1982

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**Regional implications of the geology of the Ogallala Group
(upper Tertiary) of southwestern Morrill County, Nebraska, and
adjacent areas**

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ABSTRACT

A part of a filled Ogallala Group (upper Tertiary) paleovalley system exhumed by recent stream erosion in southwestern Morrill County, Nebraska, and adjacent areas contains steep gradient gullies filled with locally derived sediments. Younger channels filled with granitic gravels derived by stream erosion of the Rocky Mountains to the west and southwest cut across and through these older filled gullies, indicating that there were at least two periods of downcutting followed by periods of filling during the development of this system.

Individual clasts from younger Ogallala gravels are often as large as or larger than clasts from Quaternary gravels transported comparable distances by streams. This fact supports the idea that streams of Ogallala age were often at least as competent as their Quaternary counterparts.

In a tributary to Greenwood Creek, six major volcanic ash lentils occur in superposition. These ash deposits range in geometry from tabular to channel-shaped and were deposited on land surfaces or in ponds and gullies at different times during the deposition of the Ogallala Group. Some of the lentils grade laterally into diatomites.

Caliches are common throughout the Ogallala Group. Major caliches are developed in older rocks directly beneath the Ogallala and in sediments beneath the eroded upper surface of the group. Caliche horizons occur at many horizons within the group and have "tepee," honeycomb, and other typical structures.

The preceding observations are in part directly opposed to observations made by earlier workers for the Ogallala in general or specifically for the study area. The Ogallala Group should be re-examined to see whether the earlier models or those offered here better explain its geologic history.

INTRODUCTION

Five generalizations which have been proposed over the years about the Ogallala Group, either regionally or specifically in western Nebraska, will be tested in this report. The first postulates the shape of paleovalleys in which Ogallala sediments were deposited. The few available studies and maps describing and depicting the shape of the paleovalleys show them to have smoothly sloping sides and few tributaries. The second generalization is that a single

major erosional event was responsible for carving the Ogallala paleovalleys. Virtually all of the subsequent history of the Ogallala is said to represent a gradual filling of these paleovalleys interspersed with short periods of equilibrium, during which paleosols formed, and with short periods of stream erosion producing valleys with relatively low relief. The third generalization in recent literature deals with maximum clast size and clast mineralogy in the Ogallala and Quaternary deposits. Quaternary gravel clasts are claimed by some authors to be

Figure 1. Location of the study area and principal physiographic features in western Nebraska (base from DeGraw, 1971).

larger than comparable Ogallala gravels, and mineralogy is claimed to be distinctive. The fourth concept is that only one or two volcanic ash beds occur in any single superposed sequence of Ogallala strata in the southern Nebraska Panhandle. Fifth, a single terminal caliche development is presumed to have occurred at the end of Ogallala deposition, completing a trend toward increasing aridity throughout Ogallala time. The validity of each of these ideas will be examined.

The area of study for this investigation includes extreme southwestern Morrill County, Nebraska, and adjacent portions of Banner and Cheyenne Counties (Fig. 1). Seven sites have been chosen to illustrate specific points. These sites, all on private land, are precisely located in Appendix 1.

Excluding Quaternary alluvium, colluvium, and eolian silt and sand, rocks of three groups are exposed in the study area (Fig. 2). Rocks belonging to the Ogallala Group of late Tertiary age were probably first reported on in western Nebraska by Stansbury in 1852 and since that time have

been studied in detail at many locations on the Great Plains. The Ogallala is dominantly a fluvial unit consisting of interbedded conglomerates, sandstones, siltstones, and pebbly sandstones and their uncemented equivalents, and air-fall volcanic ash, diatomites, and caliches. The Arikaree Group consists of friable, largely volcanically derived eolian and fluvial sands and sandstones, siltstones containing concretions of variable shape, and conglomerates made up of clasts of reworked concretions. The Whitney Member of the Brule Formation of the White River Group is primarily a volcanically derived eolian siltstone containing concretions at some locations. The Whitney also includes some widespread very pure volcanic ash beds.

Lugn (1939) redefined the Ogallala Group in Nebraska and subdivided it into the Valentine, Ash Hollow, Sidney, and Kimball Formations. Such subdivision continued to be used by Schultz and Stout (1961), Stout (1971), and Schultz and Falkenbach (1968, p. 411) in Nebraska. Frye and others (1956, p. 47), working in Kansas, have subdivided

the Ogallala Formation, as they called it, into the Valentine, Ash Hollow, and Kimball Members on the basis of "average lithologic characters that are sufficiently distinctive to distinguish them one from another in a general way, but which are not adequate to permit a sharp delineation of members in any particular section." I agree with the last part of this assertion and, therefore, at this time have chosen not to assign formation or member names to the Ogallala Group exposed in the study area. However, differences in faunal elements allow time-stratigraphic subdivision of the sequence, and this subdivision has been attempted.

GENERALIZATIONS EXAMINED

Generalization 1. Simple Paleovalley Shape

Middle and late Quaternary streams carved out the broad east-west-trending valley of Pumpkin Creek (Diffendal, 1981) lying primarily just to the north of the study area. The south side of this valley forms the

Figure 2. Generalized bedrock geologic map of the study area. Base map is a U.S. Geological Survey 1:250,000 topographic map with 100-ft contours. The Ogallala Group of late Tertiary age is shaded. The Arikaree Group of Miocene age and the Whitney Member of the Brule Formation of Oligocene age are shown in white.

Figure 3. Stream-eroded gully with an overhanging wall carved into the Brule Formation.

steeply sloping Cheyenne Tablelands escarpment. Modern tributaries draining from the tablelands to Pumpkin Creek have cut deep, often narrow valleys through the Ogallala Group strata that cap the tablelands and into the underlying rocks of the Arikaree Group and Whitney Member of the Brule Formation. Some of these deeply incised valleys carved into the Whitney contain falls, overhangs (Fig. 3), and vertical walls having reliefs of more than 35 m.

Logs of oil and gas tests in the southern Panhandle of Nebraska allowed DeGraw (1971) to produce a map of the pre-Oligocene topography and drainage pattern developed there. The pattern is extremely complex and resembles the modern drainage network of the area.

Previous attempts to depict the Ogallala-filled paleovalley systems developed on the top of the Whitney Member of the Brule Formation in the Nebraska Panhandle include maps by Lugn and Lugn (1956), Smith's map for Cheyenne County (1969), the map and geologic sections for Kimball County by Smith and Souders (1971), and for Banner County by Smith and Souders (1975). Breyer (1974, 1975) produced a geologic map and configuration of the pre-Ogallala surface for the southern Nebraska Panhandle and extreme southeastern Wyoming and a geologic section along Greenwood Creek in Morrill County.

Figure 4. (a) Older Ogallala gully fill. The gully was carved into the Whitney Member of the Brule Formation. Man is 1.9 m tall. (b) Illustration of 4a showing relationships.

All of these attempts, whether based on test holes or surficial studies, depicted simple, broad paleovalleys with 90–120 m of relief, smooth sides, and only a few tributaries. This image of the paleovalley system in which Ogallala-aged sediments were deposited was also repeated in the literature on Ogallala deposition and geologic history for many areas of the High Plains (Frye and others, 1956; Frye and Leonard, 1957; Walker, 1978). I question whether the Ogallala paleovalley systems in western Nebraska are really that simple.

In the study area and at adjacent sites, Ogallala paleovalley systems are not simple, smooth-walled features. Basal Ogallala Group gully fills tributary to main paleoval-

leys were recognized from at least one location in Nebraska as early as 1957, when Morris Skinner (unpub. field notes of August 4, 1957) of the American Museum of Natural History observed a gully fill of Ogallala age along U.S. Highway 26 in southeastern Morrill County. In 1975, after obtaining new faunal evidence, Skinner determined the age of the fill to be Clarendonian. Swinehart and Diffendal (1978) collaborated in mapping a large area of Morrill and Garden Counties, Nebraska, and demonstrated the nature of the filled gully system of Clarendonian age at the site worked earlier by Skinner. Swinehart (1979) expanded that work and found that the base of the Clarendonian fill was more than 46 m

Figure 5. (A) Location of site 2, Appendix 1, showing positions of geologic profiles. Base map is a U.S. Geological Survey 7½' topographic map. Contour interval is 30 m. (B, C) Transverse geologic profiles at site 2. Tmo represents rocks of the Ogallala Group; Tow, rocks of the Whitney Member of the Brule Formation. Qal is Quaternary alluvium. Tmo₁ is Clarendonian in age; Tmo₂ is Hemphillian. Dashed lines show inferred contacts. (D) Longitudinal geologic profile at site 2 showing the primary dip of the beds in Tmo₁ and the steep gully slope.

below the base of the adjacent rocks of the Ogallala Group containing Hemphillian fossils.

Similar relationships have also been found in the study area. Figures 4a and 4b

illustrate the relationship between the basal portion of the Ogallala Group and the underlying Whitney Member of the Brule Formation at site 1. In a distance of <0.16 km, the erosional contact between the Brule

and Ogallala drops more than 18 m. The Ogallala sediments above the contact were deposited in deep, steep-sided, often narrow gullies like those forming in the area today. As there is no evidence of faulting of surficial strata in this area to explain these features, their origin is probably solely erosional.

An even more telling example of deep gully development on the pre-Ogallala surface in the study area can be seen at site 2 (Fig. 5A). Here, the topography is "inverted" with the ancient branching gully system, filled with sediment less easily eroded than the adjacent Brule Formation, left standing topographically high. The sediment filling the system consists of interbedded gray, green, and brown sandstones

Figure 6. (a) Ogallala gully fill of site 2. Beds have approximately 4° primary dip to the southeast shown by dashed line. (b) Lithic conglomerate in the gully fill. Clasts are derived from erosion of the underlying formations up the paleoslope from this site. The hammer is ~ 40.6 cm long. (c) Partially exhumed Hemphillian gravel-filled channel at site 3. Channel sides shown by dashed lines. (d) Coarser lag covering the surface of the channel fill in 6c. (e) Sandstone on top of a coarse sand and gravel at site 4.

Figure 7. Locations of Ogallala Clarendonian channel fills and the direction of slope of channels shown by dark shading and arrow points. Base map is a U.S. Geological Survey 1:250,000 topographic map with 100-ft contours.

and conglomerates that have primary dips to the southeast and south-southeast of about 4° (Fig. 6a). Gravel clasts (Fig. 6b) include siltstones and reworked concretions eroded from the Arikaree and Brule Formations higher up the paleoslope to the north. The conglomerates may be massive, parallel-bedded, or trough cross-bedded. Where troughs occur, they plunge to the southeast or south-southeast. One longitudinal and two transverse profiles through a part of the gully system illustrate its shape and general relations to adjacent units (Figs. 5B–5D). These profiles show that the system is shallow and narrow at its upstream end but rapidly deepens with increasing slope to the south-southeast. The shape of this paleovalley system is similar to those of Recent gully systems cut into the Whitney along the sides of stream valleys.

The two Ogallala paleogullies and gully fills just described are the best-known examples in the study area for illustrating the point that the gullies along the sides of major valleys during Ogallala time were similar in size, shape, and gradient to gullies

developing today. Figure 7 shows the location and direction of slope of all such Ogallala tributary paleogullies. The change in slope directions seen on the map is a reflection of the change in direction of the long axis of the major paleovalley which these smaller valleys entered.

If the tributary system during Ogallala time was similar to the modern system, as has been illustrated, then why have so few reports demonstrated the fact? A combination of factors has contributed to the simpler interpretations made in the past. First, and probably most important, this study area, in contrast to most others, is along and subparallel to the partially exhumed valley side of an Ogallala paleovalley system rather than in a drainage developed along a paleovalley axis where tributaries would be more difficult to discern. If ancient tributaries exist, the paleogeographic position of this area is clearly the best place to look for them. Second, the paleovalley side here rises rapidly to the north to an upland underlain by pre-Ogallala sediments probably covered originally with

no more than a thin veneer of Ogallala sediments. Once the veneer was breached, Quaternary stream erosion proceeded to differentially erode the region, leaving the Ogallala exposed on the faces of high escarpments at this location where it can be easily examined. Third, reliable $7\frac{1}{2}'$ topographic maps for the southern Panhandle of Nebraska have been available only since 1980. Thus, lack of elevation and location control made detailed analysis difficult.

Generalization 2. Single Cycle of Erosion and Deposition

The commonly accepted picture of Ogallala Group erosional and depositional history throughout the Great Plains is, perhaps, best typified by Frye and Leonard's (1957) diagram shown in part in Figure 8. Their description and illustration of the deposition of the Ogallala (p. 3–5) stressed the conformable and gradational nature of contacts between rock units. They further stated (1959, p. 27–29; 1965, p. 205–207) that the oldest part of the Ogallala is

Figure 8. Frye and Leonard's model of deposition of the Ogallala Group through time (modified from Frye and Leonard, 1957). Dotted lines represent time lines.

found in the lowest parts of pre-Ogallala valleys and that the valleys were then filled completely, producing a nearly featureless depositional plain. This theme was used many times thereafter by other authors, such as Schultz and Stout (1961), Kent (1963), and Breyer (1975), to explain the depositional history of the Ogallala in parts of western Nebraska and by Walker (1978) in a study of the Ogallala in Texas.

Two recent studies of the Ogallala Group stand out as exceptions to this simple model of general alluviation through time after an initial period of valley development. Skinner and others (1977) described the stratigraphy of Cenozoic deposits in central Sioux County, Nebraska, mapped their distribution, and worked out cycles of erosion and deposition. These workers were able to establish three periods of erosion and sub-

sequent valley-filling during the Clarendonian and Hemphillian portions of Ogallala time. During the youngest of these erosional episodes, stream erosion produced a valley system cut through older Ogallala deposits and below the levels of the earlier periods of erosion. Seni (1980) studied the depositional history of the Ogallala deposits in Texas using irrigation well records combined with surficial investigation and proposed that the Ogallala was deposited as coalescent, wet alluvial fans with low gradients. He identified three fan lobes in his Texas study area which overlapped one another and which were progressively younger toward the south. Each of the three depositional lobes was preceded by a period of stream erosion.

In southwestern Morrill County, Nebraska, a second period of erosion occurred during which streams cut valleys across the valley fills previously described and into the underlying rocks of the Arikaree and upper White River Groups. These streams produced steep-sided, often narrow, valleys that were later filled with a series of very coarse-grained granitic sand and gravel

Figure 9. Location of the principal older Hemphillian channel fills in the study area. Outcrops shown in darker shading. Base map is a U.S. Geological Survey 1:250,000 topographic map with 100-ft contours.

deposits derived from erosion of the Rocky Mountains, interbedded with finer-grained sediments. Figure 6c is an aerial view of one of these filled valleys at site 3 that has been partially exhumed by recent erosion. Some of the sand and gravel filling the valley is very coarse (Fig. 6d). This valley is part of a channel system incised into the bedrock in the Morrill County study area shown in Figure 9. The principal northernmost channel of this system, preserved best at sites 4 and 5, trends west to east to the vicinity of Greenwood Canyon, where it turns east-

northeast. Breyer (1975) attempted to show the relationships at Greenwood Canyon where this northern channel fill is well exposed, but, unfortunately, he did not use an irrigation well record from the west side of Greenwood Canyon that clearly indicated that the filled Ogallala paleovalley just described was present in the area. Figures 10A and 10B show Breyer's and this author's interpretations of the geology of Greenwood Canyon. The northern paleo- valley is ~1.6 km wide at its base and in the subsurface is filled with at least a 45-m

thickness of sediment in three sand and gravel bodies separated from one another by finer-grained sands and silts. Three other stratigraphically higher sand and gravel bodies in this fill, also separated by sands and silts (Fig. 6e), are exposed by surficial erosion west of the irrigation well. Fossils from this filled paleovalley system indicate that it is Hemphillian in age, and the fossils found in the older fills described earlier are Clarendonian or older (Appendix 2).

In southwestern Morrill County, the history of the Ogallala group clearly includes

Figure 10. (A) Breyer's interpretation (1975) of the geology along east side of Greenwood Canyon, Morrill County, Nebraska. (B) Geologic profile section along west side of Greenwood Canyon. Tma? is probably part of the Arikaree Group of Miocene age. See explanation of Figure 5 for other symbols.

at least two major periods of erosion, pre-Clarendonian and pre-Hemphillian, followed by periods of filling during part of the Clarendonian and part of the Hemphillian, respectively. During the second of these cut-and-fill episodes, stream erosion produced a deeper cut that eliminated major portions of the earlier cut and fill. This view of the erosional and depositional history of the Ogallala Group in the study area is clearly closer to the sequence of events outlined by Skinner and others (1977) than to that outlined by either Breyer (1974, 1975) or Frye and Leonard (1957). Furthermore, Souders (1981, personal commun.) believes that there may have been three or four major cut-and-fill cycles in the depositional history of the Ogallala Group in other parts of western Nebraska.

Generalization 3. Distinctive Gravel Sizes and Mineralogies

Stanley (1971) and Stanley and Wayne (1972) believed that Ogallala gravels could be separated from post-Ogallala gravels in western Nebraska, and they made a number of assertions related to the general topics of sediment dispersal, source areas, and stream competence for Ogallala and early Pleistocene gravels. Stanley and Wayne (1972) stated that Ogallala gravels in western Nebraska are generally free of anorthosite, that with a few exceptions the presence of anorthosite and larger clast size may be used to separate early Pleistocene from Ogallala gravels, and that the main early Pleistocene drainage way in the Nebraska Panhandle was through the ancestral Pumpkin Creek Valley. They also concluded that Pleistocene streams were more competent than Ogallala streams in western Nebraska.

Breyer (1974, 1975) reported anorthosite-bearing gravels in the Ogallala Group from the Greenwood Canyon area of Morrill County at site 4. This type of gravel also occurs in the Ogallala sequence to the south (NW¼SE¼NW¼ sec. 12, T. 17 N., R. 50 W.) and west (SW¼SW¼NW¼ sec. 17, T. 18 N., R. 52 W.) in Morrill County and in Banner County (NE¼SW¼SE¼ sec. 21, T. 18 N., R. 53 W. and NW¼NW¼NW¼NE¼ sec. 23, T. 18 N., R. 53 W.), where anorthosite is abundant (Table 1). Such occurrences indicate that tributaries draining the Laramie Anorthosite area in Wyoming were active, if minor, contributors to the Ogallala depositional system during Hemphillian time in parts of southwestern Nebraska; because of that, I suggest that great care

should be taken in designating a gravel from western Nebraska as Pleistocene in age because it has an abundance of anorthosite.

Measurements made on the ten largest clasts by Breyer (1974, 1975) and by Swinehart (1979) generally are lower than those reported earlier by Stanley and Wayne (1972) at the same sample sites. A field check at the sites supported the values cited in the later reports. A comparison of those values with measurements made on clasts at other previously unreported localities nearby revealed that in some cases gravels from the Ogallala Group had greater mean intermediate diameters than did gravels from early Pleistocene sites. For example, Breyer (1975, p. 5) reported mean long and intermediate diameters for the ten largest clasts at the early Pleistocene Broadwater Quarries as 16.0 and 7.7 cm, respectively. South of Broadwater in the SW¼NW¼NE¼ sec. 33, T. 18 N., R. 48 W., an Ogallala gravel has mean long and intermediate diameters of the ten largest clasts of 16.6 and 11.5 cm. This Ogallala gravel is close enough to the type Broadwater area to demonstrate that generalizations on separation of gravel ages in the southern Panhandle of Nebraska based on differences in maximum size may be of questionable value.

The main source areas of Ogallala gravels and the major drainage patterns for the streams carrying these gravels have been described by Blackstone (1975). The heads of these streams were in the vicinity of the Continental Divide in Colorado at least 67 km southwest to west-southwest of the Laramie Anorthosite body. Size and mineral-

ogy comparisons made on gravels from distinctly different source areas far removed from one another and transported variable distances are of questionable value except to establish possible drainage directions and changes in these directions through time. If Breyer's maximum sizes for the Ogallala gravels at Greenwood Canyon are compared with the maximum sizes for the early Pleistocene gravels northeast of Lisco, Nebraska, making the distance from each major source area comparable, the generalization on size and competence made by Stanley and Wayne (1972) is reversed. Maximum sizes of clasts carried in some Ogallala streams were greater than their early Pleistocene counterparts, suggesting that these Ogallala streams were more competent than some early Pleistocene streams.

Generalization 4. One or Two Ash Falls

Until 1971, no more than two volcanic ash lentils had been reported in superposition in a single exposure of the Ogallala Group in the southern Nebraska Panhandle. Lueninghoener (1934) reported two volcanic ash deposits in the Ogallala at Ash Hollow in Garden County and two volcanic ash beds at Greenwood Canyon in Morrill County. Stout (1971) illustrated five ash lentils, four of which were in superpositional proximity, at Greenwood Canyon but reported none from Ash Hollow. Boellstorff (1978) reported two ash beds from each of the two localities. Diffendal (1980a, 1980b) noted at least five separate ash beds in superposition in Ash Hollow and established that there are at least four major ash lentils in superposition in the Greenwood Canyon area in addition to those reported earlier by Stout. The locations of these lentils in the Ogallala Group at site 6 in southwestern Morrill county (Fig. 11) support the earlier proposal of Swineford and others (1955) that the Ogallala sequence contains many ash beds.

The shape of the lentils at Greenwood Canyon varies from broad tabular bodies to narrow gully fills (Fig. 12). The tabular bodies may appear as outcrops for several kilometres and be as much as 6 m thick, and the gully fills may be < 15 m wide and as much as 6 m thick.

The sedimentary characteristics of the ashes vary. They may be virtually pure masses of ash shards and other associated volcanic debris, or they may contain variable quantities of nonvolcanic silt, sand, and even gravel. Ash lentils may be entirely or

TABLE 1. COMPOSITION OF ANORTHOSITIC OGALLALA GRAVEL, BANNER COUNTY

Clast type	Percentage of sample
Quartz	7.7
Granite	49.8
Anorthosite	21.4
Rhyolite	2.6
Metamorphics	3.8
Silica varieties (flint, jasper)	5.4
Sandstone	3.4
Quartzite	3.3
Limestone	2.6
	100.0

Note: Location of sample site in NE¼SW¼-SE¼ sec. 21, T. 18 N., R. 53 W. Sample obtained ranges from -4 to -5 φ.

Figure 11. Location of ash lentils at site 6. Base map is a U.S. Geological Survey 7½' topographic map.

partially cemented by calcite or silica. When the ash is partially cemented, usually the upper portions contain the greatest amount of cement and frequently form hard gray ledges. In many cases, the ash is less permeable than the surrounding sediment and produces local perched water tables with attendant small springs and seeps. Bedding is variable and may be planar, cross-stratified, or convoluted. Some lentils are massive; others are thinly laminated and have ripple marks. Shard diameters vary from coarse-sand to silt size. Fossils associated with the ash include "seeds" of grasses and borages, and bones and teeth of vertebrates.

The tabular ash bodies may grade laterally into white calcareous diatomaceous deposits commonly containing shells or molds of gastropods and ostracods as well as vertebrate remains. This gradation suggests that the ash was deposited in these cases in ponds that were probably perennial. The diatoms may have formed algal blooms after silica-rich waters formed in the ash-laden ponds.

Generalization 5. Increasing Aridity and Caliche Formation

Frye and Leonard (1965) and other workers have stated that the Ogallala envi-

ronment of deposition became progressively more arid through time, culminating in a terminal Ogallala caliche formation across the Great Plains. Near the top of the Ogallala sequence in southwestern Morrill County, coarse granitic sand and gravel deposits were laid down in subparallel channels trending east to east-southeast (Fig. 13) which have been exposed by recent stream erosion. These gravels contain trace quantities of anorthosite. At site 7, the median long and intermediate diameters of the ten largest clasts are 12.8 cm and 7.7 cm, respectively. After these and associated finer-grained beds were deposited, stream erosion began, followed by development of thick

Figure 12. Volcanic ash deposited in a gully carved into older Ogallala sediments of Hemphillian age at site 6. Gully side shown by dashed line.

Figure 13. Younger Hemphillian channel fills at and near site 7. Outcrops shown in darker shading. Base map is a U.S. Geological Survey 1:250,000 topographic map with 100-ft contours.

caliches in the surficial deposits beneath an irregular erosion surface. These caliches have pisolitic structures in some places.

While this terminal Ogallala caliche development is important, caliches with honeycomb and "tepee" structures occur locally throughout the Ogallala section in southwestern Morrill County (Stout, 1971) and may even be as strongly developed at some horizons as the caliches capping the High Plains surface. Breyer (1974, 1975) has documented the occurrence of a caliche developed in the uppermost older Tertiary rocks directly beneath the Ogallala exposed along the escarpment at the head of Greenwood Canyon (Fig. 10). This caliche can be traced south along this escarpment for about 3 km and also occurs at the heads of the canyons to the west of Greenwood Canyon. The prominence of caliches throughout the Ogallala sequence in southwestern Morrill County suggests that the environment may have been similar throughout Ogallala time in this area.

CONCLUSIONS

Seven conclusions can be drawn from studying the Ogallala Group exposures in southwestern Morrill County:

1. If an ancient Ogallala valley side is exposed by erosion, it will have a set of tributary gullies and larger tributary valleys feeding into it that are just as complex as those developing along Recent valley sides.

2. These tributaries were filled with sediment derived primarily from local sources higher up the old paleoslope.

3. These tributaries and their contained deposits were later cut through in places by streams during a second major period of erosion during Ogallala time and then were filled with coarse gravel and sand derived from distant sources, as, in this case, primarily from the southern Rocky Mountains of northern Colorado.

4. Ogallala sand and gravel deposits, when viewed from proximity to their ultimate source area, may contain clasts as large as or larger than those in adjacent Quaternary stream deposits. This comparability of maximum sizes indicates that some Ogallala streams were at least as competent as the most competent Quaternary streams.

5. A large number of volcanic ash lentils are found in superposition in the Ogallala if a thick sequence of beds is studied.

6. Ash lentils and coarse terrigenous clastics deposited in gullies at the base of and within the Ogallala sequence indicate that gullying was a common phenomenon during Ogallala time.

7. Caliches occur throughout the Ogallala sequence and are not merely restricted to a terminal Ogallala event.

These conclusions should be tested in the future throughout the Ogallala outcrop belt in the Great Plains to see if they more adequately reflect the true history of the group than do previously accepted models.

ACKNOWLEDGMENTS

I am very indebted to R. G. Corner, L. G. Tanner, M. P. Carlson, R. R. Burchett, R.

K. Pabian, J. R. Thomasson, V. L. Souders, and J. B. Swinehart, II for their helpful comments during the preparation of this paper. J. J. Gottula accompanied and aided me during portions of the field work. Special thanks are extended to N. Alexander, T. Coop, R. Corman, M. Flamig, R. Harless, C. Lapaseotes, D. Lease, M. Lund, Mrs. E. Marrin, K. Nelson, J. Newkirk, R. Rodgers, and D. Wright, all of whom allowed me to study rock exposures on their properties. M. R. Voorhies identified fossils and made valuable suggestions. I thank past and present workers who have studied the Ogallala Group across the Great Plains. Their stimulating ideas prompted me to examine this sequence of continental deposits and to test previous hypotheses.

APPENDIX 1. LOCATIONS OF STUDY SITES

1. SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 36, T. 18 N., R. 52 W.	Morrill County
2. SE $\frac{1}{4}$ sec. 28, T. 18 N., R. 51 W.	Morrill County
3. SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 20 and NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 29, T. 18 N., R. 51 W.	Morrill County
4. SW $\frac{1}{4}$ sec. 28 and SE $\frac{1}{4}$ sec. 29, T. 18 N., R. 50 W.	Morrill County
5. NW $\frac{1}{4}$ sec. 4 and NE $\frac{1}{4}$ sec. 5, T. 17 N., R. 50 W.	Morrill County
6. Sections 2, 3, 10, 11, T. 17 N., R. 50 W.	Morrill County
7. SE $\frac{1}{4}$ sec. 21, T. 17 N., R. 50 W.	Cheyenne County

APPENDIX 2. FAUNAL LIST OF FOSSILS FOUND IN THE STUDY AREA

(Derived in part from Kent, 1963)

Clarendonian or older Fossils

Merychippus cf. *insignis*

Pseudhipparion gratum

Cormohipparion occidentale

Calippus sp.

Amphicyonidae

Hemphillian Fossils*

Osteoborus sp.

Megatylopus sp.

Hemiauchenia sp.

Dinohippus sp.

Astrohippus sp.

Neohipparion sp.

Nannippus sp.

Teleoceras sp.

"*Prosthennops*" *serus*

Barbourofelis sp.

Hesperotestudo spp.—Thin and thick shelled turtle

Antilocapridae

Rodentia

*Including the Kimballian of Schultz and Stout (1961) and Schultz (1981).

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MANUSCRIPT RECEIVED BY THE SOCIETY
JUNE 5, 1981

REVISED MANUSCRIPT RECEIVED
AUGUST 24, 1981

MANUSCRIPT ACCEPTED SEPTEMBER 2, 1981