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Guidebook to the Late Pliocene and Early Pleistocene of Nebraska

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THE PRE-OLIGOCENE SURFACE IN WESTERN NEBRASKA--ITS RELATION TO STRUCTURE AND SUBSEQUENT TOPOGRAPHIES

By Harold M. DeGraw

INTRODUCTION

The pre-Oligocene, mostly pre-Chadron, surface has been exhumed and either truncated or partially eroded in Wyoming, Colorado, South Dakota, Nebraska, and probably other states of the High Plains Region. Numerous workers have observed and interpreted its relations; some workers (Pettyjohn, 1966; Schultz and Stout, 1955; and Toepelman, 1922) were essentially correct in their interpretation of its various outcrop occurrences whereas others were mostly incorrect. Much of the pre-Oligocene surface is covered by Tertiary and Quaternary sediments having a considerable range in thickness, thus making impossible detailed study of that surface from outcrops alone.

In western Nebraska, the pre-Oligocene surface consists of Cretaceous and some Jurassic rocks; Eocene and Paleocene rocks have not been recognized in the region. In that region, more than nine thousand deep exploratory wells for oil and gas and approximately two hundred shallow groundwater test wells have provided abundant data for a subsurface study of the pre-Oligocene unconformity. Electric logs, which are available for nearly all the wells, proved to be a precise tool for making subsurface correlations. Rock samples, available for most of the groundwater test wells and a few of the oil and gas exploratory wells, were used to relate lithic characteristics to electric log characteristics.

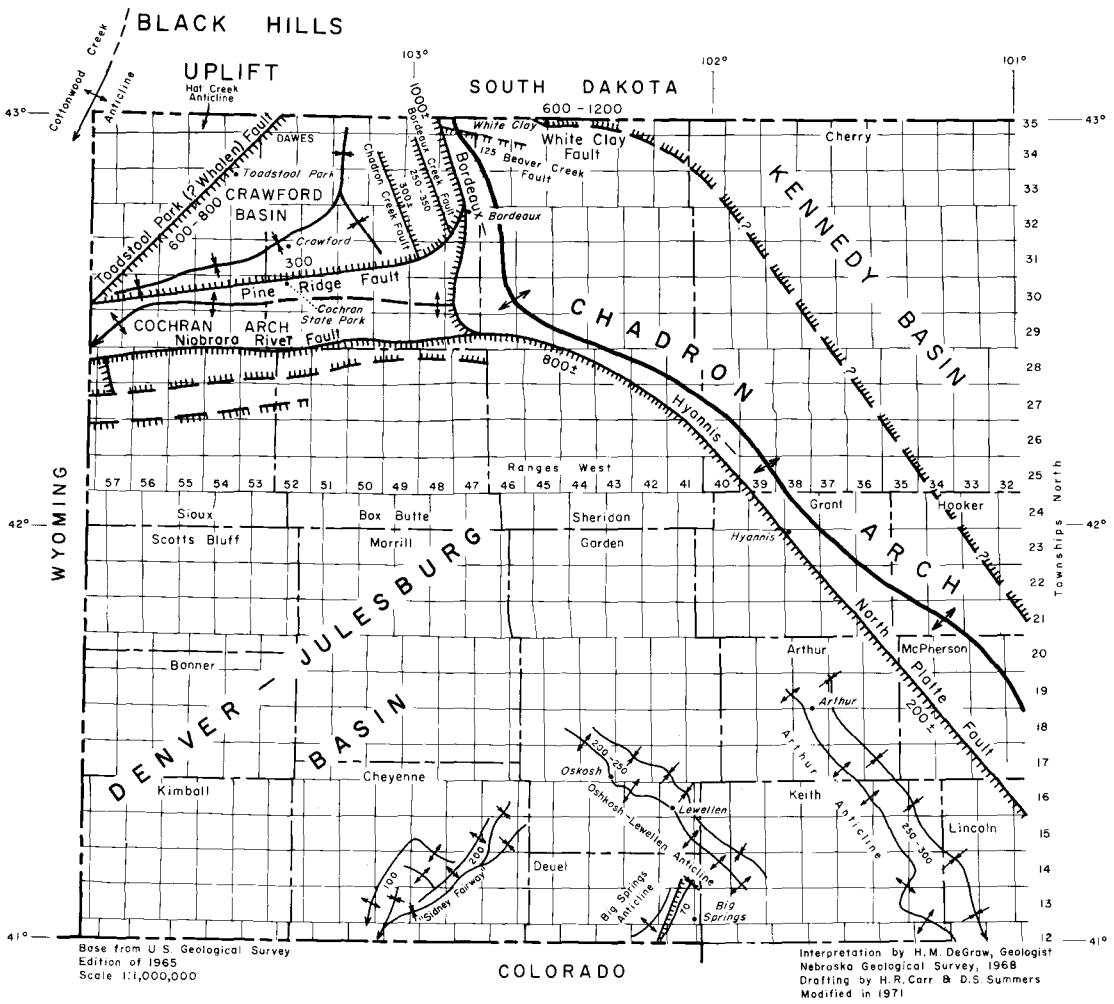
The physiographic features of the modern surface in western Nebraska are shown in figure 4.

STRUCTURAL SETTING

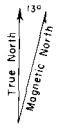
Structural relations in western Nebraska are impossible to decipher from outcrop data alone. Faults and folds in Cretaceous and older rocks are effectively concealed by the thick sequence of Tertiary and Quaternary sediments. Structural deformities within the Tertiary-Quaternary sequence are obscure owing to lateral changes in lithology within short distances, paucity of marker beds, and a succession of unconformities. However, the major structures have long been recognized, and now, through use of abundant subsurface data, several subsidiary structures have been defined by DeGraw (1969) and are shown in figure 5 with some modifications.

Large parts of the Denver-Julesburg Basin and Chadron Arch and smaller parts of the Black Hills Uplift and Kennedy Basin extend into western Nebraska. Also present are several secondary

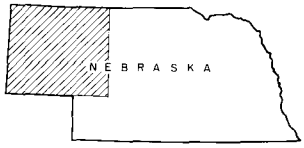
FIGURE 5



EXPLANATION



APPROXIMATE MEAN DECLINATION, 1960



INDEX MAP

Anticlinal trend or arch

Synclinal trend

Plunging anticline

Plunging syncline

Fault zone (or trend)

Figures indicate estimated structural relief or throw, in feet

• Arthur

Place name from which structural feature is named

STRUCTURAL FEATURES IN WESTERN NEBRASKA

(Interpreted from "X" Bentonite Datum of the "Graneros")

10 0 10 20 30 40

SCALE IN MILES

VI-LM-5

structural features. Two of these, informally designated the Crawford Basin and the Cochran Arch, are in the northwestern part of the state and are now considered to be subsidiary features of the Denver-Julesburg Basin. Their limits are fairly well defined but the indicated intrabasinal structural trends of the Crawford Basin are only inferred. Other secondary features, such as the informally named Arthur, Oshkosh-Lewellyn, and Big Springs Anticlines in the southeastern part of the region, cannot now be defined accurately. The "Sidney Fairway" in eastern Cheyenne County is known to be structurally complex but is shown in figure 5 as a generalized pattern as it has not been satisfactorily analyzed.

Normal faults are common structural features throughout western Nebraska and appear to be associated with all recognized structural trends as well as many undesignated features of smaller scale. Most faults have a pre-Oligocene age but some faulting has been recognized in Tertiary strata in both outcropping and subsurface situations. Some reevaluation of the interpreted pre-Oligocene surface configuration and drainage patterns (figure 7) in parts of the region are required as it is now known that Tertiary faulting is more prevalent than earlier believed.

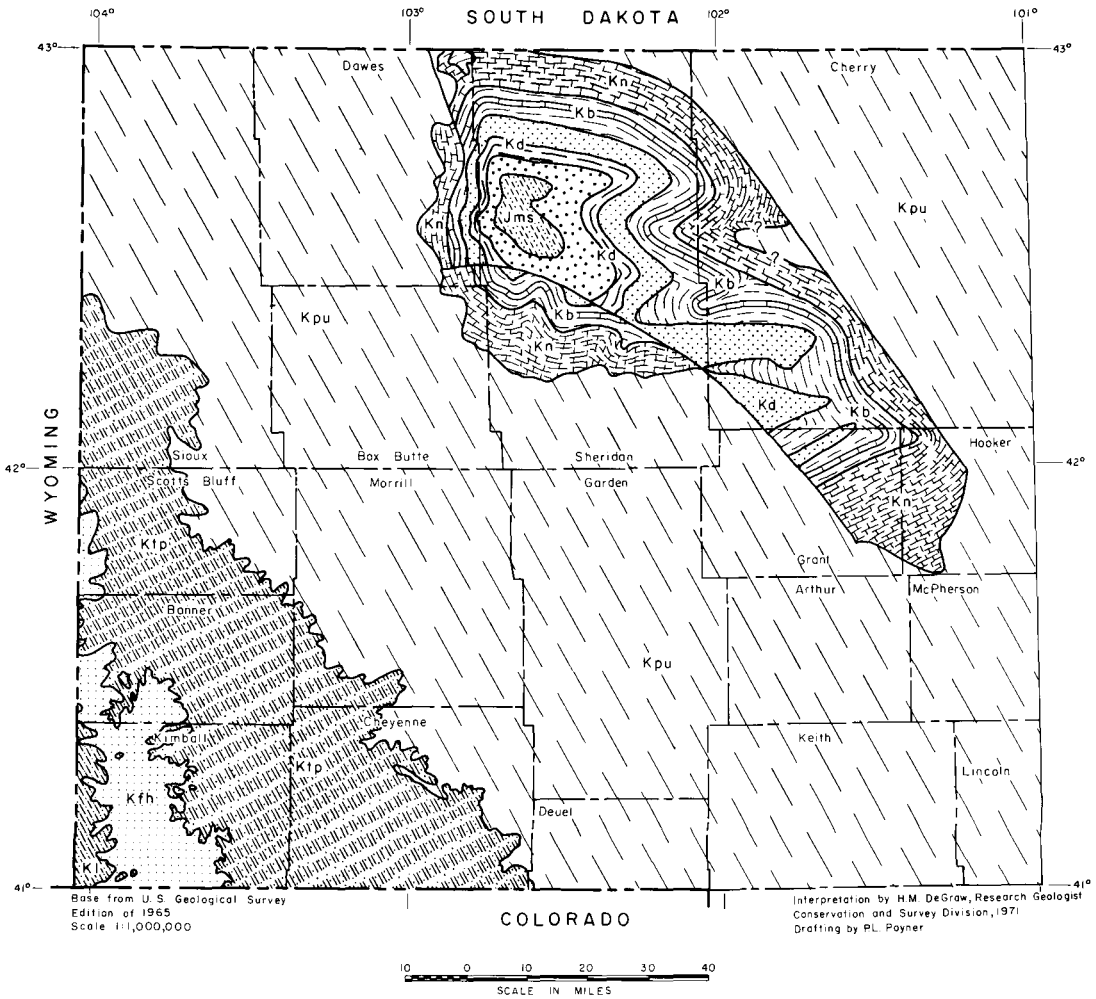
STRATIGRAPHIC RELATIONS

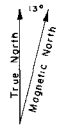
Relations of the strata overlying and underlying the pre-Oligocene surface are those expectable for a regional unconformity. In western Nebraska, as shown in figure 6, truncated formations range from uppermost Cretaceous (Lance and Fox Hills) down through basal Cretaceous ("Dakota") and locally include Jurassic (Morrison and probably Sundance). Pierre, Fox Hills, and Lance strata subcrop in the Denver-Julesburg Basin but the Pierre is by far the most extensive unit. The Pierre also subcrops in the Kennedy Basin and along the flanks and in structurally low areas of the Chadron Arch. Subcrops of the Niobrara and older strata are restricted to this arch.

Sediments resting directly on the pre-Oligocene surface are almost exclusively Chadron (basal Oligocene). The distribution patterns of different lithologies for the basal Chadron sediments show conclusively that they were topographically controlled. Furthermore, these basal sediments serve as a clue to post-Oligocene faulting in areas where their relation to the configuration of the pre-Oligocene surface appears to be out of character.

Post-Oligocene truncation and subsequent sedimentation resulted in younger sediments overlying pre-Oligocene strata in a few places. In at least one place--the modern Cheyenne Tablelands in northwestern Kimball and southwestern Banner Counties--pre-Miocene erosion (channel cutting) removed Oligocene strata, and Miocene (probably Arikaree) valley-fill sediments were deposited on Fox Hills strata (DeGraw, 1969). In a few other places, such as in the Pierre Hills area and, locally, in the North Platte

FIGURE 6





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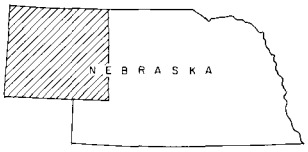


INDEX MAP

EXPLANATION

CRETACEOUS SYSTEM

- K — Lance Formation
- Kn — Niobrara Formation
- Kfh — Fox Hills Sand
- Kb — Carlile Shale, Greenhorn Limestone, Graneros Shale — Benton Group
- Ktp — Transition Zone, Pierre Shale
- Kd — Omadi Formation, Skull Creek Shale, Cloverly Formation — Dakota Group
- Kpu — Pierre Shale, Undifferentiated

JURASSIC SYSTEM

- Jms — Morrison Formation, ?Sundance Formation

PRE-OLIGOCENE GEOLOGIC MAP OF WESTERN NEBRASKA

valley, none of the Tertiary sequence remains and Quaternary sediments directly overlie Cretaceous rocks. Thus the pre-Oligocene surface in western Nebraska is an almost intact paleo-topographic surface that locally has been truncated and shifted during later erosional and tectonic episodes.

PALEOTOPOGRAPHIC CHARACTERISTICS

Across western Nebraska (figure 7), the relief on the pre-Oligocene surface exceeds 3,300 feet. The highest point, located in the southwestern corner of the state, is about 4,800 feet above sea level and the lowest point, in the eastern part of the region, is below 1,500 feet. Local relief between adjacent ridges and valleys commonly exceeds 300 feet.

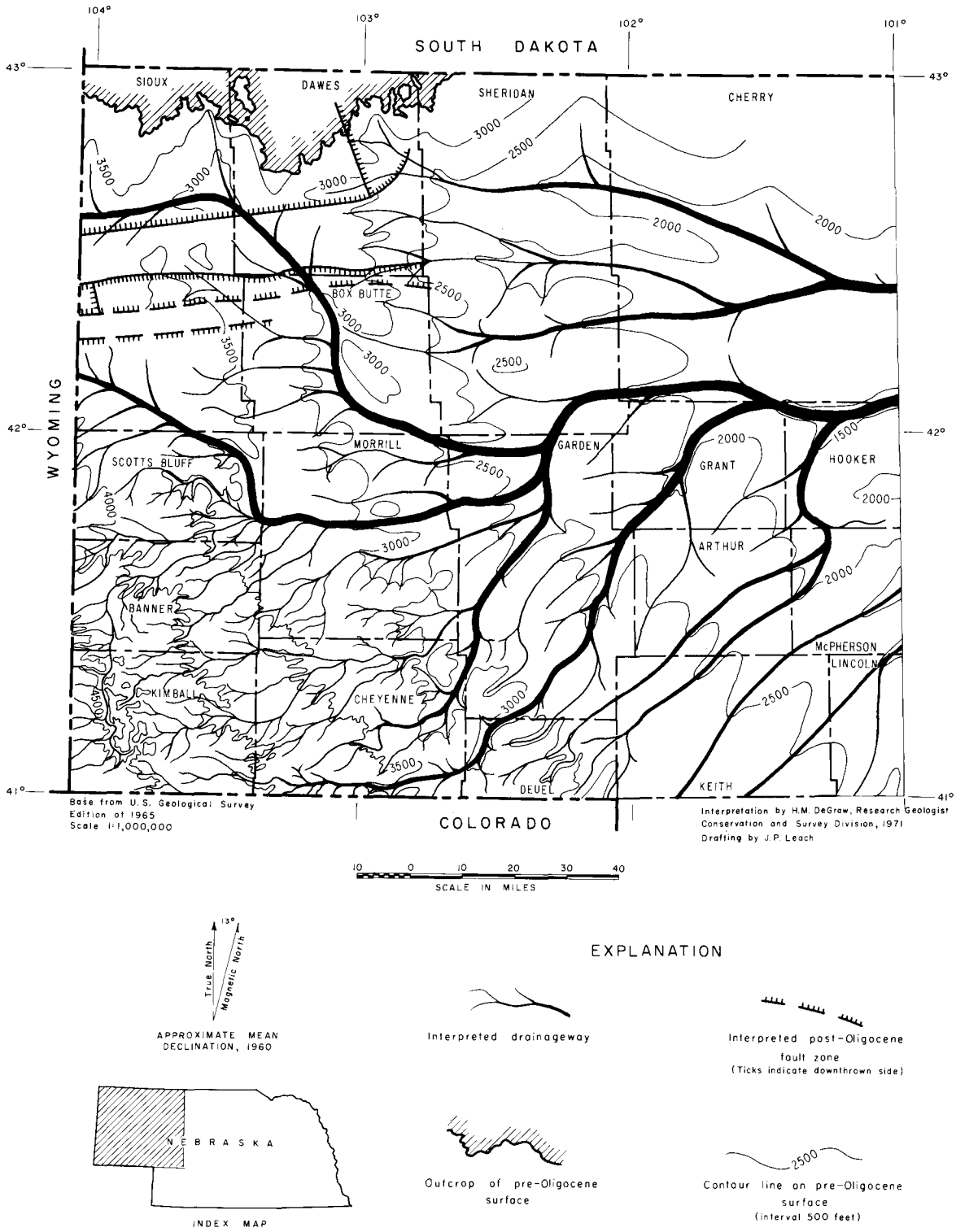
Only two principal pre-Oligocene valleys enter Nebraska from the west; one, in southwestern Sioux County, subparallels the modern North Platte River, and the other, in northwestern Sioux County, occurs south of the Pine Ridge Escarpment. These two paleo-valleys are tributaries of the same major paleo-valley which extends beneath the modern Sand Hills Region in north-central Nebraska. In fact, virtually all of western Nebraska was within the drainage basin of that major paleo-valley.

For much of the High Plains Region, in both outcrop and sub-surface situations, the "Interior Paleosol Complex" of Schultz and Stout (1955) provides an excellent "lithologic" marker of the pre-Oligocene surface. Characterized by vivid coloration, it exhibits some zonation and banding and has a wide range in thickness. This weathered zone is commonly thicker and better developed on upland areas and where formed on more permeable strata; it is thinner or entirely truncated in the larger paleo-valleys. Of great strati-graphic importance, this ancient lateritic soil has been misin-terpreted by several previous workers when making surface and sub-surface correlations. For example, varicolored strata have been considered as characteristic of the Lance (Schlaikjer, 1935; Wenzel, Cady, and Waite, 1946) and also evidence for the Fox Hills (Ward, 1922). In the Chadron Arch area, where this paleosol formed on "Dakota" strata, at least one petroleum geologist assumed it to be a local environmental characteristic of the "Dakota."

In some pre-Oligocene paleo-valleys, the coloration and lithology of basal Chadron sediments closely resemble the "Interior Paleosol," and in such places the Tertiary-Cretaceous contact is nearly impossible to define.[1/] This contact is also obscure in

1/This stratigraphic problem is common for continental deposits. For example, at one site in Banner County, Quaternary sediments consisting of reworked Brule (Oligocene) can be distinguished from *in situ* Brule only by close inspection. Also, along the base of the Pine Ridge Escarpment in Dawes and Sioux Counties, Quaternary sediments consisting of reworked Chadron so closely resemble *in situ* Chadron that different geologic maps of that area commonly are not in accord.

FIGURE 7



PRE-OLIGOCENE TOPOGRAPHY AND DRAINAGE PATTERN IN WESTERN NEBRASKA

some areas where electric log resistivities of the Oligocene and Cretaceous strata are similar. This latter problem is most common where coarse clastics occur in both sequences. In most places where considerable data are available, valid correlations can be made with much detailed study; but in a few places, additional data are required.

PALEOTOPOGRAPHIC CONTROL

Two geologic factors--structural trends and subcrop lithologies--appear to have had the most influence on the configuration of the pre-Oligocene surface as interpreted in figure 7. In those areas in which abundant well data allow detailed study, structural trends appear to have been the dominant factor.

Structural control is best considered in terms of time of occurrence--either Laramide (Late Cretaceous-Early Tertiary) or post-Laramide even though structural trends of Laramide and post-Laramide tectonisms cannot always be differentiated. Laramide tectonism most certainly provided the "grain" for topographic development on the pre-Oligocene surface, but post-Laramide tectonism materially influences interpretation of the pre-Oligocene surface (figure 7). Moreover, post-Laramide adjustments may have occurred along the Laramide zones of weakness, thus further complicating the relations.

The regional slope of the pre-Oligocene surface is attributed to epeirogeny. Although development of major drainageways commonly is controlled by structural patterns, neither the ancient nor the modern North Platte River appears to be related to any recognizable structural trend in western Nebraska. However, both drainageways are believed to have been locally controlled by structural trends in the Hartville Uplift in eastern Wyoming, and,thence, by the regional slope eastward into Nebraska.

The relation of the pre-Oligocene surface to local Laramide structural trends in western Nebraska is especially apparent when paleotopographic trends are compared with the location of oil and gas field locations (DeGraw, 1969, pl. 3). The consistent coincidence of paleotopographic ridges and oil and gas occurrence suggests a common controlling factor.

Many of the structural features in the northwestern part of the state appear to be related to post-Laramide deformation. Here, basal Chadron coarse clastics in oil-test wells on the Cochran Arch occur at elevations nearly 300 feet higher than correlative Chadron sediments in nearby wells of the Crawford Basin. In cross section, this relation is suggestive of "hanging valleys."

The influence of subcropping rock on the pre-Oligocene surface configuration (figure 7) cannot be reasonably assessed for much of the region because well control is too sparse. It is to

be expected, certainly, that differing lithologies of the subcropping formations on the Chadron Arch would be reflected in their eroding characteristics and, thus, their paleo-surface characteristics. Also, the shale lithology of the "Undifferentiated Pierre" is so uniform that it alone should not significantly affect local topographic relief. However, in western Kimball County considerable data indicate that some lithologies of uppermost Cretaceous strata exhibit preferential topographic positions. For example, sands of the Fox Hills subcrop in local drainageways whereas the Lance, which is lithologically variable, commonly forms the adjacent ridges (figures 6 and 7).

INHERITANCE OF TOPOGRAPHIES

Although the general configuration of the modern High Plains surface in western Nebraska (figure 4) differs considerably from that of the pre-Oligocene surface (figure 7), some local characteristics of the modern surface apparently were inherited from features of the paleosurface. For example, the areas of highest elevation of both surfaces nearly coincide in the southwestern corner of Kimball County. Also, as already mentioned, the course of the modern North Platte River in Scotts Bluff County is close to and subparallel to that of the ancient "North Platte" tributary in the same area.

Coincidence for segments of drainageways also has been recognized for other Tertiary unconformable surfaces. Rush Creek, a prominent north-trending tributary of the North Platte River in eastern Cheyenne and southwestern Garden Counties, coincides with an underlying pre-Pliocene (pre-Ogallala) as well as a pre-Oligocene drainageway. Additionally, the downthrown block of the Big Springs Fault in eastern Deuel County (figure 5) is overlain by both pre-Pliocene and pre-Oligocene paleo-valleys. This latter example demonstrates the relation of structure to paleotopography and the inheritance of topographies especially well.

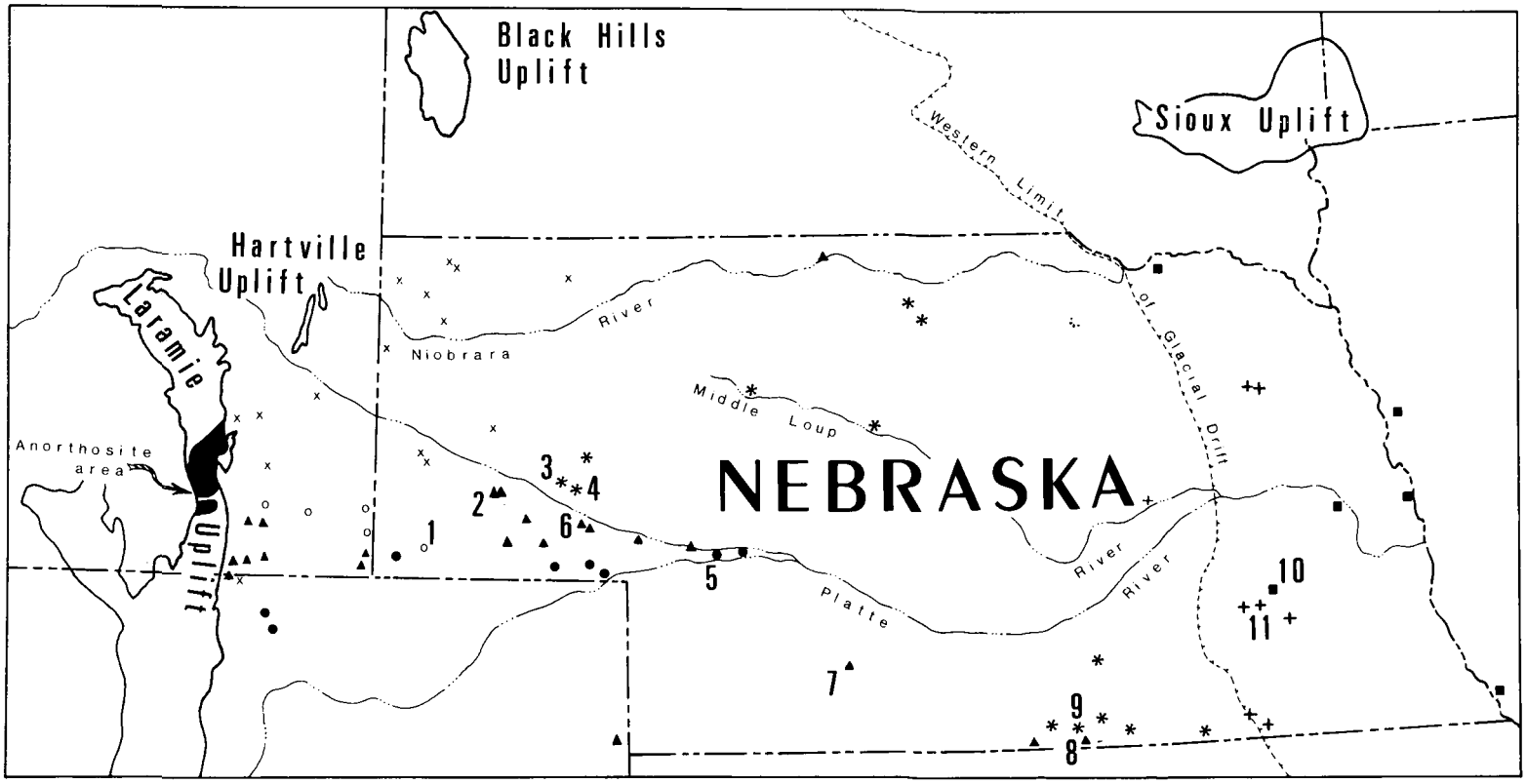
Part of the pre-Oligocene topography may have been inherited from older (Late Cretaceous and early Tertiary) topographies which, in turn, probably were structurally controlled. Certainly, the prominent south-trending valley and adjacent ridge of the pre-Oligocene surface in Box Butte County (figure 7) reflect Laramide structural "grain" (that is, they sub-parallel the Chadron Arch). They also may reflect uppermost Cretaceous drainage trends (Degraw, 1967).

Numerous topographic changes occurred during Tertiary sedimentation in western Nebraska, as is suggested by the Tertiary bedrock pattern of the Nebraska geologic map. Stratigraphic evidence supports the conclusion that previously established topographic patterns were partially inherited by progressively younger surfaces and that the significant modifications were due primarily to intervening structural movements.

SUMMARY

The pre-Oligocene (pre-Chadron) surface in western Nebraska is an important regional unconformity that truncates Cretaceous and Jurassic strata. This surface exhibits the characteristics of a moderate topography with local relief of 300 feet or more. Basal Chadron sediments relate well with this surface as coarse clastics and clays occupy the drainageways, whereas silts mantle the uplands. Topographic configuration is primarily controlled by both regional and local structural trends and is secondarily influenced by the lithic characteristics of underlying rocks. Younger structural patterns superimposed on the region complicate the relations and make valid interpretations difficult.

The coincidence of some topographic patterns of the modern and pre-Pliocene surfaces with paleotopographic patterns of the pre-Oligocene surface emphasizes the importance of topographic inheritance. Conversely, major differences in younger Tertiary and modern topographies combined with available evidence for faulting support the conclusion that lateral structural trends were the primary cause of modification in younger topographies.



OLIGOCENE AND MIOCENE GRAVEL - x, PLIOCENE GRANITIC GRAVEL-▲, PLIOCENE ANORTHOSITE-BEARING GRAVEL-o, PLEISTOCENE GRANITIC GRAVEL-●, PLEISTOCENE ANORTHOSITE-BEARING GRAVEL-*, PLEISTOCENE RED QUARTZITE-BEARING GRAVEL-■, PLEISTOCENE GRAVEL WITH ANORTHOSITE AND RED QUARTZITE CLASTS-+.

Figure 8. Index map showing the locations of Cenozoic gravel deposits exposed in Nebraska and adjoining Wyoming where pebble-composition data were collected. Columns 1 to 11 in table 1 refer to the numbered sample localities 1 to 11 on the index map.