CEMENTED SLOPE AND TERRACE DEPOSITS OF CENOZOIC AGE IN WESTERN MARION COUNTY, KANSAS

by

JOHN LYSLE RUSSELL

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Major Professor

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INTRODUCTION

General Discussion

The presence of coarse clastic rocks of Cenozoic age in the western one-half of Marion County, Kansas had been noted previously. Byrne and others (1959, p. 85) observed their presence near Hillsboro and correlated them with the Sanborn formation. Williams and Lohman (1949, p. 60) recognized their occurrence near Durham and noted their similarity to the so-called "Abilene conglomerate."

During the course of this investigation 37 outcrops of cemented deposits were observed in the western one-half of Marion County. These discontinuous sandstones and conglomerates have many similarities; 1) their geographic distribution is a north-south trending belt across the area investigated, 2) the deposits are closely aligned with the present drainage patterns, 3) they are primarily of a fluvial origin but may also include some colluvium, and 4) they are petrologically similar. The cementation is primarily by calcium carbonate. The detrital components can be categorized as; A) quartz-feldspar sand, B) "ironstone" fragments of sand- to cobble-size, C) locally derived limestone and shale fragments of granule- to cobble-size, D) pebbles and cobbles of metaquartzite, chalcedony, chert, and silicified wood. The detrital components indicate at least partial derivation from the west.

The distribution of outcrop altitudes, and the use of current (inclined) bedding as an indicator of the direction of flow during deposition suggests an eastward direction of drainage at the time of deposition. This supports Seevers' and Jungmann's (1963, p. 394) suggestion that the Cottonwood River may have breached the Flint Hills divide in pre-Kansan time.

Most of the cemented deposits overlie the Wellington shale with profound unconformity. Deposition of the materials investigated was, for the most part, the first evidence of Cenozoic deposition in western Marion County. Many of these deposits are overlain by terrace-like silts and sands. Subsequent degradation and dissection have left the cemented materials as isolated remnants along the present drainage system.

Correlation of the cemented deposits can not be unequivocally established at the present. However, similar deposits have been observed in Dickinson, Harvey, Saline, and Sedgwick Counties.

As an incidental result of this investigation two outcrops of volcanic ash were discovered in western Marion County. These outcrops are the first outcrops of volcanic ash noted in Marion County. The age of the volcanic ash deposits has not been established.

Purpose of Investigation

The purpose of this investigation was to determine the physical properties, distribution, and environment of deposition of the cemented deposits of Cenozoic age in western Marion County, Kansas. From this information it was desired to correlate these deposits with other cemented deposits in central Kansas.

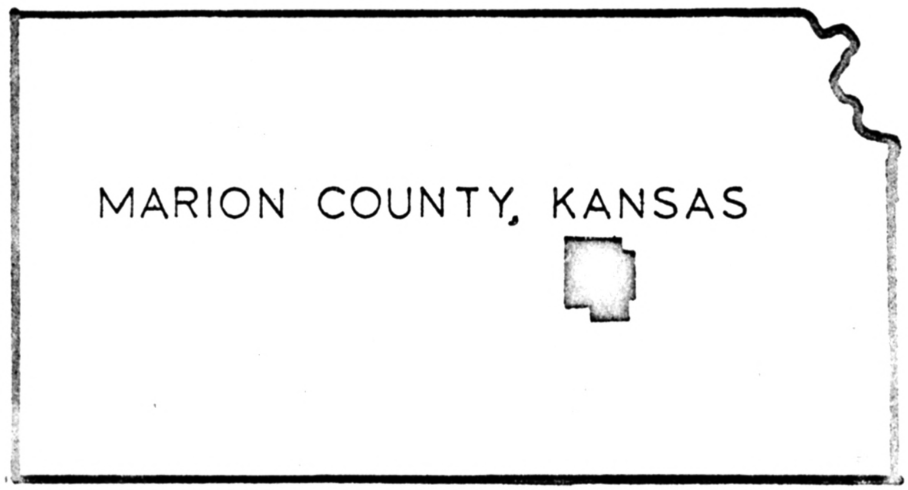
Location of Area

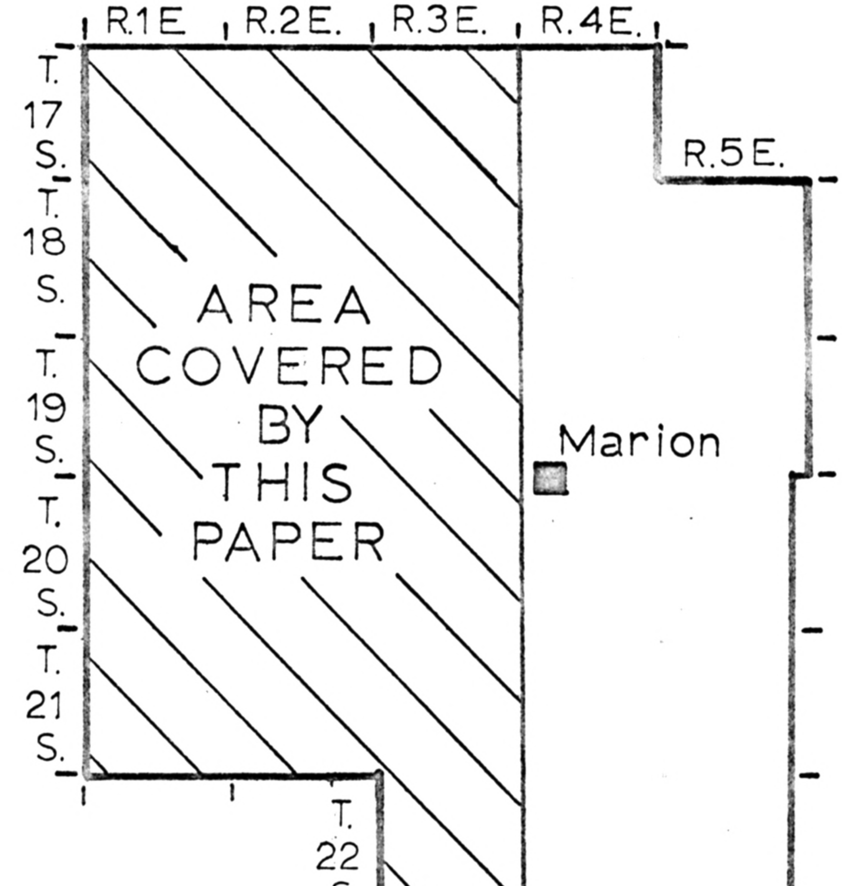
The area of investigation is that part of Marion County west of the north-south line separating Township three East from Township four East (Plate I). The area is bounded on the west by McPherson County, on the

EXPLANATION OF PLATE I

Map showing location of area of investigation.

PLATE I


MARION COUNTY, KANSAS


R.1E.
R.2E.
R.3E.
R.4E.
R.5E.
T. 17 S.
T. 18 S.
T. 19 S.
T. 20 S.
T. 21 S.
T. 22 S.
AREA COVERED BY THIS PAPER
Marion

north by Dickinson County, on the south by Harvey and Butler Counties, and on the east by the west boundary of Township four East. The region has an area of approximately 576 square miles.

Geography of Area

Climate.--The climate of the area is of a humid continental (warm summer phase) type. The summers are relatively hot and relatively long, and winters are fairly cold and short. The mean annual temperature is 56°F. and the monthly temperature range from a low of 20°F. in January to a high of 80°F. in July. The normal annual precipitation is 30.13 inches per year (Flora, 1948).

Drainage.--The drainage of the area is mostly within the Cottonwood River watershed (Plate V). The two major streams are the North Cottonwood and South Cottonwood Rivers which join to form the Cottonwood River three miles northwest of Marion. The North Cottonwood River drains much of the northern half of the area and flows southeastward to its confluence with the South Cottonwood River. French Creek is an important eastward flowing tributary to the North Cottonwood River. The South Cottonwood River drains much of the west-central portion of the area and flows eastward to its junction with the North Cottonwood River. Antelope Creek is an important tributary to the South Cottonwood River. Mud Creek drains much of the northeastern portion of the area and flows southward into the Cottonwood River at the southern city limits of Marion. Spring Branch Creek and Catlin Creek flow eastward to join the Cottonwood River east of the area of investigation. Doyle Creek drains much of the southern portion of the area and joins the Cottonwood River east of the area near Florence.

Streams of minor importance that drain a small area on the southern and west-central perimeter of the area are the Whitewater River, Henry Creek, Sand Creek, and Emma Creek. These streams flow southward and are tributary to the Arkansas River system. The northern perimeter of the area is drained by Gypsum Creek, Turkey Creek, and Lyon Creek which flow northward, and are tributary to the Smoky Hill River.

Cultural Features.--The two major towns in the region are Peabody and Hillsboro. Other smaller towns or villages are Goessel, Lehigh, Aulne, Canada, Tampa, Durham, Pilsen, and Ramona.

A branch line of the Atchinson, Topeka, and Santa Fe Railroad extends southeastward through Peabody. A second branch line crosses westward through Hillsboro and Lehigh. A branch line of the Chicago, Rock Island, and Pacific Railroad crosses the area south-southwestward through Peabody.

The major black-top highways traversing the region are U.S. 50, U.S. 56, and K-15. Many county black-top roads also are present in the area; however, most section-line roads are graveled or graded earthen surface roads.

Geology and Geomorphology of Area

Physiographically, the area near Goessel, which is characterized by smooth to almost level relief developed on the deposits of the "McPherson formation," can be classified as the McPherson Lowland division of the Arkansas River Lowlands section, which is a division of the Central Lowlands Province. The area of low to moderate relief that is underlain by Permian rocks is classified as the Flint Hills Upland division of the Osage Plains section, which is also a division of the Central Lowlands Province. This includes the area of outcrop of the Odell shale, Nolans limestone, and Wellington formation. The area of moderate to high relief in northwestern Marion County that is underlain by Cretaceous rocks can be classified as an outlier of the Smoky Hills division of the Dissected High Plains section, which is a division of the Great Plains Province. This is a modification after Schowe (1949).

The oldest rocks exposed at the surface in western Marion County are of Permian age. Permian strata crop out in all but the northwest portion of the area where rocks of Cretaceous system are exposed at the surface. Deposits of Pleistocene age consisting of gravel, sand, silt, and clay overlie much of the older rock, as scattered erosional remnants, some as thick as 20 feet. Deposits of Recent age are present in the stream valleys and are thickest in the valleys of the larger streams (Byrne and others, 1959, p. 69). Sediments of Tertiary age have not been identified in western Marion County although they crop out immediately to the west in McPherson County as the Delmore formation of Pliocene age (Williams and Lohman, 1949, p. 57).

The oldest rock unit exposed in the area of investigation is the Odell shale which is overlain by the Nolans limestone. These rock units, which are in the Chase Group of Permian age, are exposed along the extreme eastern boundary of Townships 19, 20, 21, and 22 South, Range 3 East. The topography of this area is moderately rugged with moderate relief.

In much of the area studied the Wellington formation of the Sumner Group of Permian age crops out. The Wellington formation consists primarily of clayey, silty, gray shale, with interbedded limestone and gypsum. Two persistent limestone members and one gypsum member of the Wellington formation were identified by Ver Wiebe (1937, p. 4, 5). The Hollenberg limestone member is about eight feet thick and occurs approximately 40 feet above the base of the formation.

The Hollenberg limestone member is exposed in a typical outcrop in the SE¼, SE¼, Sec.34, T.19S., R.3E. The Annelly Gypsum member is a series of interbedded gypsum lentils and dark-gray, thin-bedded shale beds near the center of the Wellington formation. An excellent outcrop of the Annelly Gypsum member is in the NW¼, NW¼, Sec.19, T.20S., R.2E. The Carlton limestone member is a thin-bedded to platy, argillacous limestone interbedded with calcareous shale. An excellent exposure of the Carlton limestone member of the Wellington shale is in the SE¼, NE¼, Sec.30, T.19S., R.2E. At this locality, a thin oolitic limestone is present and salt crystal molds are also present. The lower 450 feet of the Wellington formation crops out in Marion County (Byrne and others, 1959, p. 78).

Much of the area underlain by the Wellington formation is rolling with a few subdued terraces developed on beds of limestones. Few good natural exposures are present in the area of outcrop of the Wellington shales. This can be attributed to the weak resistance of the shales to erosion and to the low relief of the area.

Minor structures are present locally in the Wellington formation. The small scale deformation is caused by the solution of salt, anhydrite, and gypsum interbedded within the shales and by volume changes associated with anhydrite-gypsum transformations. An excellent exposure of this phenomena occurs at the locality cited above for the Annelly Gypsum member of the Wellington formation.

Triassic and Jurassic rocks are not present in the area and rocks of

Cretaceous age unconformably overlie rocks of Permian age. The unconformity is exposed in the NW¼, NW¼, Sec.4, T.19S., R.1E.

Rocks of Cretaceous age crop out in northwestern Marion County. Outcrops are present in the area just south of Lehigh and northward. The Cretaceous System of Marion County is represented by the Iowa shale and Dakota sandstone. The lithologies are a complex series of clayey, silty, and sandy shales interbedded with highly irregularily sandstone bodies. The sandstones are poorly to well cemented by calcite or ferruginous material. Lignite and bentonitic clay may be found locally.

The rocks of Cretaceous age underlie an area that is very rugged with high relief in the extreme northwestern corner of Marion County. The ruggedness of this area is caused by the dissection of the high plain of Marion County by a number of tributaries of Gypsum Creek with relatively high gradients flowing to the northwest. This area has steep hills capped by resistant sandstones. A waterfall with a drop of 15 feet is in the SE¼, SE¼, Sec.5, T.17S., R.1E. Near Lehigh, and west of Durham, the topography developed on Cretaceous rocks is much more subdued into low rolling hills with moderate to low relief.

The Quaternary System is represented by deposits throughout the region of western Marion County. According to Byrne and others (1959, p. 84), the water-lain gravel, sand, silt, and clay deposits near the McPherson County boundary close to Goessel are the oldest deposits of Quaternary age in the region. These sediments represent the eastern perimeter of the extensive McPherson valley alluvial fill of early Pleistocene age. These deposits were originally classified as the McPherson formation (Williams and Lohman, 1949, p. 59), but Byrne and others (1959, p. 84) classified them within the

Sanborn formation. They also classified as Sanborn "wind, slope wash, and gravity deposits," exclusive of terrace deposits of the major streams and Recent alluvium. Many scattered erosional remnants of silt and sand as thick as 20 feet are present over much of the area. These deposits may be remnants of a much more extensive thin, eastward extension of sediments of McPherson valley derivation.

Most major streams have moderately extensive terrace deposits but the surface expression is poor or lacking. The terrace sequence is unknown. Deposits of Recent age are present in the stream valleys and are thickest in the valleys of the larger streams.

Drainage History of Area

Frye and Leonard (1952, p. 181, 182) suggest that during the Tertiary the Flint Hills became a major drainage divide separating two contrasting depositional provinces. The western of these two provinces discharged drainage southward from Kansas into Oklahoma, and the eastern province discharged its drainage eastward into Missouri. The western depositional province was characterized by coarse, clastics derived predominantly from a western, granitic source and from local bedrock. The eastern depositional province was characterized by chert gravels derived from the Permian limestones of the Flint Hills. Frye and Leonard (1952, p. 189) also state that the Flint Hills formed an effective barrier between these two depositional provinces until after the retreat of the Kansan glacier.

Seevers and Jungmann (1963, p. 394) suggest that the Cottonwood River may have been an exception to the above generalization, and may have breached the Flint Hills divide in late Tertiary time. This is suggested by the occurrence of Cretaceous-derived quartzose sand in terrace deposits of pre-Kansan age along the lower Cottonwood River.

The drainage of western Marion County probably discharged to the west during much of Tertiary time. This is indicated by the presence of chert fragments in basal Cenozoic deposits of the area. Their derivation is thought to have been from Permian limestones to the east during Tertiary time and later reworked and incorporated into deposits of younger, eastward flowing streams.

The breaching of the Flint Hills divide by the Cottonwood River, probably occurred in late Tertiary or early Pleistocene time. The Cottonwood River then expanded its drainage area progressively westward throughout most of western Marion County. This headward encroachment was easily accomplished because of the weakly resistant nature of the bedrock and of the overlying superficial deposits in the area.

Previous Investigations

The exposures investigated have been commonly called the "Abilene conglomerate" because of their similarity to conglomeratic deposits exposed on Turkey Creek south of its junction with the Smoky Hill River near Abilene. The conglomeratic deposits on Turkey Creek were first noted by Meek and Hayden (1859, p. 16) who traversed central Kansas in two directions and compiled a general stratigraphic sequence in the area. Their description of the conglomeratic deposits is given below.

> 9. Rough conglomerated mass, composed of fragments of magnesian limestone and sandstone, with sometimes a few quartz pebbles, cemented by calcareous and arenaceous matter; variable in thickness and probably local. Locality, south side of Smoky Hill River, ten or twelve miles below Solomon's Fork...seen, 18 feet.

The exact outcrop location mentioned by Meek and Hayden is not known, but several thick, conglomeratic outcrops along Turkey Creek that are easily accessible are mentioned below. In the SE¼, SW¼, Sec.34, T.13S., R.2E. a conglomerate forms a cliff about eight feet high just north of a bridge over Turkey Creek. It also outcrops in a farmer's feed lot just north of the county road. The total thickness exposed is slightly more than 15 feet. In the NW¼, SW¼, Sec.11, T.14S., R.2E. an outcrop of conglomerate approximately six feet thick is exposed in the west stream bank of Turkey Creek immediately south of a bridge. The conglomerate overlies Permian limestones and shales with abrupt unconformity.

The "Abilene conglomerate" was included within the Permian sequence of sedimentary rocks in central Kansas and was given formational rank by Prosser (1895, p. 797). Prosser's classification included the "Abilene conglomerate" between what is now recognized as the Nolans limestone and the Wellington formation.

Beede (1908-1909, p. 248-256) described and mapped the "Abilene conglomerate" Herington limestone, and Winfield limestone in the vicinity of Marion. The area he mapped includes a small portion of the eastern perimeter of the area included within the present investigation. Beede in his definition of the "Abilene conglomerate" states:

> The stratum to which this term is applied has not been correlated with certainty with the Abilene conglomerate... It is a calcareous, conglomerate, containing some sand and sandstone pebbles, near Abilene, where it seems to be considerably thicker than in the Herington-Marion region. In the field, no sand or sandstone was noted in the rock about Herington or Marion. It is a heavy, hard, perhaps dolomitic stone, composed of fragments of yellow, orange, and gray masses firmly united in a light-grey cementing material.

Beede's map shows that the outcrop of what he called the "Abilene conglomerate" is closely aligned with what is now classified as the Hollenberg limestone member of the Wellington formation. The Hollenberg exposed within the area of Beede's investigation is a dense, dolomitic limestone, often containing an intraformational breccia with light yellow or orange fragments within a light-grey matrix. The "Abilene conglomerate" Beede described and mapped is certainly not the same as the cemented deposits observed in the present investigation. Beede confused the brecciated zone of the Hollenberg with Prosser's (1895, p. 789) definition of the "Abilene conglomerate" on Turkey Creek which Prosser inaptly referred to as "calcareous conglomerate" and "conglomeratic limestone." With the above precedents, the "Abilene conglomerate," with its type locality somewhere on Turkey Creek, was referred to Permian age until 1920 when R. C. Moore (1920, footnote, p. 63) suggested:

> It appears that the so-called Abilene conglomerate...is in reality a Tertiary deposit. It contains fragments of rock which apparently belong to Dakota sandstone, and at no point has it been observed in a stratigraphic position beneath the Wellington shale.

The term "Abilene conglomerate" was therefore removed from the Permian nomenclature of Kansas.

Ver Wiebe, in a letter noted in the "Lexicon of Geologic Names of the United States" (1957) mentioned, "Geologists of Wichita and other parts of Kansas are agreed as to the Tertiary age of Abilene Conglomerate." Although the term "Abilene conglomerate" is sometimes mentioned by geologists in reference to cemented deposits of central Kansas the term has fallen into disuse and ambiguity.

The most recent publication using the term is by Williams and Lohman (1949, p. 59-60). They state:

> Locally a conglomeratic bed occurs at the base of the older part of McPherson formation. It ranges from 1 to 6 feet in thickness and is composed of shale, quartz, and sandstone pebbles in varying proportions, cemented with impure calcium carbonate... The material in the

> conglomerate is similar to materials comprising the so-called Abilene conglomerate, a good exposure of which is located near the NW cor. sec.30, T.18S., R.2E., just east of the mapped area. It is believed that at various outcrops the beds which have been called the Abilene conglomerate may represent different ages; hence the "Abilene" may not have much stratigraphic significance. The conglomerate at the base of the McPherson in this area, however, may be equivalent to some exposures of the "Abilene conglomerate" in Dickinson County.

The outcrop of "Abilene conglomerate" mentioned above by Williams and Lohman is outcrop location 14 of this investigation.

Cemented deposits similar in appearance to those in western Marion County have been observed in Dickinson, Harvey, Saline, and Sedgwick Counties. Unfortunately little mention of these deposits is found in the literature. An exposure near Turkey Creek in Dickinson County in a quarry (SW¼, Sec.35, T.15E., R.2E.) is especially significant in that it is overlain by a silty clay with a molluscan fauna and by volcanic ash (Frye and others, 1948, p. 510, 515). Frye and others (1948, p. 522) classify the conglomeratic material as within the Grand Island member of the Meade formation. This would date the conglomeratic deposits as late Kansan. This correlation is especially important because outcrop locations 23 and 35 of this investigation are associated with Turkey Creek drainage. These two outcrop locations, the exposure in the quarry which is overlain by volcanic ash and a molluscan fauna which have been assigned a late Kansan age, and the numerous other exposures of conglomeratic materials along Turkey Creek may comprise a system of terrace remnants of fluvial sands and gravels of late Kansan age that have been subsequently cemented.

A brief description of the geology of Marion County was made by Byrne and others (1959) in particular reference to the construction material resources available in Marion County. Included with their report was a map showing the distribution of the surficial geologic deposits of Marion County.

Byrne and others (op. cit.) divided the Quaternary deposits of Marion County into three parts as follows, from youngest to oldest: alluvium, terrace deposits, and the Sanborn formation. The cemented deposits considered in this investigation are included within the Sanborn formation by Byrne and others (1959, p. 85). They list as a representative section of the Sanborn formation the same outcrop location as number nine of this investigation. Their work was mostly descriptive with little emphasis on interpretation.

Methods of Investigation

This investigation was conducted during a period from approximately 1962 to 1967. Field investigations consisted of locating and measuring sections of the cemented deposits, the determination of outcrop altitudes, hand augering to determine depths of concealed contacts, and hand dug observation pits. All county and state roads were traversed for the purpose of locating the deposits.

Aerial photographs and soil maps were used as aids in predicting outcrop occurrences. Only the extreme northern and southern perimeters of the region investigated were covered by detailed topographic maps.

Laboratory investigations consisted of analyzing 20 thin-sections cut from samples of the cemented materials, 9 thin-sections cut from pebbles and cobbles contained in the cemented deposits, and several insoluble residues of selected sandstone samples. The insoluble residues were obtained after treatment of the rock with dilute, cold, hydrochloric acid until effervesence was no longer visible.

The thin-sections were used in determining the mineralogy of the detrital constituents and the cementation of the deposits. Insoluble residues were observed with a binocular microscope to determine the mineralogy of the detrital components and check for the existence of microfossils.

DESCRIPTION OF DEPOSITS

General Description

Areal Distribution.--Thirty-seven outcrops of cemented sand and gravel deposits of Cenozoic age were observed. These outcrops are distributed in a north-south trending "belt" across western Marion County. On Plate V the outcrop locations are plotted on the township grid system. Outcrops were assigned a number from 1 to 37. Table 1 is a listing of the outcrop location numbers, representative altitudes of the outcrops, legal descriptions, and the nature of the exposures. Throughout the remainder of this paper an outcrop location number will refer to the location listed on Table 1 and plotted on Plate V.

All of the outcrops are within a north-south trending "belt" which corresponds to the tier of townships within the limits of R.2E. except six outcrops. Two of the exceptions are west of Peabody on small tributaries to Doyle Creek. These two locations, numbers one and two, are the easternmost outcrops investigated. Another exception is outcrop 37 east of Goessel which occurs on a tributary to South Cottonwood River. This outcrop is the westernmost outcrop observed. The remaining three exceptions are outcrop numbers 8, 10, and 26, which are on tributaries to the South Cottonwood River near the eastern extremity of T.20S., R.1E.

Outcrops are not abundant in any localized area with the exception of two areas south and west of Durham. Outcrops occur from the Harvey County boundary northward to Dickinson County. On Plate V two clusters of outcrop localities occur south and west of Durham. One cluster occurs in sections 19, 20, and 30 of T.18S., R.2E. Outcrops 14, 15, 16, and 17 occur

Table 1: Outcrop Locations

Location Number	Altitude	Legal Description	Nature of Exposure
1	1349	N. Line, NW¼, NW¼, Sec.11 - 22 - 3	Road ditch and backslope
2	1360	S. Line, SW¼, SE¼, Sec.2 - 22 - 3	Road ditch and backslope
3	1437	W. Line, NW¼, NW¼, SW¼, Sec.34 - 21 - 2	Road ditch
4	1488	NE¼, NW¼, NW¼, Sec.29 - 21 - 2	Road backslope and stream cut
5	1401	W. Line, NW¼, NW¼, SW¼, Sec.34 - 20 - 2	Road backslope
6	1480	W. Line, NW¼, SW¼, SW¼, Sec.8 - 21 - 2	Road backslope
7	1409	W. Line, NW¼, SW¼, SW¼, Sec.24 - 20 - 1	Road backslope
8	1441	S. Line, SE¼, SE¼, SW¼, Sec.24 - 20 - 1	Road ditch and backslope
9	1413	NW¼, NE¼, NW¼, Sec.19 - 20 - 2	Stream cut
10	1418	S. Line, SW¼, SE¼, Sec.12 - 20 - 1	Road ditch and backslope
11	1385	NW¼, NW¼, SW¼, Sec.27 - 20 - 2	Channel change
12	1431	W. Line, NW¼, SW¼, SW¼, Sec.20 - 19 - 2	Road backslope
13	1397	SW¼, SW¼, SW¼, Sec.16 - 19 - 2	Channel change
14	1419	NW¼, NW¼, NW¼, Sec.30 - 18 - 2	Stream cut
15	1398	SE¼, NW¼, Sec.19 - 18 - 2	Railroad cut

Table 1 (continued)

Location Number	Altitude	Legal Description	Nature of Exposure
16	1384	SW¼, SW¼, NW¼, Sec.20 - 18 - 2	Stream cut
17	1398	NE¼, NW¼, Sec.20 - 18 - 2	Railroad cut
18	1391	SW¼, NW¼, NE¼, Sec.16 - 18 - 2	Stream cut
19	1420	SE¼, SW¼, Sec.11 - 18 - 2	Outcrop destroyed
20	1412	SW¼, SE¼, SE¼, Sec.11 - 18 - 2	Stream cut
21	1411	SE¼, NE¼, NW¼, Sec.14 - 18 - 2	Ridge top
22	1363	NW¼, Sec.25 - 18 - 2	Road backslope
23	1445	SE¼, SE¼, SE¼, Sec.12 - 17 - 2	Stream cut
24	1493	E. Line, SE¼, NE¼, NE¼, Sec.30 - 21 - 2	Road ditch
25	1418	W. Line, NW¼, SW¼, NW¼, Sec.19 - 20 - 2	Road backslope
26	1456	S. Line, SW¼, SE¼, SW¼, Sec.1 - 20 - 1	Road ditch
27	1380	SW¼, NW¼, NW¼, Sec.3 - 19 - 2	Stream cut
28	1416	S. Line, SW¼, SE¼, SE¼, Sec.31 - 18 - 2	Road backslope
29	1413	N. Line, NW¼, NW¼, NW¼, Sec.5 - 19 - 2	Road ditch and backslope
30	1415	S. Line, NW¼, NE¼, NE¼, Sec.19 - 19 - 2	Road backslope

Table 1 (continued)

Location Number	Altitude	Legal Description	Nature of Exposure
31	1415	SW¼, SW¼, SW¼, Sec.5 - 19 - 2	Stream cut
32	1409	W. Line, NW¼, SW¼, NW¼, Sec.5 - 19 - 2	Road backslope
33	1409	SE¼, SE¼, NE¼, Sec.6 - 19 - 2	Stream cut
34	1416	SE¼n NW¼, Sec.18 - 19 - 2	Stream cut
35	1315	NW. Corner, NW¼, NW¼, NE¼, Sec.3 - 17 - 2	Stream cut
36	1375	SE¼, NE¼, NW¼, Sec.17 - 20 - 2	Gravel pit
37	1531	SE¼, SE¼, SE¼, Sec.4 - 21 - 1	Stream cut

within this area on a tributary to North Cottonwood River. The second cluster occurs in section 31 of T.18S., R.2E., and in sections 5 and 6 of T.19S., R.2E. Outcrops 28, 29, 31, 32, and 33 occur within this area, also on a tributary to North Cottonwood River. In both of the above areas more outcrops occur than are described in this paper. Only the more accessible and distinctive outcrops are listed.

The two areas south and west of Durham contain many outcrops which are certainly part of a sedimentary complex developed on tributaries to North Cottonwood River. Within each of the two areas the outcrops may be integrated into a recognizable sequence. However, the highly discontinuous, lenticular nature of the cemented deposits and the lack of good outcrops makes correlation difficult if not impossible except over distances of less than several hundred feet. Drill holes would be needed to adequately delineate the lateral extent and the relationships of the cemented deposits and provide a basis for a workable depositional sequence within restricted areas.

Outcrops are singular entities with the exception of the above two areas near Durham. Lateral continuity is lacking at all outcrop localities observed. The cemented deposits are usually continuous over only a few acres.

The sandstones and conglomerates described, crop out rather poorly throughout all of the region. The majority of outcrops are not natural exposures but are man-made exposures such as in road ditches and backslopes, channel changes, and railroad cuts. The low resistance of the cemented deposits to weathering and erosion, the low relief of the area, and the original discontinuous nature of deposition and cementation are factors which limit outcrop distribution and quality. Only in areas where relief is pronounced, and the terrain dissected, do natural outcrops occur. Natural outcrops usually occur in the channels of intermittant streams or on the valley slopes of the larger streams.

The cemented deposits rarely exhibit any topographic expression. Topographic expression observed consisted of a few badly dissected terraces hardly distinguishable from the surrounding terrain. A faint terrace expression was observed at location 21, east of Durham. At no locality does the topographic expression of the cemented deposits cover more than a few acres.

One of the most outstanding features of the distribution of the cemented Cenozoic deposits in the western one-half of Marion County is the close association of outcrops to the present drainage patterns as shown on Plate V. This relationship can be explained in two ways. First, the association between the outcrop distribution and the present drainage system may not be real, but apparent. Dissection of the Cenozoic mantle by the present drainage may have afforded the only way which outcrops could be created. The distribution of outcrops should be a function of the erosional history of the area. Secondly, the distribution of outcrops is the true, not apparent, distribution. That is, the present outcrop distribution should closely parallel the original deposition. The latter explanation is more likely the correct interpretation. Outcrops of cemented deposits have not been observed in interstream divide areas, even where dissected, but are associated with terrace-like sediments which are closely aligned with the present drainage system. The drainage system of western Marion County probably was not radically different when the cemented sands and gravels and their enclosing terrace-like sediments were deposited than from the present.

Because of the close association of the outcrop localities with the present drainage, the outcrop locations can be categorized into watersheds. Plate II shows the watersheds and the distribution of outcrops within the area of investigation. The distribution of outcrop locations and altitudes among the watersheds is tabulated in Table 2. The outcrops are listed as to decreasing altitude within each watershed.

All of the outcrops are in the Cottonwood River drainage system with two exceptions. The exceptions are outcrop 35 on Turkey Creek at the extreme northern boundary of the area and outcrop 23 on a tributary to Turkey Creek two miles south of Tampa. These outcrops are the northernmost exposures of many deposits of cemented sands and gravels present along the course of Turkey Creek to its junction with the Smoky Hill River near Abilene.

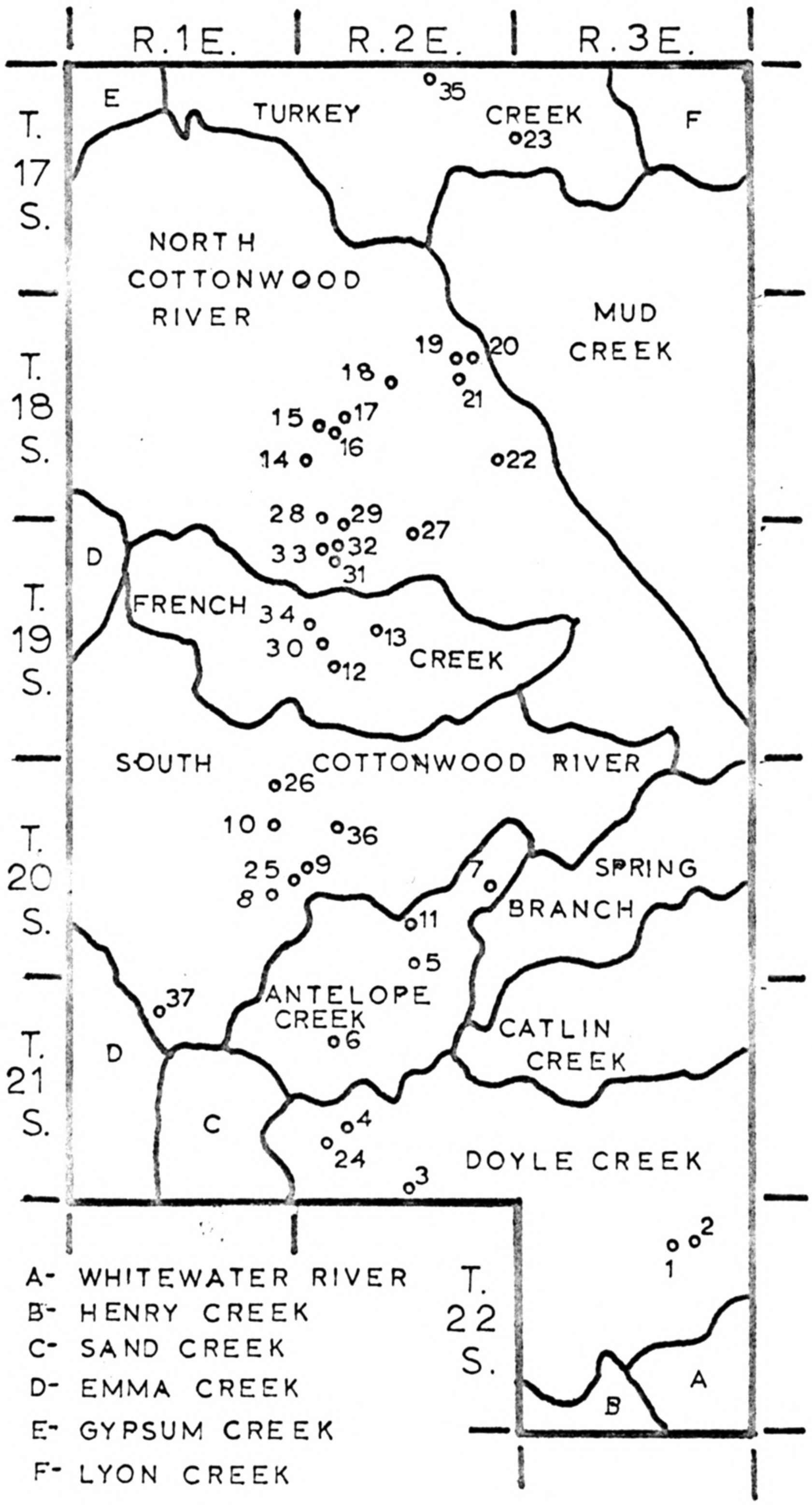
The remaining outcrop locations can be classified into five major watersheds within the Cottonwood River drainage system as determined by the association of the outcrop locations with the present drainage patterns. These five watersheds are, from south to north respectively: 1) the Doyle Creek watershed, 2) the Antelope Creek watershed, 3) the South Cottonwood River watershed, 4) the French Creek watershed, and 5) the North Cottonwood River watershed.

<u>Vertical Distribution</u>.--Altitudes of the outcrops were obtained by differential leveling from known points of altitude with one exception, locality 35, which altitude was read from a topographic map. The altitudes were taken on the tops of the outcropping cemented materials. It should be recognized that much vertical variation may occur at some outcrop locations.

EXPLANATION OF PLATE II

Map of the area of investigation showing the present watersheds and the location of outcrops.

PLATE II



R.1E.
R.2E.
R.3E.
T. 17 S.
T. 18 S.
T. 19 S.
T. 20 S.
T. 21 S.
T. 22 S.
E
F
TURKEY CREEK
NORTH COTTONWOOD RIVER
MUD CREEK
D
FRENCH CREEK
SOUTH COTTONWOOD RIVER
SPRING BRANCH
ANTELOPE CREEK
CATLIN CREEK
D
C
DOYLE CREEK
B
A
A- WHITEWATER RIVER
B- HENRY CREEK
C- SAND CREEK
D- EMMA CREEK
E- GYPSUM CREEK
F- LYON CREEK

Table 2: Occurrence of Outcrop Locations Within Watersheds

<u>Doyle Creek Watershed</u>

Location Number 24	Altitude 1493
Location Number 4	Altitude 1488
Location Number 3	Altitude 1437
Location Number 2	Altitude 1360
Location Number 1	Altitude 1349

<u>Antelope Creek Watershed</u>

Location Number 6	Altitude 1480
Location Number 7	Altitude 1408
Location Number 5	Altitude 1401
Location Number 11	Altitude 1385

<u>South Cottonwood River Watershed</u>

Location Number 37	Altitude 1531
Location Number 26	Altitude 1456
Location Number 8	Altitude 1441
Location Number 10	Altitude 1418
Location Number 25	Altitude 1418
Location Number 9	Altitude 1413
Location Number 36	Altitude 1375

<u>French Creek Watershed</u>

Location Number 12	Altitude 1431
Location Number 34	Altitude 1416
Location Number 30	Altitude 1415
Location Number 13	Altitude 1397

<u>North Cottonwood River Watershed</u>

Location Number 19	Altitude 1420
Location Number 14	Altitude 1419
Location Number 28	Altitude 1416
Location Number 31	Altitude 1415
Location Number 29	Altitude 1413
Location Number 20	Altitude 1412
Location Number 21	Altitude 1411
Location Number 33	Altitude 1409
Location Number 32	Altitude 1409

Table 2 (continued)

North Cottonwood River Watershed (continued)

Location Number 17	Altitude 1398
Location Number 15	Altitude 1398
Location Number 18	Altitude 1391
Location Number 16	Altitude 1384
Location Number 27	Altitude 1380
Location Number 22	Altitude 1363

Turkey Creek Watershed

Location Number 23	Altitude 1445
Location Number 35	Altitude 1315

In some areas cemented sands and gravels may occur immediately above an inclined bedrock surface which may vary in altitude as much as 15 feet. Outcrops 2 and 13 have much vertical variation over a short lateral distance. In this respect they resemble slope-like deposits rather than terrace-like deposits.

In the southern half of the area some of the outcrops of cemented materials are actually multiple outcrops. In these outcrops several zones of cementation are present in a vertical sequence. These cemented sand and gravel lentils are often separated by silt or sandy silt. Altitudes of multiple outcrops were taken at the highest prominent cemented zone exposed. Outcrops 12, 16, and 18 are of the multiple outcrop type.

Altitudes of outcrops vary from a minimum of 1315 feet above sea level at locality 35 near the northern boundary of the area of investigation, to 1531 feet above sea level at locality 37 east of Goessel. The variation of outcrop altitudes is difficult to evaluate because of the lack of topographic map coverage for most of the area, however, several trends are evident. First, the altitudes of the outcrops within any given watershed increase in the direction headward for the existing major stream and its tributaries. The altitudes of the outcrops located near the major collector streams are lower than the altitudes of outcrops located on their tributaries. The altitudes of the outcrops along any given tributary or collector stream decrease downstream. This is correlative with the fact the cemented deposits are phases of terrace-like sediments which are closely associated with the present drainage patterns.

Two outcrops seemingly violate this general pattern. One of the exceptions is outcrop two, east of Peabody on a tributary to Doyle Creek. The altitude of outcrop two is 1360 feet above sea level while the altitude of outcrop one, which is located on another tributary to Doyle Creek, west of outcrop two, is 1349 feet above sea level. The altitude of outcrop two would seem to be anomalously high. This can be explained in two possible ways. First, outcrop two has a great vertical variation in altitude over a short lateral distance as has been noted before on page 28. Cemented sands and gravels lie directly on a steeply inclined bedrock surface and may actually be of colluvial nature rather than terrace-like. Secondly, both outcrops one and two are on north-flowing tributaries to Doyle Creek. At the time of deposition of the sands and gravels the tributary on which outcrop two is located possibly had a steeper gradient than the tributary on which outcrop one was deposited. This would account for the higher altitude of outcrop two.

Another exception to the generalized pattern of altitudes increasing headward within the individual watersheds is outcrop seven on the South Cottonwood River southeast of Hillsboro, at an altitude of 1409 above sea level. The outcrop occurs on a bluff overlooking the valley of the South Cottonwood River. The cemented sands and gravels comprising the outcrop lie unconformably on calcareous shales of the Wellington formation. The anomalous altitude of this outcrop may also be related to deposition by a tributary which had an exceptionally steep gradient.

Another generalized trend is observed by noting the outcrop altitude distribution, is the close similarity of altitudes of the outcrops in a north-south direction across the area of investigation. The significance of this roughly concordant nature of the north-south distribution of altitudes is not known.

Reconstruction of possible stream gradients which existed during the deposition of the sediments that have been subsequently cemented is difficult. A reasonably accurate gradient can only be constructed when sedimentation occurs within a small time interval at points representing the depositional contimuum along the existing stream during the prescribed time interval. The collection of points used for the reconstruction of paleo-gradient can not include locations which occur along several independent tributaries and the main stream. At the present no suite of outcrop locations fulfill the above qualifications for the reconstruction of a paleo-gradient.

Lithologic Description.--One of the major similarities of the cemented deposits in the western one-half of Marion County is the similarity of gross lithology. The rock lithology can be described as varying from a sandstone, to a conglomerate. This variation exists both vertically and laterally in many outcrops. All gradations between conglomerate and sandstone exist. Conglomerate and sandstone end-members are rarely present. The conglomeratic outcrops are usually pebble conglomerates but cobbles may also be present in much smaller amounts. The conglomerates examined in this investigation can be classified as the petromict or lithic conglomerates of Pettijohn (1957, p. 257). The overall lithology of the sandstones can be described as the protoquarzites and subarkoses of Pettijohn (1957, p. 291). The sandstones are medium to very coarse grained. The cement of the conglomerates and sandstones is predominantly calcium carbonate.

The detrital components of these conglomerates and sandstones can be divided into the following four major categories: 1) subrounded to well-rounded quartz and feldspar detritus. These fragments are predominantly sand size but do reach pebble size in some outcrops. This detrital fraction comprises the bulk of the protoquartzitic and subarkosic sandstones. 2) Sand to cobble-size fragments of rounded to well-rounded "ironstone." "Ironstone" is a term that designates limonitic and hematitic cemented or stained, very fine grained sandstones and/or fragments of limonitic and hematitic concretions. 3) Angular granules, pebbles, and cobbles of locally derived shale and limestone. This fraction comprises the bulk of the lithic conglomerates and is most commonly of pebble size. 4) Well-rounded and often polished metaquartzite, chalcedony, some chert, and petrified (silicified) wood clasts of pebble to cobble-size. This detrital fraction is locally present in small amounts.

Table 3 lists the rock types of nine pebbles and cobbles which were obtained from five outcrops and which were thin-sectioned. Samples 29-2 and 4-2 are "ironstone" clasts. The remaining cobbles are of metaquartzites, chalcedony, and chert. They are classified in category 4) above.

The first detrital category consists primarily of subrounded quartz and feldspar sand-size fragments. Quartz is dominant over feldspar, comprising over 85 percent of this detrital category. The quartz-feldspar sand was probably derived primarily from the reworking of arenaceous sediments to the west of the area of investigation. The sources were probably pre-existing sands contained within the Pleistocene and/or late Tertiary sediments that were deposited as part of the "McPherson Valley" complex and/or from the reworking of sand derived from the erosion of arenaceous Cretaceous age sediments.

The second detrital category consists of "ironstone" fragments. The "ironstone" fragments vary from sand to cobble-size and are present in all

Table 3: Lithologies of Nine Pebbles and Cobbles Thin-sectioned

Sample no.	Outcrop no.	Maximum diameter	Rock lithology, remarks
1-2	1	66mm.	metaquartzite, low grade
1-3	1	58mm.	metaquartzite, low grade
4-2	4	78mm.	"ironstone," ferruginuous sandstone
8-2	8	86mm.	metaquartzite, low grade
9-2	9	79mm.	metaquartzite, low grade
9-3	9	84mm.	metaquartzite, low grade
9-4	9	57mm.	chert
9-5	9	80mm.	chalcedony
29-2	29	63mm.	"ironstone," orthoquartzitic sandstone, hematitic grain coatings

outcrops. Much variation of size of "ironstone" fragments may occur within any given outcrop. Often sand, granule, pebble, and cobble-size fragments of "ironstone" are present in the same outcrop. These fragments were probably derived from Cretaceous age rocks which were present to the north and west of the outcrop area of the cemented deposits under investigation. Although "ironstone" fragments are present in all outcrops observed their relative abundance is greatest in the outcrops observed in the northern portion of the area.

The three constituents, quartz, feldspar, and "ironstone" comprise the bulk of the detrital material found in the protoquartzitic and subarkosic sandstones.

The third category is composed of angular granules, pebbles, and cobbles of locally derived shale and limestone. The Wellington formation of Permian age was the predominant source of this detritus. The angular clasts which are found in the conglomeratic sandstones and conglomerates have lithologies similar to the silty shales and clayey shales of the Wellington formation. The angular limestone clasts are similar in lithology to the argillaceous limestones of the Carlton limestone member of the Wellington formation and to many minor, thin, argillaceous limestone lentils present in the Wellington formation.

The fourth detrital category is comprised of well-rounded and often polished pebbles and cobbles of resistant rock types. These are not abundant in any outcrop and decrease in relative abundance in the cemented deposits present in the northern one-half of the area of investigation. They do not comprise more than two percent of the total rock mass at any outcrop. Metaquartzite, chalcedony, chert, and petrified (silicified) wood are present, in that order of decreasing relative abundance. Metaquartzite clasts outnumber all of the remaining rock types combined.

The source area(s) of these well-rounded, resistant clasts can not be ascertained. However, they may have been derived from one, or from several sources. Several likely sources are basal Cretaceous "gravels" and pre-existing Tertiary or early Pleistocene(?) deposits. The first alternative is the pebbles and cobbles may have been derived from basal Cretaceous "gravels" known to occur as discontinuous channel deposits at the Cretaceous-Permian unconformity in Kansas. These "gravels" are composed of rock types similar to those present in the sandstones and conglomerates investigated. Where the unconformity is exposed in northwestern Marion County no basal Cretaceous gravels were observed. However, the unconformity is concealed in southwestern Marion County and could possibly have contributed pebbles and cobbles of metaquartzite and the other observed resistant rock types present in the cemented deposits of Cenozoic age. Concentration of the resistant rock types could have occurred during post-Cretaceous time as the surface of western Marion County was degraded and the unconformity was weathered progressively downdip (to the west) releasing the resistant "gravels" and concentrating them on the erosion surface. The drainage at that time might not have then had sufficient competence to transport the "gravels" out of the area. These "lag gravels" of resistant rock types would then have been incorporated into the subsequently cemented deposits during a time of increased stream competency.

The second alternative is that the pebbles and cobbles could have been derived from pre-existing Tertiary or early Pleistocene(?) deposits possibly through preferential reworking and weathering. The deposition of the pebbles and cobbles in deposits that were subsequently cemented could be accomplished by processes similar to those described above for clasts of basal Cretaceous origin.

An unusual feature of the cemented deposits investigated is the occurrence of mature detrital components and immature detrital components together within most outcrops. Pettijohn (1957, p. 253) described mature gravels as mechanically durable and chemically inert, such as quartz, quartzite, and chert. Immature gravels have a low degree of mechanical durability and are not chemically inert. The well-rounded metaquartzite, chalcedony, chert, and silicified wood are highly mature materials which have been repeatedly reworked before deposition in the cemented deposits investigated. In contrast, the angular limestone and shale clasts which were locally derived from the Wellington formation are very immature. Certainly these materials could not have been transported more than a very short distance. The quartz-feldspar sand is of medium maturity. The co-existence of both highly mature and very immature materials should be considered in the reconstruction of the environment of deposition.

The presence of chert in these deposits is of special interest. The derivation of the chert could have occurred in several ways. First, some of the chert may have its origin in the basal Cretaceous gravels as described above (page 34). This chert is thought to be the well-rounded fragments with thick alteration rinds which are occasionally observed. However, much of the chert is not as badly weathered and is more angular. This chert may have had its origin in the cherty limestones of the Flint Hills to the east of the area of investigation. It may have been transported into the area during the Tertiary when the drainage may have been westward. It may have later been reworked and incorporated into the deposits considered in this paper when the drainage pattern was reversed to the east.

The cementation observed at all outcrop localities is predominantly calcium carbonate. Cementation is more-or-less complete and often varies in degree within any given outcrop. The porosity is usually high depending on the degree of cementation. It is not within the scope of this paper to attempt a detailed explanation of the genesis of the cementation and consolidation of the cemented sands and gravels of Cenozoic age in western Marion County. Two possible methods of cementation, or sources of cement are; 1) cementation by deposition of calcium carbonate from ground water, and 2) cementation by deposition of calcium carbonate through soil forming processes.

The first possible source of cementation is by the activity of ground water. Most of the outcrops of cemented materials lie directly on relatively impermeable Wellington shales. Ground water charged with calcium carbonate could move laterally above the shale and preferentially deposit calcite in the coarser clastic sediments that comprise the cemented materials. Evidence for this origin are outcrops that have a tendency to conform to the shale surface and the presence of calcitic box-work structures in the weathered shale immediately below the cemented sands and gravels. The source of calcium carbonate in solution could be the calcareous shales and thin argillaceous limestones of the lower Wellington formation and from calcareous silts and sandy silts overlying the cemented deposits.

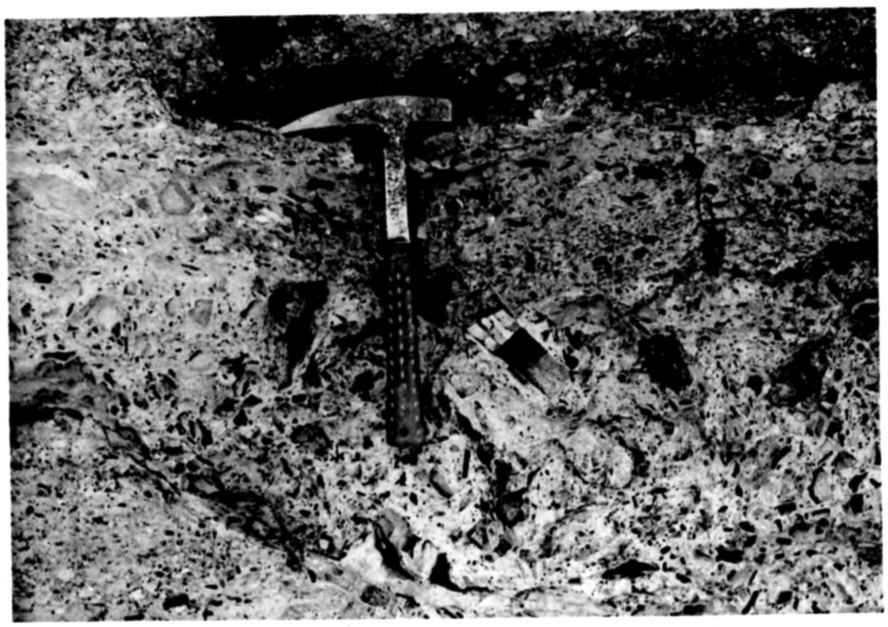
Case hardening (i.e., cementation of unconsolidated materials upon exposure to the atmosphere, principally through the deposition of calcium carbonate by evaporation of ground water charged with calcium carbonate upon contact to the atmosphere) has not been a significant factor in the cementation of most of the deposits observed in this investigation. Cementation by case hardening is unlikely as indicated by the following two observations. First, most outcrops are man-made rather than natural (see Table 1). The existence of cemented sands and gravels uncovered at a depth of about 20 feet below ground level in a sand pit in the SE¼, NE¼, NW¼, Sec.17, T.20S., R.2E. (i.e., outcrop location 36) is an extreme example. Case hardening has not had a sufficient time to develop in these outcrops. Secondly, the nature of the cement observed at many localities is such that often conglomeratic outcrops contain casts of angular shale and argillaceous limestone fragments which have weathered to form a void in the rock (see Plate III). The void is often filled with residuum resulting from the weathering of the detrital fragment. These casts indicate that cementation occurred relatively early in the history of the rock and that case hardening is relatively unimportant.

The second possible source of cementation is by concentration of calcium carbonate by weathering and soil forming processes. At many outcrop locations the cemented sands and gravels are associated with silts and sandy silts that often contain abundant caliche. The caliche occurs as nodules or thin, discontinuous lenses of impure calcium carbonate disseminated throughout the silt and sandy silt. The process of calcification and associated caliche formation at shallow depth by soil processes in a continuously degrading profile as suggested by Bretz and Horberg (1949, p. 508) or by soil processes in a continuously aggrading profile as suggested by Brown (1956, p. 11) may be partially responsible for the cementation of the deposits investigated in western Marion County. Consolidation and

EXPLANATION OF PLATE III

A close view of shale and limestone casts in conglomeratic sandstone at outcrop location 14.

PLATE III



cementation of the terrace-like deposits of sand and gravel must have occurred at a shallow depth, probably less than a few tens of feet.

Paleontology.--No fossils were observed in the cemented sands and gravels. All outcrops were examined for megascopic fossils and selected samples were examined without treatment under a binocular microscope for microfossils. Several insoluble residues obtained by treatment of selected samples with ten percent HCl failed to reveal any microfossils upon observation with a binocular microscope.

The lack of fossils can be attributed to: 1) A primary lack of fossils. That is, no organic material was preserved at the time of deposition. 2) Post-depositional processes may have destroyed pre-existing fossils. The absence of fossils in the deposits investigated may be related to one or both of the above factors. Leaching by the action of infiltrating water and ground water may be an important process in the destruction of fossils. The occurrence of abundant caliche nodules and thin layers indicates that much leaching has taken place. Gastropod and pelecypod shells would be particularly susceptible to leaching.

Although no fossils were observed in the cemented materials investigated, at four outcrop localities sandy silts associated with the cemented deposits contain a few gastropod and pelecypod fossils. These fossils indicate a fluvial environment of deposition of their enclosing sediments. Unfortunately the stratigraphic relationships could not be ascertained without drill holes. The outcrop locations at which the fossil bearing silts were observed are numbers 1, 7, 13, and 36. Vertebrate fossils were observed near outcrop 13 in a sandy silt. However the fossils were very fragmental and incomplete.

Vertical and Lateral Stratigraphic Associations.--The investigation of the stratigraphic associations of the cemented Cenozoic deposits of western Marion County was badly hampered by the poor outcrop exposures throughout much of the area of investigation. The lack of drill hole data and the lack of previous differentiation of the Cenozoic deposits within western Marion County also limited the determination of the stratigraphic associations of the cemented deposits.

The thickness of the outcrops observed varies from four feet to a featheredge. No orderly variation of thickness throughout the area of investigation was observed with the possible exception of greater thickness for conglomeratic outcrops than for outcrops of finer textured material.

The most outstanding feature of the vertical stratigraphic associations is the sharply disconformable basal contact of the cemented deposits. Most commonly the cemented sands and gravels overlie the Wellington formation of Permian age. The basal unconformity is abrupt where the cemented materials overlie the Wellington, and locally the unconformity can be angular because of small-scale deformation of the Wellington formation produced by solution and volume change of evaporites. Outcrop location nine has well developed small-scale folding in interbedded shale and gypsum of the Wellington which is truncated with abrupt angular unconformity and overlain by a conglomeratic sandstone of Cenozoic age. The small-scale deformation of the Wellington formation by solution and volume changes associated with the presence of rock salt, rock gypsum, and rock anhydrite was essentially complete when the Cenozoic cemented materials were deposited. The cemented deposits are not deformed in conjunction with deformation of the Wellington formation in any outcrop.

Many outcrops which overlie Wellington shales have a basal layer up to two inches in thickness that contains abundant angular shale clasts. This layer rests on weathered and brecciated Wellington shale. The brecciated zone may attain a thickness of four inches. Often the underlying Wellington formation has been badly weathered. Zones of calcium carbonate and iron oxide accumulation in underlying, less calcareous shales and box-work structures in underlying calcareous shales indicate high degrees of weathering prior to, and during deposition of the subsequently cemented sediments. Outcrop location 31 has several zones of iron oxide accumulation at different depths below the Wellington conglomerate contact. This may be indicative of variations in weathering intensity. Outcrop location 33 has a well developed zone of calcium carbonate accumulation in the Wellington shale as does outcrop location 37. Outcrop location seven has well developed box-work structures present immediately below a cemented sand in calcareous shales of the Wellington formation.

Not all of the outcrops observed have cemented materials underlain by the Wellington formation. Outcrop location six has poorly cemented conglomeratic sandstone underlain by light gray, calcareous, arenaceous clay. Outcrop locations 12, 16, and 18 are multiple outcrops. These outcrops are typified by the occurrence of several lenticular, cemented sand beds within a sandy silt. The cemented sand lentils are usually less than 1.5 feet thick but may extend laterally for 5 to 50 feet. The basal contact of the cemented sand lentils appears to be unconformable.

The outcrops at which sediments can be observed to overlie cemented Cenozoic materials are few. Most of the outcrops are overlain by soil. The absence of overlying sediments may be related to non-deposition or subsequent removal by erosion. At the outcrop locations where overlying sediments are present the identification and correlation of the overlying sediments was not possible because of the lack of information that would substantiate differentiation of the sediments. Byrne and others (1959, p. 84-85) included these sediments within the Sanborn formation but did not differentiate the members of the Sanborn in their investigation. Several outcrop locations at which overlying sediments can be observed are locations 1, 11, and 13.

At location number one near Peabody, the cemented sands and gravels are overlain by silts, sands, and gravels of fluvial origin. These sediments contain large amounts of caliche, and are probably terrace deposits associated with Doyle Creek. Their fluvial origin is proven by the presence of fossil pelecypods and gastropods which are commonly associated with fluvial deposits.

Location number 11, south of Hillsboro, was recently exposed in a channel change for a bridge on a county road. The cemented sands and gravels are exposed over a lateral distance of several hundred feet. No appreciable thinning is evident within the outcrop exposure as the thickness is approximately three feet. These sandstones and conglomerates are overlain by approximately ten feet of dark reddish-brown silts and silty sand and several feet of soil.

Location number 13, north of Durham, is in a channel change. At this exposure, a sandstone to conglomeratic sandstone is overlain by approximately 3.5 feet of reddish-brown silt and very-fine sand. The silt and very-fine sand do not contain fossils at the outcrop of the cemented material, but several hundred yards to the north it was observed to contain pelecypod shell fragments probably of fluvial origin. The silt and very-fine sand are overlain by approximately two feet of dark brown silt comprising the soil profile.

Where observed, the contact between the overlying sediments and the cemented materials is more gradational and conformable than the basal contact. A depositional break, or diastem, may not occur between the cemented deposits and the overlying sediments at some outcrops.

Lateral variations are difficult to ascertain because of poor outcrop exposures and the lack of drill hole data. Lateral continuity is questionable over distances greater than several hundred feet. The cemented deposits are very lenticular and pinch out very rapidly. Outcrop locations 2 and 13 have much variation in altitude over short horizontal distances. These outcrops may represent slope deposits. They may include cemented colluvium resulting from creep or lubricated creep which interfingers with strictly fluvial deposits at a lower altitude.

Relation to Soil Types.--A useful tool that aided in the discovery of outcrop locations was a soils map of Marion County by Krobel and Lewis (1930). This map shows in detail (scale: one inch equals one mile) the distribution of 29 soil units in Marion County.

The geologic parent material is an important factor in soil genesis. The soil or soils developed on certain geologic-parent materials may sometimes be used to distinguish the distribution of the parent materials. This is certainly not infallible for other factors of soil genesis may limit or eliminate the factor of parent material as a cause of soil variation.

In western Marion County the distribution of soil types correlates well with the distribution of geologic parent materials. The soil types mapped by Krobel and Lewis in 1930 roughly delineate the distribution of the terrace-like sediments which may contain Cenozoic cemented sands and gravel. Of the 29 soil types mapped in Marion County only six soil types overlie the outcrops of cemented materials investigated. Thirty-three of the 37 outcrops investigated were overlain by soils representative of three soil types. The Goessel Clay Loam, the Sogn Silty Clay, and the Idana Silty Clay soil types overlie 89 percent of the outcrops of cemented materials investigated (Table 4). The Goessel Clay Loam soil covers only about five percent of the total area of the region investigated, while it overlies 49 percent of the outcrops of cemented materials investigated.

The Goessel Clay Loam and the Sogn Silty Clay soil types were particularly useful in this investigation as an aid in delineating terrace remnants and similar alluvial deposits. These soils have, for the greatest part, been derived from unconsolidated Pleistocene(?) deposits in western Marion County.

Color of the surficial deposits of western Marion County was an aid in delineating the geologic materials present where outcrops were not plentiful. Light to dark gray colors usually indicate the presence of the Wellington formation at shallow depths. Reddish-browns often indicate the existence of sandy silts and silty sands which comprise the bulk of the high level terrace-like deposits present in western Marion County. Very dark gray to black colors represent "Recent" terraces and alluvial floodplains. Most of the outcrops of cemented materials occur at the contact of the lighter colored bedrock materials and the reddish-brown terrace-like materials. The colors are well developed in areas of shallow soils and are often well displayed in plowed fields after a rain.

Table 4: Number of Outcrop Locations Overlain by Given Soil Types

Soil Type	No. of Localities
Goessel Clay Loam	18
Sogn Silty Clay	10
Idana Silty Clay	5
Goessel Sandy Loam	2
Verdigris Silty Clay	1
Goessel Silty Clay	1

Sedimentary Structures

The bedding thickness observed can be classified as thin to thick according to Ingram's classification (Ingram, 1954, p. 937-938). The bedding thickness is less for the less conglomeratic outcrops and for the outcrops which have better developed current bedding.

Primary Structures.--Primary or syngenetic sedimentary structures observed in the Cenozoic cemented sands and gravels of western Marion County consist of inclined or current bedding, possibly graded bedding, and post-depositional slumping. The most commonly observed primary structure is inclined or current bedding. Current bedding is poorly developed in many outcrops throughout the area of investigation. Plate IV, Figure 1 illustrates the typical appearance of the current bedding. The direction of current movement can be ascertained by observing the direction of inclination of the foreset beds. The direction of flow was in the same direction as the maximum downward inclination of the foreset beds. At all outcrops where current bedding was observed the inclination of the foreset beds indicates the flow during deposition was in the same direction as the present drainage.

Graded bedding may be present in some outcrops. Vertical variations in grain size are evident within some outcrops, but the variation is rarely persistent enough to warrant the distinction of graded bedding.

At outcrop location number 33 a post-depositional slump was observed, (Plate IV, Figure 2). The slump is of conglomeratic sandstone which occurs as a unbedded mass cutting downward across a sandstone which has well developed current bedding. No other deformational structures were observed.

EXPLANATION OF PLATE IV

Fig. 1: Inclined (current) bedding in outcrop 14. Current was from right to left.

Fig. 2: Post-deposition slump in outcrop 33.

PLATE IV

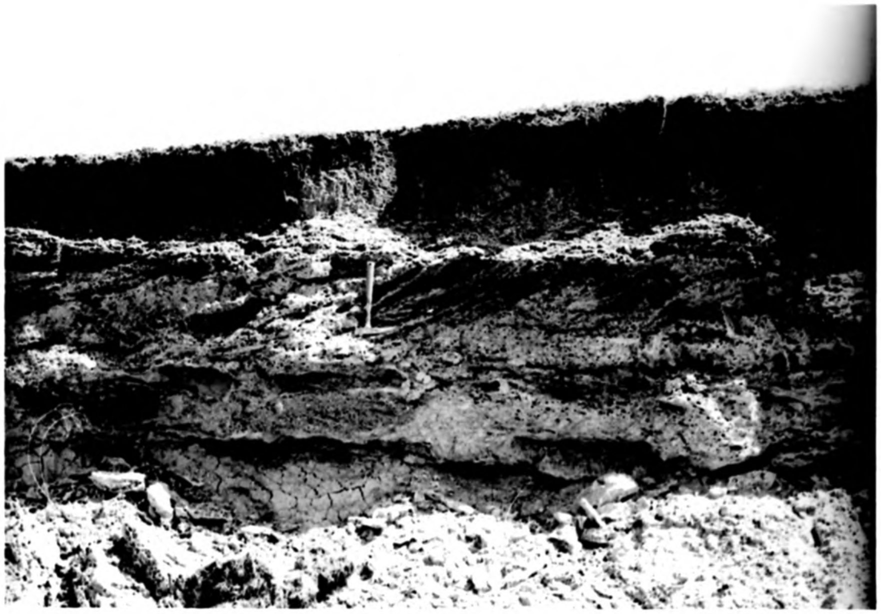


Fig. 1

Fig. 2

Secondary Structures.--Secondary or epigenetic structures consist of casts of shale and limestone fragments present in conglomeratic outcrops (see Plate III and page 37). The occurrence of these casts is quite wide spread in many of the outcrops investigated.

Problems of Correlation

It is believed that the investigation of cemented deposits of Cenozoic age in western Marion County has not been sufficient to unequivocally substantiate an equivalence of stratigraphic position or of age relations among the cemented deposits because of the following: 1) the lack of fossils within the cemented deposits, 2) the lack of physical continuity of deposits, 3) the lack of key marker beds within the cemented materials or associated sediments, 4) correlation by physiographic expression is impossible because dissection of the terrace remnants has removed all definitive topographic expression of the deposits.

During the course of this investigation two outcrops of volcanic ash were discovered in western Marion County. One outcrop occurs about four miles south of Hillsboro (SW¼, NW¼, Sec.28, T.20S., R.2E.) in the east backslope of a graveled county road. Approximately one foot of volcanic ash was present. The lateral extent could not be determined. The volcanic ash was contained within a reddish-brown sandy silt. Several samples of the volcanic ash were sent to the State Geological Servey of Kansas for analysis and possible age correlation. The memorandum of their results, dated March 9, 1967, states:

> The sample consists of very angular isotropic white glassy material, presumable volcanic glass, and occasional grains of polysynthetic plagioclase. No other minerals were noted in the samples examined. The sample definitely is volcanic ash.

> We cannot offer an opinion about the Pearlette correlation, because we are not that familiar with the unit. (Personal communication, Ronald Hardy.)

The second outcrop of volcanic ash was discovered about three miles southwest of Hillsboro (SE¼, NE¼, Sec.12, T.20S., R.1E.). The volcanic ash was exposed in a "badgers" burrow on the south bank of an intermittant stream 20 feet west of a concrete-box culvert. The thickness and lateral extent is not known. These two exposures of volcanic ash are the first described in Marion County. However, the outcrops of volcanic ash were of no aid in the correlation of the Cenozoic cemented deposits of western Marion County. The age of the volcanic ash has not yet been ascertained but may be Tertiary or late Kansan. Drill holes would probably be required to correlate the volcanic ash outcrops with outcrops of cemented sands and gravels located nearby.

The cemented Cenozoic deposits investigated have many similarities that indicate possible relationships in depositional origin and regional history. These similarities are: 1) the geographic distribution of the outcrops is restricted to a north-south trending belt, 2) the deposits are closely associated with the present drainage pattern both in areal distribution and in distribution of outcrop altitudes, 3) the petrology of the cemented sands and gravels is similar throughout the area of investigation, 4) the cemented deposits are primarily of fluvial origin but possibly include minor amounts of colluvial material. However, it is not correct to assume that these similarities unequivocally imply an equivalency of stratigraphic position or age. A valid correlation or assignment of geologic age must await further investigation, and may be accomplished by the use of drill hole data used in conjunction with the deposits of volcanic ash or the discovery of fossiliferous sediments of known stratigraphic associations to the cemented deposits. Frye and Leonard (1952, p. 40) state:

> Deposits within several drainage basins, if they possess the same lithologic character, such as a gradational sequence of gravel, sand, and silt, are nevertheless placed in the same formation when it is possible to demonstrate that they resulted from the same regional cycle of alluviation.

The cemented deposits investigated possess similar lithologic character. It is tempting to believe the deposits may have resulted from the same regional cycle of alluviation. However no definitive evidence can be advanced to prove an origin resulting from the same cycle of regional alluviation.

GEOLOGIC AND GEOMORPHIC HISTORY

Deposition Environment

The outcrops investigated are believed to be one phase of Cenozoic fluvial deposition in western Marion County. The fluvial origin of the cemented deposits is indicated by: 1) the close relationship between the outcrop distribution and the present drainage, 2) the detrital components of the sandstones and conglomerates, 3) the presence of current (inclined) bedding, 4) the lateral and vertical sedimentary associations, and 5) the association of the cemented deposits with fossiliferous fluvial sediments. Each of the above factors considered independently can not be taken as infallible proof of a fluvial origin, but the integration of the above factors is highly indicative of a fluvial mode of deposition.

The characteristics observed can be closely correlated with the principal characteristics of alluvial sand bodies outlined by Potter (1967, Table II, p. 344). Potter lists the characteristics of the detrital petrology of alluvial sand bodies as being: "abundant shale pebbles and shale pebble conglomerates...Petrographically immature to moderately mature. Pebbles and cobbles may be both local and distal...Faunal content low to absent." The outcrops investigated have all of the above characteristics. Shale and argillaceous limestone pebbles derived from the Wellington are abundant in many outcrops. The bulk of the detritus present can be classified as immature to moderately mature. The highly mature metaquartzites, chalcedony, chert, and silicified wood are present only in accessory amounts and should not be considered as adequate criteria for increased maturity. Pebbles and cobbles present are local (i.e., Wellington derived shale and limestone) and distal (i.e., metaquartzite, chalcedony, chert, and silicified wood). The size distribution of the detritus precludes deposition by geologic agents with less competence than fluvial processes. Faunal content was observed to be lacking.

Potter lists as sedimentary structures characteristic of alluvial sand bodies: "...well-oriented cross-bedding, commonly unimodal... Deformation structures are common minor accessories. Beds tend to be lenticular with erosional scour." The outcrops investigated have all of these characteristics.

Potter lists as characteristic lithologic associations: "Basal contact commonly sharply disconformable. Multistory sandstone bodies... Multilateral sandstone bodies. Correlation generally difficult." These characteristics are also present in the deposits investigated. Multistory and multilateral sandstone bodies probably are the cause of the multiple outcrops represented at outcrop localities 12, 16, and 18.

The association of the cemented deposits with fossiliferous fluvial sediments at several outcrop locations is also considered as evidence of the fluvial origin of the deposits investigated. Fluvial pelecypods and gastropods were observed at outcrop locations 1, 7, and 13 in silty sands which are associated with cemented Cenozoic deposits.

The fluvial systems along which the materials investigated were deposited were closely aligned with the present drainage patterns. With two exceptions the deposits investigated can be considered as remnants of terrace-like deposits which in several cases may have merged with colluvial deposits along an eastward trending drainage system ancestral to the present Cottonwood River drainage system. Two exceptions are outcrop locations 23 and 35 in the northern portion of the area investigated. These two outcrops are located within the Turkey Creek watershed and are believed to be the southernmost remnants of well developed terrace deposits of cemented sand and gravel occurring along Turkey Creek to its junction with the Smoky Hill River south of Abilene. The cemented materials are remnants of fluvial sands and gravels deposited when Cottonwood River drainage and Turkey Creek drainage occurred at altitudes above the present floodplains. As a generalization, the difference in altitude between the present floodplains and the terrace remnants decreases progressively headward in the present watersheds. Subsequent dissection of the terraces has removed any definitive topographic expression of the deposits.

The eastward drainage of the ancestral Cottonwood River system is evidenced by: 1) the distribution of altitudes of the cemented deposits, 2) consideration of the derivation of the detrital components, and 3) paleocurrent direction inferred from current bedding. The significance of the distribution of outcrop altitudes has previously been discussed (see page 23). The altitude distribution indicates the drainage system was similar in direction and extent as the present. The derivation of the detrital components of the cemented deposits also indicates an eastward flow during deposition. The quartz-feldspar sand could only be derived from the west by the reworking of pre-existing Tertiary or early Pleistocene(?) arenaceous sediments or possibly from the reworking of arenaceous sediments derived from the weathering of Cretaceous rocks to the west to northwest of the outcrop locations. Outcrops 5, 6, and 7 contain fragments of a peculiar variety of cone-in-cone calcite which outcrops in the Wellington formation just west of outcrop location 6. Outcrop location 5 contains less and smaller fragments of the cone-in-cone, and outcrop 7 contains even less and still smaller fragments of the peculiar cone-in-cone calcite. This is evidence for eastward transportation of the cone-in-cone from the original source in the Wellington formation with progressively less amounts and smaller-sized fragments occurring in a downstream direction. The shale and limestone fragments which are of local derivation have little significance in determining the direction of flow. The resistant cobble and pebbles are also of little use because of the uncertainty of their origin.

The paleo-current direction can be inferred from the inclination of the foreset beds of current bedding present in the cemented deposits (see page 47). At all outcrops where inclined bedding was observed the paleo-current direction was in the same direction as the present stream flow. From these considerations it is believed the drainage system present during the deposition of the rocks investigated was toward the east, and at a higher altitude than the present drainage.

Interpretation of Deposits

Despite the limitations imposed by the uncertainty of stratigraphic and age correlations among the cemented Cenozoic deposits of western Marion County, several inferences as to the geologic history of the area can be made. Proof has been advanced for the fluvial origin of these deposits, and the suggestion has been made that the present drainage patterns are closely aligned with the paleo-drainage present at the time of deposition. The deposition occurred at higher altitudes than the present floodplains and subsequent degradation has left the deposits as terrace-like remnants of gravel and sands which have subsequently been cemented.

One of the more obvious features of the cemented Cenozoic materials investigated is the fact that most, if not all, outcrops underlie the bulk of the terrace-like sediments within the area of investigation. The possible exceptions to this generalization are the multiple outcrops present in the northern portion of the area and outcrop location six which is underlain by light-gray, arenaceous clay. The cemented deposits are, for the most part, the first evidence of Cenozoic deposition in western Marion County. The similarity of the cemented deposits suggests that they may have had a similar genesis, and may represent the same phase of Cenozoic alluviation.

At least two phases of Cenozoic history of western Marion County can be inferred from the stratigraphic relationships of the cemented materials and other Cenozoic sediments present in the area of investigation. First, aggradation of many of the streams within western Marion County occurred. Deposition of the coarse clastics that comprise the cemented deposits occurred first. Subsequent deposition by aggrading streams is evidenced by the existence of sands and silts which overlie the cemented materials at some outcrop locations. Secondly, degradation occurred until the stream reached their present altitudes. This generalized sequence is certainly not all encompassing.

Evidence was also introduced that the paleo-current direction during deposition was the same as the present, that is, toward the east. This is especially notable because the often accepted generalization is that the Flint Hills were an effective barrier between drainage to the west and drainage to the east until middle to late Kansan time. The occurrence of eastward flow of an ancestral Cottonwood drainage system when the materials investigated were deposited substantiates the observations of Seevers and Jungmann (1963, p. 364) who suggest the Cottonwood River may have breached the Flint Hills divide in late Tertiary time. Their suggestion was founded on the occurrence of Cretaceous derived quartzose sand in terrace deposits of pre-Kansan age along the lower Cottonwood River.

The occurrence of similar deposits in Dickinson, Harvey, Saline, and Sedgwick Counties has been noted. It is probably not a coincidence that these deposits are aligned in a north-south trending belt across central Kansas. It is more important to note that these deposits are located in the "transition zone," or the "Wellington shale plain" which forms the dip slope of the Flint Hills cuesta, and which separates the Flint Hills to the east from the north-south trending, abandoned "McPherson valley" to the west. The significance of this distribution has not yet been ascertained.

SUMMARY

The cemented Cenozoic deposits in the western one-half of Marion County are comprised of calcitic cemented sandstones and pebble conglomerates. The deposits vary in thickness from four feet to a featheredge. Sedimentary structures present are current (inclined) bedding, possibly graded bedding, post-depositional slump, and casts of shale and limestone fragments.

Their distribution is in a north-south trending belt across western Marion County that approximately coincides with the tier of Townships comprising Range two East. Their distribution has close affinities to the present drainage system in the area. Altitudes of the outcrops are roughly concordant north to south across the area of investigation, but increase headward within the individual watersheds. Soil type distribution may be correlative with the geologic parent material present and was often useful as an aid in delineating terrace remnants.

The cemented materials often overlie the Wellington formation with marked unconformity, and most outcrops are overlain by soil. Lateral continuity is questionable over short distances. The cemented deposits are very lenticular and pinch out very rapidly.

The outcrops investigated are believed to be one phase of fluvial deposition of Cenozoic age in western Marion County. Deposition occurred at higher altitudes than the present floodplain. Subsequent degradation of the drainage and dissection has destroyed any topographic expression and left the deposits as isolated remnants. In several outcrops fluvial deposits may merge with colluvial deposits which have also been cemented.

Evidence was introduced that the paleo-current direction of the ancestral Cottonwood River was toward the east. Two phases of the Cenozoic history of western Marion County may be inferred: first, deposition of the coarse clastics that comprise the cemented materials and continued deposition of sands and silts which are found to overlie the cemented deposits, and secondly, degradation to the present altitude of the floodplains.

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PLATE V

MAP OF WESTERN MARION COUNTY, KANSAS SHOWING THE DISTRIBUTION OF OUTCROPS OF CENOZIC CEMENTED MATERIALS

CEMENTED SLOPE AND TERRACE DEPOSITS OF CENOZOIC AGE IN WESTERN MARION COUNTY, KANSAS

by

JOHN LYSLE RUSSELL

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Thirty-seven outcrops of cemented Cenozoic deposits were investigated in the western one-half of Marion County, Kansas. The lithologies observed vary from lithic conglomerates to protoquartzitic and subarkosic sandstones. The detrital components can be divided into the following categories: 1) quartz-feldspar sand, 2) sand- to cobble-sized fragments of "ironstone," 3) granule- to cobble-sized, angular fragments of locally derived limestone and shale, and 4) well-rounded pebbles and cobbles of metaquartzite, chalcedony, chert, and silicified wood. The cementation is predominantly by calcium carbonate.

The geographic distribution of the Cenozoic cemented sands and gravels is basically a north-south trending belt across western Marion County. Outcrops are usually singular entities with lateral continuity lacking at all outcrops observed. The cemented deposits are weakly resistant to weathering and topographic expression rarely exists. The distribution is closely associated with the present drainage patterns. Outcrop altitudes vary from 1315 to 1531 feet above sea level. Altitudes are roughly concordant north to south across the area of investigation but increase headward within the individual watersheds.

Primary sedimentary structures observed consist of current (inclined) bedding, possibly graded-bedding, and a post-depositional slump. The only secondary sedimentary structures observed is casts of limestone and shale fragments present in many conglomeratic outcrops.

Most of the cemented deposits overlie the Wellington formation of Permian age with abrupt unconformity. The deposits are highly lenticular and lense out very rapidly. Outcrop thicknesses vary from approximately four feet to a featheredge.

The cemented deposits are believed to be predominantly of fluvial origin. With two exceptions the deposits investigated can be considered as remnants of terrace-like deposits which in several cases may have merged with colluvial deposits along an eastward trending drainage system ancestral to the present Cottonwood River drainage system. Two exceptions are located in the northern portion of the area investigated and are believed to be terrace remnants associated with Turkey Creek. An eastward drainage at the time of deposition is evidenced by: 1) the distribution of altitudes of the cemented deposits, 2) consideration of the derivation of the detrital components, and 3) paleo-current direction inferred from current bedding.

Correlation of the cemented deposits can not be unequivocally established. However, similar deposits have been observed in Dickinson, Harvey, Saline, and Sedgwick Counties. A short review of the literature related to Cenozoic cemented deposits in central Kansas and, more specifically a discussion of the "Abilene conglomerate" is included.

As an incidental result of this investigation, two outcrops of volcanic ash were discovered in western Marion County. These outcrops are the first outcrops of volcanic ash noted in Marion County. The age of the volcanic ash deposits has not yet been established.