert zone and many *Triticites* near the top	8.0
Burroak shale	
8. Shale, gray and buff, bedded black shale in middle, fossiliferous	1.5
9. Shale, black, fissile	0.4
10. Shale, buff, fossiliferous	0.3
Haynies limestone	
11. Limestone, gray to dark bluish-gray, very fine-grained, blocky	0.8
Larsh shale	
12. Shale, buff	0.2
13. Shale, black, fissile	0.4
14. Shale, gray, silty	1.1
15. Shale, dark-gray to black, carbonaceous	2.0
Rock Bluff limestone	
16. Limestone, gray, lithographic, blocky, fine-grained; bluish gray under the microscope	1.0
Tecumseh formation	
Rakes Creek shale	
17. Shale, buff	0.3
18. Shale, dark-gray, silty, some pyrite	0.8
19. Sandstone, gray, fine-grained, blocky	1.3

This section compares well with that given for the quarry in sec. 21. The Ervine Creek here has a total thickness of slightly more than 11 feet, whereas at the quarry in sec. 21 the thickness was only about 8 feet. On the basis of this section, the validity of the Burroak-Haynies correlations in the quarry in sec. 21 seems strengthened.

Although the preceding section described the oldest member of the

Shawnee Group now exposed in Pottawattamie County, Udden (1901, p. 223) gave the following section.

	Feet
2. Black carbonaceous shale splitting into very thin laminae. (Among the shingle of this slate there were found several specimens of *Campophyllum torquium*, one *Aulopora*, and some of *Lophophyllum profundum*)	2.0
1. Bluish gray, soft limestone in layers from two to four inches thick and broken into rectangular or rhomboidal blocks by numerous joints of two quite uniform directions. This rock contained many fossils, among which were identified *Fusulina cylindrica*, *Chonetes glaber*, *C. granulifer*, *Productus cora*, *P. costatus*, *Seminula argentea*, *Aviculopecten occidentalis*, *Edmondia*, sp., *Schizodus wheeleri*, another small lamellibranch, and *Bellerophon crassus*. Some of the fossils were preserved only as casts. This limestone contained one thin layer which was filled with *Chonetes*.	1.5

The foregoing description applies to a locality on the west line of the NE¼SE¼ sec. 10, T. 74 N., R. 40 W., in the west Nishnabotna River south of Carson. The characteristic fossil of the Beil limestone, *Campophyllum torquium*, is found in the float and indicates that the black fissile shale found here is the Queen Hill shale, and that the underlying limestone is the top of the Big Springs limestone. Both are members of the Lecompton formation. This means that the Plattsmouth limestone, the principal limestone of the Oread formation should be found at a depth of about 20 feet below the top of this described section.

The foregoing exposures represent the youngest Pennsylvanian rock in this county. The only other area of exposure is in the Council Bluffs-Crescent City locality, where members of the Kansas City group are exposed and quarried.

In the NE¼NE¼ sec. 34, T. 76 N., R. 44 W., in the bluffs just north of Crescent City, the following section can be seen in a quarry. From an economic standpoint, this is a very interesting location, as it is necessary to strip up to 100 feet of overburden. However, the scarcity of rock material in the area and modern stripping methods have made this operation feasible.

Missouri series
Kansas City group

Drum limestone	Feet
1. Limestone, light-gray, weathers gray to buff, hard, finely oolitic in top part, subearthy in lower part; in 0.3 foot beds; many fusulinids	1.9

2. Shale, light-gray, very calcareous, flood of small *Triticites* 0.7

Cherryvale formation

Quivira shale

3. Shale, brownish-green, weathers buff; upper part calcareous and hard, with *Juresania* and *Neospirifer*; lower part clayey, with ramose bryozoans, crinoid fragments, *Derbyia*, contains thin seams of coquinoid limestone 4.7
4. Shale, green to buff, clayey, blocky, weathered 1.5

Westerville limestone

5. Limestone, light-gray, weathers very light gray, massive, finely oolitic, contains small fusulinids 4.2
6. Limestone, light-gray, weathers light gray, sublithographic, nodular beds with shale partings; shale is buff to olive; limestone contains brachiopod sections; *Osagia* in upper part 1.4
7. Limestone, brownish-gray, weathers buff, sublithographic, somewhat massive, brachiopod sections 2.3
8. Limestone, light-brown, weathers brown, becomes light gray and fresh toward base; light blue-gray where fresh in base; few fossil sections 2.9

Wea shale

9. Shale, bluish-gray, very calcareous, approaching limestone; crinoid stems 0.9
10. Shale, black, fissile, mottled with light-gray pyrite nodules 2.2
11. Shale, dark-gray, platy at top, massive below 0.8

Block limestone

12. Limestone, gray, shaly and nodular 0.7

Fontana shale

13. Shale, light- to medium-gray, moderately calcareous, blocky; upper 1 foot fossiliferous and bedded 11.2

Dennis formation

Winterset limestone

14. Limestone, medium-gray to light grayish-buff, hard, fine to sublithographic, in part shot through with green shale partings and thin irregular bands (up to 0.3 foot thick); thin band of gray chert 0.3 foot from bottom; moderately to sparsely fossiliferous (occasional silicified shell fragments); some thin veinlets of clear, brown-tinted calcite crystals 10.6
15. Limestone, light- to drab-gray, hard, very finely cry-

stalline; sparsely fossiliferous with rare silicified shell fragments; in part interlaminated with thin bands of medium-gray shale 12.6

The Drum limestone, as identified here, is characterized by tiny *Triticites*, and can be readily identified in the sections on this basis. Also, the subconglomeratic and oolitic beds are quite characteristic for the Westerville limestone. The principal change is the considerable expansion of the Westerville limestone, along with a thickening of the overlying Quivira shale. Where seen in outcrop in the Madison County area, these units, as now correlated by Jeffords, Reed, and others (unpublished) are approximately 3 feet and 1 foot thick respectively.

The section has been extended by a core taken from the floor of the quarry. It has been correlated from core descriptions by the Iowa State Highway Commission.

Missouri series	
Kansas City group	
Dennis formation	
Stark shale	Feet
1. Shale, gray, plastic, bedded and fissile at top and blocky below	1.5
2. Shale, black, hard, fissile, conodonts	3.1
Canville limestone	
3. Limestone, blue-gray, becoming black at top; very fossiliferous; algal (*Osagia* and *Ottonosia*)	0.7
Galesburg shale	
4. Shale, black to greenish, fossiliferous, calcareous	0.6
Swope formation	
Bethany Falls limestone	
5. Limestone, light-gray, *Osagia* abundant, black algae numerous, laminated with gray shale, thin-bedded; shaly zone at bottom 0.2 foot	2.3
6. Limestone, medium-gray, algal, dark chert 1.7 feet from top; one massive bed with irregular bedding plane at base	2.6
7. Limestone, laminated with shale; about 1 inch of gray soft shale at top; lower 0.4 foot solid algal limestone	0.9
8. Shale and limestone, laminated, dark-gray, algal; undulating contact with lower limestone, fossiliferous	0.5
9. Limestone, gray, fine to earthly, algal, 3 beds; lower 1.3 feet massive, becomes laminated with gray shale in lower 0.7 foot	3.0
10. Limestone and shale; upper 1 foot very shaly with gray shale seams separated by thin one-half to 3 inch	

limestone lenses; limestone, light-gray, algal; chert zones 1 foot and 1.5 feet up from base; base grades into a limy shale; more or less a massive unit 5.0

Hushpuckney shale

11. Shale, gray, calcareous, brachiopods; becomes dark in lower 0.3 foot 1.5
12. Shale, black, fissile, hard, brachiopods 1.4

Ladore shale

13. Shale, greenish-gray; top 1.7 feet bedded; massive below with limestone fragments in lower 1 foot; fossil zone 1 foot from top, with brachiopods 4+

Hertha limestone

14. Limestone, light-gray, sandy; fragmented with green shale in top 0.5 foot; some shale laminations throughout 5.0
15. Limestone, grayish-white, fine-grained, soft, slightly silty; in 4 beds 2.7
16. Limestone, similar to number 15, except for greenish argillaceous streaks; becomes broken and breccia-like toward base; as 2 to 5 beds 3.5

Pleasanton group

17. Shale, greenish-gray, soft; contains white limestone inclusions 2.5 feet from base; base reddish-brown and highly calcareous 7.5
18. Shale, grayish-white matrix enclosing numerous white limestone fragments 1.5
19. Shale, gray, calcareous, numerous red-brown rust spots; occasional gray limestone fragments 10.0

The Canville limestone, unit 3 in the foregoing description, is not present over much of the Pennsylvanian area to the east. At Logan, about 25 miles north in Harrison County, this limestone is about 2 feet thick. Conversely, the Middle Creek limestone member, which has the same relationship to the Bethany Falls limestone as the Canville limestone has to the Winterset limestone, is missing from this section, although generally found in other outcrop areas of this group of rocks. Like the Canville limestone, the Middle Creek limestone is referred to as a typical "middle" limestone in the cyclothem units as recognized by Moore (1935, p. 84).

The Winterset limestone has increased in thickness considerably from the eastern exposures in Iowa, whereas the Bethany Falls has thinned from about 22 feet in Madison County to about 11 feet in this section. *Triticites irregularis* is characteristically rare in the Bethany Falls limestone and very abundant in the Winterset limestone. No fusulinids have been reported in the section between the Cooper Creek limestone of the Pleasanton group and the Bethany Falls limestone. The Winterset limestone is the oldest major *Triticites*-bearing rock in the Missouri series of Iowa (Thompson, Verville and Lokke, 1956, p. 793).

Physiography

The physiographic features of Pottawattamie County are discussed by J. A. Udden in Iowa Geological Survey volume 11, p. 203-216.

Structure

Over most of Pottawattamie County the general dip of the beds appears to be to the south with a lowering of some 350 feet from the north to the south boundary of the county. A small anticlinal nose trends southwest in the vicinity of Council Bluffs with an accompanying synclinal lowering to the north. At the southeast corner of the county there is a pronounced anticline that extends south to the vicinity of Red Oak. The southeastern flank of this anticline is rather steep whereas the northwestern flank is gentle.

On the basis of a few wells in southern Harrison County, it is seen that from the structural high in northern Pottawattamie County the strata lower to the north. More data in Pottawattamie County will be necessary before any details of the structure will be evident. However, the basic features should be approximately as shown on the structure map (fig. 17).

Rock Sources

Data available at present indicate that, outside the areas of present quarrying operations near Macedonia and Crescent City, there is only one locality that appears to be promising. This locality was described by Udden (1900, p. 226) as being in the left bank of Mosquito Creek, near the center of the west line of sec. 21, T. 75 N., R. 43 W., where limestone was quarried in the past. As recently as 1951 an exposure of shale and limestone was visible on Mosquito Creek in the SW¼NW¼SW¼ of this section. Although the exposure was very limited, both vertically and horizontally, it was tentatively identified as the Argentine limestone. This exposure was covered in 1956 but drilling in this area may prove this to be a worthwhile quarry prospect.

In an area where exposures are rare, such as Pottawattamie County, it seems that the most satisfactory prospecting method would be to follow the structural trends from the areas of known rock of commercial value in an attempt to find other areas where the overburden is thin enough to make stripping economical.

RINGGOLD COUNTY

Stratigraphy

With rare exceptions the bedrock of Ringgold County is deeply buried under a mantle of glacial drift that in most places is over 50 feet thick and in some places is over 300 feet in thickness. The area of outcrop is limited to secs. 19, 20, and 30, T. 67 N., R. 29 W. An obscure exposure reported by Arey (1916, p. 48) in sec. 1, T. 70 N., R. 28 W., is now covered. On the basis of information gained from well logs, the bedrock of this county (fig. 26) is found to be made up of rocks of the Shawnee, Douglas-Pedee, Lansing, and Kansas City groups (fig. 2).

At a quarry located on the center of the south line of the SE¼ sec. 19, T. 67 N., R. 29 W., the following may be seen.

	Feet
Missouri series	
Pedee group	
Weston shale	
1. Shale, olive, weathers buff, very calcareous, grading into argillaceous limestone	1.5
2. Shale, as above but softer	1.3
3. Limestone, medium-gray, argillaceous, dense, conchoidal fracture	0.4
4. Shale, light blue-gray, weathers olive buff, clayey, blocky, clams	6.6
Lansing group	
Stanton formation	
5. Limestone, light-gray, weathers buff, thin-bedded with shale partings, argillaceous, dense to sublithographic	3.0
6. Limestone, medium-gray, weathers buff, wavy-bedded, slightly argillaceous with earthy zones, dense to sublithographic, gastropods and brachiopod sections	5.2
7. Shale, dark-gray, streaked black, blocky, clayey, calcareous, *Crurithyris*	0.8
8. Limestone, light-gray, massive, dense to fine-grained, very fossiliferous with white shelled *Marginifera, Composita*	4.5
9. Shale, dark-gray, hard, clayey (floor of quarry, the lower beds were not visible in 1953)	5.0
10. Limestone, dark-gray, hard, grading into shale above and below	1.0
11. Shale, dark-gray	0.3

It was reported that about 4 feet of limestone underlain by about 3 feet of shale was found beneath unit 11 of the foregoing section.

A core taken from the floor of the quarry extends the section downward

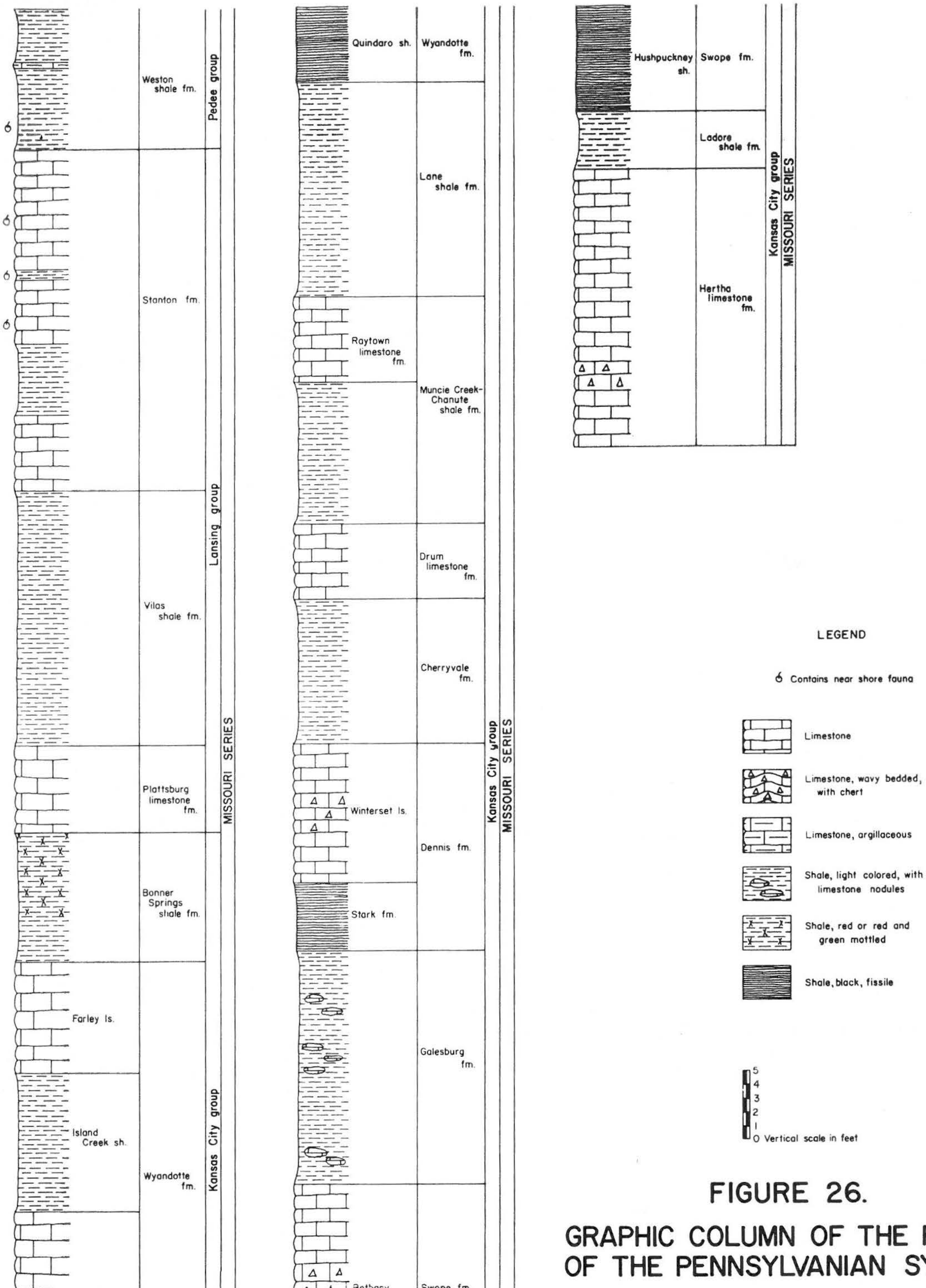


FIGURE 26.

GRAPHIC COLUMN OF THE ROCKS OF THE PENNSYLVANIAN SYSTEM RINGGOLD COUNTY, IOWA

considerably. No core is available of the first 14 feet of beds beneath the quarry floor. The detailed log follows.

Missouri series	
Lansing group	
Vilas shale	Feet
1. Shale, dark-gray, micaceous, slightly silty, platy	1.1
2. Limestone, cream, medium-fine granular texture, somewhat algal, streaks of dark-green shale and light-green shale mottling	0.6
3. Shale, gray, chunky, badly broken	2.0
Plattsburg limestone	
4. Interbedded shaly limestone and calcareous shale; limestone very light brown, earthy; shale, green	2.0
5. Limestone, white, finely granular; upper 1 foot brecciated, with green shale coatings; lower 0.5 foot has zones of fossil fragments; argillaceous zones up to 0.5 foot thick	5.0
6. Shale, light- to medium-gray, somewhat calcareous, slightly silty; few fossil fragments	1.0
7. Limestone, gray, medium- to fine-grained, fragmental, argillaceous zones, numerous fossil fragments and some productids	2.5
8. Shale and limestone interbedded; these zones grade from argillaceous limestones to carbonaceous shale; medium gray except at carbonaceous zones, which are very dark gray; fossiliferous throughout with numerous *Chonetes* and other brachiopod fragments and spines	3.7
9. Limestone, dark-gray, coarsely fragmental, fossiliferous; one stylolitic zone about 0.5 foot from bottom less coarsely fragmental	2.1
Kansas City group	
Bonner Springs shale	
10. Shale, gray to dark-gray, very fossiliferous with numerous brachiopods and phosphatic ostracodes	17.5
Farley limestone	
11. Limestone, pinkish-brown, dolomitic, sublithographic, brecciated in a light-green shale matrix with a few small veins of crystalline calcite	0.9
12. Shale, gray to dark-gray, chunky, slightly silty	1.6
13. Shale, gray to grayish-brown, waxy luster on some surfaces	1.6

14. Limestone, light-gray to brown, dolomitic, fine to sub-lithographic, brecciated in matrix of plastic green shale	1.1
Island Creek shale	
15. Shale, light green-gray, silty, platy	5.9
16. Shale, dark-gray, micaceous, slightly silty, platy	11.1
17. Shale, dark blue-gray, silty, slightly calcareous, some tendency toward fissility	1.7
Argentine limestone	
18. Shale, bluish-gray, very calcareous, silty, hard, fossiliferous in zones, a few carbonaceous zones	5.0
19. Shale, mottled dark-brown and greenish-gray; some of the greenish-gray streaks are very calcareous; calcareous material on fracture surfaces	2.1
20. Limestone, light-gray to light-brown, fragmental; crinoid remains, numerous brachiopod fragments, *Osagia, Ottonosia;* shaly in lower 1 foot	4.3
21. Limestone, gray, irregular carbonaceous zones and partings; *Osagia,* brachiopod and crinoid fragments; some of the fossil fragments coated with pyrite	1.4
Quindaro-Lane shale	
22. Shale, black, subfissile, with pyrite on the partings and a few calcareous inclusions	1.8
23. Shale, gray to dark-gray, blocky, very fossiliferous with numerous brachiopods and numerous phosphatic ostracodes	3.0
24. Shale, dark-gray, calcareous, platy, numerous fossil casts and some chitinous remains; becomes very carbonaceous at base	2.5

The 14-foot missing interval between the base of the exposure and the top of the core is believed to be the upper part of the Vilas shale. The names assigned to the units of the exposure and core have been questioned but on the basis of a log from an oil test drilled nearby the correlations seem valid. The Quindaro-Lane shale interval should contain the Frisbie limestone that corresponds to the "middle" limestones of other cyclothems and consists of a thin dark-blue or blue-gray, dense limestone. However, its counterpart, the Canville member of the Dennis limestone, is rarely present in Iowa, so the absence of the Frisbie limestone at this location is not surprising.

Physiography

The physiographic features of Ringgold County are discussed by M. F. Arey in Iowa Geological Survey volume 27, pages 38-46.

Structure

Exposures are extremely rare in Ringgold County and few wells have been drilled deep enough to yield significant stratigraphic information. The exposures are limited to two very small areas and are not definitive. As now interpreted, the dominant structure is a very broad, gentle syncline dipping to the west-southwest. As more information is gained from any deep water wells or from stratigraphic testing, this structural contour configuration will be revised and undoubtedly will be found more complex.

Rock Sources

There seems to be little chance of open-pit quarry operations being started in areas other than those now being worked because of the heavy drift cover over most of Ringgold County. The outcrop mentioned by Arey (1916) in sec. 1, T. 70 N., R. 28 W., may be of interest. Arey correlated this rock with the Westerville limestone. If this is true, the Bethany Falls limestone should be at a depth of about 40 feet at this location. Information from a core test of this area would be valuable. An obscure exposure in the SE¼SW¼NW¼ sec. 20, T. 67 N., R. 29 W., has not been correlated, but it is believed to be stratigraphically very close to the quarry rock described in sec. 19 of this township. In the past, this rock has been used for foundations of farm homes in the vicinity. This locality may be worthy of further exploration.

In view of the scarcity of limestone at or near the surface, serious thought should be given to the possibilities of vertical shaft mining. The areas where the Kansas City and Shawnee groups make up the bedrock would seemingly be the best to prospect for mining sites as these groups include the heavier limestone beds that are being sought. However, the area covered by rock of the Kansas City group is cut by two large preglacial channels and is covered by a thick mantle of glacial drift (see bedrock map, fig. 4). Prospecting should be carried on away from the deep channels and with the understanding that roof conditions may pose a problem where glacial drift is close to the minable rock.

TAYLOR COUNTY

Stratigraphy

A heavy mantle of glacial drift has effectively concealed most of the bedrock in Taylor County and natural outcrops are restricted to an area along East One Hundred and Two River near Bedford and along the East Nodaway River and its tributaries in the northwest corner of the county. The very limited exposures are of the Wabaunsee and Shawnee groups of the Pennsylvanian system (fig. 27), and rocks of these groups make up the bedrock of the entire county.

The youngest member of the Wabaunsee group now exposed in Taylor

County is the Howard limestone, the caprock of the Nodaway coal. This can be seen with the underlying Severy shale in the NE¼NW¼ NE¼ sec. 32, T. 70 N., R. 35 W. A detailed section follows.

Virgil series	
Wabaunsee group	
Howard limestone	Feet
1. Limestone, weathers dark buff, coarse-grained, poorly exposed	1.0±
2. Limestone, light-brown, weathers light buff, fine-grained	1.5
Severy shale	
3. Shale, very light-buff, chippy	0.4
4. Shale, black, almost fissile	0.5
5. Shale, yellow	0.4
6. Shale, black, very carbonaceous with a weathered coal (Nodaway coal)	1.4
7. Shale, light-gray, soft at top, harder and blocky below	2.5

The base of the Severy shale and the upper members of the Topeka formation, Shawnee group, are exposed along a small creek at a location in the center of SW¼ sec. 7, T. 69 N., R. 35 W. The outcrop is discontinuous but the following section has been described.

Virgil series	
Wabaunsee group	
Severy shale	Feet
1. Shale, buff to brown at top, yellow in middle, light bluish-gray near base; basal 1.5 feet very well indurated, with a 0.3-foot loose shale layer near top; *Chonetes*, bryozoans, in upper part, spiriferids in lower part	5.0
Shawnee group	
Topeka formation	
Coal Creek limestone	
2. Limestone, light-gray, dense, hard, in 2 or 3 ledges, upper surface very uneven; *Crurithyris* crinoids; forms waterfalls	0.9
3. Shale, black, *Derbyia* at top	1.0
4. Limestone, medium-gray, weathers light rusty gray, dense, fossiliferous	0.5
Holt shale	
5. Shale, dark bluish-gray, fossil fragments	0.7
6. Shale, black, slaty, very well-indurated, *Lingula*	0.3
7. Shale, black, slightly calcareous	0.7
8. Shale, black, fissile	0.5

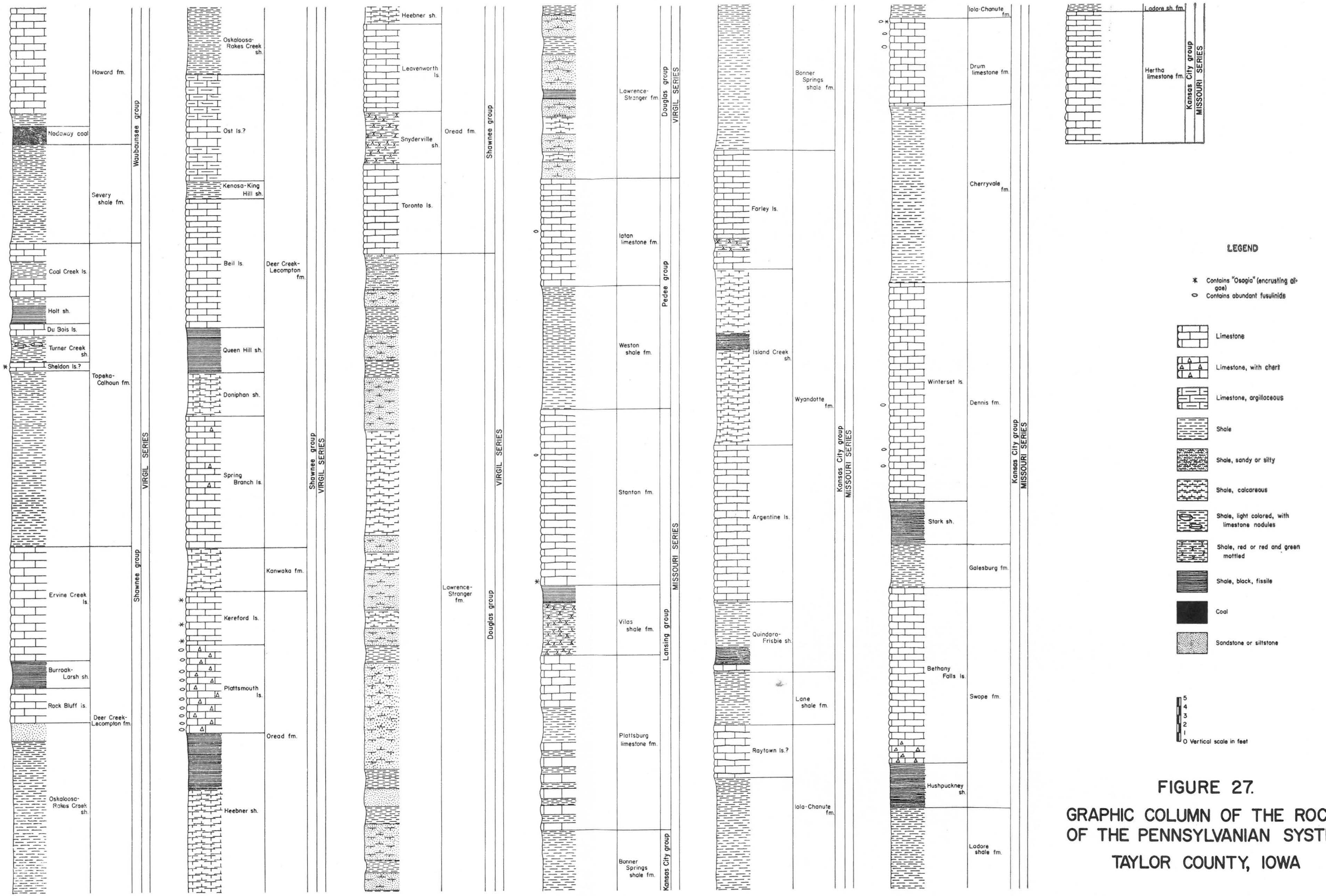


FIGURE 27.

GRAPHIC COLUMN OF THE ROCKS OF THE PENNSYLVANIAN SYSTEM

TAYLOR COUNTY, IOWA

DuBois limestone

9. Limestone, medium-gray, varies from 1 to 3 beds; upper bed forms waterfalls and contains *Myalina* and *Composita*; lower part less resistant and very fossiliferous with *Derbyia*, *Myalina*, gastropods; locally two beds with 3-inch shale layer between — 0.8–1.2

Turner Creek shale

10. Shale, buff-brown — 0.9
11. Limestone, layer of elongated nodules 2 inches thick, very fossiliferous and resistant — 0.2
12. Shale, dark brownish-gray, silty, speckled with fossil hash — 0.5

Sheldon limestone

13. Limestone, light-gray, weathers whitish gray, dense, very fine-grained to sublithographic, very argillaceous, weathers nodular; in creek bed

The DuBois limestone as seen here does not have the dark-blue color which is characteristic of this member. However, its position beneath the black, fissile Holt shale, the only shale of this type in the Topeka formation, quite definitely establishes this correlation.

The stratigraphic interval between the base of the outcrop just described and the Ervine Creek limestone is not exposed in Taylor County.

In the vicinity of Bedford the Ervine Creek crops out in several places and is quarried. At a quarry in the SW¼SW¼ sec. 4, T. 67 N., R. 34 W., the following section was measured.

Virgil series
Shawnee group
Deer Creek formation

Ervine Creek limestone	Feet
1. Limestone, light-gray, massive, sublithographic	0.7
2. Limestone, light-gray, weathers buff, wavy-bedded to massive, argillaceous to sublithographic	2.3
3. Limestone, light-gray, massive, sublithographic	0.8
4. Limestone, light-gray, weathers buff, wavy-bedded with alternating hard and soft argillaceous layers; *Triticites*	7.2
5. Shale, olive in upper 0.2 foot, dark gray to black below	floor of quarry

The various outcrops in the area closely resemble the upper limestone units of the foregoing section. Glaciation stripped off overlying rock, as shown by glacial striae found in the NW¼ sec. 35, T. 68 N., R. 34 W. Two sets of striae were found, one set running S. 12° W., and the other S. 1° E. Weathering has progressed rather deeply as a result of long exposure.

A number of cores taken from the locality extends the section below the Ervine Creek limestone. The following is a composite log for 19 cores received from the Iowa State Highway Commission.

Virgil series
Shawnee group
Deer Creek formation

Ervine Creek limestone	Feet
1. Limestone, yellowish-brown, fine- to medium-grained, argillaceous, areas of detrital material mostly fossil fragments and *Osagia*, large spines, one bed	0.7
2. Shale, yellow to yellow-brown, very calcareous, soft- to medium-hard, grades into beds above and below; large obese fusulinids up to 4 mm. in diameter, brachiopods, crinoid stem fragments and spines, one massive bed	2.1
3. Limestone, yellow-brown, fine-grained, argillaceous, yellow matrix with patches of medium-grained tan limestone, hard, large obese fusulinids, crinoid and brachiopod fragments	0.5
4. Limestone, laminated with shale, soft, yellow with gray banding, fossils as above	0.4
5. Limestone, like bed 3 but algal in the brown crystalline limestone areas; fossils as above	0.4
6. Limestone, yellow, fine-grained with medium-grained brown recrystallized areas containing numerous fossil fragments; many fusulinids	1.9
7. Limestone, yellowish-gray mottled with brown, fine-grained with medium-grained brown recrystallized areas; fossils well preserved in crystalline areas, shale parting top and base	0.9
8. Shale and limestone, yellow, laminated, soft and earthy, somewhat friable, irregular lower contact	1.4
9. Limestone, brownish-gray, mottled with yellow, fine- to coarse-grained with calcite masses up to 1 inch, small brachiopods	0.3
10. Limestone, laminated with shale, small fossil fragments in patches, *Neospirifer*, irregular lower contact	0.7
11. Limestone, light-gray, earthy, some soft brownish recrystallized areas; obese fusulinids, some *Triticites*, *Chonetes*, and other brachiopods	2.2

12. Shale, yellowish-gray, with some lenses and laminations, many fossil fragments, brachiopods, crinoids 0.7
13. Limestone, brownish-yellow, fine-grained, dense, hard, dolomitic, as one massive bed, not present in all cores; shale parting at base, fossils concentrated in lower 0.2 foot, small brachiopods 1.2
14. Limestone, yellowish-gray, dolomitic, very argillaceous, medium-hard, grades into a shale below, appears to grade laterally into a yellow shale with small lenses of limestone 1.5

Larsh-Burroak shale

15. Shale, buff in upper 1 foot; light-gray in lower part; silty, blocky, medium-hard, calcareous, a few poorly preserved brachiopod impressions, some pyrite 1.6
16. Shale, black, with light-gray mottling, subfissile, carbonaceous, clayey, pyrite, conodonts 0.2
17. Shale, gray, hard, calcareous, almost an argillaceous limestone in places, silty, some *Ottonosia*, scattered *Crurithyris*, pyritized plant stems, linguloids, 2-inch dark fossiliferous zone at base 1.0
18. Shale, black, mottled with gray silt, subfissile, grades into beds above and below 0.2
19. Shale, gray, blocky, hard, calcareous, silty, pyritic, *Crurithyris*, some microfossils 1.0
20. Shale, black, fissile, hard, pyritic, mottled with gray silt 1.4

Rock Bluff limestone

21. Limestone, light-gray, fine-grained, argillaceous, scattered black *Ottonosia* and large fusulinids, shale parting 1 inch above contact 2.1

Oskaloosa shale

22. Shale, dark-gray, bedded, top 0.5 foot blocky, hard below, numerous angular green clay inclusions up to 3 mm. diameter. Numerous fusulinids in top 0.2 foot, followed by abundant brachiopod impressions in next 0.3 foot; brachiopod spines abundant in top 0.5 foot, lower 1 foot few or no fossils, pyritized plant remains 1.6
23. Siltstone, greenish-gray, hard, very argillaceous, more or less massive, grades into a green shale at base 5.0

The very calcareous shale, unit 17, probably represents the Haynies limestone, although where this member is seen in outcrop in Mills County it is a light to dark bluish-gray, fine-grained, dense limestone and contains *Ottonosia*. However, as unit 17 here is very calcareous and somewhat algal, the correlation seems valid.

Physiography

The physiographic features of Taylor County are discussed by M. F. Arey in Iowa Geological Survey volume 27, pages 70-76.

Structure

From the meager data available for Taylor County, it appears that the dominant structural feature over most of the county is a shallow synclinal trend lowering from the northwest corner to the southwest. However, near the western boundary of the county the strata rise sharply to the crest of the New Market anticline (see fig. 17). At New Market this rise is 100 feet in about 2 miles. To the south the dip is much less and the strata lower about 150 feet in 12 miles, and to the north they lower about 50 feet in 2 miles.

As in the other counties of this report, more drilling in Taylor County will be necessary before the structure contour map can be refined. As new data become available the structure will probably be found to be more complex than is now apparent.

Rock Sources

There are only a few areas in Taylor County that seem worthy of extensive prospecting because of the heavy mantle of glacial drift. Outside the area of Bedford, where quarrying operations are now being carried on, probably the best prospect sites are in the northwest townships, where the basal formations of the Wabaunsee group are exposed.

The outcrop in the center of the SW¼ sec. 7, T. 69 N., R. 35 W., where the Severy-Sheldon interval is exposed, may prove of interest. The Sheldon limestone crops out in the bed of a small creek, and the top of the Ervine Creek limestone should be about 15 feet below the top of the Sheldon limestone. The Ervine Creek, the limestone being quarried at Bedford, should be about 15 feet thick at this location.

Another location that appears to deserve investigation is the NE¼NW¼ NE¼ sec. 32, T. 70 N., R. 35 W., where the Howard limestone is exposed. The Ervine Creek limestone should be at a depth of about 40 feet below the base of the Howard limestone.

Over the remainder of the county the drift thicknesses range from 50 to over 200 feet and there is little possibility of quarry sites being found.

UNION COUNTY

Stratigraphy

The mantle of glacial material in Union County is in few places less than 50 feet thick and in some places reaches thicknesses of over 200 feet.

Exposures of bedrock are confined to three townships and few wells furnish usable stratigraphic information. However, on the basis of the available information, the bedrock (fig. 28) in Union County is believed to be made up of rocks of the Shawnee, Douglas-Pedee, Lansing, and Kansas City groups. Because of the scarcity and obscurity of exposures, correlations in this county are difficult and tenuous. Apparently the youngest rock exposed in the county is the Bonner Springs shale in the NW¼NE¼ sec. 4, T. 71 N., R. 28 W. Here a small quarry with two pits has been operated and the following detailed section was measured.

Missouri series
Kansas City group

Bonner Springs shale	Feet
1. Shale, maroon and green-mottled	1.5
2. Shale, maroon, clayey	2.5
3. Shale, green, clayey	1.0
4. Shale, buff-gray, weathers grayish white, platy, hard	2.2
Wyandotte formation	
Farley limestone	
5. Limestone, light-gray, weathers dark brown, hard, massive, medium-granular	3.1
6. Shale, medium-gray, weathers light gray, clayey	0.4
7. Limestone, gray, weathers buff, argillaceous, nodular, *Triticites*	0.9
8. Limestone, gray, wavy-bedded, slightly argillaceous, sublithographic, some crinoids	2.9
Island Creek shale	
9. Shale, floor of quarry	2.9

A greater thickness of the Bonner Springs shale may be seen in the south bank of Grand River in the SE¼SW¼ sec. 30, T. 72 N., R. 28 W. The following section was measured at this location.

Missouri series
Kansas City group

Bonner Springs shale	Feet
1. Shale, maroon, thinly platy, rounded concretions concentrated along joints	6.5
2. Shale, olive to greenish-gray, clayey, blocky to thickly platy exposed	2.0

The maroon to red shale with limestone nodules or concretions overlying greenish-gray shale is typical of the Bonner Springs.

The complete stratigraphic interval from the Island Creek shale through the Argentine limestone is not exposed in Union County. However, the Argentine limestone and the lower members of the Wyandotte formation are exposed in the SW¼NE¼NE¼ sec. 3, T. 71 N., R. 28 W. The following detailed section was measured at this location.

Missouri series
Kansas City group
Wyandotte formation

Argentine limestone		Feet
1.	Limestone, light-gray, fine-grained, massive, crinoids	0.6
2.	Shale, greenish-gray, clayey	0.5
3.	Limestone, gray, weathers grayish brown, sublithographic, gastropods, crinoids	1.1
4.	Shale, olive, clayey, chippy	0.3
5.	Limestone, dark-gray	0.2
6.	Shale, olive, clayey	0.3
7.	Limestone, dark-gray	0.2
8.	Shale, olive, clayey	0.4
9.	Limestone, dark-gray	0.2
Quindaro shale		
10.	Shale, olive, weathers light gray, chippy, *Crurithyris*, *Marginifera*, clams	1.1
11.	Shale, black, blocky above to fissile and hard below	1.2
12.	Covered (float with tiny fusulinids)	2.7
Frisbie limestone		
13.	Limestone, light-gray, massive, abundant *Osagia* exposed	1.0

Unit 13, called the Frisbie limestone in the foregoing section, does not closely resemble the typical dark-blue "middle" limestone that should occupy this position in the cyclothem. An alternate correlation is that units 1-8 make up the lower part of the Drum limestone, units 10-11 are Quivira shale, and units 12-13 are the uppermost beds of the Westerville limestone. The occurrence of the small fusulinids in the float coming from the covered portion lends some support to the latter correlation. A core at this site would clear up this doubt.

A very obscure exposure in the SE¼NW¼NE¼SW¼ sec. 27, T. 71 N., R. 28 W., in the north bank of a small creek, shows a limestone tentatively identified as Argentine.

Missouri series
Kansas City group
Wyandotte formation

Argentine limestone		Feet
1.	Limestone, light-gray, weathers buff gray, wavy-bedded, shale partings, sublithographic, crinoidal, top eroded	3.1

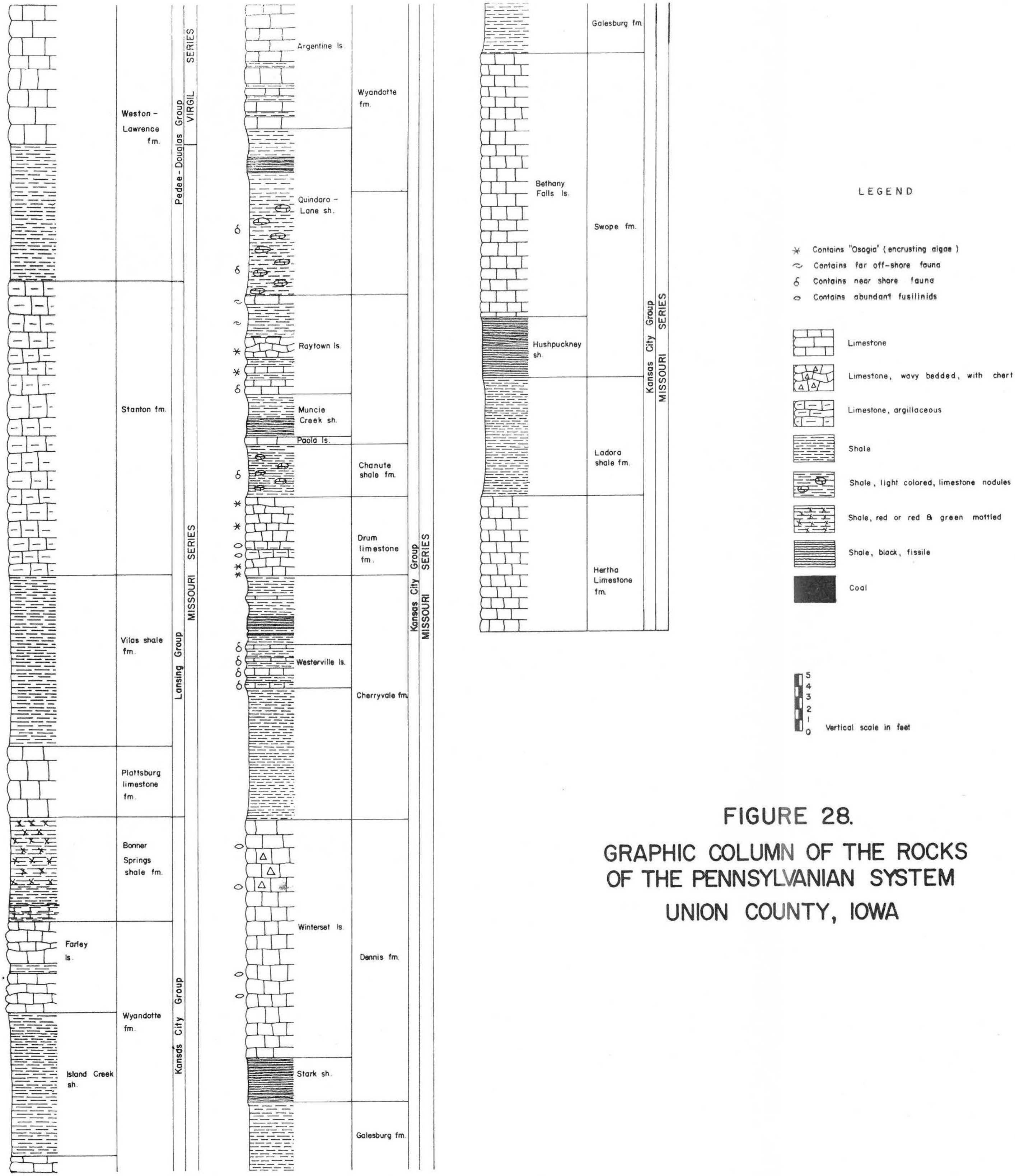


FIGURE 28.

GRAPHIC COLUMN OF THE ROCKS OF THE PENNSYLVANIAN SYSTEM UNION COUNTY, IOWA

2. Shale, light greenish-gray, with 0.1 foot limestone seam 0.5
3. Limestone, dark bluish-gray, dense, *Chonetes*, *Neospirifer* 0.3
4. Shale, buff 0.1
5. Limestone, medium-gray, weathers buff, argillaceous 0.5
6. Shale, greenish-gray, weathers light gray, clayey, *Crurithyris* 0.3
7. Limestone, bluish-gray, weathers brown, dense, argillaceous, *Osagia* 0.4
8. Shale, olive, clayey, blocky, *Crurithyris*, *Chonetes*, clams exposed 2.0

Although this is but a small exposure it is of interest as a prospect. A good exposure that shows the lower Lane shale to Muncie Creek interval occurs in the east bank of Grand River in the SE¼SW¼SW¼ sec. 28. T. 72 N., R. 28 W. This is stratigraphically only slightly below the preceding section. A detailed section follows.

Missouri series
Kansas City group
Lane shale — Feet
1. Shale, gray, weathers buff, numerous thin limestone plates that are very fossiliferous with crinoid joints, pitted and noded crinoid basal plates, ramose and fenestellid bryozoans, small *Myalina* 9.0

Iola formation
Raytown limestone
2. Limestone, light-gray, dense to sublithographic, crinoidal, *Neospirifer*, *Composita* 0.9
3. Shale, buff, limy seams, *Neospirifer*, *Composita*, ramose bryozoans 2.8
4. Limestone, light-gray, dense to sublithographic, massive but weathers slabby, *Osagia*, brachiopod sections 1.6
5. Shale, greenish-gray, clayey, poorly exposed 0.9
6. Limestone, light-gray, earthy, *Osagia* 0.5
7. Shale, gray, weathers buff 0.4
8. Limestone, light blue-gray, weathers buff, shale parting, crinoidal, *Crurithyris*, abundant *Rhipidomella* 1.2

Muncie Creek shale
9. Shale, greenish-gray, blocky, *Crurithyris* 2.0
10. Shale, black, fissile, hard exposed 1.0

A quarry in the NW¼NE¼ sec. 34, T. 71 N., R. 28 W., shows the same interval as the preceding section and a detailed section is given here for comparison.

Missouri series
Kansas City group
Lane shale — Feet

1. Shale, light-gray, weathers ash gray, green dendritic markings, hard, thickly platy — 1.7

Iola formation
Raytown limestone

2. Limestone, brownish-gray, dense, massive, slightly argillaceous — 0.9
3. Shale, dark blue-gray, weathers light gray, blocky to nodular with small concretions, *Linoproductus*, ramose bryozoans — 2.1
4. Limestone, light-gray, weathers grayish-buff, sublithographic to algal fragmental, wavy-bedded — 4.6

Muncie Creek shale

5. Shale, olive-gray, floor of quarry

These two sections may seem to differ quite markedly but under close inspection it will be seen that they are the same and the correlation between the sections is valid. However, the stratigraphic determination is somewhat tenuous in both instances and a core at each location would be very helpful.

A very good opportunity to extend the foregoing sections downward is afforded by a quarry in the SE¼SW¼NE¼ sec. 33, T. 72 N., R. 28 W. A detailed section follows.

Missouri series
Kansas City group
Iola formation
Raytown limestone — Feet

1. Limestone, very light-gray, somewhat argillaceous, nodular and not persistent, fossiliferous with brachiopod sections and spines — 0.4

Muncie Creek shale

2. Shale, dark bluish-gray, grades downward to black, clayey, bottom 0.3 foot blocky — 1.9
3. Shale, black, fissile, some pyrite nodules — 1.4
4. Shale, black, clayey — 0.4

Paola limestone

5. Limestone, dark blue-gray, sublithographic, nodular — 0.6

Chanute shale

6. Shale, black, blocky, hard — 1.0
7. Limestone, dark blue-gray, very fine-grained, nodular, some brachiopod sections — 0.1
8. Shale, dark olive-green, blocky, hard — 7.6

9. Shale, greenish-gray, very calcareous, mottled 0.9

Drum limestone

10. Limestone, very light-gray, fine-grained, dense, shot with green shale partings 0.4
11. Limestone, very light-gray, finely crystalline, fragmental in places, dark-green shale partings in upper 1 foot, dark-gray chert bands in lower 1.5 feet, massive 5.1
12. Limestone, medium dark-gray, finely crystalline, dense, massive, few fossils, to quarry floor 4.0

A core taken from the floor of the quarry was reported to show about 25 feet of shale. It is believed that this was the upper portion of the Cherryvale formation. A small exposure in a ravine in the SE¼NW¼ SE¼ sec. 35, T. 72 N., R. 28 W., shows the base of the Drum limestone and the top of the Cherryvale formation. The following detailed section was measured.

Missouri series

Kansas City group

Drum limestone — Feet

1. Limestone, very light-gray, weathers gray buff, hard, sublithographic, wavy-bedded 1.6
2. Shale, light greenish-gray, calcareous, crinoidal 0.2
3. Limestone, light-gray, weathers gray buff, wavy-bedded, crinoidal 1.1
4. Shale, light greenish-gray, nodular limestone lenses 0.5
5. Limestone, light-gray, weathers buff, crinoidal, *Osagia* 0.2

Cherryvale formation

Quivira shale

6. Shale, light greenish-gray, contains limestone nodules, *Crurithyris* 1.6
7. Limestone, blue-gray, nodular, earthy 0.2
8. Shale, light greenish-gray, blocky and olive near base, nodular limestone lenses 1.3
9. Shale, black, blocky 1.1
10. Shale, medium-gray, clayey 0.5
11. Coal smut 0.1
12. Shale, dark greenish-gray, blocky, plant fragments 0.8

Although the appearance of the Drum limestone at this locality and the preceding section is somewhat different, the correlations seem valid. Whereas the description of the Drum limestone at the quarry was that of a fresh section, the latter was of a weathered face and a difference is to be expected. Moore (1935, p. 104) states that, although the Cement City member of the Drum usually appears as a massive ledge, thin wavy beds may be observed on weathered outcrops in many places.

Probably the stratigraphically lowest exposed rock in the county is in the NE¼NE¼NE¼ sec. 34, T. 71 N., R. 28 W. The section exposed here can be easily correlated with the preceding section on the basis of the coal smut. A detailed section follows.

Missouri series		
Kansas City group		
Cherryvale formation		
Quivira shale		Feet
1. Shale, olive, blocky, clayey, coal seam 0.5 foot above base		1.5
Westerville limestone		
2. Limestone, dark blue-gray, weathers buff, crinoids, *Myalina*, *Chonetina*		0.2
3. Shale, olive, clayey, thinly slaty		0.9
4. Limestone, dark blue-gray, mottled gray, gastropods, crinoids, bryozoans		0.3
5. Shale, olive, clayey, thinly platy		0.5
6. Limestone, dark blue-gray, dense, two beds, *Chonetina*		0.5
7. Shale, olive, clayey, thinly platy		0.7
8. Limestone, blue-gray, dense, vertical joints		0.3
9. Shale, olive, clayey	exposed	0.8

Physiography

The physiographic features of Union County are discussed by H. J. Russell (unpublished thesis).

Structure

The structure in Union County is probably complex, but few definite statements about it are possible because of the scarcity of exposures of Pennsylvanian rocks and the lack of deep wells. At the southeast corner of the county there appears to be a small structural high that extends into the northeast corner of Ringgold County. From this structural high there apparently is a small southwest dipping monoclinal fold that extends for about 5 miles to the northwest where it terminates in proximity to another structural high. Over the remainder of the county the general dip of the strata appears to be to the southwest.

Rock Sources

Because of the geology of the bedrock of Union County, the most logical rock sources for quarry development are the Argentine limestone of the Wyandotte formation or the Drum limestone. Any of the outcrop areas where members that overlie these limestones are exposed should be investigated. The following paragraphs will attempt to point out some of the areas where core drilling will be of special benefit, although, because of the small amount of information available, any drilling done in this county is of great interest.

Perhaps one of the most promising areas for future prospecting is in the SW¼NE¼NE¼ sec. 3, T. 71 N., R. 28 W. The section exposed here has been previously described in this report. There is doubt as to correlation, with some calling the uppermost limestone Argentine, and others calling it Drum. If it is Argentine limestone, the area should be further investigated in the hope that the whole of that horizon can be found. On the basis that this is Drum limestone, the possibilities that it might be worked along with the Winterset limestone, which lies about 15 feet below the bottom limestone of this exposure, should be an incentive for drilling in this area. If the Drum-Westerville correlation should be correct, the Bethany Falls limestone should be at a depth of about 40 feet below the bottom of this outcrop.

The quarry previously described in the NW¼NE¼ sec. 4, T. 71 N., R. 28 W., is also of interest for further exploitation. Here the Bonner Springs-Island Creek shale interval is exposed. The Island Creek shale, which should not be more than 15 feet thick, overlies the Argentine limestone. The Farley limestone, which overlies the Island Creek shale, along with the Argentine limestone, would make a total of about 20 feet of limestone available.

In the NE cor. sec. 34, T. 71 N., R. 28 W., part of the Cherryvale formation is exposed, and in the center of the NE¼ of this same section the lower part of the Drum limestone is exposed. A quarry operated in the NW¼NE¼ of this section exposed the Lane-Muncie Creek interval. With these thoughts in mind, it would seem quite possible that the entire thickness of the Drum limestone should be found somewhere along the northern boundary of the NE¼ of this section. A few test holes in that area would be very interesting.

A possibility of obtaining a full thickness of the Argentine limestone exists in the center of the N½SW¼ sec. 27, T. 71 N., R. 28 W. Here, almost 10 feet of the Argentine limestone is exposed along a small creek south of the Bullock farm barns. Some prospecting here may prove to be valuable.

In addition to these specific localities, any testing done in the vicinity of outcrops shown in the list that accompanies this report should add much to our knowledge of the geology of Union County.

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APPENDIX

ROCK EXPOSURES IN SOUTHWESTERN IOWA BY COUNTIES

EXPOSURES IN ADAIR COUNTY

Location	Rock Units	Thickness (feet)
T. 74 N., R. 30 W., no exposure.		
T. 74 N., R. 31 W., no exposure.		
T. 74 N., R. 32 W., no exposure.		
T. 74 N., R. 33 W., no exposure.		
T. 75 N., R. 30 W.		
NE¼NE¼ sec. 1, in north side cutbank at mouth of west tributary of Middle River.	Vilas-Plattsmouth	55
SE¼NE¼ sec. 12, in cutbank on south side of southeast-flowing tributary of Brush Creek.	Leavenworth-Plattsmouth	25
T. 75 N., R. 31 W.,no exposure.		
T. 75 N., R. 32 W., no exposure.		
T. 75 N., R. 33 W., no exposure.		
T. 76 N., R. 30 W.		
SW¼ sec. 7, 100 yards downstream from bridge of west section line road over Middle River, in south cutbank. Exposure also found upstream for ½ mile.	Plattsmouth-Leavenworth	15
NW¼ sec. 18, in south side cutbank of tributary to Middle River, 200 yards above mouth and in ravine to the south.	Kanwaka-Lecompton	10
Cen. sec. 20, at site of old Port Union Dam (now out), ½ mile west of Arbor Hill; now mostly covered.	Kanwaka-Lecompton	10
NE¼SW¼ sec. 21, in southeast cutbank of Middle River, ½ mile southeast of Arbor Hill.	Tecumseh-Lecompton	22
SE¼SW¼ sec. 22, in south side cutbank of Middle River, almost on south section line.	Plattsmouth-Lecompton	22
SW¼SW¼ sec. 22, in west side cutbank in large ravine.	Tecumseh?	10

NW¼SW¼ sec. 22, in cutbanks of creek and in south bank of river ¼ mile east of creek.	Plattsmouth-Tecumseh	35
SE¼ sec. 22, in south cutbank of Middle River, 100 yards downstream from bridge.	Plattsmouth	15
NW¼NW¼ sec. 26, in hog lot and ravines.	Kanwaka-Lecompton	24
SE¼NE¼SW¼ sec. 26, in road cut on north side of road.	Snyderville-Plattsmouth	26
NW¼SE¼SW¼ sec. 26, in north road ditch.	Plattsmouth-Lecompton	20
SW¼SW¼ sec. 26, in road cut.	Leavenworth-Lecompton	41
S of cen. NE¼SW¼ sec. 26, in south road ditch just west of junction.	limestone (Oread?)	
W of cen. sec. 26, in east bank of Middle River, under bridge and upstream a few yards.	Plattsmouth	5
NE¼NE¼ sec. 27, on southeast bank of Middle River, 100 feet east of the bridge.	Plattsmouth	12
NW¼NE¼ sec. 27, on south bank of Middle River, ¼ mile west of the road.	limestone	4
SE¼SE¼ sec. 27, along a ravine.	Lecompton-Plattsmouth	50
SE¼NE¼ sec. 27, in ravine just southeast of road junction.	Lecompton-Kanwaka	
NW¼NW¼ sec. 35, by road.	Snyderville?-Plattsmouth?	25
Cen. sec. 35, along small east-flowing stream.	shale and limestone	
S½ sec. 36, in cutbank east of a creek just south of Middle River.	Leavenworth-Plattsmouth	
SE¼SW¼ sec. 36, in a ravine.	Snyderville-Plattsmouth	28
NE¼NW¼SE¼ sec. 36, in south cutbank of Middle River.	Snyderville-Plattsmouth	24

T. 76 N., R. 31 W.

SW¼SW¼SW¼ sec. 1, Schildberg Quarry.	Bethany Falls?	22
SE¼NW¼ sec. 1, in bed of ravine about 100 yards east of Middle River.	Sheldon	
SW¼NW¼ sec. 1, in gully just east of north-south section line road.	Coal Creek?	
SW¼ sec. 1, ¼ mile north of Howe Bridge in west cutbank of Middle River and in a ravine a few hundred feet to the northwest.	Coal Creek-Hartford	
Cen. N line SE¼SE¼NE¼ sec. 2, in quarry just west of road.	Coal Creek-Howard	11
NE¼ sec. 2, just upstream from bridge on north-south section line road, in south cutbank of Middle River.	Ervine Creek	7
SE¼NE¼ sec. 11, in south bank of east-flowing stream, overlain by sand and gravel.	limestone	
NE¼ sec. 11, in road gutter southwest of the bridge near the center of the east side of NE¼.	Sheldon?	
SE¼SW¼ sec. 12, old quarry.	Curzon-Howard	35
NW¼ sec. 12, old quarry.	Sheldon-Ervine Creek	14
E½ sec. 12, in south cutbank of Middle River, about ¼ mile west of bridge.	Heebner-Kereford	
Cen. E line sec. 12, in south bank of Middle River, west of bridge.	Tecumseh-Heumador	
SE¼NW¼ sec. 12, in old W.P.A. quarry.	Burroak-Turner Creek	24
NE¼ sec. 12, poorly exposed.	limestone and shale	25
NW¼ sec. 12, in quarry on southwest bank of Middle River.	Calhoun-Rock Bluff	30

T. 76 N., R. 32 W., no exposure.
T. 76 N., R. 33 W., no exposure.
T. 77 N., R. 30 W.

Cen. NW¼SW¼ sec. 35, along creek bank just east of road.	limestone and shale	3
NE¼ sec. 35, in creek bed.	limestone	

T. 77 N., R. 31 W.

NE¼NW¼ sec. 17, Schildberg Quarry.	Bethany Falls	5
SE¼SE¼ sec. 17, in southwest bank of Middle River about 300 yards west of north-south road.	Coal Creek?	1.5
SE¼SE¼ sec. 17, on west side cutbank of Middle River about 100 yards north of bridge.	Coal Creek	
NE¼ sec. 20, in southwest cutbank of Middle River about 150 yards south of bridge.	Coal Creek	
Cen. sec. 21, in south bank of tributary of Middle River 300 yards west of the river.	limestone	6
Cen. sec. 21, in south and southeast cut-bank of a tributary to Middle River near mouth.	Ervine Creek	7
NW¼SE¼SE¼ sec. 21, in south bank of river, 400 feet west of bridge.	Holt-Coal Creek	
Cen. sec. 21, in south cutbank of Middle River.	Sheldon-Jones Point	
NE¼SW¼ sec. 27, about 50 yards west of Middle River, 60 feet south of bridge.	limestone	1
NE¼SW¼ sec. 27, in bed of a tributary west of Middle River, below a farm bridge.	Turner Creek?	
Cen. NW¼SW¼ sec. 34, in southeast bank of creek about 150 yards east of bridge of County Road "B."	limestone (Coal Creek?)	5

T. 77 N., R. 32 W., no exposure.
T. 77 N., R. 33 W., no exposure.

Location	Rock Units	Thickness (feet)
T. 71 N., R. 32 W., no exposure.		
T. 71 N., R. 33 W., no exposure.		
T. 71 N., R. 34 W.		
SW¼NW¼ sec. 2, old abandoned quarry.	Deer Creek?	11
NW¼NW¼SE¼ sec. 3, in river bottom parallel to railroad tracks, about ¼ mile west of quarry.	limestone	
SE¼NE¼ sec. 3, county quarry.	Ervine Creek	14
SE¼SE¼ sec. 3, old quarry, Adams County Limestone Company.	Deer Creek	
NW¼SE¼SW¼ sec. 3, quarry.	Ervine Creek-Calhoun	18
SE¼SW¼ sec. 3, old quarry and core hole.	Deer Creek	40
Cen. SW¼ sec. 3, Missouri Valley Limestone Company quarry.	Ervine Creek-Calhoun	18
NE¼NW¼ sec. 3, old quarry		
Cen. E½ sec. 3, old quarry in south bank of East Nodaway River, ½ mile south of Corning railroad station.	Ervine Creek	
Cen. E½ sec. 4, old quarry on north side of river and east side of hill, about 100 yards south of road west of Corning.	Ervine Creek-Iowa Point	21
N of cen. S line sec. 8, in bank of East Nodaway River, poorly exposed.	limestone and shale	3
Cen. NW¼ sec. 9, in river, poorly exposed.	limestone and shale	7
NE¼NE¼ sec. 9, in south cutbank of East Nodaway River, ½ mile west of road, now slumped and overgrown.	Jones Point-Iowa Point	8
NW¼ sec. 10, in east bank of river, now covered.	Ervine Creek?	1
T. 71 N., R. 35 W., no exposure.		
T. 72 N., R. 32 W., no exposure.		

T. 72 N., R. 33 W., no exposure.
T. 72 N., R. 34 W.

N of cen. sec. 6, now covered.	shale	2
NW¼NE¼ sec. 6, in river bed, now covered.	shale and limestone	3.5
SE¼SW¼ sec. 7, coal mine.	shale and coal	64
Cen. NW¼ sec. 7, coal mine, Chatterton Coal Company.	Nodaway	

T. 72 N., R. 35 W.

SE¼SE¼ sec. 2, coal mine, Ruth Coal Company.	Nodaway	
NE¼NE¼ sec. 2, coal mine, Gebbie Coal Company.	Nodaway	
SE¼NE¼ sec. 4, coal mine, Hendrickson Mine.	Nodaway	98
SE¼SW¼ sec. 9, in west bank of creek, ½ mile south of County Road "K," coal mine.	White Cloud	45
NE¼SW¼ sec. 9, coal mine, Dal Detty Coal Company.	Nodaway	
SE¼NE¼ sec. 9, coal mine, Franzine Coal Company.	Nodaway	
E½SW¼NW¼ sec. 9, in east bank of small branch.	Cretaceous-Pennsylvanian	16
NW¼SE¼ sec. 9, coal mine.	Nodaway	113
SW¼SE¼ sec. 10, coal mine, Gale Coal Company.	Nodaway	
Cen. sec. 12, in Middle Nodaway River, northeast of bridge west of Carbon.	Howard?	
NE¼SW¼ sec. 12, coal prospect.	Nodaway	65
NW¼SW¼ sec. 13, coal mine, Haley Coal Company.	Nodaway	
Cen. NW¼ sec. 13, coal mine, Drake Coal Company.	Nodaway	

SW¼NW¼ sec. 13, coal mine, Cloyd Smith.	Nodaway	
NE¼SW¼ sec. 13, coal mine, Boham Coal Company.	Nodaway	
NE¼SW¼ sec. 13, coal mine, Albert Mack.	Nodaway	
NW¼NE¼ sec. 15, coal mine, Thomas.	Nodaway	
W½SW¼ sec. 16, on north side of road at foot of hill.	Cretaceous-Pennsylvanian	37
NW¼SE¼ sec. 16, coal mine, Roy Thomas.	Nodaway	
SE¼SW¼ sec. 16, coal mine, Stern Coal Company.	Nodaway	
Cen. E½NE¼ sec. 17, in gully.	shale	12
NW¼NW¼SW¼ sec. 19, in ravine.	Cretaceous	45
SW¼ sec. 19.	Cretaceous	15
SE¼NW¼ sec. 26, coal mine, Lockwood.	Nodaway	
NW¼NW¼ sec. 26, coal mine, Hunter.	Nodaway	
NE¼SE¼ sec. 29, coal mine, Action Coal Company.	Nodaway	
SE¼SE¼ sec. 29, coal mine, Ruben and Anderson.	Nodaway	
NW¼NW¼ sec. 30.	Cretaceous	
NW¼SW¼ sec. 31.	Cedar Vale-Taylor Branch	17
NE¼NE¼ sec. 32, coal mine, Linker and Lanrus.	White Cloud-Coal Creek	100
N of SW¼ sec. 32.	Cretaceous-Elmo Coal	

T. 73 N., R. 33 W., no exposure.
T. 73 N., R. 33 W., no exposure.
T. 73 N., R. 34 W.

Cen. S line SW¼ sec. 14, in bed of Nodaway River, west of bridge.	limestone	

SE¼NE¼ sec. 14, old quarry.	Curzon-Sheldon	12
N of cen. sec. 22, old quarry, now covered.	Sheldon	
NE¼NW¼ sec. 23, old quarry, now covered.	Sheldon	
W½SW¼ sec. 28, in south bank of river north of road culvert.	Deer Creek?	3
W½SE¼NW¼ sec. 29, coal mine in pasture west of road.	Howard	22
Cen. S line SW¼ sec. 29, about 400 feet north of bridge, now covered.	shale	2
SE¼SE¼ sec. 29, on south bank of Middle Nodaway River, ¾ mile east and ¼ mile north of bridge in SW¼, poorly exposed.	limestone, shale and coal (Nodaway?)	6
SW¼ sec. 29, in south cutbank of Middle Nodaway River.	White Cloud-Coal Creek	
SE¼NE¼ sec. 29, coal mine, Henton Coal Company, 100 yards north of road on east hill slope.	Howard-Severy	
SE¼NE¼ sec. 31, at old Eureka Bridge site, ⅜ mile southwest of present bridge site, exposed in river just south of bend.	Coal Creek	2
T. 73 N., R. 35 W.		
NW¼NW¼ sec. 2, coal prospect.	limestone, shale, coal	34
NW¼NE¼ sec. 10, old quarry in southwest bank of Williams Branch, now covered.	limestone	5
SE¼NE¼ sec. 19, in south cutbank of creek, about 750 feet south of road and about 100 feet east of the quarter section line, float only.	Happy Hollow?	
NW¼NE¼ sec. 25, coal mine, Henton Coal Company.	Nodaway	

EXPOSURES IN CASS COUNTY

Location	Rock Units	Thickness (feet)
T. 74 N., R. 34 W., no exposure.		
T. 74 N., R. 35 W.		
SW¼SW¼ sec. 17, now covered.	Cretaceous	17
NW¼SW¼SW¼ sec. 31, Phelps Quarry.	Spring Branch-Plattsmouth	22
T. 74 N., R. 36 W.		
NW¼SW¼ sec. 17, old quarry, now covered.	Cretaceous	9
NE¼SE¼SE¼ sec. 36, old Fox Quarry, west of road; now slumped and overgrown.	Plattsmouth-Kereford	8
T. 74 N., R. 37 W., no exposure.		
T. 75 N., R. 34 W., no exposure.		
T. 75 N., R. 35 W., no exposure.		
T. 75 N., R. 36 W.		
NW¼NE¼ sec. 33, along banks of branch of Seven-Mile Creek, in timber.	Cretaceous	20
S½ sec. 35, along creek.	Cretaceous	
T. 75 N., R. 37 W.		
NE¼SE¼ sec. 1, in south cutbank of a south tributary of Turkey Creek about 200 yards west of bridge.	Plattsmouth	7
SE¼NW¼ sec. 1, on Turkey Creek.	Leavenworth-Plattsmouth	7
NE¼SE¼ sec. 2, downstream along creek and southward into ravine.	Lawrence-Stranger?	13
SE¼SW¼SE¼ sec. 3, in west bank of Nishnabotna River under bridge on Highway 6.	Plattsmouth	4
SE¼SW¼ sec. 5, in east cutbank of Indian Creek, about 75 yards north of Highway 6 and upstream for about 150 yards.	Plattsmouth-Spring Branch	24
NW¼SW¼ sec. 8, Missouri Valley Limestone Quarry.	Queen Hill-Spring Branch	27

NE¼NE¼ sec. 9, old quarry.	limestone and shale	6
NE¼SE¼ sec. 9, on west side of Nishnabotna River about 200 yards downstream from bridge.	Plattsmouth-Big Springs	24
S line NE¼ sec. 9, on east bluff of Spring Creek, in road ditches.	Cretaceous	
SE¼NW¼ sec. 9, on Spring Creek a few yards north of bridge and extending up a small ravine to the west, parallel to the road; now only partially exposed.	Cretaceous over Plattsmouth	45
SE¼NE¼ sec. 9, about 75 yards north and 100 yards west of road intersection, in ditches.	Cretaceous-Big Springs	
NW¼SE¼ sec. 15, exposure reported.	Plattsmouth?	
SE¼SW¼ sec. 15, at Crystal Lake, now mostly covered.	Cretaceous	65
NE¼SE¼NE¼ sec. 16, in rock cut of Nishnabotna River.	Leavenworth-Plattsmouth	15
NE¼NE¼ sec. 16, along ravines in bluff above flood plain of the Nishnabotna River.	Big Springs-Plattsmouth	25
SW¼ sec. 17, SE¼ sec. 18, and NE¼ sec. 19, in southeast cutbank of Nishnabotna River, on both sides of Highway 48 and in ravines at ends of river exposure.	Kanwaka-Big Springs	21
NE¼NE¼NE¼ sec. 18, in entrance of gully into west side road cut of Highway 48, now covered.	Queen Hill?	
NE¼SE¼ sec. 22, in road ditch.	Cretaceous	
NE¼ sec. 23.	Cretaceous	5

T. 76 N., R. 34 W., no exposure.
T. 76 N., R. 35 W., no exposure.
T. 76 N., R. 36 W., no exposure.
T. 76 N., R. 37 W., no exposure.
T. 77 N., R. 34 W., no exposure.
T. 77 N., R. 35 W., no exposure.
T. 77 N., R. 36 W., no exposure.
T. 77 N., R. 37 W., no exposure.

Location	Rock Units	Thickness (feet)
T. 67 N., R. 40 W., no exposure.		
T. 67 N., R. 41 W.		
Cen. S line sec. 18, about 100 feet north of road bridge.	Wabaunsee	20
T. 67 N., R. 42 W.		
SE¼SW¼SE¼ sec. 2, at base of north-facing bluff.	limestone and shale	thin
SE¼NW¼SW¼ sec. 5, in ditch on south-east side of road.	shale	4
NE¼SE¼NE¼ sec. 6, in road near east section line, now covered.	limestone and shale	3
SW¼NE¼SW¼ sec. 11, in drainage ditch near base of bluff, about 300 yards west of road.	limestone and shale	3
SW¼SW¼ sec. 18, in creek, close to west section line.	shale and coal	10
Cen. SE¼SE¼ sec. 21, just south of school.	sandstone and shale	18
NE¼NW¼ sec. 23, test pit on north hill slope, now covered.	limestone	2
NE¼ sec. 24 and SE¼ sec. 13, McKissick Grove, south tributary of main stream below a highway bridge and a few hundred yards to the south.	Friedrich-Table Creek	34
T. 67 N., R. 43 W., no exposure.		
T. 68 N., R. 40 W., no exposure.		
T. 68 N., R. 41 W.		
Cen. NW¼SW¼ sec. 33, on Mill Creek, about 400 feet east of County Road "U."	Wabaunsee	34
T. 68 N., R. 42 W.		
SE¼NW¼SE¼ sec. 31, in bluffs on east side of road.	Wabaunsee	22

SE¼ sec. 35, in slope east of farm buildings.	Wabaunsee	7
SE¼NE¼NW¼ sec. 36, in west bank of West Nishnabotna River.	Wabaunsee	2
T. 68 N., R. 43 W., no exposure.		
T. 68 N., R. 44 W., no exposure.		
T. 69 N., R. 40 W., no exposure.		
T. 69 N., R. 41 W., no exposure.		
T. 69 N., R. 42 W., no exposure.		
T. 69 N., R. 43 W.		
NW¼SW¼NW¼ sec. 1, in road cut on east side of road, and between two houses on west side of road.	Wabaunsee	9
W. side sec. 12 in scattered exposures along bluff.	Wabaunsee	15
NW¼NW¼ sec. 13, in road cut of County Road "K" about 200 yards north of farm house and in barnyard south of road.	Wabaunsee	15
T. 69 N., R. 44 W., no exposure.		
T. 70 N., R. 40 W., no exposure.		
T. 70 N., R. 41 W., no exposure.		
T. 70 N., R. 42 W.		
SE¼NW¼NE¼ sec. 17, in Plum Creek, about 50 yards downstream from bridge.	Coal Creek	2
Cen. SW¼NE¼ sec. 17, along east bank of Plum Creek, about 200 feet east of County Road "D" and about 100 yards south of house.	Iowa Point-Sheldon	7
SE¼SW¼ sec. 17, extending south to cen. NW¼ sec. 20, Jack Stanley Quarries.	Ervine Creek-Curzon	24
NE¼NW¼NW¼ sec. 31, in east bank of creek between two bridges.	Wakarusa?-Elmont?	33
T. 70 N., R. 43 W.		
Cen. NW¼NE¼SW¼ sec. 14, old quarry.	Sheldon	
SE¼SW¼ sec. 14, Fred Wenke Quarry.	Ervine Creek-Coal Creek	

SW¼SE¼SW¼SW¼ sec. 14, old quarry.	Ervine Creek-Sheldon	
Cen. sec. 14, in north bank of North Fork of Indian Creek, ½ mile east of the road.	Coal Creek-Howard	
SW¼SE¼ sec. 14, on Indian Creek.	Howard?	25
Cen. sec. 14, in north bank of North Fork of Indian Creek, ½ mile east of the road.	Coal Creek-Howard	
SW¼SE¼ sec. 14, on Indian Creek.	Howard	25
S line sec. 14, coal prospect, in bluff, a short distance south of Wabaunsee Lake.	Howard?	21
Cen. sec. 14, in base of bluff.	limestone and shale	14
SW¼NW¼ sec. 23, in quarry 0.2 mile north of road intersection.	Ervine Creek-Holt	38
NW¼SW¼ sec. 23, in quarry 0.2 mile south of road intersection.	Coal Creek-Howard	11
SW¼ sec. 23, in quarry between Ed Baldwin home and Wilson place.	Ervine Creek-Coal Creek	49
E of cen. W line NW¼ sec. 26, old quarry.	limestone	4
NW¼ sec. 26, in bluff.	limestone	6
Cen. N½SE¼SW¼ sec. 36, on south bank of Plum Creek, about ⅛ mile south of bridge on Highway 145.	Elmont?-Pierson Point	22

EXPOSURES IN MILLS COUNTY

Location	Rock Units	Thickness (feet)
T. 71 N., R. 40 W., no exposure.		
T. 71 N., R. 41 W.		
NW¼SW¼ sec. 5, in an old quarry behind creek bank in woods just opposite drainage ditch that goes west to bridge opposite hangar of private airport.	Plattsmouth	5
SW¼NW¼ sec. 31, about 200 yards east of road, in creek bed.	limestone	1
T. 71 N., R. 42 W.		
Cen. N½ sec. 36, in south side of Spring Valley Creek.	Rock Bluff-Calhoun	19
NW¼NW¼ sec. 36, Jack Stanley Quarry.	Ervine Creek-Hartford	14
T. 71 N., R. 43 W.		
SW¼NW¼SE¼ sec. 10, at waterfall just north of Clay Dashner farm house.	Queen Hill-Avoca	20
Cen. N½NW¼ sec. 15, Jack Stanley Quarry.	Burroak-Kenosha	12
E½NW¼NW¼ sec. 15, old quarry on bluff line just east of road.	Ost-Ervine Creek	34
SW¼NW¼ sec. 15.	Oskaloosa-Hartford	34
Cen. SE¼SE¼ sec. 16, opposite Dashner farm house.	Ervine Creek-Sheldon	19
SW¼SE¼NE¼ sec. 21, 1/5 mile north of Burr Oak School.	Ervine Creek-Turner Creek	23
NE¼SE¼SE¼ sec. 21, along bluff road between Burr Oak School and Burr Oak Church.	Ervine Creek-Hartford	14
Cen. NE¼SW¼ sec. 25, on east bank of Waubonsie Creek.	Holt-Coal Creek	6
SE¼NW¼ sec. 27, Jack Stanley Quarry.		

Near cen. SW¼ sec. 27, in bluff.	shale and limestone	8
SE¼SW¼NW¼ sec. 27, in road cut by small bridge, 3/10 mile north of intersection.	Larsh-Ervine Creek	13
E½SW¼NW¼ sec. 27, about 150 yards north of intersection, between houses.	Burroak-Ervine Creek	15
SE¼SW¼ sec. 27, quarry in bluff line.	Ervine Creek-Hartford	15
NW¼NW¼ sec. 27, Stanley Construction Company Quarry.		
SE¼ sec. 27, south of fork in road, can be traced in bluff.	Ervine Creek	
NE¼ sec. 34, on northeast side of road and extending as far to the southeast as the east line of section 34.	Ervine Creek	
T. 72 N., R. 40 W., no exposure.		
T. 72 N., R. 41 W.		
N½SE¼SE¼ sec. 31, in bed of Silver Creek, about 1,500 feet downstream from bridge.	Spring Branch?	2
T. 72 N., R. 42 W., no exposure.		
T. 72 N., R. 43 W.		
SE¼ sec. 22, in old channel of Keg Creek just south of railroad, now covered.	Plattsmouth	13
NW¼SW¼ sec. 23, in quarry near Missouri River bluff at Mills Station, now covered.	limestone and shale	9
NE¼NE¼ sec. 27, now covered.	Oread	8
T. 72 N., R. 44 W., no exposure.		
T. 73 N., R. 40 W.		
SW¼SW¼SW¼ sec. 14, about 100 yards east of corner of road, in field.	Cretaceous	12
NW¼SW¼NE¼ sec. 22, old quarry on north end of long ridge, about 150 yards west of house.	Cretaceous	5

T. 73 N., R. 41 W., no exposure.
T. 73 N., R. 42 W., no exposure.
T. 73 N., R. 43 W.

SE¼NW¼ sec. 20, road cut, poorly exposed.	Stull-Big Springs	17
N½SW¼NW¼ sec. 29, old Folsom Quarry, just east of the road.	Spring Branch	6
SW¼SE¼SW¼ sec. 29, about ½ mile south of Gowin School.	Doniphan-Beil	14

T. 73 N., R. 44 W., no exposure.

EXPOSURES IN MONTGOMERY COUNTY

Location	Rock Units	Thickness (feet)
T. 71 N., R. 36 W., no exposure.		
T. 71 N., R. 37 W.		
SW¼ sec. 16, about 100 yards north of bridge.	Wabaunsee	7
NE¼NW¼ sec. 20, about 150 yards south of road bridge.	Wabaunsee	2
NE¼SE¼ sec. 20, in rapids on Tarkio Creek, just north of bridge on east-west road.	Wabaunsee	5
Cen. S line NW¼ sec. 20.	Auburn-Elmont?	15
SE¼NE¼ sec. 29, about 50 feet west of road bridge.	limestone	1.5
T. 71 N., R. 38 W.		
SE¼SW¼ sec. 17, old quarry.	Cretaceous	20
S½ sec. 17, two quarry openings.	Cretaceous	18
SE¼SE¼ sec. 18, about 30 feet above flood plain, about 75 yards west of the east section line and 1/10 mile north of SE¼ sec. 18.	Cretaceous	8
NE¼NE¼ sec. 19, about 200 yards south of the NE¼, 50-75 yards west of the section line, now covered.	Cretaceous	10
SW¼NW¼SE¼ sec. 20, quarry north of Ruben Bergstein farm house.	Cretaceous	15
N of cen. S line sec. 30.	Cretaceous	35
E½ sec. 31, at fork of stream.		
S½SW¼ sec. 34, in creek bed and gully about ¼ mile from north-south road between sections 33 and 34.	Soldier Creek-Reading	16
T. 71 N., R. 39 W.		
SW¼SE¼ sec. 35, in west bluff of Nishnabotna River in farmyard driveway.	Wabaunsee	1

T. 72 N., R. 36 W.

Cen. SE¼SE¼ sec. 21, in south bank of small creek about 100 yards south of road.	Cretaceous	28
NW¼NE¼ sec. 25, in bank of creek about 50 yards south of road.	Cretaceous	19
NE¼NW¼ sec. 25, in east bank of small creek.	Cretaceous	15
SW¼SE¼ sec. 25, in ravine about 100 yards north of Highway 34.	Cedar Vale-Soldier Creek	52
NW¼NE¼ sec. 36, in ravine about 100 yards south of Highway 34.	Cedar Vale?	8

T. 72 N., R. 37 W., no exposure.

T. 72 N., R. 38 W.

SE¼NE¼ sec. 2, about 400 feet downstream from bridge on southwest side of creek.	Cretaceous	7
Cen. NW¼ sec. 3, south of railroad and river, about 1 mile south and ¼ mile west of Stennett, Old Gammel Quarry, mostly covered now.	Plattsmouth-Spring Branch	20
NE¼NW¼NW¼ sec. 4, in ditch south side of road.	Spring Branch?	1
SW¼SE¼ sec. 5, in road on west side of river, now covered.	Lecompton	
SW¼SW¼ sec. 9, now covered.		
NW¼SW¼ sec. 17, Red Oak Quarry, west of river and 1½ miles north of crossing of road with Highway 34.	Heebner-Spring Branch	32
NW¼NE¼ sec. 17, Riverview Park, on left bank of river at a bridge on side road west of Highway 48, now covered.	limestone and shale	9
SW¼SE¼ sec. 22, in small creek bank about 100 feet west of south side of bridge on gravel road.	Cretaceous	4
SW¼ sec. 27, on small tributary of Nishnabotna River.	Cretaceous	21

S½SE¼ sec. 28, at Red Oak waterworks and along creek to the east.	Cretaceous	
SW¼SW¼ sec. 32, in mouth of small ravine, now covered.	limestone	7
NW¼ sec. 34.	Cretaceous	
T. 72 N., R. 39 W.		
Cen. NE¼SE¼ sec. 1, along Walnut Creek, about 100 yards southwest of bridge.	Kanwaka?	6
T. 73 N., R. 36 W.		
SE¼SW¼ sec. 1, along west bank of small intermittent stream, considerable float and obscure outcrops.	shale, limestone, coal	
NW¼SE¼ sec. 3, old quarry, now covered.		
Cen. N½SW¼ sec. 3, ½ mile north of Grant.	Plattsmouth-Kereford	14
E½NW¼ sec. 3, in ravine along west bluff of West Nodaway River, north of Kaser Quarry.	Plattsmouth	10
NW¼NE¼ sec. 5, Kaser Construction Co. Quarry.	Plattsmouth-Spring Branch	34
Near cen. sec. 9, in bed of drainage ditch at foot of northeast-facing bluff where south-trending ditch makes a right angle turn to the east, now covered.	Spring Branch?	
Cen. NE¼NW¼ sec. 9, about 300 yards south of road, at mouth of drainage ditch.	limestone and shale	8
SE¼SW¼NW¼ sec. 10, Missouri Valley Limestone Company Quarry, north of county road and east of Highway 71.	Plattsmouth-Spring Branch	20
T. 73 N., R. 37 W., no exposure.		
T. 73 N., R. 38 W.		
SW¼SW¼ sec. 13, in bank behind farm house.	Cretaceous	20
NE¼SW¼SE¼ sec. 21, on south bank of stream about 900 feet upstream from bridge.	Plattsmouth-Kereford	11

Cen. E line SE¼SE¼SE¼ sec. 21, on both sides of road just south of bridge.	Kereford-Spring Branch	10
Cen. SW¼SE¼ sec. 21, on south fork of creek about 1,000 feet northwest of bridge.	Heumader-Kanwaka	4
NE¼SE¼ sec. 22, quarry in bluff of Nishnabotna River close to the road, poorly exposed.	Plattsmouth-Spring Branch	
SW¼ sec. 22, along creek and in road to the south and west.	Plattsmouth	
SW¼NW¼ sec. 26, old quarry southeast of railroad and about 400 yards northeast of County Road "H."	Kereford-Spring Branch	13
NW¼SE¼ sec. 26, approximately 100 yards upstream north of bridge on east-west road.	Doniphan-Beil	8
SE¼SE¼ sec. 27, old quarry opposite railroad tracks at Stennett.	Plattsmouth-Spring Branch	25
Cen. NE¼ sec. 27, Kaser Quarry.	Plattsmouth-Doniphan	50
SE¼SW¼NE¼ sec. 27, at intersection of east-west road and road along base of bluff of Nishnabotna River.	Snyderville-Plattsmouth	16
Cen. N½NE¼ sec. 27, old Van Buskerk Quarry.	Plattsmouth-Kereford	7
Cen. N line NW¼NW¼NW¼ sec. 27, in south road ditch.	Plattsmouth	1
NW¼SE¼ sec. 33, in old quarry and along bluff line.	Plattsmouth	6
SE¼SE¼NE¼ sec. 33, about 100 yards north of center east section line, in road ditch.	Plattsmouth	10
Cen. S½ sec. 34, in northwest bank of Nishnabotna River, now covered.		

T. 73 N., R. 39 W., no exposure.

EXPOSURES IN PAGE COUNTY

Location	Rock Units	Thickness (feet)
T. 67 N., R. 36 W.		
Cen. S line sec. 30, just south of the Braddyville Bridge on west bank of the Nodaway River.	Turner Creek-Coal Creek	9
T. 67 N., R. 37 W.		
NW¼ sec. 29, Lowrey Coal Mine.	Severy	
T. 67 N., R. 38 W., no exposure.		
T. 67 N., R. 39 W., no exposure.		
T. 68 N., R. 36 W.		
SE¼SW¼NE¼ sec. 7, at site of old Shambaugh Mill near Clarinda, now covered.	type section, Nodaway	
S of cen. sec. 7, in east road ditch, now covered.	shale and limestone	10
SE¼ sec. 7, now covered.	Howard	
SW¼SE¼ sec. 7, in east road ditch about 30 feet north of high bank.	shale	3
SW¼NE¼ sec. 7, Clarinda Coal Mine, about 100 yards north of main road at the foot of the northwest-facing bluff.	White Cloud-Severy	
SW¼NW¼ sec. 7.	shale, limestone, coal	
NW¼SE¼ sec. 18, in bed of East Nodaway River.	limestone	
NE¼ sec. 18, abandoned coal diggings.	limestone and shale	
NW¼NE¼ sec. 19, in west bank of river, now covered.	shale and limestone	5
T. 68 N., R. 37 W.		
NE¼ sec. 11, Ingraham Coal Mine.	shale, limestone, coal	78
NW¼ sec. 36, Shambaugh Coal Mine, about ¼ mile west of Highway 71 and about ¼ mile north of Shambaugh mine dump.	Howard-Severy	21

T. 68 N., R. 38 W.		
SW¼NW¼NW¼ sec. 21, in east bank of Middle Tarkio River.	Wabaunsee	11
NW¼ sec. 28, on Middle Tarkio River, now covered.	shale and limestone	28
SE¼SW¼SE¼ sec. 29, just west of underpass on north side of road.	Reading?-Auburn?	10
NE¼NW¼ sec. 32, Coin Quarry, just west of Highway 208 and south of section line road; float now found.	Reading?-Auburn?	
T. 68 N., R. 39 W., no exposure.		
T. 69 N., R. 36 W.		
SE¼SE¼ sec. 12, in a small ravine that drains into East Nodaway River, now covered.	limestone and shale	17
NE¼SW¼ sec. 13, in east bank of stream, about 200 yards south of Hawleyville bridge on County Road "A."	Coal Creek	6
Cen. SW¼ sec. 26, about ¼ mile north of bridge.	DuBois-Coal Creek	9
T. 69 N., R. 37 W.		
SW¼SW¼ sec. 26, Pearson Coal Mine, just north of Highway 2.	Severy-Auburn	160
SW¼ sec. 28, coal mine, about 4 miles west of Clarinda.	White Cloud	
NE¼ sec. 34, Clarinda Coal Mine, about 2 miles west of Clarinda.	White Cloud-Coal Creek	
T. 69 N., R. 38 W.		
SE¼ sec. 2 and NE¼ sec. 11, about 3/10 mile east of house on north side of road.	Auburn-Elmont	35
SE¼ sec. 10, old quarry.		
NE¼ sec. 15, old quarry.	limestone	
NW¼ sec. 20.	coal	
SW¼NW¼NE¼ sec. 22.	Reading-Tarkio	16

Cen. W line SE¼ sec. 22, in ledge cutting across road and in ditch.	Wabaunsee	2
SW¼NW¼ sec. 26, at point where small tributary turns west. The tributary is on east side of Middle Tarkio River, on south side of road.	Wabaunsee	19
SW¼NW¼SW¼ sec. 26, exposed in a ravine about ¼ mile northwest of first farm house west of County Road "H" on north side of Highway 2.	Wabaunsee	12
SE¼NE¼NW¼ sec. 27, ledge in road just west of junction.	Elmont?-Reading?	9
SE¼SW¼ sec. 27, now covered.	Elmont-Reading	
Cen. S line sec. 34, about ¼ mile south of bridge in the center of section 34, on east bank of Middle Tarkio River.	Wakarusa?-Reading?	17

T. 69 N., R. 39 W.

SE¼SE¼ sec. 25, on West Tarkio Creek, on east side in gully about 10 feet above water level, now covered.	shale	2.5

T. 70 N., R. 36 W., no exposure.
T. 70 N., R. 37 W.

N½SW¼SE¼ sec. 7, about 200 yards upstream from bridge.	Auburn?-Reading?	6
NE¼NW¼NE¼SW¼ sec. 7, in west bank of creek, about 200 yards west of center of section 7.	Auburn?-Reading?	20
NW¼ sec. 18, in road ditch on south side of road, 1/5 mile east of bridge.	Table Creek?	7
NW¼NE¼NW¼ sec. 19, about 100 yards upstream from bridge, with scattered exposures continuing upstream for ¼ mile.	Table Creek?-Dover?	15
SW¼NW¼NW¼ sec. 32, in small ravine behind barn.	Wabaunsee	3

T. 70 N., R. 38 W.

NE¼SW¼NW¼ sec. 3, in creek behind Eldon Calvin home.	limestone	3
W½SE¼NE¼ sec. 13, in east bank of Middle Tarkio River opposite to a tributary flowing in from the west.	Table Creek?-Dover?	15
N½SE¼ sec. 18, exposure starts about 150 yards downstream from bridge and continues for about 250 yards.	Auburn?-Reading?	20
NW¼NW¼ sec. 24, in south road ditch, about halfway between two houses on north side of road.	shale and coal Nyman?	3
NE¼SW¼NE¼ sec. 24, in small creek east of bridge in lane about 2/5 mile south of Cale Wallin farm.	limestone and shale	9
NW¼NW¼NE¼ sec. 25, in ravine about 1/5 mile east of bridge.	Wakarusa-Burlingame	14
W of cen. NE¼ sec. 25, in ravine west of farm buildings.	Cretaceous-Pennsylvanian	11
NW¼NE¼ sec. 35, old CCC Quarry in east-facing slope.	limestone	

T. 70 N., R. 39 W.

NW¼NW¼NW¼ sec. 2, east of gate on east side of County Road "H," about 200 yards south of the Montgomery County line.	Wabaunsee	3
SW¼SE¼ sec. 10, in small hillside; float only.	limestone	
SE¼NW¼SW¼ sec. 10, in ravine behind house.	limestone and shale	5
SW¼NW¼NE¼ sec. 15, in small ravine behind house.	limestone and shale	3
NE¼SE¼ sec. 36, along south bank of creek under south bridge, extends 200 yards downstream.	Wakarusa-Burlingame	15

EXPOSURES IN POTTAWATTAMIE COUNTY

Location	Rock Units	Thickness (feet)
T. 74 N., R. 38 W.		
Near cen. N line sec. 1.	Cretaceous	
T. 74 N., R. 39 W.		
SW¼NE¼ sec. 30, in west bank of creek about 200 yards east of road and 100 yards southeast of house.	Cretaceous	20
Sec. 28, in right bank ravine a few rods east of road bridge.	Cretaceous	
T. 74 N., R. 40 W.		
SE¼SE¼ sec. 3, in David Snapp Quarry at base of bluff west of river and north of mill.	limestone and shale	10
E½NE¼ sec. 3, old quarry.		
SW¼SE¼ sec. 3, at base of bluff.	limestone	
W line NE¼SE¼ sec. 10, in left bank of West Nishnabotna River, now covered.	Beil-Big Springs	4
NW¼NE¼ sec. 10, in west bank of new river channel.	limestone	
SW¼ sec. 14, Missouri Valley Limestone Company Quarry.	Ervine Creek-Coal Creek	30
SE¼ sec. 21, Missouri Valley Limestone Company Quarry.	Ervine Creek-Coal Creek	30
NE¼NW¼ sec. 22, scattered exposures.	limestone	
SE¼ sec. 22 and NE¼ sec. 27, Tomkin Quarry.	Ervine Creek	13
NW¼ sec. 23, John Martin Quarry.	limestone and shale	22
NW¼SW¼ sec. 27, old mill site at Macedonia.	limestone and shale	17
SW¼ sec. 27, foot of west river bluff, ¼ mile north of bridge, float only.	Coal Creek?	
T. 75 N., R. 39 W., no exposure.		
T. 75 N., R. 40 W., no exposure.		
T. 75 N., R. 41 W., no exposure.		

T. 75 N., R. 42 W., no exposure.		
T. 75 N., R. 43 W.		
NE¼SW¼ sec. 1, in bottom of east branch of stream junction.	Cretaceous	2
Near SE¼ sec. 1.	Cretaceous	
SE¼SW¼SE¼ sec. 36, in bluff.	Cretaceous	15
W line NE¼ sec. 36, in bluff.	Cretaceous	
Cen. N line NE¼ sec. 36, in ravine.	Cretaceous	
T. 75 N., R. 39 W., no exposure.		
T. 75 N., R. 40 W., no exposure.		
T. 75 N., R. 41 W., no exposure.		
T. 75 N., R. 42 W., no exposure.		
T. 75 N., R. 43 W.		
SW¼NW¼SW¼ sec. 21, in east bank of Mosquito Creek about 100 feet south of railroad bridge.	Argentine	8
SE¼SE¼NE¼ sec. 29, in east cutbank and bed of Mosquito Creek about 150 feet north of road bridge, poorly exposed.	Argentine?	
T. 75 N., R. 44 W., no exposure.		
T. 76 N., R. 38 W., no exposure.		
T. 76 N., R. 39 W., no exposure.		
T. 76 N., R. 40 W., no exposure.		
T. 76 N., R. 41 W., no exposure.		
T. 76 N., R. 42 W., no exposure.		
T. 76 N., R. 43 W., no exposure.		
T. 76 N., R. 44 W.		
NE¼NE¼ sec. 34, Missouri Valley Limestone Company Quarry, about ¾ mile south of the Crescent Railroad station. Exposures extend north into SE¼ sec. 27, along the base of the Missouri River bluff.	Winterset-Drum	60
T. 77 N., R. 38 W., no exposure.		
T. 77 N., R. 39 W., no exposure.		
T. 77 N., R. 40 W., no exposure.		
T. 77 N., R. 41 W., no exposure.		
T. 77 N., R. 42 W., no exposure.		
T. 77 N., R. 43 W., no exposure.		
T. 77 N., R. 44 W., no exposure.		
T. 77 N., R. 45 W., no exposure.		

EXPOSURES IN RINGGOLD COUNTY

Location	Rock Units	Thickness (feet)
T. 67 N., R. 28 W., no exposure.		
T. 67 N., R. 29 W.		
Cen. S line sec. 19, Concrete Materials Company Quarry.	Stanton-Weston	27
SW¼SE¼ sec. 19, old Waterson Quarry, south of river and east of road.	Stanton?	
SE¼SW¼NW¼ sec. 20, in south bank of East Fork of Grand River, 4/5 mile South of road and directly north of an abandoned house; rubble only.	limestone	
T. 67 N., R. 30 W.		
NE¼ sec. 3, near bridge, now covered.	limestone	
T. 67 N., R. 31 W., no exposure.		
T. 68 N., R. 28 W., no exposure.		
T. 68 N., R. 29 W., no exposure.		
T. 68 N., R. 30 W., no exposure.		
T. 68 N., R. 31 W., no exposure.		
T. 69 N., R. 28 W.		
NE¼ sec. 33, reported along creek, now covered.	limestone	
T. 69 N., R. 29 W., no exposure.		
T. 69 N., R. 30 W., no exposure.		
T. 69 N., R. 31 W., no exposure.		
T. 70 N., R. 28 W.		
Near cen. N line sec. 1, in south bank of Thompsons Fork.	Westerville	
T. 70 N., R. 29 W., no exposure.		
T. 70 N., R. 30 W., no exposure.		
T. 70 N., R. 31 W., no exposure.		

EXPOSURES IN TAYLOR COUNTY

Location	Rock Units	Thickness (feet)
T. 67 N., R. 32 W., no exposure.		
T. 67 N., R. 33 W., no exposure.		
T. 67 N., R. 34 W.		
SW¼SW¼ sec. 4, Missouri Valley Limestone Company Quarry.	Ervine Creek	18
NW¼NW¼ sec. 10, in river.	limestone	
NW¼NW¼ sec. 21, in stream.	limestone	
T. 67 N., R. 35 W., no exposure.		
T. 68 N., R. 32 W., no exposure.		
T. 68 N., R. 33 W., no exposure.		
T. 68 N., R. 34 W.		
SW¼SE¼ sec. 26, at east end of dam at Bedford Waterworks.	Ervine Creek	3
SE¼SW¼SE¼ sec. 26, in stream cut about 150 yards long, on East Branch of One Hundred and Two River; only rubble now exposed.	limestone	3
Near cen. E line sec. 26, abandoned quarry, filled with water.	Ervine Creek	
NW¼NE¼ sec. 35, Missouri Valley Limestone Company Quarry.	Ervine Creek	14
T. 68 N., R. 35 W., no exposure.		
T. 69 N., R. 32 W., no exposure.		
T. 69 N., R. 33 W., no exposure.		
T. 69 N., R. 34 W., no exposure.		
T. 69 N., R. 35 W.		
Cen. SW¼ sec. 7, in creek just east of bridge over north-south section line road.	Sheldon-Severy	30
SE¼ sec. 32, New Market Coal Mine.	Howard?	
SE¼ sec. 34, John Bean Coal Mine.		
T. 70 N., R. 32 W., no exposure.		
T. 70 N., R. 33 W., no exposure.		
T. 70 N., R. 34 W., no exposure.		
T. 70 N., R. 35 W.		

NE¼ sec. 20, in creek bank.	limestone	2
NW¼SW¼ sec. 28, about ½ mile northeast of bridge, now covered.	limestone and shale	4
NE¼SW¼SE¼ sec. 29, in tributary to Nodaway River.	limestone and shale	6
NW¼NE¼ sec. 32, upstream to southeast about 300 feet from quarry.	limestone and shale	4
NW¼NE¼ sec. 32, old quarry on south bank of a small west-flowing stream.	limestone and shale	11

Location	Rock Units	Thickness (feet)
T. 71 N., R. 28 W.		
Cen. SE¼SE¼ sec. 2, along small south-flowing stream east of Grand River, about ¼ mile north of the SE¼, now badly slumped.	limestone	7
SE¼NW¼ sec. 3, in east cut of Grand River, now covered.	Drum-Quivira	8
NE¼NW¼ sec. 3, Schildberg Quarry.		
SW¼NE¼NE¼ sec. 3, in north bank of Grand River 200-300 feet west of bridge and about 100 feet west of first ravine from the north.	Argentine-Quindaro	10
NE¼NE¼ sec. 4, in south bank of Grand River, about 190 feet west of NE¼ sec. 4.	limestone and shale	14
NE¼ sec. 4, about ¼ mile east of north-south road and east of a farmyard on the northwest bank of a small north-flowing stream.	limestone	4
Near cen. E line sec. 4, in south bank of Grand River about ½ mile from road.	limestone and shale	11
SE¼ sec. 4, County Quarry.		
NW¼NE¼ sec. 4, old quarry.	Bonner Springs-Island Creek	15
NE¼SW¼ sec. 27, Bullock Quarry.	Argentine	8
SE¼NW¼NE¼SW¼ sec. 27, in north bank of creek, south of road and south of barn, about 1/3 mile west of bridge.	Argentine-Quindaro	6
NW¼SE¼SW¼ sec. 33, in south bank of Grand River about 200 yards west of road.	Raytown-Chanute	9
Cen. NE¼ sec. 34, southeast road ditch about 350 feet west of bridge.	Drum	3
NE¼NE¼NE¼ sec. 34, just north of Twelve Mile Creek.	Cherryvale	5

SW¼NE¼ sec. 34, along creek.	Drum	2
NW¼NE¼ sec. 34, Sargent Quarry.	Lane-Muncie Creek	12
Near cen. E½ sec. 34, in two cutbanks on east-flowing tributary to Twelve Mile Creek, about 150 yards apart, ⅛ mile southwest of bridge.	Drum?-Quivira?	
SW¼NW¼ sec. 35, along a small north-flowing tributary to Twelve Mile Creek, now poorly exposed.	Drum	2
NW¼SE¼ sec. 36, in west bank of old Grand River Channel about 150 yards southwest of bridge.	Cherryvale?	2

T. 71 N., R. 29 W., no exposure.
T. 71 N., R. 30 W., no exposure.
T. 71 N., R. 31 W., no exposure.
T. 72 N., R. 28 W.

NW¼NW¼ sec. 20, now covered.	limestone and shale	10
NE¼NW¼ sec. 20, in south bank of Grand River at the mouth of a southeast tributary, ⅛ mile south of Highway 34 and ⅜ mile southwest of bridge.	Raytown?-Chanute?	
NE¼SW¼NW¼ sec. 20, in south bank of Grand River, now mostly covered.	Chanute-Lane	25
SE¼SW¼SW¼ sec. 28, on east side of Grand River, about 150 feet north of bridge.	Muncie Creek-Lane	19
SE¼NW¼ sec. 30, on south side of Grand River, ¼ mile north of road at edge of old gravel pit.	Bonner Springs?	8
Cen. NE¼ sec. 30, old railroad pit.	shale	10
SE¼NW¼NE¼ sec. 33, Schildberg Quarry.	Raytown-Drum	23
NW¼SE¼SW¼ sec. 33, along creek.	Frisby-Argentine	12
Cen. W line SE¼SE¼ sec. 33, in east bank of Grand River.	Argentine	3

NW¼SE¼NE¼ sec. 33, county quarry, now mostly covered.	Argentine-Lane?	12
NE¼SE¼ sec. 33, old quarry.	Argentine-Farley	
NW¼SE¼ sec. 33, along a small south-flowing creek.	limestone and shale	10
NW¼SE¼SW¼ sec. 33, at foot of ravine in south bank of Grand River about 200 yards west of road.	Raytown-Chanute	4
SE¼SE¼ sec. 33, about ¼ mile southeast of County Quarry on east bank of river.	limestone and shale	5
SW¼NE¼ sec. 35, in stream bank ⅛ mile east of County Road "P."	limestone and shale	13
SE¼NW¼SE¼ sec. 35, north of south line in first large ravine on east, along creek leading to river.	Cherryvale-Drum	9
SE¼SW¼NE¼ sec. 35, in second ravine east of road from intersection on south line of sec. 35, at mouth of creek and about 150 feet north along west side of river (two exposures).	Chanute-Drum	5
T. 72 N., R. 29 W.		
Cen. S½SW¼ sec. 11, along creek northeast of bridge about due east of a point 200 feet north of bridge.	Cherryvale?	1.5
T. 72 N., R. 30 W., no exposure.		
T. 72 N., R. 31 W., no exposure.		
T. 73 N., R. 28 W., no exposure.		
T. 73 N., R. 29 W., no exposure.		
T. 73 N., R. 30 W., no exposure.		
T. 73 N., R. 31 W., no exposure.		