POST-PERMIAN GEOLOGY
AND
GROUND WATER RESOURCES
OF
JEFFERSON COUNTY, NEBRASKA

by

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INTRODUCTION

Purpose of Investigation

The purpose of this study was to describe the post-Permian stratigraphy, geologic history, ground water resources and geo-economic materials present in Jefferson County, Nebraska. The objectives of the study were best attained only by doing the study as an exploration project. Presentation of previously unpublished surface and subsurface data was possible by using large scale parallel series cross sections. Cross sections, Plates 2-4 (which are located on Plate 1 in pocket), constitute the framework of this study and are the most important single element produced as a result of the study. Large scale cross sections of this type are not only practical but essential for field workers, whether they are geologists, water well contractors, hydrologists, soil scientists, sand and gravel contractors or men representing clay product industries. The post-Permian geologic evolution of Jefferson County and the control which geology has on the ground water resources are clearly illustrated by these cross sections.

Geography

Jefferson County, Nebraska is located in southeastern Nebraska, on the Kansas-Nebraska state line (Fig. 1). Civil boundaries define the borders of the county. Washington County, Kansas borders the county on the south, Thayer County, Nebraska on the west, Saline County, Nebraska on the north and Gage County, Nebraska on the east (Fig. 1). Plate I shows the location of towns, townships north and ranges east. The county is 24 miles long east-west, and 24 miles north-south.

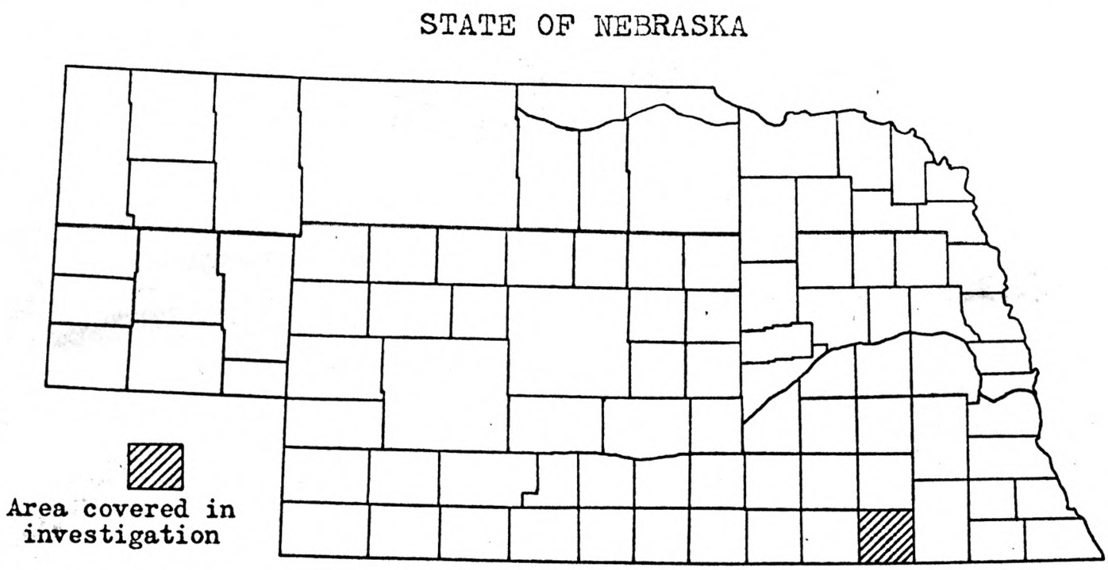


Fig. 1. Area index map.

Relief relationships existing in the county were used to sub-divide it into five physiographic units (Plate 5). Under such a classification system the following units are recognized: (1) plains; (2) dissected plains; (3) rolling hills; (4) bluffs and escarpments; and (5) valleys. Geologic control is reflected by these major physiographic units. This point is illustrated by comparing Plate 5 with the geologic cross sections

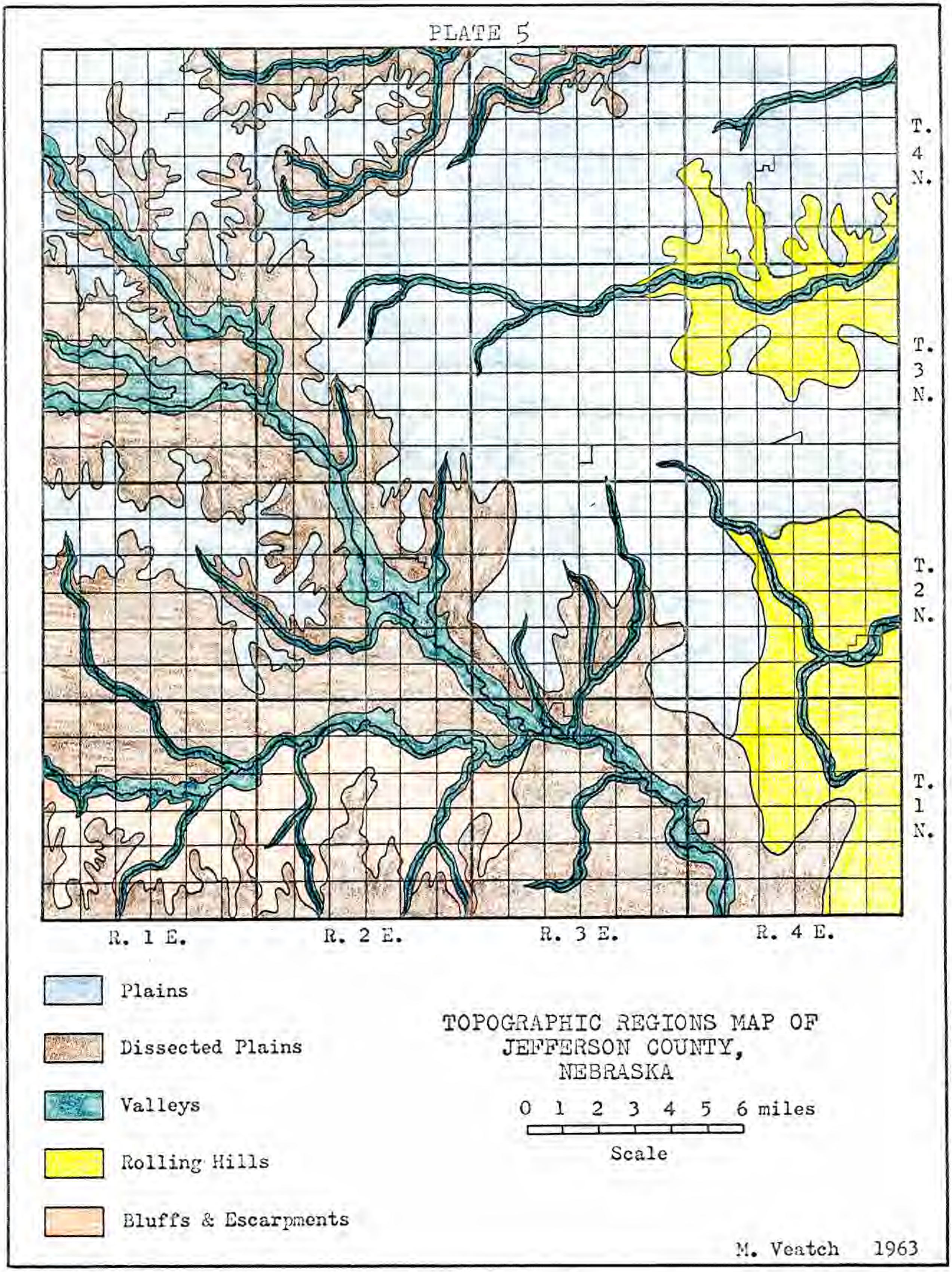


PLATE 5
T. 4 N.
T. 3 N.
T. 2 N.
T. 1 N.
R. 1 E.
R. 2 E.
R. 3 E.
R. 4 E.
Plains
Dissected Plains
Valleys
Rolling Hills
Bluffs & Escarpments
TOPOGRAPHIC REGIONS MAP OF
JEFFERSON COUNTY,
NEBRASKA
0 1 2 3 4 5 6 miles
Scale
M. Veatch 1963

(Plates 2-4). Present-day landforms of the area are mainly the result of pluvio-fluvial denudation of the underlying geologic material. Lowland features, such as flood plains and their associated deposits are the result of fluvial aggradation (alluviation). A detailed discussion on the geomorphic evolution of the area is presented in the discussion on the geologic history of the area.

The climate of the area is marked by wide seasonal variations. Winters are usually long and cold. The frost-free period ranges from 160 to 180 days from late April to early October. This period can be considered the field season. Average annual precipitation ranges from 25 to 30 inches. Mean annual temperature ranges from 50 to 55° F. Climatic environment controls the vegetation and geomorphic processes that are most active.

Land use and vegetation are summarized in Table 1. Vegetation can be interpreted from this table by associating it with land usage. Geology is both directly and indirectly responsible for the types of land usage present. Most of the loess mantled areas of the county are under cultivation. Principal cultivated crops are corn, wheat, sorghum and alfalfa. Cretaceous and Kansan Till outcrop areas are mainly uncultivated and support native grass stands. These locations represent the principal grazing areas within the county.

Table 1. Jefferson County land usage.

Present Land Usage	Present Acres	Precent of Total Acres
Cropland (non-irrigated)	234,000	63.4
Cropland (irrigated)	10,300	2.8
Range and Pasture	93,900	25.4
Forest and Woodlands	11,800	3.2
Urban and Built-up	11,400	3.1
Small water areas	100	trace
Other Land	7,800	2.1
Total acres in county	369,300	100.0

Statistics from Nebraska Soil and Water Conservation Needs Inventory, Table 8.

METHODS OF INVESTIGATION

Several different methods of investigation were used on this project. Surface and subsurface exploration methods were used extensively. Integration of the data made a practical study of the area economically possible. Laboratory methods were used to a limited extent, but only to obtain qualitative results. Listed below is a summary of the methods:

1. Areal geologic framework of the area was accomplished by approximately 230 miles of surface cross section traverses.
2. Hypsometric and planimetric control for the cross sections, water wells and test holes were obtained by the following methods: (a) U. S. Geological Survey 7.5 Minute series, 1:24,000, 10 foot contour interval, (Topographic) Quadrangle maps where coverage was available; (b) U. S. Geological Survey, Western United

States 1:250,000, 50 foot contour interval, Lincoln NK-14-12 topographic map; (c) Altimeter surveys supplied additional control on the Lincoln NK-14-12 topographic map; (d) Planimetric location of wells and test holes in areas not covered by method (a) was obtained from aerial photographs.

3. Representative rock samples were obtained for all the major Cretaceous outcrop types present in the area. These samples, along with detailed field notes, subsurface samples and well log descriptions, are the criteria used to establish the lithologic and hydrologic characteristics of the geologic formations in the area.

4. Measured sections of outcrops were not made, except for one detailed measured section of the Greenhorn Limestone. An adequate study of this area cannot be made with measured sections because of the lack of outcrop exposures in most of the area.

5. A rock color chart prepared by E. N. Goddard and others, and distributed by the Geological Society of America, was used to describe rock colors in the field. Throughout the remainder of this report, color adjectives, followed by a color notation symbol, represent rock color based on this chart. Color adjectives not accompanied by a color notation symbol are broad generalizations.

6. Field descriptions of grain size are based on the Udden-Wentworth grade scale.
7. Subsurface data was obtained from logs of water wells, test holes and electric logs. Several different sources supplied this information and they are listed in the appendix. Water well and test hole location numbers are in accordance with the system used by the Ground Water Branch of the U. S. Geological Survey.
8. Textural peels were run on Greenhorn Limestone samples obtained from the site of the detailed measured Greenhorn Limestone section given on Page 39. The peels were studied under the petrographic microscope and classified by the system of Folk (1959).
9. Qualitative insoluble residue tests were run on some samples of Greenhorn Limestone and calcite-cemented sandstones of the Dakota Group.
10. Large scale parallel-to-nearly-parallel cross sections were used to illustrate the subsurface geology. It is possible by this technique to show areal and temporal distribution of rock stratigraphic units in a form readily assimilated and interpreted by the professional geologist or the layman. An understanding of the ground water resources of the area is not possible until some understanding of the sedimentational history is known. Plates 2-4 provide the reader with an illustration by which sedimentational history and the resulting distribution of ground water resources can be

understood.

The methods of investigation just outlined were employed while conducting field work in the area. Field work was carried on continuously from June to early September, 1962 and then intermittently until late December, 1962.

IMPORTANT PREVIOUS INVESTIGATIONS

Many workers concerned with the geology of Nebraska have contributed ideas related either directly or indirectly to the geology of Jefferson County. A detailed summary of previous work in the area is given by Weidler (1954). Only what is considered the more important of previous investigations that have yielded large amounts of data on a county-wide basis will be discussed. There are seven such investigations. Some of the data compiled has been published, but a larger amount remains unpublished.

Hayes (1925) describes the soils and their areal distribution in the county. When this investigation was carried on, Nebraska soil scientists realized the importance of parent material. Armed with this concept, field workers turned out a soils map of the area which can be used to make a reliable geologic map that shows the areal distribution of outcropping bedrock and mantle rock.

Lugn (1935) made a detailed study of the Pleistocene geology of Nebraska. Lack of abundant subsurface data forced Lugn to study Pleistocene sediments at the surface in many areas of the state. It is now recognized that the Pleistocene sediments are most adequately studied only with the aid of subsurface drill hole information. This statement applies equally as well to Jefferson County; however, there are good Pleistocene exposures in the area. Lugn makes many references to the surface Pleistocene geology of Jefferson County. Lugn's discussion puts forth ideas that are substantiated by the Pleistocene sediments in Jefferson County.

Reed (1946) compiled a preliminary ground water map and several profile sections of the county. This is the first report on the area based mainly on subsurface data. The test hole data secured by Reed and his co-workers is the best subsurface Pleistocene data available on the area.

Weidler (1954) studied the pre-Pleistocene geology of the county and was concerned mainly with Cretaceous stratigraphy. Two significant contributions of the investigation were: (1) a geologic map of southern and western Jefferson County, Nebraska; and (2) an excellent detailed discussion on the evolution of the terminology of the Dakota Group.

Test hole drilling has and still is being carried on by the Conservation and Survey Division of the University of Nebraska in cooperation with the U. S. Geological Survey in this area. Rotary type drilling equipment is used in this drilling program. This investigation has obtained accurate subsurface Pleistocene data which is used extensively in this report. The data is available and can be obtained from the Conservation and

Survey Division of the University of Nebraska.

Stanolind Oil Company during the early 1950's drilled approximately 160 stratigraphic tests that ended in Council Grove and Chase Group rocks of Permian age. Average depth of these tests ranged from 600 to 800 feet. Electric logs of these holes were made available to the writer by Pan American Petroleum Corporation. Analysis of these logs yielded vital new data on depth to the Permian-Cretaceous unconformity. The electric logs also provided pertinent lithologic data on the Dakota Group.

The Dale Veatch Water Well Drilling firm has been and still is actively investigating the area. This business establishment is very interested in the Cretaceous and Pleistocene ground water aquifers. Most of the work has been done with cable tool drilling equipment. This drilling method provides excellent samples, depth control and data regarding hydrologic properties of formations drilled. Over 250 detailed driller's logs plus many less detailed logs were provided by this firm. These logs were correlated and data tabulated on a well log form of the type shown in the appendix, Page 127. All well altitudes and locations were determined by the author.

STRATIGRAPHIC NOMENCLATURE AND CORRELATION

Stratigraphic nomenclature used to map the rock units of the area is that being employed by the Nebraska Geological Survey. A thorough discussion of this nomenclature can be found in Condra and Reed (1943, 1959) and Condra, Reed and Gordon (1950). A full discussion of the rock-stratigraphic units with formal stratigraphic nomenclature is not possible.

It is not the purpose here to discuss the evolution of stratigraphic nomenclature or the regional correlation of formal rock-stratigraphic units present in the area. Condra, Reed and Gordon (1950), Weidler (1954) and Condra and Reed (1959) cover this phase of the stratigraphy in detail. Correlation in the area and with adjacent areas is based on both surface and subsurface data. Integration of these data provides correlation for most of the rock-stratigraphic units. The correlation of certain rock-stratigraphic units is less well founded and most certainly open to question.

STRATIGRAPHY

The stratigraphic relationship of the units of Permian, Cretaceous and Pleistocene age is illustrated on Plates 2-4. A generalized geologic section for the area is given on Plate 6.

Permian System

Rock-stratigraphic units belonging to this system do not cropout in the county. Subsurface data indicate that the entire area is underlain by limestone and shale formations of the Chase Group. Present Nebraska usage places the Chase Group as the uppermost group in the Big Blue Series. This series is approximately equivalent to the nationally recognized Wolfcamp Series.

PLATE 6

Generalized geologic section of post-Admire Group (Permian System) rock-stratigraphic units present in Jefferson County, Nebraska.

System	Series	Group	Stage	Rock-Stratigraphic Units	General Character
			Recent	Valley Alluvium & Loess	Clay, silt, sand & gravel.
Quaternary	Pleistocene		Wisconsin	Peorian Formation	Light grayish tan, clayey silt.
			Sangamon		
			Illinoian	Loveland Formation	Reddish brown, clay loess with sand laminae in lower part.
				Crete Formation	Sand & gravel.
			Yarmouth		
			Kansan	Sappa Formation	Greenish gray, silty clay.
				Grand Island Formation	Sand & gravel.
				Kansan Till	Yellowish gray, boulder clay till.
				Atchison Formation	Poorly sorted, sand & gravel, very heterogeneous.
			Aftonian	Fullerton Formation	Light yellowish brown, clayey silt.
			Nebraskan	Holdrege Formation	Sand & gravel.
				Seward Formation	Medium-light gray, calcareous silt, basal limestone gravel.
Cretaceous	Upper	Colorado		Carlile Shale (Fairport Shale Member)	Light gray shale with thin limy layers.
				Greenhorn Limestone	<u>Inoceramus</u> bearing limestone beds with interbedded marl and shale beds.
				Graneros Shale	Medium-dark gray calcareous, carbonaceous shale.
	Lower	Dakota		Omadi Sandstone	Fine-medium, friable sandstone with interbedded gray clay shale & some varicolored clay.
				Skull Creek Shale	Varicolored clay with some interbedded sandstone beds.
				Cloverly Formation	Fine-medium, friable sandstone & varicolored clay.
Permian	Big Blue		Chase Group	Nolans Limestone thru Wreford Limestone	Limestone & shale.
			Council Grove Group	Speiser Shale thru Foraker Limestone	Limestone & shale.

Drilling depth to the Chase Group can be determined from Plates 2-4. These data were obtained mainly from electric logs. An error of plus or minus 25 feet is present at places. This results from the lithologic character of the overlying Dakota Group of Cretaceous age being similar. Thin sandstone units of the Dakota Group were undistinguishable from Chase Group limestone units on many of the electric logs. It is possible to pick the Permian-Cretaceous unconformity accurately only part of the time with electric logs of the type used. This unconformity can be accurately picked with good drill samples and drilling time records.

Depth to the Chase Group is greatest in the southwest corner of the county and is about 600 feet. The most shallow subsurface occurrence of the Chase Group is in the Little Blue River Valley south of Steele City, Nebraska on the Kansas-Nebraska line. Bonham No. 1, A1-1-31dd, surface altitude 1594 feet drilled out of the Dakota Group into the Nolans Limestone of the Chase Group at a depth of 591 feet. Logs of two deep water wells indicate the shallow depth of the Chase Group in T. 1 N., R. 4 E. Partial data from the logs follow:

	Depth in feet.
A1-4-19 bad, altitude 1313 ft.	
Dakota Group--Chase Group unconformity.	73
A1-4-26 bbb, altitude 1379 ft.	
Dakota Group--top Herington Limestone Member (?) Nolans Limestone (?), Chase Group.	98

The Chase Group is overlain unconformably by the Dakota Group throughout the area except for two local areas. In these two areas, Pleistocene sediments rest unconformably on the

Chase Group. Alluvial sediments filling the main channel of the Little Blue River Valley below Steele City, Nebraska may be resting unconformably on the Chase Group. Pleistocene sediments rest unconformably on the Chase Group in the northeast part of T. 4 N., R. 4 E. Test hole <u>A4-4-10dd</u>, surface altitude 1381 feet confirms this statement.

	Depth in feet.
Quaternary System--Pleistocene Series.	
Sand and Gravel	85 to 288
Permian System--Chase Group.	
Shale, light gray to bluish green; medium to dark gray below 290.6 ft. . . .	288 to 300

Plates 2-4 illustrate the magnitude and areal relationship of the Permian-Cretaceous unconformity.

Cretaceous System

The Cretaceous System in Jefferson County consists of the Dakota Group and the Colorado Group. The complete Dakota Group includes the Cloverly Formation, Skull Creek Shale and Omadi Sandstone. The Colorado Group is represented by the Graneros Shale, Greenhorn Limestone and Fairport Shale Member of the Carlile Formation.

<u>Dakota Group</u>. Three formations compose the Dakota Group in Eastern Nebraska. These three formations are recognizable at the surface and in the subsurface from Jefferson County northward to Dakota County, Nebraska. The Group was named by Meek and Hayden, 1862, (Condra and Reed, 1959). Since that year, the Dakota Group has become one of the most controversial and least understood groups present on the North American

Continent. Meek and Hayden confused the issue by not establishing a standard section or type locality in Dakota County, Nebraska. Condra and Reed (1943) selected such a type locality in conformance with the purposes of Meek and Hayden, i.e., in Dakota County. Tester (1931, 1952) discussed the terminology of the Dakota Group in detail with special emphasis on the age of the group. Weidler (1954) discussed in detail the evolution of the nomenclature of the Dakota Group in Nebraska. The same three map units are employed in this study as used by Weidler in the southern part of Jefferson County to map the Dakota Group.

Dakota Group nomenclature as now used in eastern Nebraska can best be illustrated by the renaming of several formations encountered in Jefferson County wells with the type locality selected by Condra and Reed (1943) and by regional correlation which is shown on Plate 7. The following excerpt from Condra and Reed (1959) summarizes the change in terminology:

> Cretaceous System (pp. 14-20) In the Dakota Group the Omadi formation of eastern Nebraska is now recognized as equivalent to the Mowry sandstones of western Nebraska including the oil productive Gurley ("D") and Cruise ("J") sandstones; the "Fuson" shale of eastern Nebraska is now correlated as equivalent to the Skull Creek, and the "Lakota" sandstone of eastern Nebraska is equivalent to the Fall River sandstone of western Nebraska and the Black Hills. The Fuson shale and Lakota sandstones seem to be represented only in western Nebraska, principally in the northern part of the Panhandle, but may have thin equivalents in the Denver-Julesburg Basin of the southern Panhandle.

Following is a section of the Dakota Group made by (Condra and Reed (1943) in the vicinity of the proposed type locality, on the outcrop and from well logs, total thickness is 392 feet, located in NE¼ sec. 13, T. 27 N., R. 8 E.

		Thickness in feet.
1.	Omadi sandstone formation (new name)	147.3
(1)	Sandstone, massive, indurated, with some ironstone	3
(2)	Interbedded shales and sandstones . . .	22
(3)	Sandstone, medium light gray to brown-gray, medium grained, in part friable, in part indurated	30
(4)	Interbedded yellow to rusty sandstones and gray, slightly sandy clay shales, with four zones of ironstone	11
(5)	Sandstone, rusty, friable	2.2
(6)	Interbedded gray, sandy, clay shales and yellow, unconsolidated sandstones . . .	2.2
(7)	Sandstone, massive, crossbedded, with an ironstone zone at top	3
(8)	Sandstone, buff to yellow, massive, friable, with an ironstone zone at top .	16
(9)	Interbedded rusty yellow sandstone with ironstone zones and gray, sandy, clay shale	38
(10)	Sandstone, buff to rusty, massive, crossbedded	11
(11)	Sandstone, light gray, fine to medium grained	9
2.	Fuson shale (Skull Creek Shale)*, drilled in a well northwest of Homer	75
(1)	Shale, varicolored red and light gray, argillaceous to slightly sandy	10
(2)	Shale, medium dark gray, with some red mottling, argillaceous to sandy	15
(3)	Shale, medium light gray, part brown and red tinged, sandy	50
3.	Lakota sandstone (Cloverly Formation)* thickness 170 feet in well northwest of Homer . .	170
(1)	Sandstone, light gray and brown-gray, in part coarse-grained, and friable, in part fine grained and dense, (Fuson ?)	15
(2)	Shale, gray, red brown and yellow varicolored, sandy, with common spherulitic siderite concretions, (Fuson ?)	20
(3)	Sandstone, light gray, fine-grained, some interbedded dark gray, carbonaceous shale	10
(4)	Sandy shale and argillaceous sandstone, light gray, with much spherulitic siderite	15
(5)	Sandstone, light gray, fine-grained, friable, with much spherulitic siderite	15

		Thickness in feet.
(6)	Sandstone, light gray, medium to coarse-grained, friable	8
(7)	Sandy shale, red and light gray, varicolored	12
(8)	Sandstone, light brownish gray, fine-grained, friable and spherulitic siderite concretions	15
(9)	Sandstone, argillaceous, light gray, grading to sandy shale	5
(10)	Sandstone, light gray, fine-grained, friable	20
(11)	Argillaceous sandstone to sandy shale, gray to pink, micaceous	5
(12)	Sandstone, light gray, fine to medium-grained, micaceous, spherulitic, friable	20
(13)	Sandstone, light pinkish gray, medium to coarse-grained with some chert pebbles	10

NOTE: The beds above numbered 3 (1) and 3 (2) were measured on outcrop located 3¼ mi. SE of Ponca (Middle east side, sec. 31, T. 30 N., R. 7 E.); number 3 (3) is from the record of a well in NW-NE Sec. 33, T. 28 N., R. 8 E.); numbers 3 (4)-(10) on outcrops in SW ¼ Sec. 23, T. 27 N., R. 8 E.; number 3 (11) and lower are from the record of the well in the NW-NE, Sec. 33, T. 28 N., R. 8 E.

(————)* renaming by author.

The following well log is from the records of the Nebraska Geological Survey and the description of the samples is by E. C. Reed. The correlation using new names is by the author. Bonham #1 well, Center SE¼ SE¼ sec. 31, T. 1 N., R. 1 E., altitude 1594' (altitude determined by author).

	Thickness in feet.
I. Recent and Pleistocene loess	15
II. Cretaceous System -- Colorado Group	120
1. Greenhorn Limestone	35
(1) Fragments of light gray to white limestone, many <u>Globigerina</u>	5
(2) Limestone, yellowish and light gray, granular, foraminiferal, with common aragonite and fragments of <u>Inoceramus labiatus</u>	30
2. Graneros Shale	85

	Thickness in feet.
(1) Shale, dark gray speckled, very calcareous, foraminiferal <u>Globigerina</u> and dark gray, argillaceous, foraminiferal limestone	45
(2) Limestone, bluish-gray, dense, granular to crystalline, in part sandy, with much pyrite	20
(3) Limestone, as above, with common sandy limestone, much pyrite and some aragonite	10
(4) Shale, bluish-gray, argillaceous, massive, soft, very slightly calcareous	10
III. Cretaceous System -- Dakota Group	456
1. Omadi Sandstone	185
(1) Shale, medium dark gray to black, argillaceous to silty with some sandstone laminae	35
(2) Shale, as above, and sandstone, fine to medium-grained, subangular, gray, with some spherulitic siderite . . .	20
(3) Shale, varicolored light green-gray, rouge red, and yellowish, and some spherulitic siderite	10
(4) Spherulitic siderite and varicolored shale, as above	10
(5) Light gray to white, argillaceous clay and siltstone	10
(6) Sand, fine to medium-grained, subangular, light gray, with common light gray calcareous cemented sandstone	10
(7) Silt-fine sand, brownish-gray with some calcareous sandstone	10
(8) Sand, brownish, ferruginous, fine to medium-grained, subangular, with some light gray and purplish clay shale	10
(9) Sand, brownish-gray, fine to medium coarse, subangular to subrounded, ferruginous, and same as above . . .	25
(10) Sand, fine to medium coarse to pebbly, brownish-gray with some pyrite and some shale	35
2. Fuson Shale (Skull Creek Shale -- new terminology)	100
(1) Clay shale, rouge red and light green-gray varicolored, argillaceous, massive, silty near base, sandy near top	30

		Thickness in feet.
	(2) Sand, brownish, fine to medium coarse and clay shale, medium-gray, argillaceous	10
	(3) Clay shale, light green-gray and rouge-red, argillaceous to silty . .	4
	(4) Sand, pink to brown, fine to medium coarse varicolored shale	6
	(5) Clay shale, varicolored red, green-gray, and dark gray, argillaceous massive, sandy near top	13
	(6) Clay shale, mottled light greenish-gray and pinkish to red, argillaceous to silty	37
3.	Lakota Sandstone (Cloverly Formation -- new terminology)	171
	(1) Sandstone, light yellowish-gray to pinkish, fine-grained at top, medium coarse at base, friable	40
	(2) Clay shale, mottled greenish-gray, brownish-red, and dark gray	30
	(3) Sandstone, light buff, fine to medium coarse, friable, with some coal from 500' to 510'	38
	(4) Clay shale, light greenish-gray and reddish-brown mottled, with common sand, and some light gray to bluish-gray, argillaceous limestone in lower part	22
	(5) Sandstone, light yellowish-gray, medium coarse, subangular to subrounded, friable, with some greenish-gray, bluish-gray, and pink clay shale	30
	(6) Clay shale, reddish-brown and greenish-gray, massive	6
	(7) Sandstone, yellowish-gray, fine to medium coarse, friable, with some dark gray shale and argillaceous limestone	5
IV.	Permian System	739

The following well log is from Condra, Schramm, and Lugn (1931), but the correlation is by the author; Reynolds well, Jefferson County, Nebraska, Sec. 35, T. 1 N., R. 1 E., altitude about 1574', depth, 1047'.

		Thickness in feet.
(1)	Shale, dark gray speckled, very calcareous, foraminiferal <u>Globigerina</u> and dark gray, argillaceous, foraminiferal limestone	45
(2)	Limestone, bluish-gray, dense, granular to crystalline, in part sandy, with much pyrite	20
(3)	Limestone, as above, with common sandy limestone, much pyrite and some aragonite	10
(4)	Shale, bluish-gray, argillaceous, massive, soft, very slightly calcareous	10
III.	Cretaceous System -- Dakota Group	456
1.	Omadi Sandstone	185
(1)	Shale, medium dark gray to black, argillaceous to silty with some sandstone laminae	35
(2)	Shale, as above, and sandstone, fine to medium-grained, subangular, gray, with some spherulitic siderite . . .	20
(3)	Shale, varicolored light green-gray, rouge red, and yellowish, and some spherulitic siderite	10
(4)	Spherulitic siderite and varicolored shale, as above	10
(5)	Light gray to white, argillaceous clay and siltstone	10
(6)	Sand, fine to medium-grained, subangular, light gray, with common light gray calcareous cemented sandstone	10
(7)	Silt-fine sand, brownish-gray with some calcareous sandstone	10
(8)	Sand, brownish, ferruginous, fine to medium-grained, subangular, with some light gray and purplish clay shale	10
(9)	Sand, brownish-gray, fine to medium coarse, subangular to subrounded, ferruginous, and same as above . . .	25
(10)	Sand, fine to medium coarse to pebbly, brownish-gray with some pyrite and some shale	35
2.	Fuson Shale (Skull Creek Shale -- new terminology)	100
(1)	Clay shale, rouge red and light green-gray varicolored, argillaceous, massive, silty near base, sandy near top	30

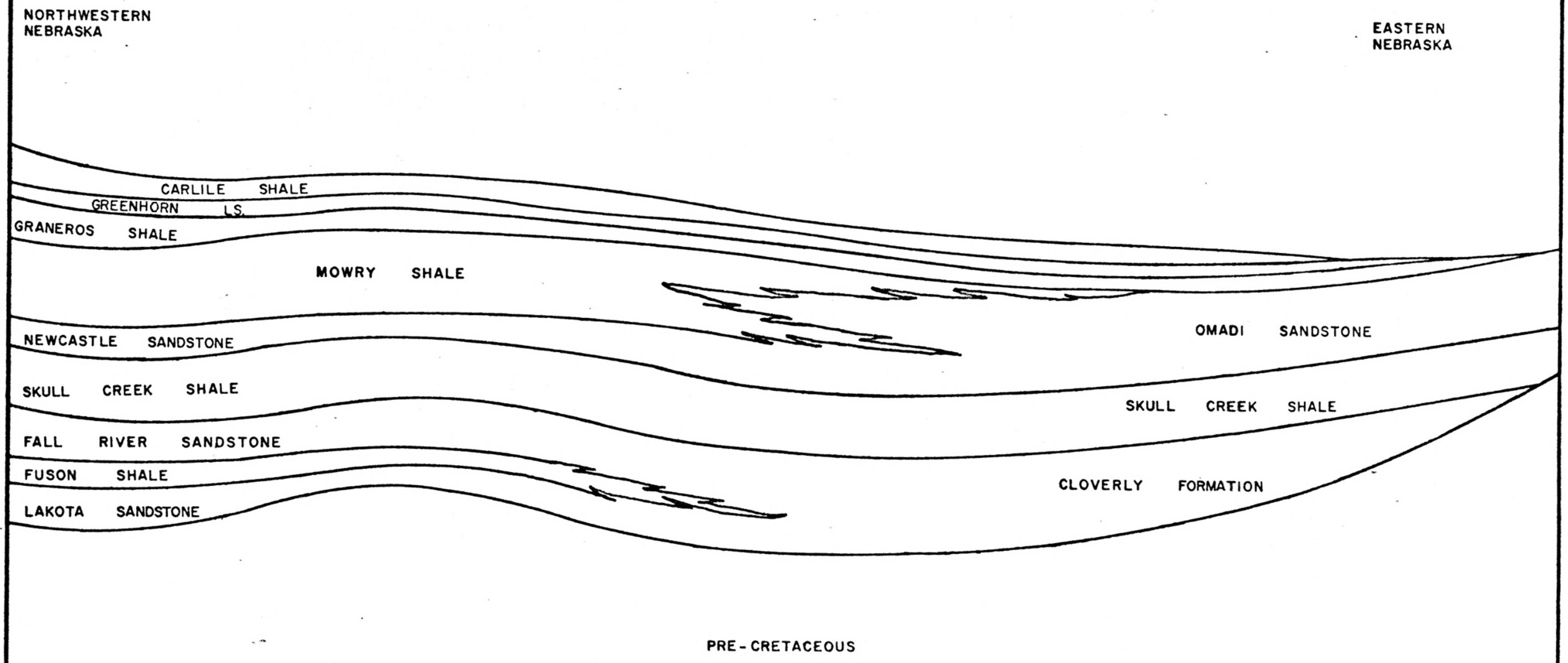
part of the formation. The formation rests unconformably on the Chase Group and is overlain conformably by the Skull Creek Shale. Formation thickness ranges from 0-175 feet. It is thickest in the southwest corner of the county and thins eastward. Eastward thinning results from depositional overlap onto the underlying Chase Group which rises relatively rapidly in the subsurface of eastern Jefferson County.

A vertical sandstone escarpment forms the west bank of the Little Blue River just south of the bridge west of Steele City in sec. 24, T. 1 N., R. 3 E. Weidler (1954) suggests that the lower 20-25 feet of the outcrop represents the Cloverly Formation. He assigned the middle and upper parts of the sandstone outcrop to the Skull Creek Shale. The author tentatively suggests that the entire sandstone unit is in stratigraphic continuity with the Skull Creek Shale.

Weidler (1954) reports lenticular beds of granule and pebble conglomerate. These conglomerates were investigated but no lenticular beds were found enclosed within the sandstone. Sandstone occurs below the conglomerate lenses but not above them. A post-Dakota Group channel has been cut into the sandstone body exposed along the river bank (Fig. 2). All conglomerate lenses found are on this old erosional surface that was filled by sand and gravel in early Pleistocene time. Iron and magnesium oxide-cemented conglomerate lenses are present in sand and gravel deposits that are unquestionably of Pleistocene age. They occur in the east bank of a northeastward trending intermittent stream in the NE¼, sec. 23, T. 1 N., R. 3 E. (Fig. 3).

PLATE 7

CORRELATION OF DAKOTA GROUP AND COLO. GROUP
ROCK-STRATIGRAPHIC UNITS
IN
EASTERN AND NORTHWESTERN NEBRASKA



FORMATION THICKNESS NOT DRAWN TO SCALE

M. VEATCH 1963

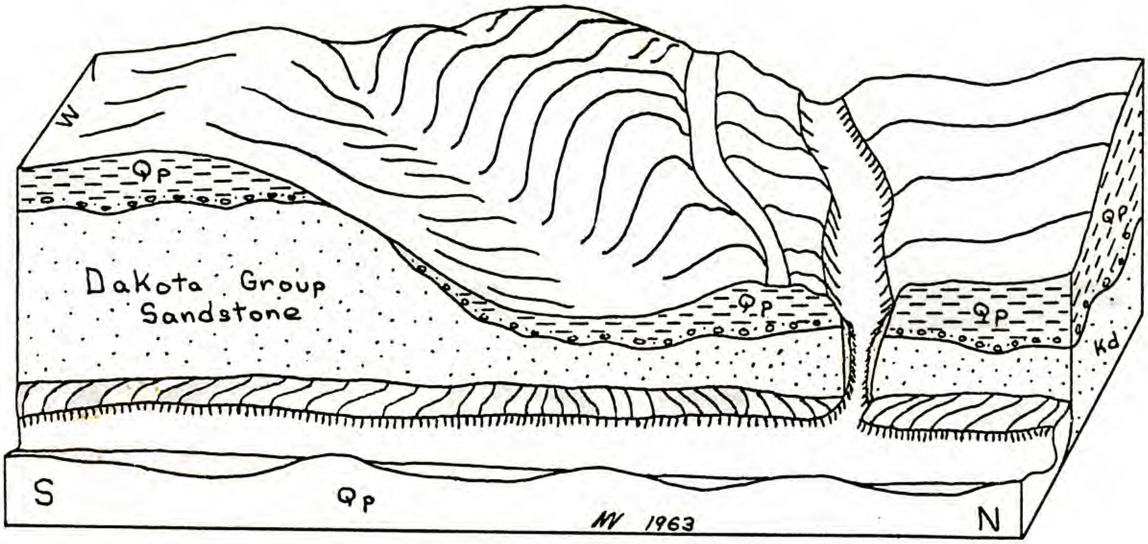


Fig. 2. Post-Dakota Group channel.

Fig. 3. Pleistocene, iron and magnesium oxide-cemented conglomerate lenses. East bank of intermittent stream in the NE¼, sec. 23, T. 1 N., R. 3 E.

Samples from both localities have been compared megascopically and were found to be indistinguishable from the basis of mineralogic composition. These lenticular conglomerates should not be confused with thin case hardened sandstone zones containing weathered Skull Creek Shale granules and pebbles that have formed at places as a resistant cap on some sandstone bodies.

The Cloverly Formation-Skull Creek Shale contact as shown on Plates 2-4 is nothing more than an arbitrarily placed line that most certainly is open to question and several different interpretations. Information obtained from test hole drilling programs is almost useless for correlation purposes unless the entire thickness of the Dakota Group is drilled.

Sandstones of the Cloverly Formation are ground water aquifers under considerable hydraulic pressure. Both salt and fresh water aquifers are thought to be present. An industrial well, A2-2-25aaa, Plate 4, cross section H-H', is pumping fresh water from a sandstone aquifer under approximately 110 feet of hydraulic pressure. Only a few wells in the area produce water from the Cloverly Formation, but all known wells pump fresh water. These wells are in the central, not the western part of the county where the aquifers are thought to be dominantly salty. The formation will probably be proved saline in the southwestern part of the county, and possibly all along the western tier of townships.

Skull Creek Shale. Varicolored clay is the dominant lithology of the formation. The Skull Creek Shale is continental in origin. Local inhabitants refer to the unit as fire clay because it is the raw material used in the manufacture of high quality building brick and tile. The clay is massive and possesses no bedding features. The clay is best described as a mottled clay possessing high plasticity. Base color of the clay ranges from medium light gray (N 6) to very light gray (N 8). This base color is mottled from light red (5 R 6/6) to very dark red (5 R 2/6). Red mottling is caused by the presence of finely disseminated iron oxides (mainly hematite) present in the clay. Granular and pebble hematite gravels weather out on exposed surfaces. Lenticular, cross-bedded, fine to medium grained, friable, quartz sandstone beds occur within the mottled clay, but probably account for less than 10 percent of the total. Light gray (N 7) to very light gray (N 8) poorly indurated silt lenses are also present, but relatively unimportant. Small lens-shaped calcited-cemented concretionary sandstone bodies may exist within larger sandstone bodies.

Four diagnostic characteristics of the Skull Creek Shale are:

1. Red mottling.
2. Abundance of iron granules and pebbles (hematite very abundant--siderite much less abundant).
3. Lack of bedding.
4. Non-calcareous nature and plastic properties of the clay when wet.

The thickness of the formation varies considerably and it ranges from 0-200 feet. Post-depositional pre-Pleistocene erosion has completely removed the formation in the northeast corner of the county. The Skull Creek Shale rests conformably on the Cloverly Formation where it is present and elsewhere it rests unconformably on the Chase Group. Where the varicolored clay belonging to the Skull Creek Shale lies on varicolored clay of the Cloverly Formation, it is impossible to differentiate the two units. Overlying the Skull Creek Shale is the Omadi Sandstone which rests conformably in places and disconformably at other places on the shale (Plates 2-4). Where the Omadi Sandstone has been removed by erosion, the Skull Creek Shale crops out at the surface or is overlain unconformably by Pleistocene sediments.

Good surface outcrops of the Skull Creek Shale occur in the southeastern part of the county. An excellent exposure occurs in sec. 8, T. 1 N., R. 3 E., at the open pit mine of the Endicott Clay Products Company. Surface outcrops of the Skull Creek Shale can be traced southward for miles into Kansas. This shale is equivalent to what Plummer and Romary (1942) called the Terra Cotta Clay Member of the Dakota Formation. These workers make an important statement regarding their measured section of the Dakota Formation. They show no sandstone bodies, but state that one can be inserted anywhere in the section with assurance that it will occur in some locality. This relationship is well substantiated by both surface and subsurface data for the Skull Creek Shale in Jefferson County.

Sandstone bodies within the Skull Creek Shale are saturated with salt or fresh water except where drained by unfavorable topography. These sandstone aquifers are confined and under considerable pressure. Some of the sandstone bodies contain salt water while others contain fresh water, but no specific sandstone body is known to contain both salt and fresh water. From analysis of many well logs, it is thought that these sandstone aquifers will be salty in T. 1 & 2 N., R. 1 & 2 E. Fresh water sandstone aquifers are present in T. 1 & 2 N., R. 3 & 4 E. Summarizing these data, the sandstone aquifers within the Skull Creek Shale are probably salty south of the Little Blue River to the Kansas state line from the point where it enters the county to a point where it leaves sec. 36, T. 2 N., R. 2 E.

A test hole drilled for the City of Fairbury, A2-2-15dbb penetrated eight feet of sandstone containing salt water under 101 feet of hydraulic pressure. Confining pressure equal to 175 feet of hydraulic head is known to exist in sandstones within the Skull Creek Shale. Permeability of the iron oxide-cemented sandstones is relatively high because the sandstones in general are poorly cemented but are cemented well enough to permit open bore hole completion of domestic wells. Permeability does vary within and between different iron oxide-cemented sandstone bodies and is explained by differing degrees of cementation. The porosity and permeability are greatly reduced where calcite-cemented sandstone bodies are encountered. Such zones make very poor aquifers, and in most cases are so impermeable that they are unsaturated.

Omadi Sandstone. Condra and Reed (1943) named the Omadi

Sandstone. The lithologic types, sandstone, ironstone, vari-colored clay and gray shale are present in the unit. Sandstone beds consist of yellowish gray to reddish brown, cross-bedded, fine to medium, friable, slightly micaceous and feldspathic, iron oxide-cemented, quartz sandstone beds. Tabular and lenticular cross-stratification bedding is common. Inclination of foreset beds present in the tabular type cross-stratification ranges from 15-25 degrees.

Limonite and hematite form thin surface films on the sand grains and loosely cement them together. Some cement in the form of siderite may be present. Spherulitic siderite is present but hard to recognize on the outcrop for it weathers to limonite. Ellipsoidal shaped sandstone bodies occur within larger sandstone bodies (Fig. 4). The ellipsoidal bodies are generally cemented with calcite. These calcite-cemented sandstones are well cemented and are classed as orthoquartzites by some workers. Pebble-sized concretions are abundant in the Omadi Sandstone. A tabular-shaped calcite-cemented sandstone bed two feet thick crops out at the edge of a lake in an old clay pit mine in the SW¼, sec. 10, T. 2 N., R. 2 E. Spherulitic siderite pellets are present in the sandstone but the pellets have weathered to limonite. Swineford (1947) found this same occurrence in some calcite-cemented sandstones from the Dakota Formation of Kansas. Though the amount of calcite-cemented sandstone is small, it is much more abundant than in the underlying Skull Creek Shale.

Fig. 4. Ellipsoidal-shaped concretionary sandstone body, SE¼ NW¼, sec. 26, T. 1 N., R. 2 E.

Conspicuous ironstone zones occur along bedding planes and cap many of the sandstone hills in T. 1 N., R. 2 & 3 E. These ironstone zones are moderate brown (5 YR 4/4) to dark yellowish orange (10 YR 6/6), well indurated, slightly micaceous, fine to medium, highly ferruginous, quartz sandstone. Some beds are composed entirely of limonite which was deposited by precipitation of iron from solution in circulating ground waters. Thickness of the ironstone beds ranges from less than one inch to about one foot. A zone composed of several beds may attain a thickness of several feet. Plummer and Romary (1942) speak of these ironstone zones as case hardened sandstones. Thorp and Reed (1949) interpreted some of these zones as being ground water laterites.

Varicolored clay is present but is far less abundant than in the Skull Creek Shale. Dark gray (N 3) to medium light gray (N 6) shale is the dominant facies present in the western part of the area. The shale is still quite clayey but is laminated and displays true shale bedding characteristics. Pyrite concretions and disseminated pyrite are minor constituents. Selenite crystals are present at some localities. In the western part of the county, the gray shale contains very thin interbedded lignite seams averaging less than one-half inch in thickness. A good exposure of the gray shale occurs at an open pit mine just east of highway N 15 S in sec. 14, T. 1 N., R. 2 E. Associated with the shale are light gray, pyrite concretion bearing, silty, poorly cemented, fine, quartz sandstone beds. These sandstone units are generally less than five feet thick. Several units with interbedded gray shale may form a zone 10 to 30 feet thick. This sandstone with interbedded gray shale zone is an important aquifier in the area surrounding Gladstone, Nebraska.

Outcrops of Omadi Sandstone produce bluff and escarpment type topography south of Rose Creek in T. 1 N., R. 1-3 E. Fluviatile cut and fill channel sandstone bodies are present in T. 1 N., R. 2 & 3 E. They give the false impression that the Dakota Group is dominantly sandstone. The Omadi Sandstone in the southern part of the area may approach a maximum sandstone-shale ratio value of 1, but the ratio is somewhat less over an area of several square miles. In the western part of the area, especially T. 2 N., R. 1 E., a sandstone-shale ratio ranging from 1/10 to 1/20 is realistic and substantiated by well log data.

The Omadi Sandstone ranges in thickness from 0-200 feet. Erosional thinning of the formation occurs to the east and north. It is absent in the extreme eastern and northern part of the area. The fine textured sediments of this formation contrast with the clays of the Skull Creek Shale in that they are characterized by laminated bedding for the most part and are considerably lighter in color possessing less red mottling. The Omadi Sandstone rests conformably on the Skull Creek Shale in the western part of the area, but marked disconformity exists between these two formations in T. 1 N., R. 2 & 3 E. Many deep fluviatile cut and fill channels have been cut into the Skull Creek Shale that were later aggraded during the time of Omadi deposition. The formation is overlain conformably by the Graneros Shale, but at other places is overlain unconformably by Pleistocene sediments (Plates 2-4).

Fluvial erosion has dissected the county south of Rose Creek, with many valleys cut into the Skull Creek Shale. The deep dissection has caused dewatering of many of the sandstone bodies which would otherwise be good aquifers. Some sandstone aquifers are still saturated in the extreme southern part of the area along the Kansas-Nebraska state line. Permeability in the iron oxide-cemented sandstone beds is high but varies within and between sandstone bodies. Most of the wells in the

Omadi Sandstone yield fresh water. The sandstone in the lower part of the gray shale facies of the Omadi Sandstone becomes salty west from Fairbury toward Gladstone, Nebraska. The pyritic, silty, fine sandstone zone occurring in the upper 100 feet of the gray shale facies yields fresh water. With proper drilling and completion methods employed by competent drilling contractors, excellent domestic wells can be developed in these thin pyritic, silty, sandstone zones.

Most of the Omadi Sandstone aquifers are under pressure, but the magnitude of the pressure is somewhat less than that present in the Cloverly Formation or Skull Creek Shale. Hydraulic pressure ranging from 20-50 feet is of the correct order of magnitude for the Omadi Sandstone. Low confining pressures and lack of pressure in some of the aquifers is the combined result of topographic position, shallow depth and loss of pressure and water to overlying unconsolidated Pleistocene sediments. The highly ferruginous sandstone or ironstone beds are aquifers where saturated. As a result of their low permeability, these ironstone zones are suitable only for the development of domestic supplies. The water pumped from an ironstone zone in sec. 14, T. 1 N., R. 2 E. is abnormally high in iron.

In summary, the existence of three formations is recognized; however, their contacts are not well defined. Until more subsurface information from more complete bore holes is available, the contacts or formation tops will be open to question. Very little is known about the Cloverly Formation. The

Skull Creek Shale consists of mottled clay possessing high plasticity when wet. Cut and fill channel sandstones are present within this clay. The Omadi Sandstone is a gray shale facies in the western part of the area but becomes progressively coarser textured and continental to the east. Considerable lateral variation can be expected in lithology, and color when dealing with the Omadi Sandstone because of its several facies.

Many good domestic water supplies and some industrial supplies have been developed in sandstones of the Dakota Group. Though salt water sandstone aquifers are present, the number of known fresh water sandstone aquifers far outnumber the salt water saturated sandstones.

Colorado Group. Only the lower part of the Colorado Group (Graneros Shale, Greenhorn Limestone, and the Fairport Shale Member of the Carlile Shale) is present. It occurs in the western and extreme southern part of the county (Plates 2-4). This marine group provides a striking contrast with the underlying continental Dakota Group and overlying continental Pleistocene sediments. Thickness of the group ranges from 0 to 120 feet. Thinning is a result of post-depositional erosion exept for about 15 feet of thickening and thinning present in the Graneros Shale.

Graneros Shale. The Graneros Shale was named for Graneros Creek in Pueblo County, Colorado. It consists of dark gray, carbonaceous, calcareous, laminated shale. The shale weathers with a fissile bedded appearance. Carbonaceous material is more abundant in the basal part of the formation. The shale becomes progressively more calcareous in its upper part; thus, the shale is better indurated near the top of the formation. In many localities, the upper part of the shale is so well indurated that drillers incorrectly call it a blue limestone. Bentonite layers two to six inches thick are common in the upper part of the shale. Specimens of Inoceramus labiatus occur throughout the shale but tend to be concentrated in thin, soft, limy layers and very finely crystalline limestone beds one-half to two inches thick. The thin, soft, limy layers are confined mainly to the upper part of the shale whereas the very finely crystalline limestone beds occur as individual beds with Inoceramus labiatus fragments and fossil fish remains as common constituents in the middle and lower part of the formation. These thin, very finely crystalline limestones are petrographically distinct from the overlying Greenhorn Limestone and become sandy and abundant in the basal part of the shale at some localities. Extensive petrographic study of some of these sandy limestones may actually change the field classification, for some samples may possess more than 50 percent sand by volume. Cone-in-cone structure is in the shale immediately overlying these very finely crystalline limestones and sandy limestones in the basal part of the shale. The shale is sandy in its lower part but the first light gray friable, silty sandstone in layers greater than six inches thick marks the top of the Omadi Sandstone (gray shale facies). In the SW¼, sec. 36, T. 1 N.,

R. 2 E., sandy limestone beds with interbedded gray shale rest on varicolored clay of the Omadi Sandstone.

It is difficult to recognize the contact between the gray Graneros Shale and the underlying gray shale facies of the Omadi Sandstone throughout most of the area where the younger formation is present. The Greenhorn Limestone conformably overlies the Graneros Shale. Thickness of the Graneros Shale ranges from 50 to 85 feet except where thinning is due to post-depositional erosion. Many workers think it is impossible to pick the boundary between the gray shale facies of the Omadi Sandstone and the overlying Graneros Shale. This difficulty is recognized but the boundary can be at least narrowed down to a zone of plus or minus five feet from good bore hole samples and at good outcrop exposures. Four useful criteria helpful in picking this boundary are: (1) the Omadi Sandstone (gray shale facies) is non-calcareous whereas the basal part of the Graneros Shale is slightly calcareous; (2) sandy limestone (Graneros Shale) rests on the gray shale facies at places in the southern part of the county; (3) the upper part of gray shale facies may contain limonitic material not known to occur in the Graneros Shale in this area; (4) the first light gray, silty, friable sandstone, which appears as sand in rotary drilled samples, marks the top of the gray shale facies. Thickness of individual sandstone units may be as little as six inches.

Test hole A2-1-5ddd, altitude 1530 feet logged by A. E. Caswell from rotary drilled sample, illustrates the field application of criteria (4) and also provides an adequate description of Upper Dakota Group and Lower Colorado Group rock units present in the area of Gladstone, Nebraska. Several comments are made in this log and are marked by the author's initials.

		Thickness in feet.
Peorian Formation		
(1)	Silt, some clay, yellowish light brown . .	8
Loveland Formation (M. V.)		
(2)	Buried Sangamon soil, brown silt	2.2
(3)	Silt, with some clay, dark reddish brown to reddish brown	13.9
Fairport Shale Member of the Carlile Shale (M. V.)		
(4)	Chalk, weathered, soft, clayey and sandy, buff, mottled orange	0.9
(5)	Ls, chalky, clayey, partially weathered, yellowish buff	1.6
Greenhorn Limestone (M. V.)		
(6)	Ls, hard, chalky, mixed with seams of chalky shale and scattered bentonite seams, yellow to buff	5
(7)	Ls, very hard, fossiliferous, white to light gray, numerous; <u>Inoceramus</u> <u>labiatus</u>	4.6
(8)	Ls, hard, chalky, mixed with seams of chalky shale and scattered bentonite seams, yellow to buff	4.9
(9)	Ls, very hard, fossiliferous, white to light gray, numerous; <u>Inoceramus</u> <u>labiatus</u>	4.9
Graneros Shale		
(10)	Shale, numerous thin, hard, fossiliferous seams, blue gray speckled	2.5
(11)	Shale, hard, gray, limestone seams at 48.5' to 49.5', blue gray speckled	2.3
(12)	Shale, very hard, dense, gray to light blue limestone seam at 50.8' to 51.0' bluish gray	9.2
(13)	Shale, bluish gray	34.2
(14)	Shale, chalky, clayey, plastic to very plastic, fissile black to gray black . . .	30.1
Omadi Sandstone		
(15)	Sand, intermixed with shale and sandy shale, gray black	3.4
(16)	Shale, clayey, plastic to very plastic, fissile, gray black, dark	37.1
(17)	Shale, clayey, plastic to very plastic, fissile, gray black	3

		Thickness in feet.
(18)	Shale, clayey, plastic, fissile, few limonite pellets, thin hard layers of pyrite concretions, dark gray	25
(19)	Shale, plastic, clayey, fissile, gray . .	7
Omadi	Sandstone--Skull Creek Shale, undifferentiable (M. V.)	
(20)	Shale, clayey, plastic to very plastic, fissile, gray with red mottling	10
(21)	Shale, clayey, plastic to very plastic, fissile, red gray mottled half & half . .	5
(22)	Shale, clayey, fissile, plastic gray with red mottling, some very hard layers or lenses of concretionary iron and fossiliferous, 236.0'-241.0' few thin hard layers or lenses of concretionary iron (siderite-limonite)	25
(23)	Shale, fissile, plastic gray with some red mottling (same as above)	5
(24)	Shale, fissile, plastic, gray with heavy red mottling (same as above)	5
(25)	Shale, fissile, light gray with moderate amount of red mottling	20
(26)	Shale, plastic, scattered red mottling, light gray	10
(27)	Shale, sandy fine, slightly plastic, gray	6.8
(28)	Shale, fairly plastic, many clear crystals, gray scattered red mottling	0.7
(29)	Shale, fairly plastic, many small lenses of limonite and hematite, multicolored with dark and light gray and red	7.5
(30)	Shale, plastic to very plastic, iron lenses, light gray scattered red mottling	5.8

Cable tool drilling samples from the area indicate that hard limestone units are not nearly as thick as indicated at places in this log; and (2) from 281 feet to the bottom of the test hole, the lithology is sandstone (salt water bearing) and interbedded shale as interpreted from the electric log of this hole by the author.

Greenhorn Limestone. The Greenhorn Limestone was named for Greenhorn Station south of Pueblo, Colorado. As recognized in Nebraska, this formation that is 25 to 30 feet thick, consists of gray limestones with interbedded gray shales (Condra and Reed, 1943). Many workers have included the overlying basal part (in some instances all) of the Fairport Shale Member belonging to the Carlile Shale in the Greenhorn Limestone. Some have even included the highly calcareous underlying upper part of the Graneros Shale, such as the Kansas Geological Survey. These above described practices are most certainly not in conformance with G. K. Gilbert's concept of the Greenhorn Limestone as presented in Wilmarth (1938).

The formation in Jefferson County consists of thin, light gray, aphanitic limestone beds interbedded with somewhat thicker light-medium gray irregularly laminated marl, chalk and calcareous shale beds. Individual limestone beds range in thickness from 0.2 to 1.5 feet with the average thickness of 0.4 foot. The beds become thicker in the upper part. Bentonite seams do occur in the formation but its main characteristic is the presence of abundant specimens of *Inoceramus labiatus* in limestone beds near the middle and top of the formation. The formation weathers buff and is often times mottled by dark yellowish orange (10 YR 6/6) iron stains. Maximum thickness of the Greenhorn Limestone does not exceed 35 feet. Poor roadcuts and lack of good natural exposures in this area make this formation difficult to study in detail. The formation occurs only in the western part and extreme southern part of the county. Subsurface drill thickness data indicate an average thickness ranging from 20-25 feet. Post-depositional erosion removed the upper part of the formation except where it is overlain conformably by the Fairport Shale Member and it is quite possible that in places the original thickness never exceeded 20 feet. The Greenhorn Limestone rests conformably on the Graneros Shale but has been removed from most of the area by post-depositional erosion.

Following is a detailed measured section of the Greenhorn Limestone prepared as a research problem under the guidance of Dr. Page C. Twiss, Assistant Professor of Geology, Kansas State University. The section measured is in the south bank of a hill side road cut approximately 25 feet south and 600 feet west of the northeast corner of sec. 36, T. 1 N., R. 1 W.

		Thickness in feet.
Pleistocene Series -- Loveland Formation.		
(29)	Clay resting unconformably on the Greenhorn Limestone	19
Colorado Group -- Greenhorn Limestone		
(28)	Partly covered; Limestone with interbedded marl and calcareous shale. <u>Inoceramus</u> cf. <u>labiatus</u> very abundant in limestone ledges cropping out in road bed. The shale partings thicker in the upper ten feet and this segment of the section may in part belong to the basal part of the Fairport Shale Member of the Carlile Shale. However, this segment will be tentatively considered as the upper part of the Greenhorn Limestone	18
(27)	Limestone, aphanitic, good porosity, very light gray (N 8), weathers yellowish gray (5 Y 8/1) slightly mottled to dark yellowish orange (10 YR 6/6). <u>Inoceramus</u> cf. <u>labiatus</u> very abundant and phosphatic fossil remains sparse.	1
	<u>Inoceramus</u> sp., foraminifera; BIOMICRITE, with spar-filled vugs and cavities.	
(26)	Marl, aphanitic, irregular laminated, very light gray (N 8), weathers yellowish gray (5 Y 8/1) mottled to dark yellowish orange (10 YR 6/6) when wet, <u>Inoceramus</u> cf. <u>labiatus</u> very abundant and phosphatic fossil remains sparse.	1.6

Thickness in feet.

(25)	Limestone, aphanitic, light gray (N 7), weathers yellowish gray (5 Y 8/1) mottled to pale yellowish orange (10 YR 8/6), Inoceramus cf. labiatus very abundant and phosphatic fossil remains sparce; (few elongated granule size cavities filled with medium-coarse crystalline calcite).	0.2
	Inoceramus sp., foraminifera; BIOMICRITE, with spar-filled vugs and cavities	
(24)	Marl, aphanitic, irregular, very thinly bedded-laminated, very light gray (N 8), weathers yellowish gray (5Y 8/1) mottled to dark yellowish orange (10 YR 6/6). Inoceramus cf. labiatus very abundant and phosphatic fossil remains sparse.	0.7
(23)	Limestone, dense, aphanitic, light gray (N 7) to medium light gray (N 6), weathers yellowish gray (5 Y 8/1) mottled to yellowish orange (10 YR 6/6), Inoceramus cf. labiatus very abundant.	0.4
	Inoceramus sp., foraminifera; BIOMICRITE, with spar-filled vugs and cavities.	
(22)	Chalk and marl interbedded, aphanitic, very light gray (N 8), weathers yellowish gray (5 Y 8/1) mottled to dark yellowish orange (10 YR 6/6), Inoceramus sp. very abundant and phosphatic fossil remains sparse. . .	1.0
(21)	Limestone, dense, aphanitic, very light gray (N 8) to light gray (N 7), weathers yellowish gray (5 Y 8/1) mottled to dark yellowish orange (10 YR 6/6), Inoceramus cf. labiatus abundant, (few granule size cavities filled with finely-medium crystalline calcite).	0.3
	Inoceramus sp., foraminifera, BIOMICRITE, with spar-filled vugs and cavities.	
(20)	Marl, aphanitic, irregular laminated-thinly laminated, very light gray (N 8), weathers yellowish gray (5 Y 8/1), mottled to dark yellowish orange (10 YR 6/6), Inoceramus cf. labiatus very abundant.	1.0
(19)	Limestone, dense, aphanitic, very light gray (N 8), weathers yellowish gray (5Y 8/1) mottled to dark yellowish orange (10 YR 6/6), Inoceramus cf. labiatus very abundant, (sand size cavities filled with very fine crystalline calcite).	0.4

		Thickness in feet.
(18)	Marl, aphanitic, irregular thinly laminated, very light gray (N 8), weathers yellowish gray (5 Y 8/1) mottled to dark yellowish orange (10 YR 6/6), <u>Inoceramus</u> sp. abundant.	0.6
(17)	Limestone, aphanitic, very light gray (N 8), weathers yellowish gray (5 Y 8/1) mottled to dark yellowish orange (10 YR 6/6), <u>Inoceramus</u> sp. and sparse phosphatic fossil remains.	0.2
	<u>Inoceramus</u> sp., foraminifera bearing; MICRITE, with spar-filled vugs and cavities.	
(16)	Marl, aphanitic, irregular thinly laminated-laminated, very light gray (N 8), weathers yellowish gray (5 Y 8/1) mottled to dark yellowish orange (10 YR 6/6) when wet, <u>Inoceramus</u> sp. abundant.	0.6
(15)	Limestone, aphanitic, very light gray (N 8), weathers yellowish gray (5 Y 8/1) mottled pale yellowish orange (10 YR 8/6), <u>Inoceramus</u> sp. fragments and phosphatic fossil remains.	0.2
(14)	Marl, aphanitic, irregular thinly laminated, very light gray (N 8), weathers yellowish gray (5 Y 8/1) mottled to dark yellowish orange (10 YR 6/6), <u>Inoceramus</u> sp. fragments and phosphatic fossil remains.	1.8
(13)	Limestone, aphanitic, very light gray (N 8), weathers pale yellowish orange (10 YR 8/6) when wet, tubular shaped cavities filled with fine crystalline calcite.	0.5
	<u>Inoceramus</u> sp., foraminifera bearing; MICRITE, with spar-filled vugs and cavities.	
(12)	Chalk, aphanitic, irregular thinly laminated to laminated, very light gray (N 8), weathers dark yellowish orange (10 YR 6/6) when wet, <u>Inoceramus</u> sp. fragments. . . .	0.8
(11)	Limestone, aphanitic, sandy (very fine sand), very light gray (N 8), weathers yellow gray (5 Y 8/1), mottled to dark yellowish orange (10 YR 6/6), <u>Inoceramus</u> sp. fragments.	0.2

		Thickness in feet.
(10)	Marl, aphanitic, sandy (medium texture), irregular laminae very light gray (N 8), weathers mottled to dark yellowish orange (10 YR 6/6), Inoceramus sp. sparse. . .	0.4
(9)	Limestone, aphanitic, sandy (medium texture) in basal part of bed, very light gray (N 8), weathers dark yellowish orange (10 YR 6/6), fine to very coarse sized cavities filled with very fine crystalline calcite.	0.4
	Inoceramus sp., foraminifera bearing; sandy MICRITE, with spar-filled vugs and cavities.	
(8)	Marl, aphanitic, irregular laminae, very light gray (N 8), weathers mottled to dark yellowish orange (10 YR 6/6), Inoceramus sp. sparse.	0.3
(7)	Limestone, dense, aphanitic, very light gray (N 8), weathers yellowish gray (5 Y 8/1) mottled to dark yellowish orange (10 YR 6/6), Inoceramus sp., fine to very coarse sized cavities filled with very fine crystalline calcite.	0.4
Colorado Group — Graneros Shale		
(6)	Shale, very calcareous, carbonaceous, irregular laminae, medium light gray (N 6), weathers dark gray (N 3) when wet; grades upward into marl which grades into chalk, aphanitic, thinly laminated, very light gray (N 8), weathers yellowish gray (5Y 8/1), shale contains Inoceramus sp. fragments and phosphatic fossil remains.	5
(5)	Bentonite, subangular blocky structure, very light gray (N 8), weathers mottled to dark yellowish orange (10 YR 6/6).	0.5
(4)	Chalk, very light gray (N 8), weathers light gray (N 7).	0.2
(3)	Shale, very calcareous, carbonaceous, irregular thinly laminated, medium gray (N 5), weathers grayish black (N 2) when wet, Inoceramus sp. fragments and phosphatic fossil remains.	6.5
(2)	Bentonite, subangular blocky structure, very light gray (N 8), weathers mottled to dark yellowish orange (10 YR 6/6).	0.2
(1)	Shale, very calcareous, carbonaceous, irregular laminae, medium gray (N 5),	

Thickness
in feet.

(1) (Cont'd)
weathers grayish black (N 2) when wet;
with interbedded limestone laminae,
aphanitic, very light gray (N 8),
Inoceramus sp. and phosphatic pelecypod
and fossil fish remains. ———

No rock-stratigraphic unit of Cretaceous age present in the area rivals the Greenhorn Limestone as a correlation horizon or as a structural datum. All other Cretaceous formations are too variable in thickness and lithology to be reliable horizons for correlation let alone structural datums. The detailed measured section provides adequate criteria for picking the Graneros Shale-Greenhorn Limestone contact accurately so it can be used as a structural datum.

The Greenhorn Limestone is generally not considered to be a ground water aquifer; however, in the vicinity of Gladstone, Nebraska it yields small amounts of fresh water to shallow wells. Yield of the wells is variable, ranging from 150 gallons per day to several hundred gallons per day. Special well completion techniques are employed to develop this aquifer to its full potential. Although 150 gallons per day seems insignificant, it is really significant in local spots where the underlying Omadi Sandstone is salty.

Fairport Shale Member of the Carlile Shale. This member was named for exposures a few miles south and west of Fairport, Russell County, Kansas. It consists of medium to light gray shale with thin fossiliferous limy layers. Little is known about the occurrence of this member in Jefferson County. It is thought to occur in the subsurface at a shallow depth in sec. 6 & 7, T. 2 N., R. 1 E. and in Sec. 19, T. 1 N., R. 1 E. Bore hole information will eventually prove or disprove this statement. The shale rests conformably on the Greenhorn Limestone and is overlain unconformably by Pleistocene loess (Loveland and Peorian Formations). Post-depositional erosion removed this formation almost entirely from the area but where present its thickness is probably less than 10 feet.

Cretaceous Economic Resources

Varicolored clay from the Skull Creek Shale and gray shale from the Omadi Sandstone are used in brick and tile manufacturing by the Endicott Clay Products Company. Mining by this company is done in open cuts with a shale planer. The varicolored clay is mainly kaolinite. It could be called a low grade, plastic, siliceous fire clay or a high grade brick clay. Thin, high grade refractory fire clay zones may be present but are not extensive enough to be commercial deposits. Plummer and Romary (1942, p. 335, Table 2) give a chemical analysis of a clay obtained from the Terra Cotta Clay Member (Skull Creek Shale in Nebraska) in the SE¼ sec. 14, T. 1 S., R. 3 E., Washington County, Kansas. This analysis was as follows:

Constituents	Sample W - 5
Silica	59.88%
Alumina (Al_2O_3)	30.90%
Iron oxide (Fe_2O_3)	1.69%
Calcium oxide (CaO)	0.24%
Loss on ignition	7.26%
	99.97%

This company also mines gray shale from the Omadi Sandstone; however, it is relatively high in carbon content. The carbon content is objectionable because it raises manufacturing costs. The Graneros Shale could be used in the manufacturing of light weight concrete aggregate.

Exceptional high quality clay building products are manufactured at the Endicott Clay Products Company. Plant capacity is 60,000 bricks per day (Roger Judd, oral communication). Location of the plant is in sec. 8, T. 1 N., R. 3 E.

> For many years architects and builders have regarded Endicott Clay Products Company as a leading source for the finest in face brick and face tile.... The excellent rose and buff burning shale and clay deposits have produced a distinctive standard of color of lasting beauty (<u>Endicott Imperial Face Brick</u>).

Four Endicott Imperial blends are illustrated on Plate 8.

The clays of the Dakota Group are a valuable natural resource. The economic value and use of this resource shall increase as more and more individuals become familiar with the high quality clay material present within the Dakota Group of Nebraska.

Stone for structural and road-building material has been mined from the Greenhorn Limestone and sandstones of the Dakota Group. Sand from the friable, iron oxide-cemented sandstones is usable as molding sand. This sand has been mined in sec. 7, T. 1 N., R. 2 E. for use as a filler material in asphaltic road surfacing material. The sand could be used in the manufacture of colored bottle glass if surface iron oxide films can be economically removed.

EXPLANATION OF PLATE 8

Fig. A. Imperial Rose Blend Roman Matt in 1/2 bond.

Fig. B. Imperial Buff Blend Standard Matt in 1/2 bond.

Fig. C. Imperial Buffish-Brown Blend Norman Matt in 1/3 bond.

Fig. D. Imperial Deep Iron Spot Standard Matt in 1/2 bond.

PLATE 8

ENDICOTT IMPERIAL FACE BRICK BLENDS

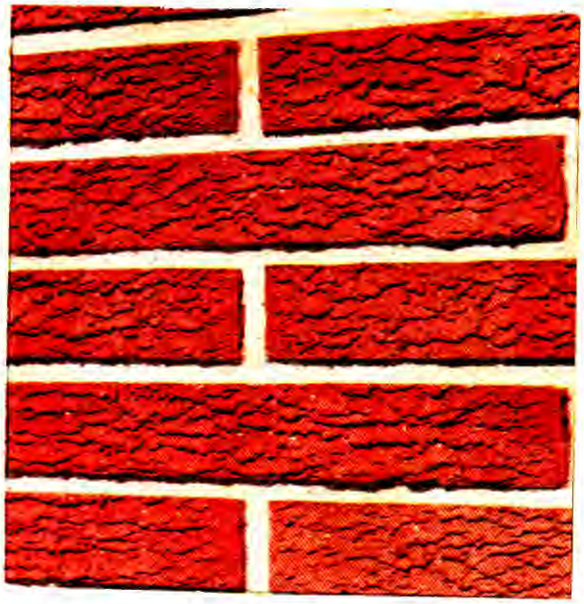


Fig. A.

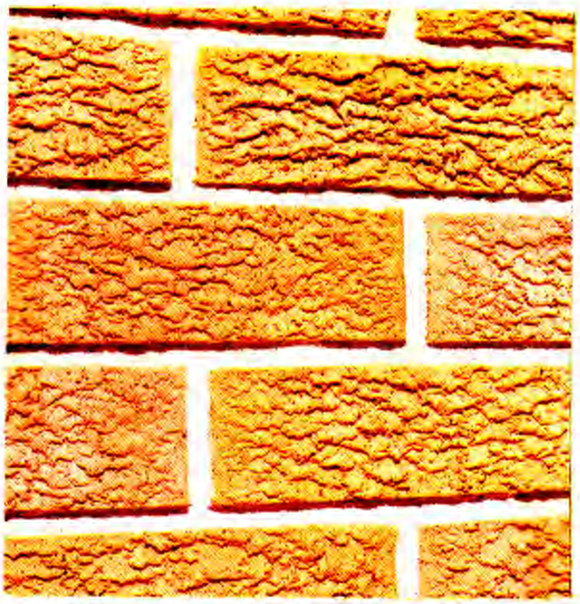


Fig. B.

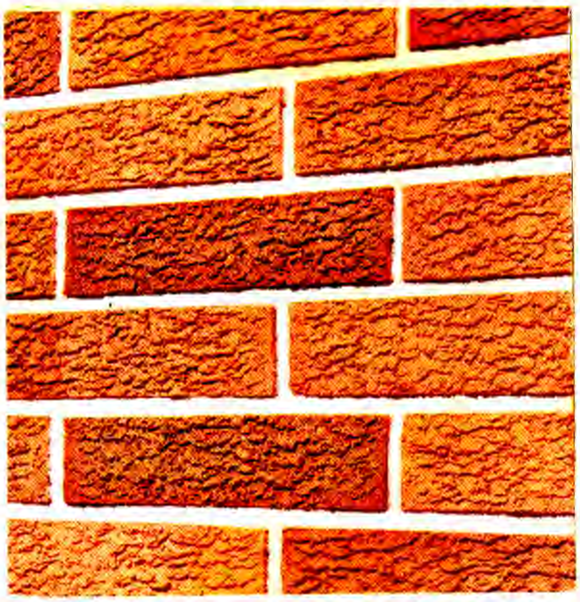


Fig. C.

Fig. D.

During the last decade and at present agriculture lime is mined from limy layers in the upper part of the Graneros Shale and from the Greenhorn Limestone. The lime is mined in the SW¼ sec. 10, T. 1 N., R. 2 E. in a quarry that is working back into the hillside. Many of the so-called interbedded shale units in the Greenhorn Limestone are actually marls according to the classification system of Dunbar and Rodger (1957). These marls are soft and may be 60 percent calcium carbonate by volume. Mining and processing of this material is very economical and lowers the over-all cost of mining the entire Greenhorn Limestone section. The marl varies in calcium carbonate content and at places may be replaced by a calcareous shale.

Pepperberg (1908) reports a bed of lignite seven inches thick (possibly Graneros) was worked in 1903 at Powell, Nebraska along the Little Blue River. No commercial coal deposits are recognized in the area and it is improbable that there ever will be any.

Sandstone aquifers of the Dakota Group constitute an important artesian water supply throughout the high bedrock areas. Water quality is good but naturally varies somewhat from place to place. Certain sandstone bodies are known to be salty; however, this is not sufficient criterion to condemn stratigraphically lower sandstone bodies as being salty in an area where the first encountered sandstone body is salty. The artesian ground water supply is unquestionably the most important presently utilized natural resource of Cretaceous age present in Jefferson County.

Lastly, the important relationship existing between soil development and agriculture land use as related to Cretaceous formations must be recognized. The topography is rough but the soil supports good stands of native grass. This is important because it tends to check erosion. Once the soil is removed, erosion of Cretaceous formations proceeds with such rapidity that economical conservation methods become ineffective. Maintenance of these areas in grassland that is in balance with its environment is the best conservation practice man can utilize in Cretaceous outcrop areas of the county.

Quaternary System

Pleistocene Series. The Pleistocene sediments of Jefferson County are of continental origin and lie unconformably on Cretaceous formations except in the northeastern corner of the county where they rest on Permian formations. During the great time span represented by this unconformity, degradational processes succeeded in producing a mature topography with 450 feet of relief. This point is of profound significance because this topographic surface was well developed by the close of Pliocene time. It was the formidable barrier which would play the all important role of controlling the distribution of post-Pliocene sediments. An understanding of the history of Pleistocene sedimentation of the area requires an understanding of geomorphology.

Pleistocene terminology and cycles of sedimentation and erosion (Plate 9) used in this report are those of Condra, Reed and Gordon (1950). Parts of certain cycles shown are not

PLATE 9

Pleistocene Cycles of Sedimentation and Erosion

Numbered in chronological order from oldest upward for their occurrence in the Missouri and Upper Mississippi River basins.

Substages Wisconsin:

4(4). Mankato glaciation, erosion, alluviation, eolation and soil formation

4(3). Cary glaciation, erosion, alluviation, eolation, and soil formation

4(2). Tazewell glaciation, erosion, alluviation, eolation, and soil formation

Peorian complex (4(3) and 4(2))

4(1). Iowan glaciation, erosion, alluviation, eolation, and soil formation

Stages:

3. Illinoian-Sangamon glaciation, erosion, alluviation, eolation, soil formation

2. Kansan-Yarmouth glaciation, erosion, sedimentation, soil formation

1. Nebraskan-Aftonian glaciation, erosion, sedimentation, soil formation

(After Condra, Reed and Gordon, 1950)

present in Jefferson County. Many of the lithologic variations within a formation are not extensive enough to be considered true facies and the term phase is used to denote the smaller areal changes in lithology. The Pleistocene record is most satisfactorily studied by use of bore hole data. Many of the facts presented are based on test hole samples that were obtained and described by the test drilling program of the Nebraska Geological Survey. The terminology is over 15 years old and is based largely on subsurface data and has stood the test of use. Many holes have been drilled in the last 15 years revealing much information which leads to refinement of previous terminology, however, this new data is still being analyzed. New interpretations may change some of the minor details especially those regarding age of certain units. Until synthesis of the new data are published, the Pleistocene terminology used in this report is satisfactory for mapping and correlating the Pleistocene geology of the area.

The stratigraphic relations of Pleistocene formations are clearly evident on Plates 2-4; thus, little is said about their areal distribution. The terms sand and gravel, when used without a descriptive adjective in this report, are to be understood to mean sand and gravel composed of granitic material with some metamorphic rock fragments mixed in.

Seward Formation (Nebraskan). This formation was named and described by Condra, Reed and Gordon (1947). At that time the formation was believed to be an eastern fine-textured facies of the Ogallala Formation of Tertiary age. Evidence accumulated during this study suggests the formation is a fine clastic deposit of early Nebraskan Age. These fine clastics (with some coarse clastics) are fluviatile deposits that succeeded in aggrading pre-existing, well-developed Pliocene valleys to a considerable depth. V. H. Dreeszen (oral communication) has studied this formation extensively from test hole samples and would correlate the deposit as Pleistocene (early Nebraskan Stage). He reports (oral communication) finding limestone gravels eroded from a Paleozoic limestone source area within the Seward Formation in Seward County (test hole A9-1-1ba). Seward County is 24 miles north of Jefferson County. The source area for such gravels was eastern Nebraska. Reworking of Paleozoic limestone fragments by fluvial processes during westward transportation in early Nebraskan time would make the Seward Formation of Pleistocene age.

The formation consists principally of medium to light gray, calcareous silt. Very fine to medium sand occurs mixed in and interbedded with the silt as a minor constituent. Volcanic ash has been reported in samples from test hole A4-1-13dd (Nebraska Geol. Survey). Included in the formation locally is a basal gravel member composed of pebbles of reworked sandstone and ironstone of the Dakota Group and Greenhorn Limestone. Thickness of the basal gravel ranges from 0 to 5 feet. The presence of some yellowish to brown samples from test holes indicate the upper part of the formation has been weathered. The basal gravel and coarse clastic lenses are saturated with fresh water.

Thickness of the formation ranges from 0 to about 150 feet. Major thinning is due to depositional onlap on pre-Pleistocene valley walls. Some thinning is also the result of post-Seward pre-Holdrege erosion. The formation rests unconformably on the Dakota Group and is overlain unconformably by the Holdrege Formation.

The coarser basal clastic sediments were derived from the local high bedrock areas existing south and north of the site of deposition. The finer clastics constituting most of the formation may be partly of local derivation, but most of this material was probably transported in by streams draining the pre-Pleistocene outcrop areas to the west.

Holdrege Formation (Nebraskan). Lugn and Condra (1932) named and described the Holdrege Formation. It consists of sand and gravel composed of quartz, and other fragments of granitic and metamorphic rocks. The formation generally grades upward from a medium sand to coarse gravel to a fine sand to fine gravel. Lenses of silt and clay several feet thick occur locally within the section but are relatively unimportant.

Porosity and permeability of this formation are high, making it the best fresh water aquifer in the region. Present data indicate the formation is completely saturated throughout most of the area where it is present. Most of the irrigation wells in the county produce water from this aquifer. This formation is essentially an unconfined aquifer; however, questionable data suggest that in places it may be under slight artesian pressure.

The formation ranges in thickness from 0 to about 200 feet. Depositional onlap onto pre-Pleistocene valley walls accounts for most of the thinning. Some post-depositional thinning by erosion occurred on the upper surface of this formation at places. This formation rests unconformably on the Seward Formation, Colorado Group, Dakota Group and Chase Group. It is overlain conformably to unconformably by the Fullerton Formation throughout most of its area of occurrence but in the west, it is overlain unconformably by the Grand Island and Sappa Formations.

The Holdrege Formation is a fluvial inwash and glacial outwash deposit. It is the result of streams aggrading the valley and uplands with sand and gravel. As the Nebraskan glacier moved across eastern Nebraska, its western border became a barrier damming eastward-trending valleys causing their streams to deflect southward. Before establishing a new course, the streams succeeded in aggrading their valleys for many miles to the west. Two principal sediment-source areas existed at this time. Coarse clastic debris was washed out westward from the glacial front or till border by proglacial streams. The effectiveness of this source area steadily declines farther west from the position of the glacial front. The major source area was to the west. The highly competent eastward flowing streams eroded, reworked and transported material from the Tertiary formations of central and western Nebraska into the clogged eastern valley where they were deposited. Some clastic material probably came from as far west as the Rocky Mountains.

Fullerton Formation. (Aftonian). Lugn and Condra (1932) named and described the Fullerton Formation. It consists of yellowish brown to very light reddish brown, calcareous silt and clay. Locally, the formation is sandy and grades into fine sand. Most of the surface exposures are yellowish brown. The color may be gray and in the NW¼, sec. 6, T. 3 N., R. 2 E., surface outcrops are very light reddish brown. The lithologic

Fig. 5. Kansan Till resting unconformably on yellowish brown Fullerton Formation. SE¼, sec. 4, T. 4 N., R. 2 E.

character of this formation is not uniform everywhere, which is of significant importance in correlating the formation from bore hole to bore hole.

Porosity of the formation may be high but the permeability is low because of fine grain size. The formation is usually unsaturated, but locally it may be saturated especially if it is a coarse silt or very fine sand phase. At places, this formation is an unconfined fresh water aquifer and specific capacities of wells obtaining water from the formation may be as low as 1/30 gallon per foot of drawdown. This clearly illustrates the low transmissibility of the formation.

The Fullerton Formation thickness ranges from 0 to about 75 feet. Depositional onlap onto the upper part of pre-Pleistocene valley walls and their associated uplands accounts for some of the thinning; however, most of the thinning is a result of post-depositional erosion. This formation rests unconformably on the Holdrege Formation and formations of the Dakota Group. It is overlain unconformably by the Kansan Till. In the western part of the county, it is overlain unconformably by the Grand Island and Sappa Formations.

The Fullerton Formation is a fine textured formation of fluvial-eolian origin. The decrease in grain size in Aftonian time suggests that the competency of streams had decreased considerably since the time of Holdrege deposition. Such a situation would be expected in an interglacial or retreating glacial stage. The coarser phases of the formation may be due to reworking of the underlying sand and gravel of the Holdrege Formation. On Plate 2-4 the name Fullerton Formation is used as a mapping unit to include the Fullerton Formation and the so-called "Aftonian Silts" present beneath the Kansan Till. These two units are considered as one formation in which the eastern source areas become important as one approaches the Nebraska

Till border (Fig. 6).

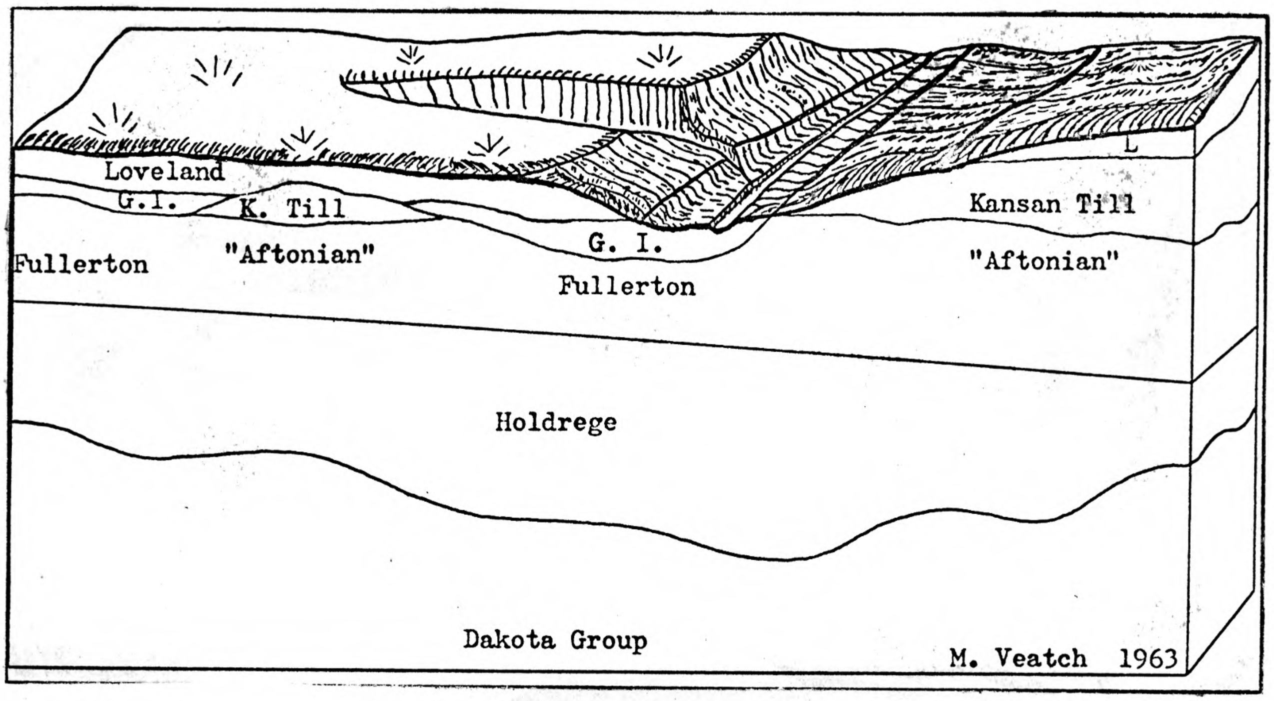


Fig. 6. Illustration of usage of the names Fullerton Formation and "Aftonian Silts" as they have been applied to the same map unit in eastern Nebraska.

Atchison Formation (Kansan). Moore and others (1951) named and described the Atchison Formation. At places the formation is composed entirely of sand, while at other localities it contains a poorly sorted, sandy, pebble-cobble gravel. The basal gravel is composed of reworked limestone fragments, sandstone and ironstone fragments of the Dakota Group, Sioux quartzite, greenstones, and granite (Fig. 7).

Despite the fact that the formation is heterogeneous and poorly sorted, it does have low to moderate permeability. It serves as an unconfined fresh water aquifer in the southeastern corner of the county. The formation supplies wells with enough water for small rural domestic supplies. Saturation in the formation is quite variable, because the formation has been dewatered in places by unfavorable topographic relations.

Fig. 7. Atchison Formation; north grader ditch SE¼ SE¼, sec. 21, T. 1 N., R. 4 E., poorly sorted gravel consisting of Dakota Group sandstone and ironstone fragments, Sioux Quartzite, granite, greenstone and limestone fragments.

The formation is estimated to range in thickness from 0 to 10 feet. It rests unconformably on the Fullerton Formation throughout most of its area of occurrence but in the southeast, it rests unconformably on the Skull Creek Shale. The formation is overlain by the Kansan Till. This formation is of glacio-lacustrine origin and it was deposited as glacial outwash in front of the advancing Kansan glacier. The lacustrine phase of the formation is represented by sand which accumulated in proglacial lakes bordering the glacier front. This formation is confined to the area of the Kansan Till in the county. It appears equivalent in age with the Red Cloud Sand and Gravel (Schultz, Reed and Lugn, 1951) in the periglacial region west of the till border. The Red Cloud Formation was formerly called the lower Grand Island Member of the Grand Island Formation.

Kansan Till (Kansan). This is the only direct ice-contact deposit (excluding berg-floated outwash) present in the area. The Nebraskan glacier failed to reach Jefferson County but the Kansan glacier glaciated the northeastern half of the county. This event destroyed the previous existing eastward trending drainage system and initiated the drainage system present throughout most of the area today. A good section of till is present, but it is covered at many localities by post-Kansan loess deposits.

The lithologic character of the till is quite variable. The till has weathered to a yellowish gray-brown and is gray where unweathered. In many localities the upper part of the formation has been completely oxidized to a reddish brown. Boulders several feet in diameter occur within the till and also as a residual lag concentrate of boulders on its upper surface. The boulders are rock detritus derived from Sioux quartzite, Canadian Shield granite and greenstone, local limestone and local sandstone and ironstone materials of the Dakota Group

(Plate 10). The pebbles, cobbles and boulders constitute less than five percent of the formation. Drill hole data indicates the presence of sandy zones in the lower part of the till. The middle and upper part of the till is less sandy and is classed as a boulder-clay till.

Granitic material is common in the Kansan Till of Jefferson County, but Sioux quartzite is the dominant boulder material present. The granitic material becomes very scarce southward into Kansas along the till border. Oxidation has given the upper part of the till sheet a reddish-brown color that is very similar to the oxidized Loveland Formation. This situation has led to some miscorrelation in the past. The oxidized portion of the till generally contains Sioux quartzite pebbles and coarser material which helps differentiate it from the Loveland Formation. The colluvial phase of the Loveland Formation is a slightly gravelly reddish brown clay at many localities with Sioux quartzite a common gravel type. This phase of the Loveland Formation has often been wrongly identified as Kansan Till. Correlation is based mainly on lithologic detail, areal distribution, and topographic position. This correlation problem is more complex when working only with well samples.

The Kansan Till ranges in thickness from 0 to 75 feet. The thickness of the formation is extremely variable and can be attributed to (1) the highly irregular surface that the till has overridden, especially in a zone bounded on the west by the till border and an imaginary line several miles inside the till border; (2) thinness of the marginal part of the glacier whose

EXPLANATION OF PLATE 10

Fig. A. Sioux quartzite, granitic and greenstone boulders weathered out of Kansan till. SE¼ SE¼, sec. 4, T. 4 N., R. 3 E.

Fig. B. Sioux quartzite boulders weathered out of Kansan Till. NW¼ NE¼, sec. 27, T. 2 N., R 3 E.

PLATE 10

Fig. A.

Fig. B.

distribution was controlled by local topography; and (3) severe late Kansan erosion which severely dissected the till sheet. Throughout much of its area of occurrence, the till sheet rests unconformably on the Fullerton Formation. In a zone several miles wide north of the Little Blue River below Powell, Nebraska, the till rests unconformably on formations of the Dakota Group. The Grand Island Formation overlaps the till border at places. The Loveland Formation overlies the Kansan Till unconformably at many localities throughout the area.

As the Kansan glacier moved across eastern Nebraska southward into Kansas, it filled the still remaining upper parts of eastward trending valleys and occurs high in the present topography (Plates 2-4). The glacier was grounded against the high bedrock hills bordering the north side of the present Little Blue River Valley. It never succeeded in crossing a zone defined by the Little Blue River Valley in Jefferson County, Nebraska.

Grand Island Formation (Kansan). Lugn and Condra (1932) named and described the Grand Island Formation. The sand and gravel of the Grand Island Formation is little different from the sand and gravel of the Holdrege Formation. The Grand Island Formation occupies a higher topographic position and contains more local gravels (less than five percent of deposit) than are known to exist in the Holdrege Formation of Jefferson County. The local gravels consist of reworked sandstone and ironstone fragments of the Dakota Group, Greenhorn Limestone fragments and outwash from the Kansan Till plain. Granitic sand and gravel still account for over 95 percent by volume of the deposit.

The porosity and permeability of the formation are high but locally, zones within the formation are poorly consolidated by iron and magnesium oxide cementing agents precipitated from circulating ground water causing lower permeabilities (Fig. 3). It is saturated only in its lower part that is attributed to (1) relatively high topographic position of the formation; (2) effluent streams whose channels are cut into the lower part of the formation; and (3) the existence of a major drainage system (Little Blue River Valley) whose lower course is well entrenched in bedrock of Cretaceous age. The formation is a good unconfined aquifer where saturated. The formation is unsaturated over large areas along the lower course of the Little Blue River Valley. The nearly unsaturated nature of the formation is clearly evident by the fact that all of the major sand and gravel pits are in this formation. The water table is encountered only in the basal part of these pits.

The Grand Island Formation ranges in thickness from 0 to about 75 feet. Thinning can be attributed to (1) depositional onlap; and (2) post-depositional erosion. It rests unconformably on the Fullerton Formation, Holdrege Formation and formations of the Colorado and Dakota Groups. In the northwest part of the area and along the north valley wall of the Little Blue River, this formation may lap unconformably upon the Kansan Till. The formation is overlain conformably by the Sappa

Formation and unconformably by all younger formations (Crete, Loveland and Peorian Formations) which rest on the formation throughout most of its area of occurrence.

The Grand Island Formation is a fluvial inwash and glacial outwash deposit. The origin of the formation is similar to that of the already discussed Holdrege Formation. Over 95 percent of the material in the deposit originated in the tablelands and mountains to the west and was transported to eastern Nebraska by fluvial processes. Local source material (less than five percent by volume of the formation) is present in greater quantity than is known to exist in the Holdrege Formation of the area.

On Plates 2-4 the Grand Island Formation map unit includes the Crete Formation. Considerable material is present that eventually will be correlated as the Crete Formation. This is especially true of the upper part of the high terrace deposit present along the Little Blue River Valley. The aggradation of this valley began in early Kansan time (beginning of Grand Island deposition) and continued intermittently up through deposition of the Loveland Formation. At present the Grand Island-Crete-Loveland contacts are not well enough understood to map separately in this area. This is an important problem and further study and new subsurface data will eventually show a mappable sand and gravel of Illinoian Age in this area.

Sappa Formation (late Kansan-Yarmouthian). Condra, Reed and Gordon (1950) were the first to apply this name to a Pleistocene unit in Nebraska. Lugn (1935) described the formation originally as the Upland Formation consisting of gray to greenish gray, calcareous silt and clay. Test hole data indicate that the formation is sandy in part.

The Sappa Formation ranges in thickness from 0 to 35 feet and it rest unconformably on the Fullerton Formation, Holdrege Formation, and conformably upon the Grand Island Formation. The Crete and Loveland Formations overlay the Sappa Formation unconformably. Condra, Reed and Gordon (1950) suggest that the deposit is of aqueous-eolian origin and is late Kansan in age. They further point out that the deposition may have continued up into early Yarmouthian time. The formation as now recognized in the area is mainly restricted to the western part of the county. Lugn (1935) recognized an erosional remnant of the Upland Formation (now Sappa Formation) in a sand and gravel pit in the SE¼, sec. 7, T. 1 N., R. 3 E.

Crete Formation (Illinoian). Condra, Reed and Gordon (1950) assigned this name to the unit originally designated by Lugn (1935) as the "Valley Phase" of the Loveland Formation. The Loveland Formation possesses a true valley phase but the unit originally described by Lugn (1935) is pre-Loveland in age. This unit is now called the Crete Formation in Nebraska.

The following discussion is a summary of the findings of Condra, Reed and Gordon (1950) which are applicable to Jefferson County. These workers established a type locality approximately 20 miles north of Jefferson County. The formation is a channel fill deposit which rests unconformably on the Sappa Formation or older Pleistocene deposits. The formation consists of sand and gravel but is quite variable in mineralogical and textural characteristics. This variability can be attributed to the importance of local material available for reworking in Crete time. Distribution of the formation is generally limited to channels associated with present well developed valleys; however, during Crete time these valleys were considerably broader than they are now. This last statement fits the Little Blue River Valley well in Jefferson County. The formation possesses an upland equivalent in the Kansan Till area where it consists of a very thin lag-gravel concentrate resting on eroded Kansan Till and is overlain by Loveland loess. This upland Crete deposit was observed in several road cuts in the northeast part of the area. In most places the formation is covered by the Loveland Formation and since the sand and gravel of the Crete Formation is difficult to distinguish from the underlying Grand Island Formation, the presence of the formation is hard to detect. Careful study of these terraces and the acquiring of more shallow subsurface data are needed before the formation can be mapped successfully in this county.

Locally Derived Pleistocene Deposits. A unique Pleistocene deposit exists in sec. 7, 8, 17, 18 and 20, T. 1 N., R. 2 E. It is a limy, clayey, pebbly-cobbly gravel. The pebbles and cobbles consist of reworked rock fragments from the Greenhorn Limestone, thin limestone and cone-in-cone fragments from the

Graneros Shale and sandstones and ironstones of the Dakota Group. Adjacent hills to the south and west were the source area. The deposit is very poorly sorted as evidenced by material ranging in texture from clay to cobbles.

The deposit is interpreted as a valley fill in a pre-Pleistocene valley which exists relatively high in the present topography. In part it may be essentially a colluvial deposit. The clastic detritus present in the deposit was transported from adjacent hills by colluvial slope wash and streams. Its thickness ranges from 0-30 feet. The Loveland Formation overlies the deposit. The deposit is probably post-Nebraskan and pre-Late Illinoian in age. This deposit has not been reported or described prior to this time. It has been mapped incorrectly by earlier workers as an outlier of the Graneros Shale. The deposit is significant for it illustrates the importance of local source material in the southern part of Jefferson County beyond the till border.

Loveland Formation (late Illinoian to Sangamonian). Shimek (1909) named and described this unit as the Loveland Loess, regarding it as of fluvial origin. Later Kay and Apfel (1944) re-described it and other Loveland deposits, calling them the Loveland Formation, and recognizing two phases (alluvial and eolian) of deposition. Condra, Reed and Gordon (1950) recognized three phases, (1) valley phase; (2) colluvial or slope phase; and (3) upland phase. All three phases are present in Jefferson County.

The upland phase of the Loveland Formation consists of light reddish brown, massive, silty clay loess. It mantles a pre-Loveland surface throughout a large part of the area, but grades into a colluvial and valley phase near broad valley areas like the Little Blue River Valley.

The valley phase of the Loveland Formation consists of unconsolidated stratified clay, silt and laminae of sand. The color grades upward from light gray-buff into a pinkish-very light reddish brown. This phase of the formation is thicker than the upland phase into which it grades. The valley phase can be traced up into the upland phase along a north-south road cut running from the Rose Creek Valley northward into the upland along the western boundary of the county, sec. 6 & 7, T. 1 N., R. 1 E.

The colluvial phase consists of a poorly sorted light reddish brown, silty, sandy, gravelly clay. It occurs rather high on the steeper slopes of the pre-Loveland valleys. This phase is widely distributed along the upper slopes of the Little Blue River Valley. The following statement by Condra, Reed and Gordon (1950) should be considered when mapping the colluvial phase of the Loveland Formation:

> It is easily confused with highly weathered till because of its poor sorting and because till boulders are occasionally incorporated in it, having been rolled or washed down the steep slopes from the till. However, it rests unconformably on the till or is separated from it by a lag-concentrate gravel layer (upland phase of the Crete Formation).

The formation thickness is estimated to range from 0 to 75 feet. Its average thickness throughout the area will average less than 30 feet. Thinning is attbributed to both depositional onlap and post-depositional erosion. The formation is thickest along the western border of the county in sec. 6 and 7, T. 1 N., R. 1 E., and sec. 31, 30, 19 and 18, T. 2 N., R. 1 E. The formation rests unconformably on older sediments of Pleistocene and Cretaceous age (Fig. 8). It is overlain unconformably by the Peorian Formation. An erosional topography developed on the Loveland Formation during post-Loveland, pre-Peorian time. At this time the Loveland Soil (Sangamon soil of Illinois) developed on the formation. This buried soil is recognizable in road cuts and bore hole samples.

Fig. 8. Loveland Formation resting unconformably on the Skull Creek Shale. North road cut, SW¼, sec. 23, T. 1 N., R. 4 E.

The Loveland Formation in this area had a complex history. It is a fluvio-colluvial-eolian deposit. The formation is mapped on Plates 2-4 as a unit. No attempt was made to map its several phases separately though they are recognizable at many places.

Peorian Formation (Middle Wisconsinan). During the time-interval existing between the Iowan and Mankato Substages, sediments of aqueous-eolian origin were deposited in Nebraska. They are collectively called the Peorian complex. As noted by Condra, Reed and Gordon (1950) this term Peorian should not be applied formationally where the interval includes both till and loess substages. This problem does not exist in Nebraska.

The formation consists of a light grayish tan, clayey silt and contains calcareous nodules of granule size. Limonitic nodules and iron weathering stains are present in the formation at some localities. The silty nature, color and topographic position make the formation easily recognizable over large areas.

Formation thickness is quite variable and ranges from 0 to 20 feet, with 10 feet a good average where the formation mantles the upland areas. The formation rests unconformably on the Loveland and older formations (Fig. 9). Material constituting the Peorian Formation on Plates 2-4 is of eolian origin. The alluvial phase of the Peorian complex is confined to the river valleys and is included in the informal mapping unit designated Recent and Wisconsin Stage sediments.

Fig. 9. Peorian Formation resting unconformably on the Loveland Formation. North road cut, SW¼ SW¼, sec. 9, T. 1 N., R. 1 E.

Valley Alluvium and Loess (Recent and Wisconsinan). Alluvial deposits occur throughout the flood plain and low terrace areas along the present rivers and intermittent streams of the county. These deposits are of post-Illinoian age. At places the main channels of the Big and Little Sandy Creeks are cut into the Grand Island Formation. The channel fill material present under the adjacent flood plains and in the main channel is reworked material from the Grand Island Formation. This reworking started in post-Illinoian time and is still in progress.

The lithology of the channel deposits is quite variable.

Local source material available for reworking in post-Illinoian time determines the petrography of the deposits. Most of the channels were filled with granitic sand and gravel similar to older coarse clastic Pleistocene sediments from which they were reworked. The deposits grade upward into silt and clay. Some of the finer sediments were blown from the channel and flood plain and deposited upon low-lying adjacent terraces.

The channel deposits along Rose Creek are different from those in the rest of the county. Along Rose Creek, from the west side of sec. 4, T. 1 N., R. 2 E., upstream channel deposits consist of clay and silt that rest on a basal gravel several feet thick except where it is absent. The basal gravel consists of fragments of limestone, sandstone and ironstone. They were reworked from the adjacent uplands composed of Cretaceous formations that form the south valley wall of Rose Creek. East of section 4 the basal gravel becomes thicker, more uniform in areal distribution, and granitic gravels become common and dominant in the upper part of the gravel. The basal one-to-two feet is predominantly reworked sandstone and ironstone fragments of the Dakota Group. The upper part of the channel deposit consists of silt and clay which are the dominant lithologic type upstream.

Permeabiltiy is high in the channel gravels of the Little Blue River Valley and they are almost completely saturated. Thickness of the gravel ranges from 0-30 feet with an average thickness of 15 feet throughout most of the valley. This channel gravel aquifer supplies water to many wells in the Little

Blue River Valley. The valley is one of the five ground water provinces present in the county.

An entirely different situation exists in the channel deposits in Rose Creek Valley. The basal gravels are saturated but are not as thick as those of the Little Blue River Valley. Overall permeability is somewhat less in Rose Creek Valley in the headward regions of the stream where granitic gravels are absent. Ground water exploration is a real challenge all along the Rose Creek Valley because the thin basal gravel is locally absent, and the first sandstone of the Dakota Group encountered at depth west of highway N 15 S has proved salty along this valley. Deeper sandstone aquifers remain to be tested that may be salty or fresh. East of the western part of sec. 4, T. 1 N., R. 2 E., good domestic wells can be developed in the basal gravel, but local exceptions do exist. West of section four as much as five feet of basal gravel is present but it is very poorly sorted and contains a lot of interstitial silt and clay. The present wells in the area yield only minimum rural domestic supplies. Local exceptions may exist, but remain to be found by drilling.

Jefferson County is an excellent area to study recent processes of fluvial erosion and sedimentation. Intermittent streams in the uplands have cut narrow, vertical-walled channels into late Wisconsinan deposits, leaving paired terraces whose surface is of late Wisconsinan age. Coarse granitic, sandstone, ironstone and limestone gravels are accumulating on channel bottoms. Gravel types present are entirely a function of local source area. The material is transported to the channels by colluvial slope wash and fluvial processes. Plate 11 illustrates some of these deposits and the characteristics of the channels in which they were deposited.

Pleistocene Economic Resources

Vast quantities of ground water used for domestic, irrigation, industrial, municipal and air conditioning purposes are supplied by Pleistocene sand and gravel aquifers. The Holdrege Formation is the largest aquifer present. Sand and gravel aquifers of Wisconsinan Age are important along the Little Blue River Valley. The Grand Island Formation, though saturated only in its lower part, still supplies a considerable amount of ground water.

Sand and gravel production is an old industry in Jefferson County. Large gravel pits are located all the way up and down the Little Blue River Valley. All of the large sand and gravel contractors mine their sand and gravel from the Grand Island Formation that accounts for most of the thickness of the high terrace deposits along the Little Blue River Valley. The fact that this formation is partly-to-completely unsaturated at many localities makes it ideal for low-cost mining operations. Many smaller, temporary operations have utilized the channel fill sand and gravel of Wisconsinan Age present within the flood plain area of the Little Blue River Valley. To date less than one percent of the total sand and gravel reserves of the area

EXPLANATION OF PLATE 11

Fig. A. Recent stream channel with Dakota Group sandstone and Sioux quartzite pebbles and cobbles. Terrace from edge of channel to terrace-hill slope break is a Wisconsinan Age surface. Hill slope is outcropping Kansan Till. SE¼, sec. 21, T. 2 N., R. 3 E.

Fig. B. Recent stream channel with fine clastic sediments. Terrace from edge of channel to terrace-hill slope break is a Wisconsinan Age surface. NW¼, sec. 5, T. 4 N., R. 3 E.

PLATE 11

Fig. A .

Fig. B.

have been mined, which is significant since millions of cubic yards of sand and gravel have already been mined.

Soils developed on the Pleistocene formations are highly fertile and of high value regarding the agricultural development of the area. The most extensive soil present is the Grundy silt loam (Hayes, 1925). This soil developed mainly upon the Peorian Formation. The several formations consisting entirely or partly of loess and the finer textured alluvial sediments provided parent material for the highly fertile and tillable soils of the area. If the Peorian and Loveland Formations were absent, the agricultural productivity of the county in dollars, would be greatly reduced. Parent material was certainly an important factor of soil formation in this area.

STRUCTURE

The structural relations in Jefferson County are relatively simple. Surface structural mapping is possible only in the outcrop area of the Greenhorn Limestone. The base of this formation is the only reliable structural datum of Cretaceous age present. Surface evidence indicates a regional dip of about eight feet per mile to the northwest (N 45 W plus or minus 5 degrees) that has been modified locally by several poorly defined flexures in the southwestern part of the area. Structural attitude of the underlying Permian System is not in agreement with the overlying Cretaceous System. Subsurface regional dip of the Permian System appears to be about 14 feet per mile to the southwest (S 80 W plus or minus 5 degrees). It is not implied here that the development of structure in the Cretaceous rocks was independent of the underlying structure now present in the Permian rocks of the area; however, surface-mapped structure in Cretaceous rocks is misleading when one attempts to project such structure to depth. This results because (1) the Permian erosional surface possesses at least 50 feet of relief locally; (2) the thick sequence of clays interbedded with cut and fill channel sandstones of the Dakota Group act as possible localizing centers for post-depositional differential compaction; and (3) the existence of local unconformities within the Dakota Group. These three conditions tend to localize regionally-applied stress which succeeded in rotating the dip of Cretaceous rocks to the northwest. Rotation was, however, not of great enough magnitude to produce a regional dip to the northwest in the underlying Permian rocks. The Permian rocks still dip to the southwest as they did originally in pre-Cretaceous time.

Some of the local structural expression present in the Greenhorn Limestone may have resulted, in part, from differential compaction in late Cretaceous time, before the time of regional tilting which affected not only rocks of Cretaceous age but also those of pre-Cretaceous age. Such differential compaction may have produced closed structures, but later regional tilting to the northwest caused such structures to open up considering that their present axes trend north-northwest to south-southeast. If the present areal distribution of the Greenhorn

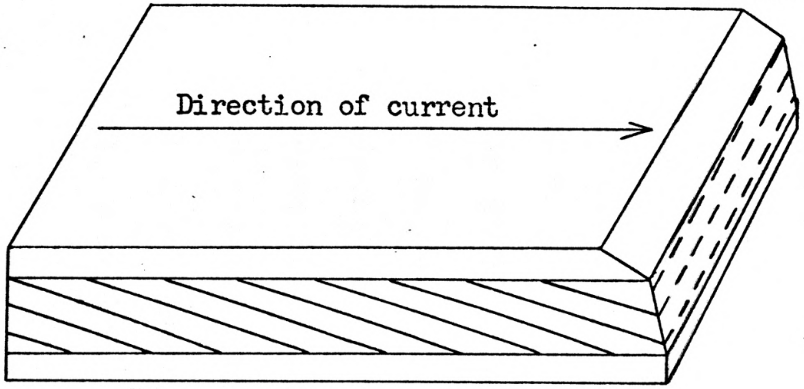
Limestone could be accurately contoured, it would be found that all but one flexure would be open and that they would tend to nose out in a direction somewhat west of north. In the extreme southwestern part of T. 1 N., R. 1 E., the dip may actually reverse, giving a closed structure in this area with 5 to 10 feet of closure.

Cross-stratification is well developed in the sandstone of the Dakota Group and must not be mistaken for tectonic structure. Fore-set deltaic beds can be seen in road cuts. They give the area a local pseudo-structure with dips as high as 25 degrees. The main usefullness of cross-stratification studies in the area is for setting up flow directions of transporting mediums which in turn indicate the direction to one or more possible source areas. Several types of cross-stratification are common in the area (Plate 12).

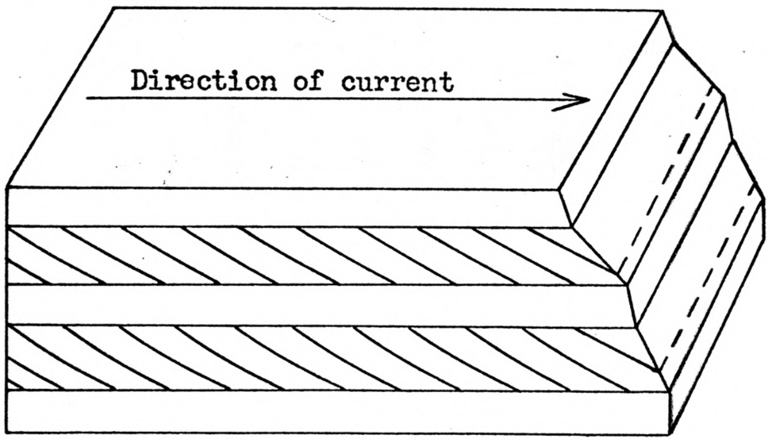
Visible joints are confined to the competent units of the rock column. Joint development is confined to the sandstone beds of the Dakota Group and to the Greenhorn Limestone. Joint density in the Dakota Group is low and spacing is irregular. In the larger road cuts through sandstone bodies, joints are usually present but are generally closed. The joints trend in a general north-south and east-west direction. Joint spacing is greater than 20 feet and generally speaking is much greater than this. The occurrence of joints in sandstone bodies appears to be local in nature. Joint development in the Greenhorn Limestone is much better than in the Dakota Group. The limestone beds are fractured with both open and closed joints.

PLATE 12

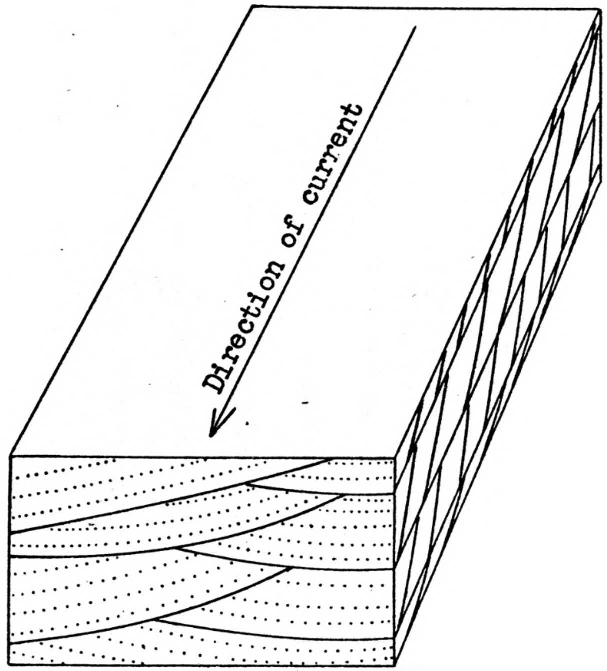
Cross-stratification types present in the Dakota Group



Fore-set deltaic beds (large scale tabular cross-stratification type)



Tabular cross-stratification



Lenticular cross-stratification

M. Veatch 1963

The degree of secondary enlargement which the open joints have undergone by the solution activity of percolating ground water is of prime importance in some areas where the formation constitutes the main aquifer. Some degree of jointing is evident at all known outcrops. Lost circulation drilling problems have been encountered while drilling this formation. Available data to date indicates that the number of joints per unit area of the formation is quite variable throughout the area. This point is further illustrated by the fact that in the drilling of some wells in and through the formation, no lost circulation problems are encountered. Whereever the Greenhorn Limestone exists, water bearing joints are very important and special well completion techniques largely determine the capacity of wells developed in this formation.

GEOLOGIC HISTORY

The Herington Limestone Member of the Nolans Limestone, Chase Group, Big Blue Series is the youngest unit of Permian age present in the subsurface of Jefferson County. Younger rocks of Permian age were deposited in the area but were later removed by erosion in pre-Cretaceous time. With the culmination of Permian sedimentation in lower Leonardian time, the marine sea regressed southward leaving the area as an emergent landmass. Thus, this area was subjected to erosion throughout late Permian time.

The area remained emergent during Triassic and Jurassic time with erosion the dominant operative geologic process. Triassic and Jurassic sedimentation was confined to western Nebraska; however, Jurassic rocks occur farther east in the subsurface than do Triassic rocks. It is possible that Triassic and Jurassic sediments were deposited in eastern Nebraska and were later removed by erosion. The area under investigation was an emergent landmass undergoing erosion throughout all of Triassic and Jurassic time (Eardley, 1951, Plates 10-14).

By late Jurassic time, the strandline of the Sundance Sea had transgressed from the north, southeastward into the mid-continent. At the same time, the Mexican geosynclinal sea strandline was transgressing northward; however, these two seaways did not coalesce in Jurassic time. Coalescence of the seaways occurred in late (?) early Cretaceous time producing the Rocky Mountain Seaway (Rocky Mountain Geosyncline) which reached maximum development in late Cretaceous time. Maps showing the areal relations of the events so far described can be found in Eardley (1951, Plates 10-16) and Dunbar (1960; Fig. 5, p. 7; Fig. 251, p. 295; Fig. 273, p. 320).

Jefferson County and the rest of eastern Nebraska were an emergent landmass undergoing erosion throughout the time span from late Permian to middle early Cretaceous time. This erosion succeeded in sculpturing a topography in the Permian rocks with a maximum relief of about 200 feet. Local relief approaching 50 to 100 feet may exist within an area the size of a township. This buried topography is of profound significance because: (1) it is evidence of a Permian-Cretaceous unconformity; (2) it, along with the lack of late Permian to middle lower Cretaceous sedimentary rocks, illustrates the magnitude of this unconformity which most certainly is of first order magnitude; (3) this topography would cause the transgressing sea front locally to be erratic; and (4) locally it controlled the dispersal of terrigenous sediment coming in from the east to underlie and intertongue with marine sediments.

Deposition of the Cloverly Formation began in the late early Cretaceous time. In early and middle early Cretaceous time the Lakota Sandstone and Fuson Shale were deposited in western Nebraska, followed by deposition of the Fall River Sandstone in late early Cretaceous time. It would appear that the Cloverly Formation, which marks the beginning of Cretaceous history in Jefferson County, is time-equivalent with the Fall River Sandstone of western Nebraska (Plate 7). The Cloverly Formation of the area is predominantly continental; however, carbonates have been reported in the extreme southwest corner of the county (Bonham well #1, pp. 17-19). This would suggest that marine inundation of the extreme southwestern and western part of the county occurred during early Cloverly time; however, sedimentation was to remain dominantly continental with minor transgression and regression of the sea. Sea level must have fluctuated for it is the only reasonable mechanism one can use to explain the occurrence of salt water-saturated sandstone bodies that are completely interbedded in fine terrigenous material which to date has been unquestioned as to its continental origin. The connate nature of the water is questioned because the sandstone bodies appear to be backshore lowland fluvial deposits whose primary water would have been fresh. This line of reasoning, if correct, suggests that the primary fresh water was flushed out and replaced by salt water which should not be called connate water. If one must maintain it is connate water, then it should be qualified as secondary connate water, for it is not the original water present at the time of deposition.

The source of coarse terrigenous material from the east, northeast and southeast greatly diminished in Skull Creek time. Fine terrigenous material was supplied to the area from the east throughout Skull Creek time and thus the formation is dominantly a mottled clay of continental origin. During Omadi time, coarse terrigenous material once more became abundant in the central and eastern part of the area where it was deposited as fluvial cut and fill channel sands which later were cemented into sandstone with iron oxide cement. The channels that these sands were deposited in were in some instances cut down into the underlying Skull Creek Shale. Such evidence indicates extensive erosion in post-Skull Creek pre-Omadi time. Throughout most of Dakota time, erosion was occurring locally along with deposition in areas of continental sedimentation. The amount of erosional energy was appreciable in Cloverly time, somewhat less in Skull Creek time, and probably highest in Omadi time.

The abundance of gray shale, pyrite, occasional thin lignite layers and general thinness of absence of sandstone in the western part of the county, especially T. 2 & 3 N., R. 1 E. is significant. By early Omadi time, the east edge of the seaway projected into western Jefferson County and it was bordered by a lowland backshore area a few miles wide to the east. This lowland backshore area was probably swampy; an environment that would favor the preservation of the gray color in the shale. The environment would also favor the formation of iron sulfides and the preservation of organic matter introduced from the continental flora that flourished on the continental sediments to the east. At the same time, some of the gray shale was probably deposited locally in a true marine environment in the extreme western part of the area already mentioned. If the clay mineralogy of this gray shale was determined from well samples, and if the analysis showed a predominance of illite, then it could be assumed with some certainty that a true marine environment did exist in this area. Even though there may be a predominance of illite, one should expect some montmorillonite, chlorite and even minor amounts of kaolinite. Kaolinite should become progressively more abundant as one moves eastward near shore. The lack of carbonates in the gray shale facies is explained by the presence of too high an influx of terrigenous muds from the east. Only one surface exposure of carbonate rock was found in the Dakota Group. It was an impure lithographic limestone lens about one foot thick in the east road cut of highway N 15 S, 1500 feet south from the center of sec. 23, T. 1 N., R. 2 E. This lenticular limestone is situated in the upper part of the Omadi Sandstone (here the facies is quite shaly).

Two things should be kept in mind when dealing with the sedimentational history of the Dakota Group in Jefferson County and eastern Nebraska in general; (1) a transgressive seaway was expanding eastward; however, if it had expanded as far east as Jefferson County its expansion was confined to the extreme western part of the county; and (2) the terrigenous material making up the continental deposits was transported from the east and these deposits tended to build out westward while the transgressive seaway deposits tended to build eastward. With such a condition, intertonguing of continental and marine sediments is bound to occur. Evidence suggests that such a process did occur in the western part of Jefferson County at least in Omadi time.

The age of the Dakota Group is a controversial problem which is not agreed upon by all workers. The group, as present in Nebraska, is early Cretaceous in age. It is older in western Nebraska than in eastern Nebraska; however, by late early Cretaceous time, sedimentation of the Dakota Group began in Jefferson County. The completion of this sedimentation interval marks the end of early Cretaceous time and the beginning of late Cretaceous time. Todd (1911) was of the opinion that the Dakota Formation belonged to the lower Cretaceous Series. He summarizes the situation quite adequately. As he pointed out, when one studies the areal stratigraphy, paleontology and lithology of the Dakota Formation, there is no basis for placing this formation in with the Benton Group (now the Graneros Shale, Greenhorn Limestone and Carlile Shale), the basal group of the upper Cretaceous Series. Tester (1952) reconfirms his earlier statements (Tester, 1931) and concludes that the Dakota Group definitely belongs to the lower Cretaceous Series. Dunbar (1960, p. 329) summarizes the situation as follows:

> The sea spread slowly to the north and east, reaching Colorado and Kansas late in the Early Cretaceous Epoch and then spread rapidly eastward to Iowa and northward over Wyoming. Here the Dakota group forms the base of the Cretaceous System. It includes the initial marine deposits of the interior seaway as well as the underlying and intertonguing non-marine deposits laid down in advance of the sea. It includes alternating sandstone and shale formations with sand predominating in the southern part (Colorado, Kansas and Nebraska) and shale in the northern part. It contains a depauperate marine fauna now known to be largely if not entirely Lower Cretaceous. (Until recently it was considered basal Upper Cretaceous.)

Condra (1908) recognized the nature of the Dakota Group in eastern Nebraska early as evidenced by the following statement:

> The Dakota is....a tangential deposit made by streams along migrating shore lines. Its sediments in eastern Nebraska seem to have been carried westward by rivers whose load was gathered in Iowa and bordering states.

At the beginning of late Cretaceous time, the sea transgressed rapidly eastward over eastern Nebraska. This is in strong contrast with the sea present during the time of the Dakota Group. At the time of the Dakota Group, the sea appears to have fluctuated for long periods of time with local eastward transgression and regression. In Jefferson County the Graneros Shale is the basal unit of the upper Cretaceous Series. The carbonate content of the shale becomes progressively higher near its upper boundary. This relationship clearly testifies to a rapid eastward transgression of the sea. The sea was clearing which was highly advantageous for carbonate sedimentation which was to follow, and is recorded in the record as the Greenhorn Limestone.

The environment of deposition changed from a marine clay mud to a limy clay mud marine environment near the end of Graneros sedimentation. At the same time, vigorous volcanic activity many miles to the west and southwest loaded the eastward-moving air masses with volcanic ash. As the winds of these air masses lost their competency, the ash settled out into the marine basins of Nebraska and adjacent areas. The ash was converted to bentonite beds averaging less than one-half foot in thickness in Jefferson County. Culmination of the ash falls produced a time datum that locally approximates the close of Graneros sedimentation and the beginning of Greenhorn sedimentation.

The fact that the limestones are micrites strongly suggests a Greenhorn environment of low mechanical energy. Such an environment would also favor the faunal assemblage that is present. Cyclic type sedimentation of alternating limestone and marl units clearly indicates that the environment was by no means static for a long time span. Intermittent fluctuations in local environmental energy are indicated by coarsening of units 9-11, p. 42. The characteristic phosphatic faunal assemblage so prevalent in the Graneros environment extended into the Greenhorn environment but was suppressed by a prolific _Inoceramus_ cf. _labiatus_ assemblage in the middle and upper part of the formation. The change in petrographic limestone types from a fossil-bearing Micrite to a Biomicrite clearly illustrates this point. There also appears to be a less prolific pelagic foraminifera population in the upper part of the formation. This is accompanied by an increase in clay and a decrease in carbonate in the upper part of the formation.

Following the close of Greenhorn sedimentation, a sequence of upper Cretaceous sediments was deposited as the seaway continued to expand eastward. This expansion of the seaway continued well up into late Cretaceous time (Pierre Shale). By this time the eastern edge of the seaway was well over into Iowa (Eardley, 1951, Plate 16). It would appear that the seaway reached its masimum extent in late Pierre time and then withdrew from the mid-continent region relatively rapidly (beginning of the Larimide orogeny) and this brought to a close the end of an Era.

Iowa and eastern Nebraska were left emergent by the retreat of the sea. Jefferson County was once more subjected to an extensive period of subaerial erosion which began in very late Cretaceous time and ended at the close of Tertiary time. Erosion progressed uninterrupted from very late Cretaceous time throughout all of Tertiary time and throughout most of Quaternary time until mid-Illinoian time in the southwestern part of the county. This long interval of erosion succeeded in removing all post-Greenhorn sediments except for local remnants of the Fairport Shale of the Carlile Formation in the extreme western part of the county.

It has always been assumed that the northern part of the Missouri River drainage basin drained northward into Hudson Bay in pre-glacial times and that farther south, drainage was to the Gulf of Mexico. These old drainage patterns differ in places from the present pattern. During late Permian, Cretaceous and early to middle Tertiary time the streams of Jefferson County drained westward. By late Tertiary time, streams were flowing east to northeast across Jefferson County. The one in the northern part of the area was well developed and contained in a much broader valley than the present day valleys of the area. One also flowed across the southern part of the county but was somewhat smaller than the northern one. These streams continued to flow east-northeast after leaving Jefferson County. Whether or not they intercept a larger northward drainage system is not known by the writer. The streams intercept a drainage system, but the question that remains to be answered is whether the system drains north or south.

The land surface of Jefferson County was relatively rough by the close of the Tertiary. Relief in the area exceeded 450 feet and it approached 250 feet in areas the size of townships. This post-Cretaceous, pre-Pleistocene surface is most certainly an unconformity of first order magnitude. From the beginning of Pleistocene time on, this topographic surface has controlled sedimentation throughout the area. Erroneous conclusions about the Pleistocene history are reached if this fact is not recognized.

The erosional energy present in the late Pliocene environment was relatively low. At the beginning of Pleistocene time, several important things happened: (1) M. K. Elias (Condra and Reed, 1943) suggests that the Tertiary was closed out by uplift in western Nebraska followed by a cycle of erosion that marks the beginning of the Pleistocene; (2) a continental glacier began to build up and move southward out of Canada; and (3) the glacial climate of the north drastically altered the previous Pliocene climate in the periglacial region as the glacier moved southward. The climatic conditions changed from temperate and dry to arctic and humid. Environmental energy increased, introducing a new erosional cycle. The cycle caused stream gradients to increase along with increasing stream competency.

The first sediment to be deposited in early Nebraskan time in the county was the Seward Formation (page 50). After deposition of several feet of this coarse clastic material, the sediment became finer in texture, forming the Seward Formation (silt). The front of the Nebraskan glacier entered the state from the north-northeast and moved southward over eastern Nebraska. Deposition of outwash gravel preceeded the advancing front and was later overridden by the ice. Though the glacier was hundreds of feet thick there were probably some high bedrock areas that it was forced to encircle; it succeeded in filling the pre-glacial valleys of eastern Nebraska. The Nebraskan glacier did not reach as far west as Jefferson County, but it dammed the lower courses of the two pre-glacial eastward flowing streams that drained the area.

Damming of the streams caused them to aggrade their valleys westward with fluvial inwash and glacial outwash material. The valleys of Jefferson County were aggraded high up onto their valley walls by sand and gravel which becomes finer in the upper part of this cycle. Most of this material was derived from the Tertiary formations of central and western Nebraska. As the front of the Nebraskan glacier receded, drainage ways were opened on the newly formed till plain to the east and erosion became active removing the till completely at places. Farther west in Jefferson County, erosion was occurring on the upper surface of the newly formed Holdrege sand and gravel plain. This erosion was followed by deposition of the Fullerton Formation in Jefferson County. This formation is considered by some to be a fine textured final depositional phase that began with the building of the Holdrege sand and gravel plain. However, the Fullerton Formation is, at places in Jefferson County, separated from the underlying Holdrege Formation by an erosional interval. Fullerton sedimentation succeeded in filling the old pre-glacial valleys and even mantled some of the upland. Deposition of the Fullerton Formation began in late Nebraskan time and continued through Aftonian time and possibly into very early Kansan time. Soil development occurred in Aftonian time but the soils were in general removed by erosion. Thus, the Nebraska-Aftonian cycle of sedimentation as conceived by Condra, Reed and Gordon (1950 had come to an end.

A new cycle of sedimentation was started in early Kansan time (Kansan-Yarmouthian cycle) in the county. Once again a continental glacier moved southward from Canada. As the glacier moved southward across eastern Nebraska, it spread farther westward than the previous Nebraskan glacier and succeeded in glaciating most of the northeastern half of Jefferson County. The glacier once again dammed what was left of the old pre-glacial drainage ways. As the glacier advanced, outwash material was deposited in its path which it later overrode. This is the Atchison Formation. Upon entering Jefferson County, the glacier was forced to move over a high topographic surface which became a formidable barrier along what is now the northeastern valley wall of the Little Blue River Valley from Powell, Nebraska southeastward. The ice was thin at the glacier margin. This condition, coupled with the high local relief, caused the front of the glacier to become lobate and the remaining glacial energy was dissipated west to southwestward through outlet valleys. Condra, Reed and Gordon (1950) suggest that the maximum ice advance occurred early in Kansan time.

The Little Blue River Valley below Powell, Nebraska came into existence as a deflected ice marginal stream when the Kansan glacier began its retreat. This valley is known to be an ice contact stream valley for the following reasons: (1) pre-Pleistocene valleys trended east-west; (2) present valleys in the outcropping Cretaceous formations form a dendritic pattern; However, the smaller intermittent streams drain into larger ones that trend north-south; (3) the Little Blue River Valley cuts diagonally across these other two drainage patterns; and (4) undisputable evidence is contained in the fact that Kansan Till occurs high up on the northeast valley wall and is absent on the southwest valley wall of this river valley from a few miles northwest of Fairbury, Nebraska southeastward to the Kansan-Nebraskan line. Thus, the Little Blue River Valley in the area outlined had its beginning in middle to late Kansan time and it defines the channel of an ice contact stream.

Active erosion and sedimentation were going on in late Kansan time. Stream gradients were high. West of the till border in the northwestern township of the county, the upper part of the old pre-glacial valley that drained eastward in preglacial times was still not completely filled. Fluvial inwash and glacial outwash material rapidly accumulated against the Kansan Till barrier and the old eastward trending stream valleys were once more aggraded by coarse clastics (Grand Island Formation). The northern valley was completely filled west of the till border in Jefferson County. While the northern valley was being aggraded, the newly formed Little Blue River Valley was also being aggraded by coarse clastics. Even though the area is near the till border, most of the clastic material filling the valleys must have come from the mountains and tablelands of the west. This situation had already occurred once before when the Holdrege Formation was deposited.

While the Grand Island Formation was being deposited, the till sheet to the east was undergoing extensive erosion. In Jefferson County, the upper surface of the till sheet was badly eroded and at places a considerable thickness was removed. In the meantime, Grand Island sedimentation was coming to a close. Subdrainage of the Grand Island Formation was good so erosion was negligible. In very late Kansan time or early Yarmouthian time, the aqueous-eolian Sappa Formation was deposited upon the Grand Island sand and gravel plain. Some Sappa sediments may occur locally on the Kansan Till. During Yarmouthian time, soil development occurred on the Kansan Till sheet and associated deposits; however, the soil zone was largely destroyed by later erosion. Soil formation brought to a close the Kansan-Yarmouthian cycle of sedimentation in the county.

The Illinoian-Sangamonian cycle of sedimentation is well recorded in Jefferson County. Though the Illinoian glacier only penetrated the extreme northeastern part of Nebraska (Condra, Reed and Gordon, 1950), it produced a new erosional cycle which caused valley erosion that would soon be followed by alluviation. The sand and gravel deposits that now form a relatively high terrace deposit along the valley walls of the Little Blue River Valley are of Grand Island age in their lower and middle part, but of Crete age in their upper part. The upper surface of this now dissected terrace is most certainly a constructional surface of Illinoian age that has been somewhat modified by post-Illinoian erosion. These sand and gravel deposits were mapped as Grand Island because they are difficult to separate accurately; however, they are Grand Island-Crete in age.

The Illinoian-Sangamonian cycle of sedimentation was brought to a close by eolian sedimentation and soil formation. The loess deposits of the Loveland Formation covered the whole county except in the valleys where the valley and colluvial phases were dominant. Large portions of the loess deposits remain; however, the upper surface was dissected somewhat and complete removal of the deposit occurred throughout much of the southern part of the county. Deposition of the Loveland Formation may have continued into Sangamonian time. The soil profile developed upon the Loveland Formation in Sangamonian time is known as the Sangamon soil in Illinois but in Iowa and Nebraska it is known as the Loveland Soil (Condra, Reed and Gordon, 1950). The soil is often recognizable in well cuttings as well as in good outcrop exposures.

The last Pleistocene cycle of sedimentation is the Wisconsinan cycle. During this time, Jefferson County was some distance out in the periglacial zone. The lower course of the Little Blue River was cut down into the Skull Creek Shale at this time if it had not already occurred in Illinoian time. The down-cutting was followed by alluviation of the river valley. Preliminary reconnaissance work indicates that the Rose Creek drainage system and other smaller systems were non-existent before Wisconsinan time. During this time of valley alluviation, the upland areas were being mantled by eolian deposits (Peorian Formation). This loess material covered the area extensively but has been removed by late Wisconsinan and Recent erosion in some areas of the county. Some soil formation occurred in early Wisconsinan time but no such soil was found in this area.

Recent erosion and sedimentation has tended to slightly modify the topography that existed at the close of Wisconsinan time. Recent erosion and sedimentation features of this area can best be summed up as the micro-topographic and micro-sedimentational features that have been superimposed on a more easily recognizable pre-Recent macro-topography.

Several different geomorphic processes are active in the area and some are the same processes and agents that were so important in the pre-Recent erosional and sedimentational history of Jefferson County. The present importance of one geomorphic process compared to another is shown by a series of diagrams (Plates 13-14). These are the diagrams of Louis Peltier as they appear in Thornbury (1954, pp. 58-60). The following conclustions about the theoretical ideal presented on Plates 13-14 are probable:

1. Moderate chemical weathering predominates with mechanical weathering being less important.

2. Mass movement is at a mimimum.

3. Maximum to moderate wind action.

4. Maximum pluvial erosion.

Field evidence suggests the main processes are as follows:

1. Pluvial including fluvial erosion is most certainly the dominant erosional agent in the county.

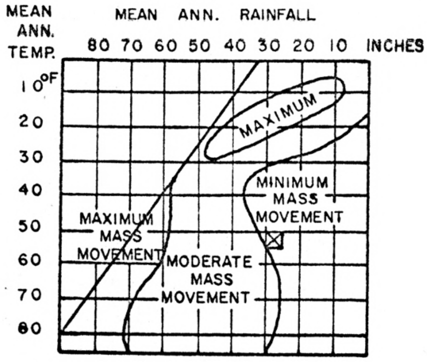
EXPLANATION OF PLATE 13

Fig. A. Diagram suggesting the relative importance of mass-wasting, stream erosion, and wind erosion under varying climatic conditions. Diagram A represents mass movement.

Fig. B. Diagram suggesting the relative importance of mass-wasting, stream erosion, and wind erosion under varying climatic conditions. Diagram B represents pluvial erosion.

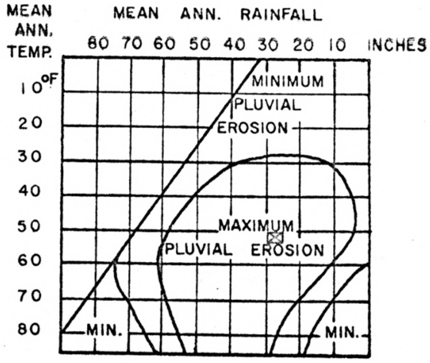
Fig. C. Diagram suggesting the relative importance of mass-wasting, stream erosion, and wind erosion under varying climatic conditions. Diagram C represents wind action.

PLATE 13



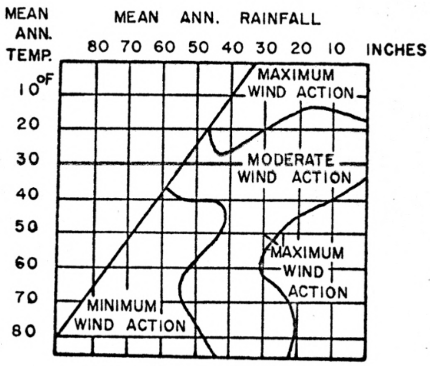
MASS MOVEMENT

A



PLUVIAL EROSION

B



WIND ACTION

C

CONDITIONS:

MEAN ANN. PRECIPITATION 25-30 INCHES
MEAN ANN. TEMP. 50-55°F

⊠ DELINEATES AREA COVERED BY ABOVE CONDITIONS.

(AFTER LOUIS PELTIER)

M. VEATCH 1963

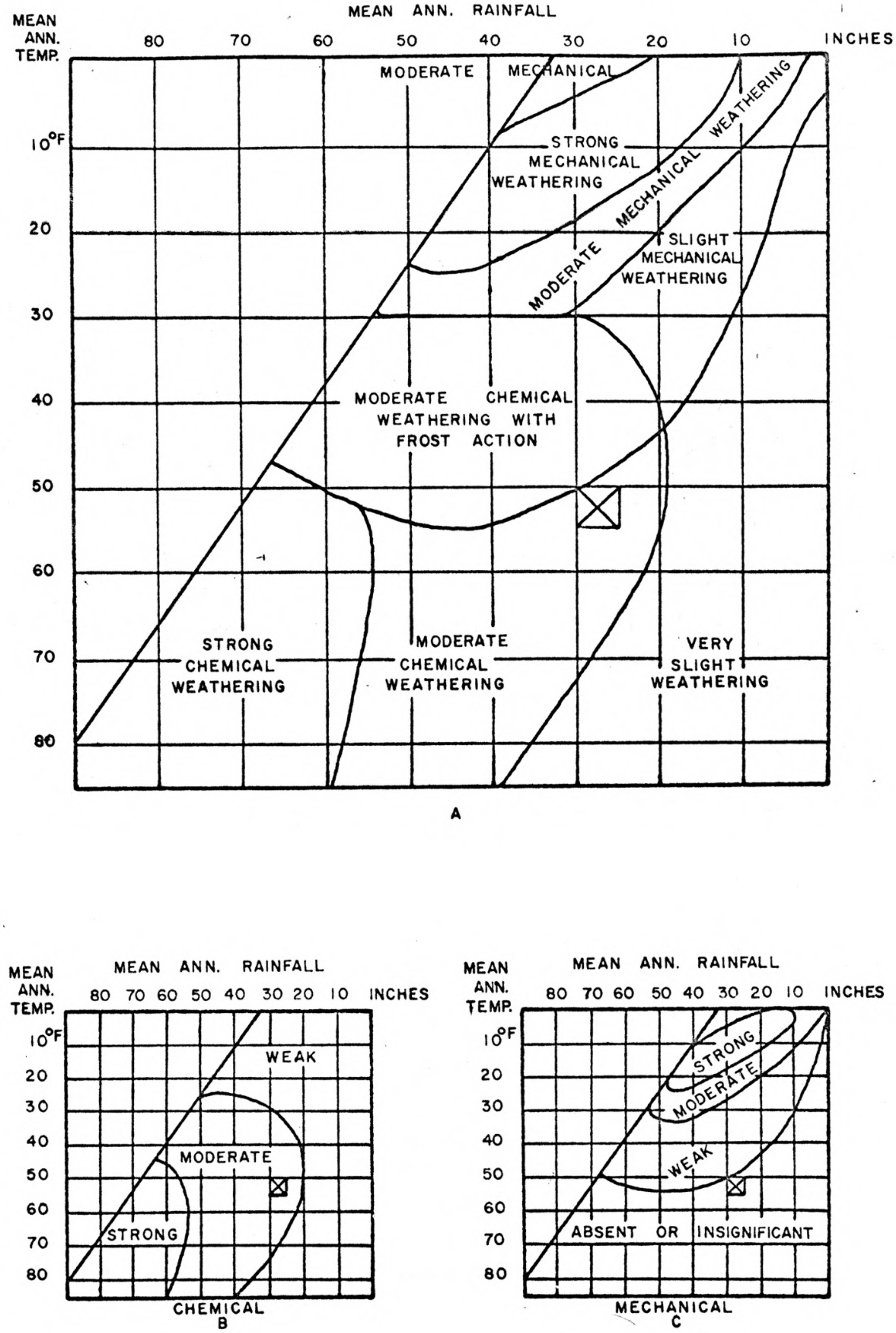
EXPLANATION OF PLATE 14

Fig. A. Diagram suggesting the relative importance of various types of weathering under varying temperature and rainfall conditions.

Fig. B. Diagram suggesting the effects of rainfall and temperature variations upon the relative importance of chemical and mechanical weathering. Diagram B. represents chemical weathering.

Fig. C. Diagram suggesting the effects of rainfall and temperature variations upon the relative importance of chemical and mechanical weathering. Diagram C represents mechanical weathering.

PLATE 14



CONDITIONS:

MEAN ANN. PRECIPITATION 25 - 30 INCHES

MEAN ANN. TEMP. 50 - 55°F

DELINEATES AREA COVERED BY ABOVE CONDITIONS.

(AFTER LOUIS PELTIER)

M. VEATCH 1963

2. Mass movement is at a minimum but certainly detectable in the Cretaceous outcrop areas of the county.

3. Wind action is moderate but probably is never maximum for over 30 days out of the year. The 1930's was a time when wind action was at a maximum for a considerable period of time.

4. The soils of the area tend to support the conclusion that chemical weathering (decomposition) is more important than mechanical weathering (disintegration). The weathering of granitic boulders near the surface of the Kansan Till and weathering at Greenhorn Limestone outcrops clearly illustrate the dominance of chemical decomposition. Summarizing, moderate chemical action is present with mechanical disintegration being less important but present in the processes of frost action and freeze and thaw.

This theory portrays a fairly accurate picture for the present, for man known variables. The readable record of the past is blurred, thus, man's knowledge of the variables is questionable; however, this method gives an insight into the past regarding geomorphic processes. The theory works well for broad areas, for it is based on climate which is regional in nature. Local inconsistencies in the theory will appear as it is applied to smaller and smaller areas.

SURFACE WATER

Four major watersheds drain the county. Within these drainage basins are mature streams whose stage of development varies with the larger streams being more mature than the smaller streams. A dendritic drainage pattern has developed throughout the area. The four major watersheds are the (1) Little Blue River watershed; (2) Cub Creek watershed; (3) Indian Creek watershed; and (4) Swan Creek watershed. Perennial streams are present only in the Little Blue River watershed with the Little Blue River being the largest perennial stream. The southwestern half of the county is drained by the Little Blue River and its main tributaries which are Rose Creek with its tributaries on the south and Big Sandy, Little Sandy and Rock Creek on the north. Swan, Cub and Indian Creeks are tributaries of the Big Blue River watershed which drains southward through Gage County. The Swan Creek watershed drains the extreme northeast corner of T. 4 N., R. 1 E. and the northern part of T. 4 N., R. 2-4 E. Cub Creek watershed drains the NE½ T. 3 N., R. 2 E., southern part of T. 4 N., R. 3-4 E., and most of T. 3 N., R. 3-4 E. Indian Creek watershed drains most of T. 2 N., R. 4 E. and the northern part of T. 1 N., R. 4 E.

Storage of surface water is very limited. Surface storage is confined to small stock-water ponds and recreation lakes. Surface storage of water will increase in the future as the grade stabilization and flood water retarding structures of the small watershed projects in the area are completed. During high water stage, the larger streams are influent and therefore constitute a local source of ground water recharge. During low water stage, the larger perennial streams are effluent. This is particularly true of the Little Blue River. At the gaging station on the Little Blue River near Fairbury, Nebraska during the years 1956-60, the following data were obtained (Nebraska's Water Story, 1963):

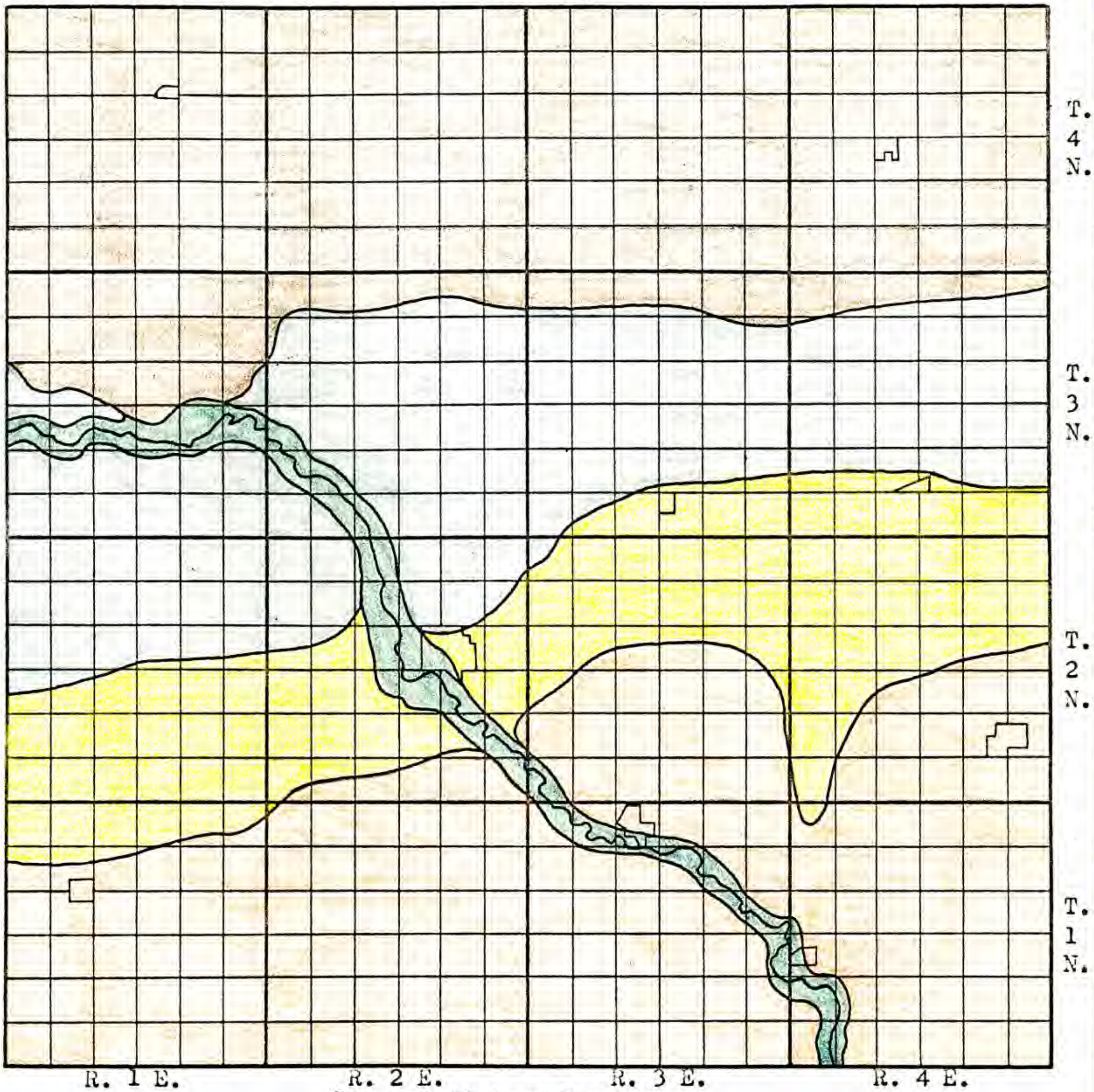
1. Lowest daily mean discharge 20 million gallons per day (60 acre feet per day).
2. Lowest monthly mean discharge 54 million gallons per day (165 acre feet per day).
3. Mean of yearly discharges for water years 1956-60, 415 cubic feet per second (822 acre feet per day).

The lowest daily mean discharge (60 acre feet per day) is because of ground water discharge. The lowest monthly mean discharge of 165 acre feet per day may be the result of ground water discharge. At least this much ground water per day on the average is lost from the Little Blue River basin. This drainage basin encompasses more than Jefferson County so the loss is not entirely from ground water storage in Jefferson County.

GROUND WATER RESOURCES

Five ground water provinces are here recognized in Jefferson County. They are: (1) Northern Jefferson County Buried Valley Ground Water Province; (2) Southern Jefferson County Buried Valley Ground Water Province; (3) Central Jefferson County High Bedrock Ground Water Province; (4) Southern Jefferson County High Bedrock Ground Water Province; and (5) Little Blue River Valley Ground Water Province. The general location and characteristics of these provinces are shown on Plates 15-16.

PLATE 15



Ground Water Provinces

Northern Jefferson County Buried Valley Ground Water Province

Central Jefferson County High Bedrock Ground Water Province

Southern Jefferson County Buried Valley Ground Water Province

Little Blue River Valley Ground Water Province

Southern Jefferson County High Bedrock Ground Water Province

M. Veatch 1963

PLATE 16
CHARACTERISTICS OF JEFFERSON COUNTY'S
GROUND WATER PROVINCES

(1) Northern Jefferson County Buried Valley Ground Water Province
(2) Central Jefferson County High Bedrock Ground Water Province
(3) Southern Jefferson County Buried Valley Ground Water Province
(4) Little Blue River Valley Ground Water Province
(5) Southern Jefferson County High Bedrock Ground Water Province

Major aquifer	Minor aquifer	Dir. of Gd. Water flow	Discharge by	Recharge by	Well yield	Water quality
(1) Holdrege sd.&gr. uncon-fined		East	Subsurface outflow to east, Irr. & Dom. wells	Subsurface inflow from W., surface infiltra-tion	over 1000 gpm	Fresh
(2) Dakota Gr. Ss. confined	Green-horn Ls. in west	Down dip	Subsurface flow to L. Blue river, Dom. & Mun. wells	Surface in-filtration, some Ss. beds are not re-charged	less than 250 gpm	Fresh central & east Salty in W. except upper part
(3) Holdrege sd.&gr. uncon-fined		East-northeast	Subsurface outflow to E., Irr. & Dom. wells	Subsurface inflow from W., surface infiltra-tion	500 to 1000	Fresh
(4) Wiscon-sin Stage sd.&gr.		Southeast	Subsurface outflow to SE., ef-fluent stream discharge, Dom., Ind., Mun.&AC.W.	Subsurface inflow from W., in-fluent stream, surface in-filtration	Gen-eral-ly less than 500 gpm	Fresh
(5) Dakota Gr. Ss. confined	Gd. Is. terrace sd.&gr.	Down dip	Effluent streams & springs Dom.&Ind. wells	Surface in-filtration, some Ss. beds are not re-charged	less than 250 gpm	Fresh central & east Salty in W. except upper part

Dom.(domestic),Ind.(Industrial),Irr.(irrigation),Mun.(municipal), AC(air conditioning),W(wells), upper part(refers to upper part of Dakota Group).

Water is supplied to wells by both unconfined and confined aquifers. The unconfined aquifers are limited to formations of Pleistocene age except where a sandstone aquifer of Cretaceous age is overlain by permeable Pleistocene sediments. Confined (artesian) aquifers are limited to formations of Cretaceous age. Some semi-confined conditions may occur locally in Pleistocene aquifers. It is now known that some of the confined sandstone aquifers of the Dakota Group are leaky, thus producing semi-confined conditions. The confined aquifers encountered in the area are generally under positive hydrostatic pressure. In some localities, confined sandstone beds are saturated only in their lower part and thus are under no hydrostatic pressure. This latter condition has resulted from drainage of the upper part of the upper part of the aquifer by spring discharge.

The approximate water table is shown on the cross sections (Plates 2-4). Data used as control for plotting the water table were collected over a period of almost 30 years. The water table shown in the unconfined aquifers is within plus or minus 10 feet of being correct in most of the area. In the high bedrock areas, a discontinuous water table (not a piezometric surface) is shown because of the nature of the Cretaceous formations of the area. Where saturated sandstone beds are present, there will be a confined water table. If the sandstone beds are absent, then the depth to water increases until a sandstone aquifer is encountered. With such a condition existing as just outlined, there cannot be a continuous water table in the ground water provinces that utilize aquifers of Cretaceous age. An important conclusion drawn from the foregoing discussion is that a water table contour map is valid only for the hydraulic system it is drawn on. That system happens to be an aquifer that is defined in three dimensional space and when one tries to connect the water table contours of two different systems (aquifers), the resultant map is erroneous. This is a concept that has been forgotten by too many workers in the past. The geology of a ground water province must be fairly well understood before a good water table contour map for the province can be constructed. This was one of the main purposes of the investigation and the cross sections on Plates 2-4 outline the general three dimensional configuration of the area's ground water provinces.

Ground water recharge, discharge and movement is variable and each ground water province is a separate study in itself. The following conclusions and speculations are made regarding ground water recharge, discharge and movement as occurring in Jefferson County.

In the Northern and Southern Jefferson County Buried Valley Ground Water Provinces, the lateral ground water movement is eastward and is estimated to be not in excess of 200 to 300 feet per year. In the northern province, the eastward lateral movement of ground water which causes subsurface discharge of unconfined water eastward from underneath the area is compensated for by subsurface inflow of unconfined water from the west-northwest. The same condition exists in the southern province except the subsurface inflow is from the west-southwest and subsurface outflow is in an east-northeasterly direction. The inflow does not simultaneously balance the outflow thus producing a water table of equilibrium. Heavy pumping in the northern basin will not cause ground water inflow from the west to come rushing in overnight to replace the withdrawn water.

The water will continue to percolate eastward into the Jefferson County portion of the basin at the relatively slow rate of several hundred feet per year. With such a hydraulic system local anomalies occur within the water table of a ground water province. The magnitude of subsurface discharge is unknown but another large source of discharge is the artificial discharge caused by domestic and irrigation wells (most of the area's irrigation wells are in the two provinces being discussed, with the majority being in the northern province). Statistics presented in "Nebraska: Irrigation Wells", (1963) indicates that as of January 1, 1963 the area had 111 irrigation wells with an average capacity of 890 gallons per minute per well. A large source of the annual recharge for the five ground water provinces is the infiltration of precipitation and infiltration of water applied by irrigation practices. Some of the water used for irrigation is lost to the atmosphere by evaporation and transpiration processes and some water is lost as surface runoff. Until recently, emphasis was always placed on recharge areas that were many miles away. This concept is valid for many confined aquifers; however, in Jefferson County as at many other places, a large increment of recharge received by unconfined aquifers is local within the area of outcrop.

The Little Blue River Valley Ground Water Province receives subsurface inflow from the west, and ground water movement is in a southeasterly direction from this province into Kansas. A portion of the ground water discharge of this province is by effluent stream flow as previously mentioned. The province receives influent seepage from streams during normal and high water stages. This source of recharge occurs in all the provinces. Infiltration of precipitation in this province is high because of the permeability of the terrace deposits; this same precipitation is discharged by springs along the valley where the river has cut its channel into bedrock 0 to 50 feet below the base of the high terrace deposits. This spring discharge is lost from the province as stream discharge.

The Central and Southern Jefferson County High Bedrock Ground Water Provinces differ considerably from the other three provinces of the area. This results because of the different types of hydraulic systems (confined aquifers instead of unconfined aquifers). Many of the sandstone aquifers are receiving little or no recharge.

The areal distribution of Dakota Group aquifers is not well enough known to try to connect an individual subsurface sandstone body with an outcroping sandstone body. Undoubtedly some subsurface sandstone beds do move up dip to the east and appear as surface outcrops. Where such a condition exists, the confined aquifer is recharged by direct infiltration of precipitation.

Known salt water saturated sandstone aquifers are present in these two provinces especially in the western and southwestern parts of the provinces. When the two provinces are considered in their entirety, the majority of the aquifers contain fresh water. Most of the discharge from these confined aquifers is by domestic wells. Several industrial wells also utilize water from confined sandstone aquifers.

Pressure conditions within the confined aquifers of these two provinces are still high. Ground water movement in these confined aquifers is down dip if the aquifer is hydraulically connected with the surface. Many of the deep channel sandstone aquifers are thoroughly interbedded within impermeable material. Theoretically, when water is withdrawn from these confined aquifers, all local flow within the aquifer becomes radial and the pressure is only reduced. The amount of water in storage at point of pumping theoretically will not begin to decrease until the pressure surface is lowered to the altitude of the top of the aquifer at point of pumping. Actual complete depressurization of the confined aquifers has occurred only locally in the southern part of the county where topography has caused natural springs to drain confined sandstone aquifers on the down dip side.

Ground water quality is good in this area except for those aquifers that are saline. Conclusions about the water chemistry of the aquifers cannot be made because an adequate sample analyses throughout the area has not been made. Actually, a fully analyzed water sample is of little practical value in areal studies if a detailed log of the well from which it came is not available. This is a fact future workers should keep in mind. The following chemical analysis of Fairbury, Nebraska's water supply gives some indication of quality of water from sand and gravel aquifers of Pleistocene age.

Data from Nebraska's Water Story, 1963:

Fairbury, Nebraska sample taken from a fluorinated source. The water is fluorinated after distribution from the well field so disregard the fluoride ion. The sample was not taken directly at the well field.

	Parts per million
Total solids	432.0
Total hardness ($CaCO_3$)	210.0
Total alkalinity (CO_3)	208.0
Iron (Fe)	0.0
Calcium (Ca)	---
Manganese (Mn)	0.02
Chloride (Cl)	75.0
Fluoride (F)	0.1
Sulfate (SO_4)	24.0
Nitrate (as N)	less than 10.0
Sodium (Na)	---
Potassium (K)	---

Since this sample was taken from Fairbury's distribution system one must also be skeptical of the chloride content reported, because of chlorination.

Average temperature of the area's ground water is 56° F. This low average temperature makes the water highly desirable for industrial use and air conditioning purposes. Many of the business establishments in downtown Fairbury, Nebraska have their own wells for supplying water to their air conditioning systems.

WELL FIELDS AND PROBLEMS

Jefferson County's ground water resources are mainly being used for the following purposes: (1) domestic use (includes stock watering); (2) irrigation; (3) air conditioning; (4) municipal use; and (5) industrial use. There are over 1000 domestic wells in the area. Most of these wells range in size from two inch tubular wells to six inch steel cased wells. Many of the wells are pumped by electric pumps, with average pump capacity ranging from 5 to 10 gallons per minute; however, many of the stock pasture wells are pumped by windmills. As of January 1, 1963, the county had 111 registered irrigation wells that are intended to irrigate an average acreage of 137 acres per well. Average depth of these wells is 169 feet with an average depth to static water level of 105 feet. Average well yield is 890 gallons per minute (above statistics from _Nebraska: Irrigation Wells_, 1963). Most of these wells are 16 to 18 inch cased wells. The wells are cased either with concrete or steel casing and they were drilled by reverse circulation rotary drills. Generally speaking, a 30 inch hole is drilled and gravel packed back to casing size. These irrigation wells obtain their water from unconfined aquifers.

Air conditioning wells at Fairbury, Nebraska range from 6 to 24 inches in diameter and are cased with several different types of steel casing. They range from 30 to 50 feet in depth with capacities ranging on the average from 25 to 100 gallons per minute. These wells obtain their water from an unconfined sand and gravel aquifer in the Little Blue River Valley Ground Water Province.

Municipal wells are located at Fairbury, Diller, Plymouth, Reynolds, Jansen and Daykin, Nebraska. The largest well field is the Crystal Springs well field at Fairbury where several million gallons a day are pumped from large diameter wells and a gallery system. Fairbury also has a municipal well pumping from sandstone in the Dakota Group. This is well number A2-2-llcaa. It is used as a pressure maintenance well and it has yielded 28 million gallons of water over a 144 day period of continuous pumping. This is the best proved well of the area in a confined sandstone aquifer of Cretaceous age.

A few industrial wells are in operation in and around Fairbury. One of these wells belongs to the Roode Packing Company and pumps from a sandstone aquifer of the Dakota Group and it may prove to be a better well than the one belonging to the above mentioned municipal system.

At several localities in the area there are enough wells pumping from a single aquifer for the locality to be considered as a well field. These fields are briefly outlined as follows:

1. Central and southern Fairbury, Nebraska well field. It is located in the Little Blue River Valley Ground Water Province. Water is being pumped from wells in a sand and gravel aquifer. Wells are 30 to 50 feet deep. The water is used for air conditioning and industrial purposes.

2. Crystal Springs well field. It is located on the

southwestern edge of the Little Blue River Valley Ground Water Province. Water is pumped from wells in a sand and gravel aquifer. Wells are about 30 feet deep. The water is used for municipal purposes.

3. Northern Fairbury, Nebraska well field. It is located on the southern edge of the Central Jefferson County High Bedrock Ground Water Province. Water is being pumped from confined to semi-confined Dakota Group sandstone aquifers. Well depths range from 120 to 200 feet. The water is used for domestic purposes except City of Fairbury's pressure maintenance well which is used for municipal purposes.

4. Endicott, Nebraska well field. It is located on the northern flank of the Southern Jefferson County High Bedrock Ground Water Province. Water is pumped from wells in a confined sandstone aquifer of the Dakota Group. Well depth ranges from 70 to 150 feet. The water is used for domestic purposes.

5. Northern Jefferson County Buried Valley Ground Water Province. The province is rapidly becoming a well field. Water is being pumped from wells in a sand and gravel aquifer. Well depth is about 175 feet. Many of the wells do not fully penetrate the aquifer, a factor that raises pumping costs. The water is used for irrigation purposes.

Well construction practices have improved over the past and will continue to improve in the future. Many poor well construction practices are not the fault of competent drilling contractors but result from the prospective owner's unwillingness to supply the economic incentive necessary for the construction of ultimate designed wells and their general ignorance of ground water and related well construction problems. The following specifications should be insisted on by a new prospective well owner as well as the contractor: (1) the well is to be cased with steel well casing or standard pipe; (2) at least the upper 20 feet of the hole should be cement-grouted outside of the casing; (3) construction of a good cement platform around the well at surface; (4) installation of a sanitary well seal when pump is installed in well; and (5) the water should be tested for pathogenic bacteria before using the well water for human consumption. No serious sanitation problems exist in this area and there need be none in the future if present and prospective well owners give sanitation the consideration it deserves. A polluted aquifer benefits no one. It represents bad conservation of a natural resource and is an unnecessary economic loss.

Mass-wasting along road cuts is becoming a problem of importance. In most of the new road cuts through shales of Cretaceous age, creep and slump of earth materials is taking place. The processes are slow but easily recognized in this area. The sides of the road cuts are not too steep for dry earth material; however, this material becomes somewhat saturated in the fall and especially in the spring. In partially-to completely saturated condition, the road cut banks are unstable and they creep or flow down toward the road. The force is gravity and the trigger mechanism is water. The problem could be greatly eliminated by use of wet weather drains under the highways and from the sides of large road cuts. A decrease in road cut bank slopes is also necessary. Some of the hard surfaced road beds are becoming slightly hummocky. This indicates poor road bed drainage, a problem that will become serious in time, especially where the road bed material contains an abundant amount of the clay mineral montmorillonite. Good road bed drainage is essential if this problem is to be avoided.

Some well construction problems are directly related to geology. Where the Greenhorn Limestone must be utilized as an aquifer, special well completion techniques are necessary. These techniques make use of acid and clay dispersing agents. The poorly consolidated, silty sandstone beds in the gray shale facies of the Omadi Sandstone present another interesting completion problem. A good domestic well that pumps clear, sand-free water from this aquifer, must be constructed by the following procedures: (1) the driller must know where the sandstone beds are and their thickness (rotary drilled holes seldom yield this data); (2) good hole conditions must be maintained; (3) a continuous slot well screen must be set adjacent to the sandstone beds; (4) the screen must be centered in the hole and packed around its outside with sand; (5) steel pipe or well casing must be run from the screen to the surface; and (6) the upper part of the hole should be cement-grouted from 5 to 10 feet below the top of the Graneros Shale to the surface. There are many more completion problems in the area however, that are beyond the scope of this report. Most of the completion problems result from an inadequate knowledge of the geology of the well site.

Good well samples must be obtained and their depth of occurrence accurately determined if the most effective well completion method is to be utilized.

SUMMARY AND CONCLUSIONS

This investigation in essence has been nothing more than a detailed reconnaissance. By its nature it has dealt with generalities (not specific details) read from the record of the rocks. As a result of the investigation the following conclusions are justifiable:

1. Two major unconformities occurred within the geologic time span covered by this report. They are the Permian-Cretaceous and Cretaceous-Pleistocene unconformities.

2. Cretaceous structure mapped at the surface is not an exact mirror image of the underlying Permian structure.

3. Three mappable rock-stratigraphic units are recognizable in the Dakota Group; however, their boundaries are not well defined. This situation results from the general absence of detailed bore hole data and the continental nature of the Dakota Group.

4. Relief in the area at the close of Tertiary time was greater than present day relief.

5. Nearly a complete Pleistocene section is present. The cyclic nature of this time stratigraphic series is clearly evident in the Pleistocene Series.

6. Topography was the main sedimentational control throughout the Pleistocene Epoch.

7. Two broad pre-Pleistocene valleys that were buried in Pleistocene time are present. These constitute the area's two largest ground water provinces when one thinks in terms of ground water in storage.

8. Five distinct ground water provinces are present.

9. Four major natural resources of the area are; (1) ground water resources; (2) high grade brick clay resources; (3) sand and gravel resources; and (4) soil resources.

10. The post-Permian geologic history encompasses the approximate past 225 million years. An impressive sedimentational record was produced during this time; however, throughout the majority of this time, erosion was the dominant geologic process, not sedimentation.

ACKNOWLEDGMENTS

The author is indebted to many persons for unpublished and published data used in the preparation of this thesis. Cooperation by many individuals greatly facilitated field work in the area of investigation. Among those who contributed most in this manner were Marvin F. Hollingshead and his associates of the U. S. Soil Conservation Service in Jefferson County, Nebraska; the many citizens of Jefferson County who gave the writer permission to conduct field work on their land; John A. Masters, Kerr-McGee Oil Industries, Inc.; W. F. Bunker, Pan American Petroleum Corporation; Roger Judd, Endicott Clay Products Company; Albert Veatch, water well drilling contractor, Mahaska, Kansas; Dr. Page C. Twiss, Kansas State University.

The writer is especially indebted to Professor Henry V. Beck, Kansas State University, who was the major instructor supervising the project; personnel of the Nebraska Geological Survey (especially to E. C. Reed, V. H. Dreeszen and V. J. Hines); this organization is responsible for drafting and reproducing the large scale cross sections contained on Plates 2-4; Mrs. R. Richard Gobel, who proofread and typed the original manuscript. Lastly, the writer is deeply indebted to Dale M. Veatch, water well drilling contractor, Fairbury, Nebraska. This private enterprise organization financed the project and furnished a tremendous amount of data which has been of a confidential nature prior to 1963.

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APPENDIX

Detailed logs of the bore holes used as control for constructing the cross sections on Plates 2-4 are not presented in this report for the following reasons: (1) many of the logs are of little value in correlation work to others unless they are presented in their entirety; to accomplish this would require nearly as much space as was devoted to the body of this thesis; (2) formation tops and bottoms interpreted from the bore hole data were carefully plotted on the cross sections and at a scale of 1 inch = 100 feet, one can determine tops and bottoms within plus or minus 5 feet at bore hole locations by direct measurement from the cross sections. It should be noted that post-Holdrege Formation tops and bottoms are questionable where the bore hole data were obtained from State Irrigation Well Registration Records. These holes are designated as Irrig.; and (3) logs of the bore holes are on file and can be examined by interested individuals or organizations.

Logs of bore holes may be inspected by contacting the following sources:

(1) Logs of Test Holes Jefferson County, Nebraska. Based on test holes drilled by the Conservation and Survey Divisioh, University of Nebraska, in cooperation with the Geological Survey, United States Department of the Interior, during the period 1931-1952, inclusive. Published.

(2) Records of all later work done by source (1) can be inspected but it has not been published.

(3) Logs of bore holes by the Dale Veatch Water Well Drilling Firm were correlated by the author and are on file at this business establishment in Fairbury, Nebraska.

(4) Logs of irrigation wells that have been correlated by the writer are entered under source (3). Uncorrelated driller's logs of these wells are on file at the Jefferson County Soil Conservation office, Fairbury, Nebraska.

It should be noted that on Plates 2-4 the altitude of certain test holes does not agree with the original source (source (1), page 124). This results because the writer corrected some altimeter altitudes where U. S. G. S. topographic map data indicated they were apparently in error.

A number of topographic maps are available for this area. The following topographic maps are available for Jefferson County, Nebraska:

Scale 1:24,000, contour interval 10 feet, coverage 7.5 minute series.

Published map -- Plymouth (1957)

<u>Advance--prints</u>

Fairbury	1	SE	
Fairbury	1	SW	(Western SW)
Fairbury	2	SE	(Daykin)
Fairbury	3	NE	(Gladstone)
Fairbury	3	SE	(Reynolds)
Fairbury	4	NW	(Fairbury)
Fairbury	4	SW	(Fairbury SW)

(The names in parentheses are the names under which the new maps will be available, which will be very soon in some cases.)

Published map. Western United States 1:250,000, Lincoln, NK 14-12, contour interval 50 feet.

Maps listed on page 125 are for sale by the U. S. Geological Survey, Topographic Division, Box 133, Rolla, Missouri.

Source of data used on Plates 2-4, in pocket:

(1) Driller's logs, supplied by Dale Veatch and Albert Veatch, water well drilling contractors.

(2) Logs of Test Holes, drilled by the Conservation and Survey Division, University of Nebraska.

(3) Driller's logs, from State of Nebraska Irrigation Well Registration Records.

(4) Electric logs of stratigraphic test holes, drilled by Stanolind Oil & Gas Company, information released by Pan American Petroleum Corporation.

(5) Detailed surface geologic studies made by Maurice D. Veatch, 1961-1962.

Formation and Fluid Log Data Form
For Water Well or Test Hole

Location: A2-2-21abc County: Jefferson State: Nebraska

Owner: City of Fairbury, Nebraska Date: (6-28-52)

Driller: Dale Veatch Well Drlg., Fairbury, Nebraska Date: (6-28-52)

Drilling Method: Cable tools Type Hole: Cased test hole

Correlation by: Maurice Veatch From: Driller's log

Date (10-10-62) Topography: Upland, side slope

A2-2-21abc (670 ft. south and 2380 ft. west of the northwest corner). Ground altitude, 1323 ft., (t). Depth to water, 8 ft. (6-28-52).

	Depth, in feet From	Depth, in feet To	Thickness in feet.
Quaternary System	0	27	27
Pleistocene Series	0	27	27
Soil..........................	0	2	2
Clay..........................	2	6	4
Muck, sandy.....................	6	8	2
Muck, sandy, water bearing.......	8	16	8
Sand and gravel; texture grades from sand to medium gravel, water bearing................	16	17	1
Sand and gravel; texture grades from sand to coarse gravel, median: coarse gravel, water bearing......................	17	19	2
Gravel, coarse texture, water bearing......................	19	20	1
Sand and gravel, water bearing..	20	21	1
Sand and gravel, cemented, water bearing......................	21	22	1
Sand; texture grades from fine to medium sand, water bearing..	22	23	1
Sand and gravel; texture grades from sand to fine gravel, water bearing......................	23	27	4
Cretaceous System	27	---	---
Dakota Group	27	---	---
Sandstone, yellow, with interbedded shale....................	27	28	1
Shale..........................	28	29	1
Shale, varicolored clay.........	29	31	2

POST-PERMIAN GEOLOGY
AND
GROUND WATER RESOURCES
OF
JEFFERSON COUNTY, NEBRASKA

by

MAURICE D. VEATCH

B. S., Kansas State University, 1962

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology and Geography

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1963

ABSTRACT

This investigation describes the post-Permian stratigraphy, geologic history, ground water resources and geoeconomic materials present in Jefferson County, Nebraska. Exploration methods were used extensively to obtain both surface and subsurface data. These data are summarized in the illustrative form of ten large scale geologic cross sections covering approximately 230 miles of traverse at a scale of 1:24,000. These cross sections illustrate the areal and temporal distribution of the rock stratigraphic units in a form that can be assimilated and interpreted readily by the professional geologist or the layman.

Triassic and Jurassic rocks are absent from the area because it was emergent and undergoing erosion during this interval of time. The Dakota Group (Cretaceous) consisting of clays, shales and channel sandstone strata of continental origin rests unconformably on the marine strata of the Chase Group (Permian). During Dakota time, a true marine environment was intermittently present in the western part of the county. The Colorado Group (Cretaceous) composed of marine strata, rests conformably on strata of the Dakota Group. Tertiary rocks are absent from the area because it was emergent and undergoing erosion during this time interval. Jefferson County was relatively rough, possessing over 450 feet of relief at the close of Tertiary time. This pre-Pleistocene surface controlled sedimentation throughout Pleistocene time. Ten regionally correlative and several local units were deposited during Pleistocene time. As a result,

almost a complete record of Pleistocene sedimentation and erosion is present in the area.

Sandstone aquifers of the Dakota Group contain fresh water throughout most of the area, but some aquifers are salty in the western and southwestern parts of the area. These confined aquifers supply most of the water to wells in two of the five ground water provinces of the county. Wells yielding up to 250 gpm can be developed where 50 to 75 feet of saturated sandstone are present. Pleistocene sand and gravel aquifers supply water to wells in the other three gound water provinces of the county. Wells yielding over 1000 gpm have been developed in the unconfined Holdrege Formation of Pleistocene age.

Two major unconformities are present. They are the unconformities between the Permian and Cretaceous and between Cretaceous and Pleistocene rocks. The surface structure is not a true reflection of the subsurface Permian structure. The Dakota Group consists of three formations whose boundaries are not well defined. Relief present at close of Tertiary time exceeded that present today in the county.

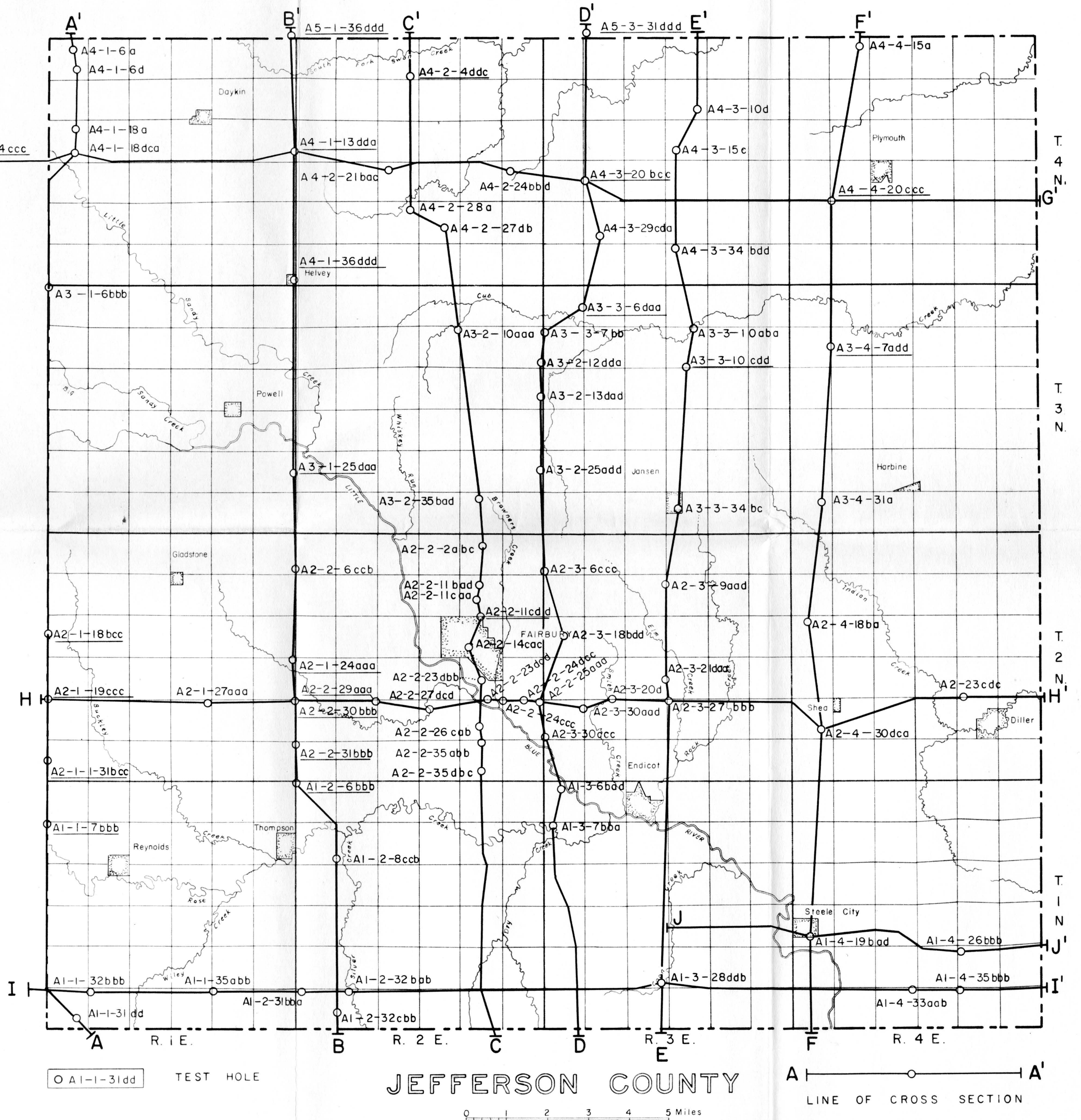
The cyclic nature of Pleistocene sedimentation is illustrated by the thick Pleistocene section of the area. Two broad pre-Pleistocene valleys were buried in Pleistocene time by alluvium and today they constitute the two largest ground water provinces of the area from the standpoint of ground water in storage.

Four major natural resources in the area are ground water, high grade brick clay, sand and gravel, and soil resources. The post-Permian record of sedimentation in this area is impressive but during the majority of this time erosion was the dominant geologic process, not sedimentation.

LD
2668
T4
1963
V39
chart 1
Spec. Coll.

PLATE I

LOCATION OF TEST HOLES AND CROSS SECTIONS



○ A1-1-31dd TEST HOLE

JEFFERSON COUNTY

0 1 2 3 4 5 Miles
SCALE

A ⊢———○———⊣ A'
LINE OF CROSS SECTION

PLATE 2

GENERALIZED

GEOLOGIC CROSS SECTIONS
across
JEFFERSON COUNTY, NEBRASKA

PREPARED BY
MAURICE D. VEATCH
1962-1963

COLUMNAR SECTION
(not drawn to scale)

System	Series	(Stage)	Rock-Stratigraphic Units	Lithology
Quaternary System	Pleistocene Series	Recent	Valley Alluvium & Loess	
		Wisconsin	Peorian Formation	
		Sangamon		
		Illinoian	Loveland Formation	
			Crete Formation	
		Yarmouth	Sappa Formation	
		Kansan	Grand Island Formation	
			Kansan Till	
			Atchison Formation	
		Aftonian	Fullerton Formation	
		Nebraskan	Holdrege Formation	
			Seward Formation	
Cretaceous System	Upper	Colorado Group	Carlile Shale (Fairport Shale Member)	
			Greenhorn Limestone	
			Graneros Shale	
	Lower	Dakota Group	Omadi Sandstone	
			Skull Creek Shale	
			Cloverly Formation	
Permian System	Big Blue Series	Chase Group	Nolans Limestone thru Wreford Limestone	
		Council Grove Group	Speiser Shale thru Foraker Limestone	

1 — 1/2 — 0 — 1 MILE

Horizontal Scale 1:24,000
Vertical Scale 1" = 100'
Vertical Exaggeration 20

Control, U.S.G.S., Topographic Contour Maps

Source:

(1) DRILLER'S LOGS, SUPPLIED BY DALE VEATCH AND ALBERT VEATCH WATER WELL DRILLING CONTRACTORS.

(2) LOGS OF TEST HOLES, DRILLED BY THE CONSERVATION AND SURVEY DIVISION OF THE UNIVERSITY OF NEBRASKA.

(3) DRILLER'S LOGS, FROM STATE OF NEBRASKA IRRIGATION WELL REGISTRATION RECORDS.

(4) ELECTRIC LOGS OF STRATIGRAPHIC TEST HOLES, DRILLED BY STANOLIND OIL & GAS COMPANY, INFORMATION RELEASED BY PAN AMERICAN PETROLEUM CORPORATION.

(5) DETAILED SURFACE GEOLOGIC STUDIES MADE BY MAURICE D. VEATCH, 1962-1963.

1010 Permian — Cretaceous Unconformity
Top picked from electric log. Source (4).

1060 Structural datum
Topography
Structural control picked from electric log. Source (4).

Key to Lithology

- Silt & Clay
- Sandy, Silt & Clay
- Calcareous Sh./W thin limy layers
- Shale
- Shale /w interbedded sandstone
- Varicolored clay & shale
- Sand & Gravel
- Sandstone
- Lignite seams
- Limestone
- Marl & Chalk
- Bentonite

R. 1 E.
T. 1 N.
5
° A1-1-5bad

A4-1-24bad, 1424 (a)

A = Range east, no prefix for range west.
4 = T. 4 N.
1 = R. 1 E.
24 = Section
bad = NW1/4 NE1/4 SE1/4
1424 = Altitude, (a) determined by altimeter, when 1424 stands alone it has been estimated from a topographic map.

A4-1-24bad, 1424 (a) Source (2) above
A1-1-24aaa, 1395 Source (1) above Dale Veatch only
A4-2-16abc, 1524 Irrig Source (3) above

All other sources acknowledged behind well location number

Drafting by Vernon J. Hine

PLATE 3

GENERALIZED

GEOLOGIC CROSS SECTIONS
across
JEFFERSON COUNTY, NEBRASKA

PREPARED BY
MAURICE D. VEATCH
1962-1963

COLUMNAR SECTION
(not drawn to scale)

System	Series	(Stage)	Rock-Stratigraphic Units	Lithology
Quaternary System	Pleistocene Series	Recent	Valley Alluvium & Loess	
		Wisconsin	Peorian Formation	
		Sangamon	Loveland Formation	
		Illinoian	Crete Formation	
		Yarmouth	Sappa Formation	
		Kansan	Grand Island Formation	
			Kansan Till	
			Atchison Formation	
		Aftonian	Fullerton Formation	
		Nebraskan	Holdrege Formation	
			Seward Formation	
Cretaceous System	Upper	Colorado Group	Carlile Shale (Fairport Shale Member)	
			Greenhorn Limestone	
			Graneros Shale	
	Lower	Dakota Group	Omadi Sandstone	
			Skull Creek Shale	
			Cloverly Formation	
Permian System	Big Blue Series	Chase Group	Nolans Limestone thru Wreford Limestone	
		Council Grove Group	Speiser Shale thru Foraker Limestone	

1 1/2 0 1 MILE

Horizontal Scale 1:24,000
Vertical Scale 1" = 100'
Vertical Exaggeration 20

Control, U.S.G.S., Topographic Contour Maps

Source:

(1) DRILLER'S LOGS, SUPPLIED BY DALE VEATCH AND ALBERT VEATCH WATER WELL DRILLING CONTRACTORS.

(2) LOGS OF TEST HOLES, DRILLED BY THE CONSERVATION AND SURVEY DIVISION OF THE UNIVERSITY OF NEBRASKA.

(3) DRILLER'S LOGS, FROM STATE OF NEBRASKA IRRIGATION WELL REGISTRATION RECORDS.

(4) ELECTRIC LOGS OF STRATIGRAPHIC TEST HOLES, DRILLED BY STANOLIND OIL & GAS COMPANY, INFORMATION RELEASED BY PAN AMERICAN PETROLEUM CORPORATION.

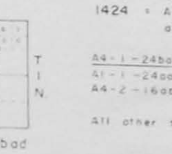
(5) DETAILED SURFACE GEOLOGIC STUDIES MADE BY MAURICE D. VEATCH, 1962-1963.

1010 Permian — Cretaceous Unconformity
Top picked from electric log. Source (4).

1060 Structural datum
Topography
Structural control picked from electric log. Source (4).

Key to Lithology

- Silt & Clay
- Sandy, Silt & Clay
- Calcareous Sh./w thin limy layers
- Shale
- Shale /w interbedded sandstone
- Varicolored clay & shale
- Sand & Gravel
- Sandstone
- Lignite seams
- Limestone
- Marl & Chalk
- Bentonite



A4-1-24bad, 1424 (a)

A = Range east, no prefix for range west.
4 = T. 4 N.
1 = R. 1 E.
24 = Section
bad = NW1/4 NE1/4 SE1/4
1424 = Altitude, (a) determined by altimeter, when 1424 stands alone it has been estimated from a topographic map.

A4-1-24bad, 1424 (a) Source (2) above
A1-1-24aaa, 1395 Source (1) above Dale Veatch only
A4-2-16abc, 1524 Irrig Source (3) above

All other sources acknowledged behind well location number


PLATE 4
GENERALIZED
GEOLOGIC CROSS SECTIONS
across
JEFFERSON COUNTY, NEBRASKA
PREPARED BY
MAURICE D. VEATCH
1962-1963
COLUMNAR SECTION
(not drawn to scale)
Horizontal Scale 1:24,000
Vertical Scale 1" = 100'
Vertical Exaggeration 20
Control, U.S.G.S., Topographic Contour Maps
Source:
(1) DRILLER'S LOGS, SUPPLIED BY DALE VEATCH AND ALBERT VEATCH WATER WELL DRILLING CONTRACTORS.
(2) LOGS OF TEST HOLES, DRILLED BY THE CONSERVATION AND SURVEY DIVISION OF THE UNIVERSITY OF NEBRASKA.
(3) DRILLER'S LOGS, FROM STATE OF NEBRASKA IRRIGATION WELL REGISTRATION RECORDS.
(4) ELECTRIC LOGS OF STRATIGRAPHIC TEST HOLES, DRILLED BY STANOLIND OIL & GAS COMPANY, INFORMATION RELEASED BY PAN AMERICAN PETROLEUM CORPORATION.
(5) DETAILED SURFACE GEOLOGIC STUDIES MADE BY MAURICE D. VEATCH, 1962-1963.
Permian — Cretaceous Unconformity
Top picked from electric log. Source (4).
Structural datum
Topography
Structural control picked from electric log. Source (4).
Key to Lithology
A4-1-24bad, 1424 (a)
Permian - Chase Group (Shale & Limestone)