STRATIGRAPHY OF THE BOX BUTTE FORMATION NEBRASKA

TED GALUSHA

BULLETIN
OF THE
AMERICAN MUSEUM OF NATURAL HISTORY
VOLUME 156 : ARTICLE 1 NEW YORK : 1975

STRATIGRAPHY OF THE BOX BUTTE FORMATION NEBRASKA

TED GALUSHA
Frick Associate Curator
Department of Vertebrate Paleontology
The American Museum of Natural History

BULLETIN
OF THE
AMERICAN MUSEUM OF NATURAL HISTORY
VOLUME 156 : ARTICLE 1 NEW YORK : 1975

BULLETIN OF THE AMERICAN MUSEUM OF NATURAL HISTORY
Volume 156, article 1, pages 1-68, figures 1-16

Issued September 18, 1975
Price. $4.30 a copy

ISSN 0003-0090

CONTENTS

FIGURES

ABSTRACT

Sedimentary deposits of northwestern Nebraska formerly assigned to the Box Butte Member of the Sheep Creek Formation are redefined as the Box Butte Formation, new rank. Two new members are proposed: the Red Valley Member, new name, the lower unit; and the Dawes Clay Member, new name, paraconformably overlying it. Type localities, type sections, and a series of reference sections are proposed for each new or redefined unit.

Deposits assigned to the two members of the Box Butte Formation crop out in irregular exposures, some of which occur in well-defined paleovalleys in an area covering nearly 900 square miles situated high along the rims and ridges of tablelands forming the northern border of the High Plains. Sediments of the Red Valley Member are red siltstones or clayey siltstones predominantly, with occasional sandstone lenses or admixtures of sand. Coarser clasts are confined to the bottom and sides of paleovalleys and are mostly small cobble- or pebble-sized sandstone concretions reworked from the underlying Runningwater Formation = Upper Marsland Formation.[1] The Red Valley Member occurs only in paleovalleys, which are narrow and steep-walled on the more westerly outcrops, but widen to a few hundred yards along the easterly exposures and are incised as much as 140 feet into the Runningwater. White to gray, hard, nodular calcareous concretions are the most distinctive lithologic feature of the Dawes Clay Member; they are conspicuously absent in the Red Valley Member. The Dawes Clay Member commonly is 25 to 30 feet thick but may range from 20 to 40 feet. It crops out as a distinctive set of mottled reddish and greenish clayey siltstones on which the characteristic white calcareous nodules may be concentrated at certain horizons. Where the Red Valley Member is absent, the Dawes Clay lies unconformably on the Runningwater Formation, and on most outcrops it is in contact with the Platy Bench, a topographic feature formed at several levels in the upper part of the Runningwater. In western Dawes, western Box Butte, and eastern Sioux counties, the Dawes Clay Member is overlain by beds correlated with the Sand Canyon Member of the Sheep Creek Formation.

Mammalian fossils collected in the Box Butte Formation show that the formation was deposited earlier than the earliest beds of the Sheep Creek Formation and later than any beds assigned to the Runningwater Formation; thus the Box Butte was deposited during a segment of time heretofore not recognized formally in the Nebraska geologic section.

INTRODUCTION

The stratigraphic position of the Box Butte Member of the Sheep Creek Formation as described by Cady (1940) has been the subject of bitter controversy almost from the date of description. Workers dealing with the late Tertiary beds of northwestern Nebraska have argued extensively, sometimes heatedly, at meetings and field conferences regarding the Box Butte, but little field work has been directed toward resolving the problem of age of the deposits or stratigraphic allocation of them.

New rock-stratigraphic and biostratigraphic evidence that I have collected during several field seasons since 1962 indicates that the Box Butte deposits are pre-Sheep Creek in age; they are a distinct unit in their own right and, moreover, underlie beds that are equivalent to the Sand Canyon Member of the Sheep Creek Formation (Skinner, Skinner, and Gooris, MS).[2] Data presented in the present report should help clarify the position of the Box Butte, which in the past was assigned a stratigraphic position as the

[1]The term Runningwater Formation=Upper Marsland Formation is used here to direct attention to the existence of two formational names that currently are being applied to the same set of beds. Until clarification of the status of the beds is published, proponents of either of the terms are advised to read Runningwater Formation=Upper Marsland Formation wherever Runningwater Formation appears in the present report.

[2]Field men for the University of Nebraska and the Nebraska State Geological Survey consider the Lower Snake Creek beds to be an upper part of the Sheep

uppermost member of the Sheep Creek Formation by A. L. Lugn (1939, p. 1258) and by most later workers, a position that was particularly crucial because this automatically made it the uppermost part of the Hemingford Group (A. L. Lugn, 1939, pp. 1253, 1256, 1258) by original definition.

Reexamination of the Box Butte Member of the Sheep Creek Formation (Cady, 1940) and of vertically contiguous deposits has demonstrated the desirability of redefining, and changing, the Box Butte from the rank of member of the Sheep Creek Formation to that of a full-fledged formation. The Box Butte Formation, as proposed in the present report, presents an unusual degree of internal lithologic homogeneity and distinctive lithologic features when compared with other Tertiary formations exposed in western Nebraska. The typical deposits are red or green siltstone, or clayey siltstone, with minor amounts of sandstone, all having a distinct tendency to be mottled red and green on fresh exposures. These deposits are predominantly reddish, brownish, or pinkish on weathered outcrops. These and other distinguishing lithologic features are given in detail in the subdivisions describing the proposed new members.

Diagnostic mammalian fossils were found at several sites in Cady's (1940) Box Butte and in the underlying deposits he (p. 666) correlated as "a channel-fill of Sheep Creek sediments." These fossils (present report, p. 54) are different from any collected from the type area of the Sheep Creek Formation in Sioux County, Nebraska, and provide for the first time sufficient biostratigraphic evidence to interpret confidently the age of the Box Butte sediments. They furnish evidence of the existence of deposits representing a segment of time, heretofore unrecognized in northwestern Nebraska, bridging part of the hiatus between the Runningwater Formation and the Sheep Creek Formation.

Two new members of the Box Butte Formation are recognized in the present report and they crop out discontinuously over an area of more than 865 square miles. Each member proved to be readily mappable at a scale of 1:24000 and was particularly amenable to plotting on aerial photographs. Despite the presence of distinctive sedimentary features that permit easy identification and differentiation of the two members, the similar lithology and vertical intergradation of the two deposits compel recognition that they belong to the same formation.

ACKNOWLEDGMENTS

An adequate acknowledgment that would include all the people who have contributed more than minimal assistance in field and laboratory work in the preparation of this report, and in the actual writing of it, would be too long to be included here.

First of all I am grateful to the late Childs Frick for providing the opportunity to do the field work, and for support for all other phases of the report. Many ranchers in the study area permitted me to work on their land, and I especially thank the following for their kindly interest and help extended over many years: Mr. and Mrs. Archie Shimek, Dr. and Mrs. William Colwell, Mr. and Mrs. Hugh Foley, Mr. and Mrs. E. G. Homrighausen, Mr. and Mrs. Ralph Stamen, Mr. and Mrs. Harold W. Leetch, Mr. Roy Randall, Mr. Roy Mansfield, Messrs. John and Frank Havorka, Mr. Emmett Foley, and Mrs. Louis Planansky.

Advice and assistance were given by Drs. Bobb Schaeffer and Malcolm C. McKenna. Dr. Richard H. Tedford identified, or aided in the identification of, the Carnivora mentioned herein. Mr. Morris F. Skinner gave the same assistance with the Equidae, and Mr. Beryl E. Taylor helped with the Camelidae, Antilocapridae, and Cervidae. I owe a great debt to these colleagues for

Creek Formation. Morris F. Skinner, S. M. Skinner, and R. J. Gooris of the American Museum of Natural History have a report in the final stage of preparation in which they unravel the geology of the Sheep Creek-Lower Snake Creek type area and assign formational status to the Lower Snake Creek beds by adopting and adequately defining a replacement name. They also provide a cogent argument for eliminating Lower Snake Creek beds, but not Lower Snake Creek fauna, from the literature, and in both of these decisions I am in full accord. In the interim, to preclude confusion in the stratigraphic nomenclature pending publication of the Skinner, Skinner, and Gooris report, I have decided to use Elias's term Sand Canyon Member of the Sheep Creek Formation for deposits covered in the present report that are equivalent to the Lower Snake Creek beds.

their patient counsel regarding matters of biostratigraphy and rock-stratigraphy, but the synthesis and interpretation of the stratigraphy and biostratigraphy are my own, and none of these gentlemen necessarily endorse my conclusions. I thank each of these colleagues for critically reading the manuscript and for their helpful suggestions. I am grateful to Dr. Patricia V. Rich who identified the owl and to Dr. Max K. Hecht who identified the toad recorded in the preliminary faunal list.

Mr. Raymond J. Gooris handled the map and figures with his usual expertise, and it is a pleasure to acknowledge his help. My wife, Marian, aided in the field and in the task of criticism, editing, and typing of the manuscript.

ABBREVIATIONS

The following abbreviations are used:

AMNH, Department of Vertebrate Paleontology, the American Museum of Natural History
ASCS, Agricultural Stabilization and Conservation Service
F:AM, Frick American Mammals, Department of Vertebrate Paleontology, the American Museum of Natural History
USGS, United States Geological Survey

HISTORY OF THE NAME BOX BUTTE

BOX BUTTE AS A STRATIGRAPHIC UNIT

A discussion of the history of the name Box Butte should be a valuable adjunct to a better understanding of the important changes in rank proposed in the present report. Because each of the previous workers used Box Butte in a slightly different way, it is appropriate to investigate these differences and to comment on those aspects of the early history of the term concerning which I have firsthand knowledge.

The Box Butte Member of the Sheep Creek Formation, Nebraska, was named and described by Cady (1940, p. 663) under rather unusual circumstances, for in the previous year Alvin L. Lugn described briefly, but did not name, the same beds. Lugn (1939, p. 1258) stated that, "The privilege and responsibility of supplying a name for this formational subdivision belong to Richard C. Cady, of the United States Geological Survey, who is its discoverer and who is senior author of a publication in preparation on the geology and ground-water resources of Box Butte County, Nebraska." Lugn, however, was explicit and repeatedly designated these beds as the upper member of the Sheep Creek and said at one point (p. 1258) that, "This upper member of the Sheep Creek generally has been included with and measured as a part of the Marsland formation, on which it rests unconformably at most places, where no separating Sheep Creek valley fill deposits occur to reveal the true relationships." It is interesting to note that he also said that, "The total maximum thickness of this new member of the Sheep Creek formation is about 85 feet, and it is most fully developed in T. 29 and 30 N., R. 47 W., in southeastern Dawes County, Nebraska, a few miles northeast of Dunlap." Sand Canyon Quarry, which I discovered in 1931, is in sect. 29, T. 30 N., R. 47 W., Dawes County, and this site figured in many subsequent discussions of the relations of the Sheep Creek and the Box Butte. It was mentioned by Cady (1940, p. 666), Elias (1942, p. 132), and Cady and Scherer (1946, p. 34), and mislocated by each of them. Remarks concerning the Sand Canyon Quarry site are included in the present report (pp. 35, 53, 57), for it is designated as the type section of the Red Valley Member of the Box Butte Formation.

As mentioned, Cady (1940, p. 666) mislocated the site of Sand Canyon Quarry as being in sect. 33, T. 30 N., R. 47 W. (there are no beds of either member of the Box Butte Formation in sect. 33, T. 30 N., R. 47 W., Dawes County); I am certain that he meant to describe the Sand Canyon Quarry site for we discussed its deposits when he visited me in 1938 while I was leader of a Frick Laboratory field party working Potter Quarry, which is situated in Sand Canyon about one and a half miles northwest of Sand Canyon Quarry.

Cady (1940, p. 665) described the Box Butte sediments in general terms and discussed their relationship to the underlying Marsland Formation (these Marsland deposits are now considered to be part of the Runningwater Formation by some workers) and to other late Tertiary rocks in the area. A type section was cited and also a second section, which he apparently considered representative. The type section was given as "situated in sec. 27, T. 28 N., R. 49 W." (present report, fig. 1, site 1), and a more unfortunate selection of a type section is hard to imagine. I have studied carefully all the beds exposed in sect. 27, T. 28 N., R. 49 W., Box Butte County, as well as the beds exposed in adjacent localities. I am convinced that the type section published by Cady was measured in sect. 22, T. 28 N., R. 49 W. No beds are exposed in section 27 that remotely resemble his published section (fig. 8C), but such beds are well exposed in sect. 22. Regrettably Cady did not survive World War II; if he were alive no doubt some of the problems that have arisen concerning the Box Butte easily could be resolved. At this late date it is impossible to prove that an error existed in the designation of section 27 as the type section, but it is interesting to speculate how it might have happened. It would be a simple mistake for a

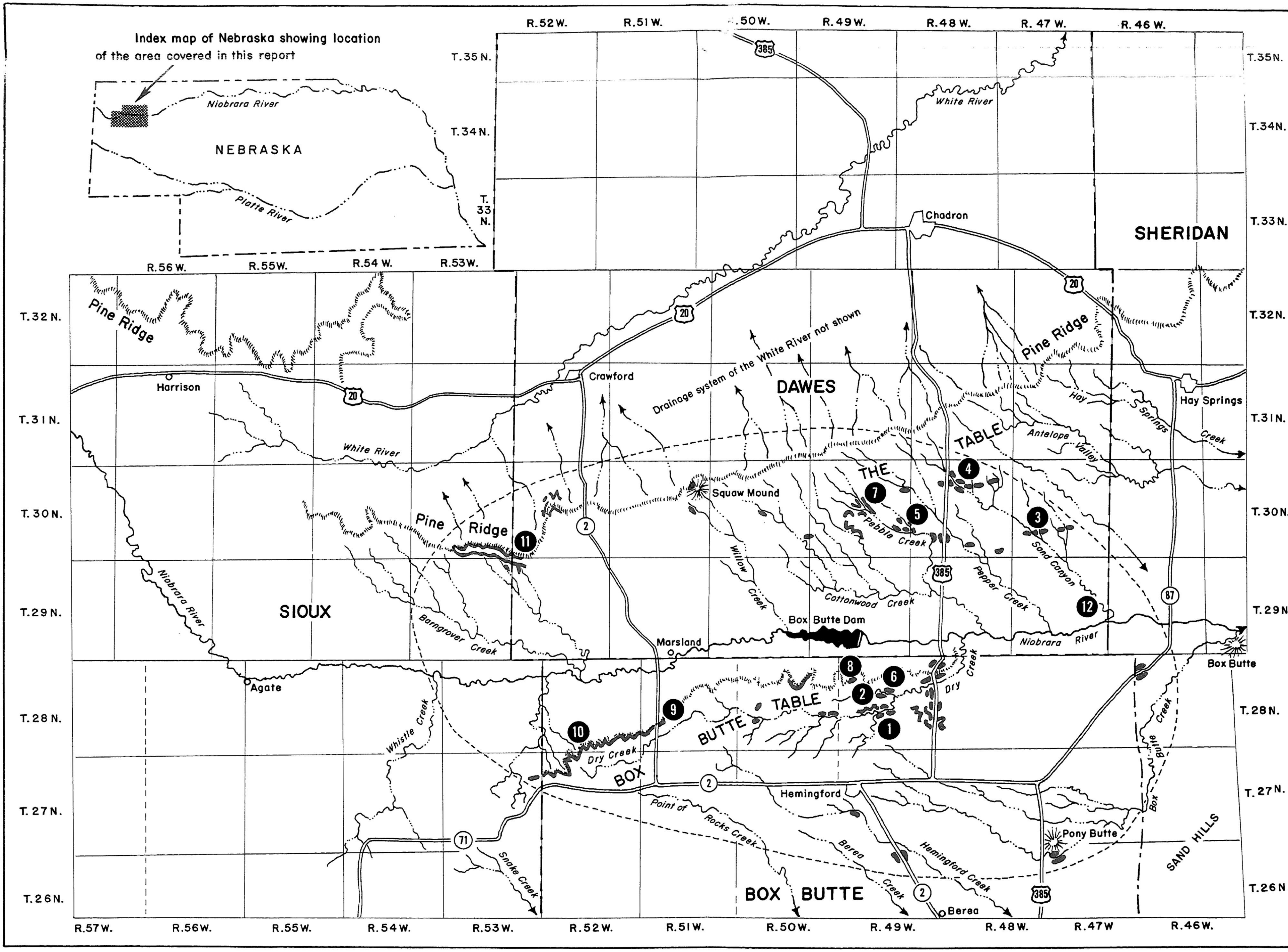


FIG. 1. Parts of Dawes, Box Butte, and Sioux counties, Nebraska, showing some outcrops of the Box Butte Formation. Area within the dashed ellipse shows approximate known extent of formation. Small, numbered, dark circles identify the following: (1) type section of Box Butte as established by Cady (1940); (2) principal reference section of Box Butte Formation; (3) Red Valley Member type section at Sand Canyon Quarry; (4) Red Valley Member reference section 1; (5) Red Valley Member reference section 2; (6) Red Valley Member reference section 3, Dry Creek Prospects locality; (7) Dawes Clay Member type section, Pebble Creek Ranch locality; (8) Dawes Clay Member reference section 1; (9) Dawes Clay Member reference section 2; (10) Dawes Clay Member reference section 3, Shimek bench mark locality; (11) Dawes Clay Member reference section 4; and (12) type locality of Sand Canyon Member of Sheep Creek Formation.

typist to misread section 27 for section 22 from handwritten notes; however, this would require also an error in proofreading. No topographic maps were available when Cady was doing field work in the locality, and he may have been misled by the peculiar arrangement of fences marking the subdivisions of the land at this particular site. He may have thought that he was measuring beds in the north part of section 27, but in reality he was in the south part of section 22. This explanation cannot be proved, but I believe it is reasonable, for it is almost inconceivable that the poorly exposed, largely covered, and partially represented beds in section 27 (see fig. 4) would have been selected as the type section of a new member when an essentially complete set of beds of the new member was well exposed in immediately adjacent outcrops.

The Wood Committee (Wood et al., 1941, p. 15) listed the Box Butte in the Glossary as "for the present best considered the upper member of the Sheep Creek formation, Barstovian, Box Butte County, Nebraska, mammalian fauna still undescribed." The Box Butte was shown on its correlation chart (pl. 1; present report, fig. 2) as early Barstovian.

In the guidebook for the first field conference of the Society of Vertebrate Paleontology, Schultz and Stout (1941, p. 43) mentioned the Box Butte, "The name 'Box Butte member' has recently been proposed by Cady (1940) for a part of the Sheep Creek formation in this general area." In the same guidebook, Elias (1941, p. 19) stated, "In the Box Butte clay member of the Sheep Creek the same species of *Stipidium* with smooth husk is found accompanying another species of the genus which has tuberculate husk and which become the characteristic grass of the succeeding Valentine vegetation."

The following year, in his monographic report on the Tertiary prairie grasses from the High Plains, Elias (1942) described several new species of grasses and speculated at length regarding the evolution of prairie grasses, and, in addition, wrote rather extensively on the stratigraphy of the late Tertiary rocks from which the described plant remains were collected. The fossil grass seeds and fossil mammalian remains that I collected and were reported by Elias (1942) will be reviewed in a report on the stratigraphy of the Hay Springs, Nebraska, area that I am preparing, in which stratigraphic allocations of the mammalian specimens will be made. At this time, however, attention is directed only to the deposits Elias called the "Box Butte Clay Member" of the Sheep Creek. He (1942, p. 132) gave another version of the location of the channel deposits, which herein are designated the type section of the Red Valley Member (present report, fig. 1, site 3) and contains the site of Sand Canyon Quarry. These he placed "in about the northeast corner sec. 32, T. 30 N., R. 47 W." No Red Valley Member deposits crop out in sect. 32, T. 30 N., R. 47 W., Dawes County.

As a result of his study of the Tertiary grass seeds, Elias reordered the stratigraphy of the Sheep Creek Formation and emphasized the position of the Box Butte as the upper member of the Sheep Creek. Owing to the impact that his report has had on subsequent studies involving the stratigraphy of the Box Butte, it is imperative that several of the specific examples he cited be reviewed.

An analysis of the biostratigraphic evidence on which Elias relied in assigning the Box Butte to the stratigraphic position as the uppermost member of the Sheep Creek Formation shows that the assignment was based solely on the occurrence of the fossil seeds of *Stipidium dawesense* mutation *alpha*, a new mutation, and *S. asymmetricum*, new species. It is regrettable that a small part of an otherwise excellent, scholarly, and important pioneer study must be selected for comment and firm refutation. This small part concerns the Box Butte, and therefore the following extended, but necessary, remarks apply solely to that part of the report.

Elias (1942, p. 77) directed attention to the differences between *Stipidium minimum* and those of the other two species of *Stipidium* from the Spottedtail, or lower member, of the Sheep Creek. He showed (pl. 17) the Spottedtail Member as the stratigraphic equivalent essentially of his *Stipidium minimum* zone in the system of zones based on herbaceous seeds that he proposed on the chart. *Stipidium dawesense*, which was characterized by moderate size and by having a smooth shiny lemma, is present in the Spottedtail Member, but became the dominant species in the Sand Canyon Member of Elias's terminology of the Sheep Creek Formation. The Sand Canyon form was designated "mutation *alpha*" on the basis of a larger hull than typical of *S. dawesense*. Elias (1942, p. 79) stated, "The hull of this mutation differs only in being larger than *S. Dawesense*. Because of this and its higher stratigraphical position it seems desirable to differentiate it as a late mutation of the species."

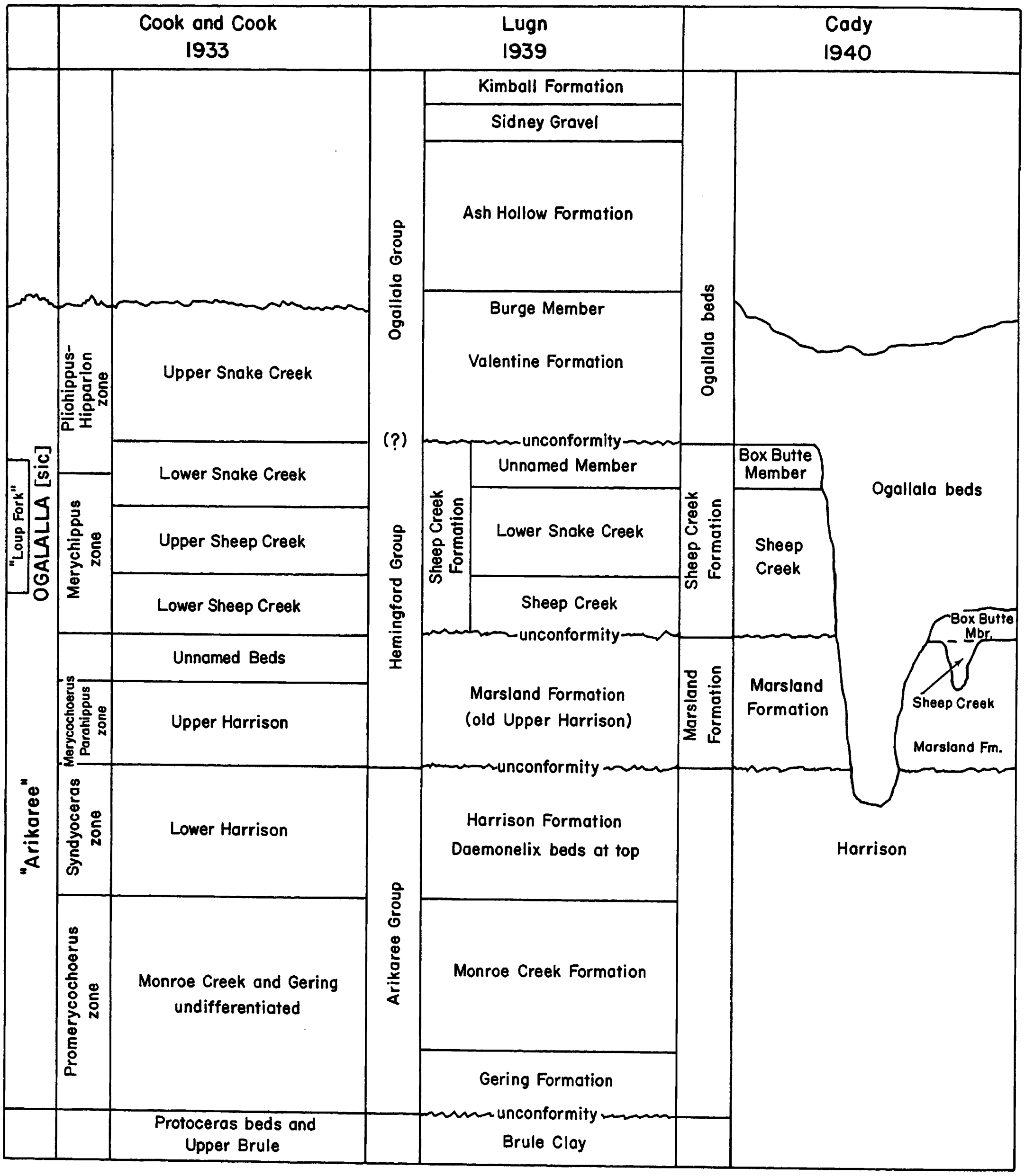
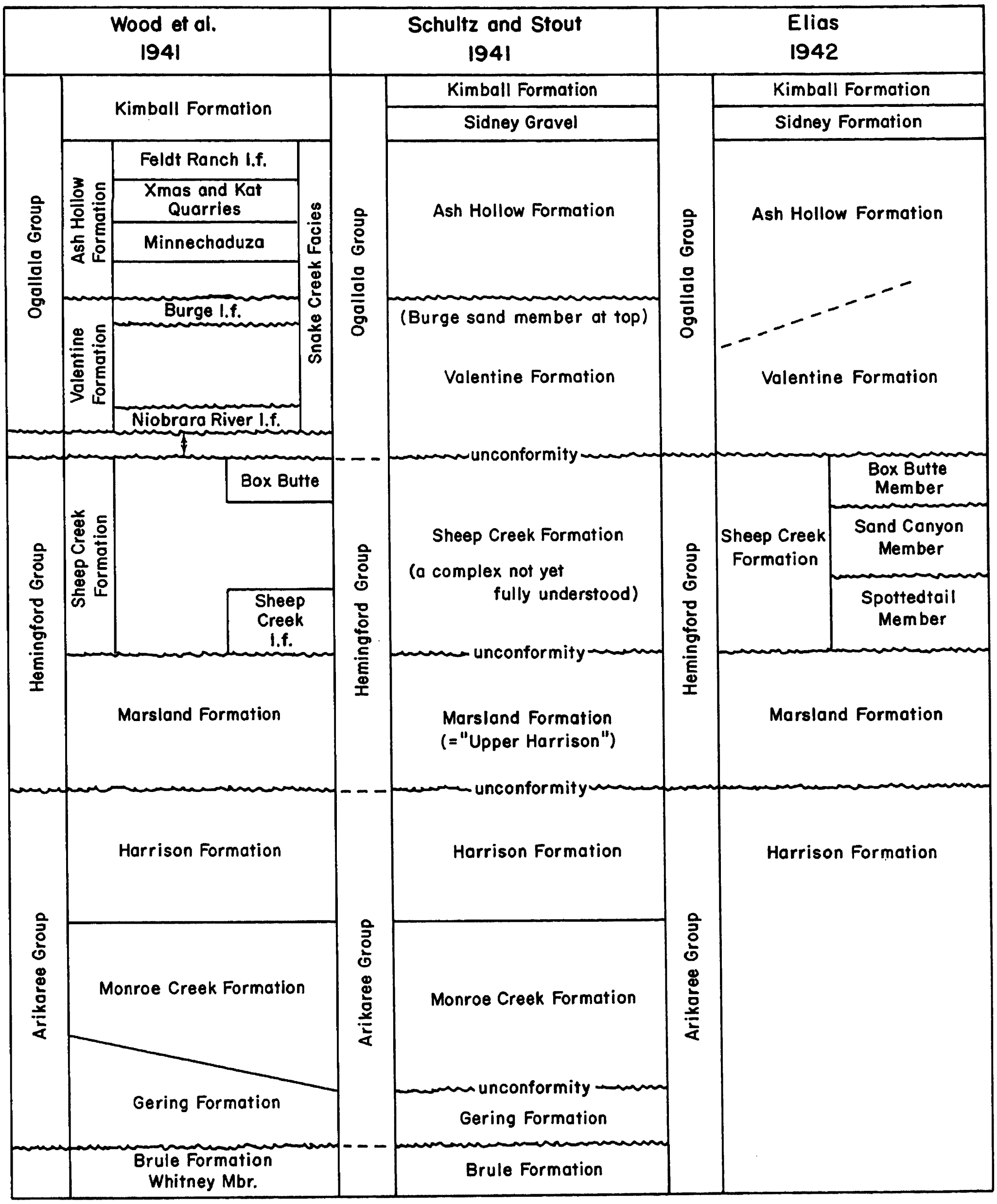


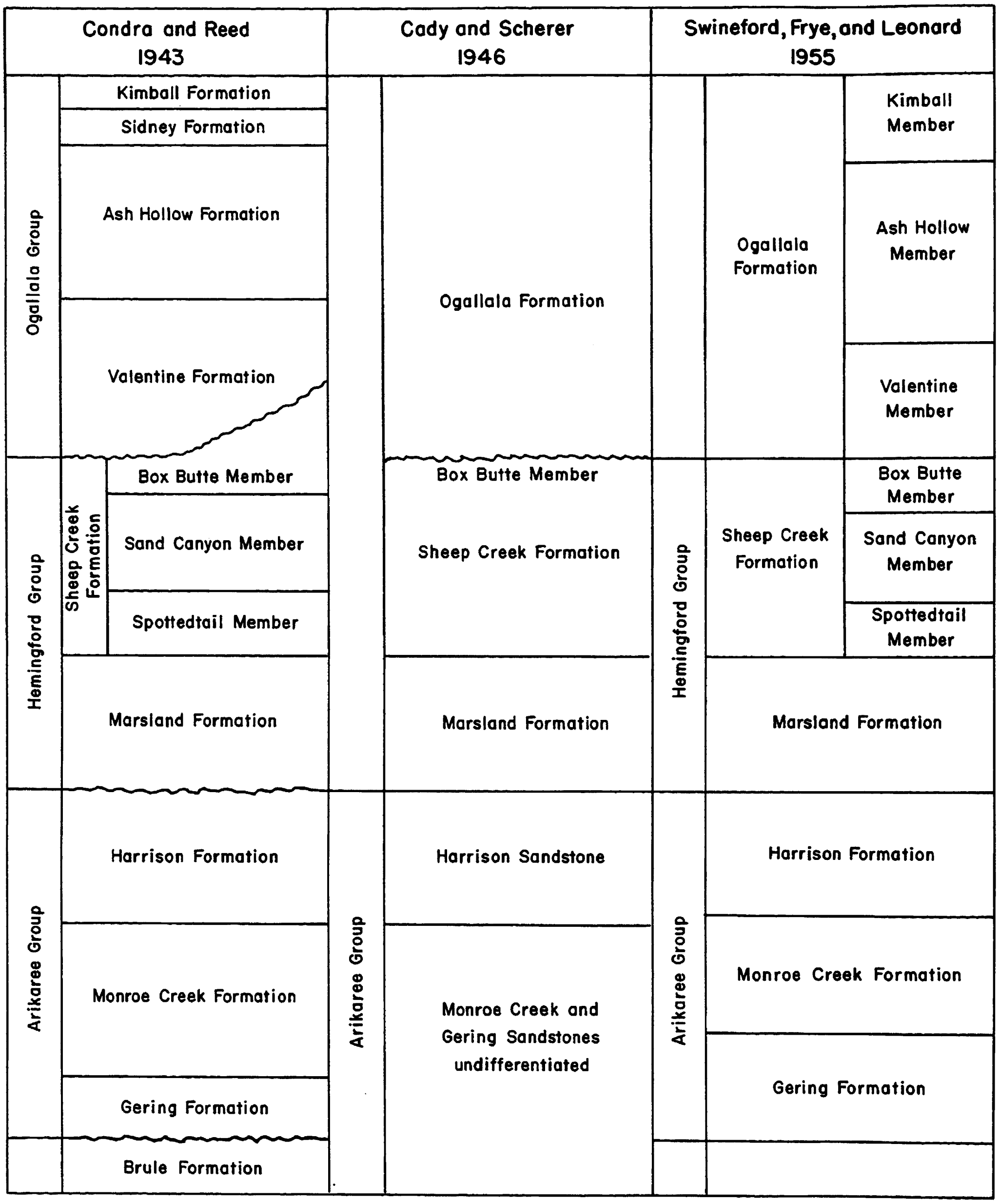
FIG. 2. Eight published correlation charts or data (on consecutive pages) that include interpretations of the stratigraphic position of Box Butte.

Its occurrence was given as "about 75 feet above the dark-gray volcanic ash, in SE ¼, sec. 11, T. 28 N., R. 47 W., Dawes County, Nebraska."

It is significant that Elias listed *S. dawesense* as occurring in the Sand Canyon Member of the Sheep Creek Formation and cited (1942, p. 79) three specific localities as follows: (1) the area in Sand Canyon that includes the type section of the Sand Canyon Member, and (2) a butte from which A. L. Lugn, Elias, and I collected seeds in 1934 on the occasion of their visit to the site of my Jorgenson Quarry. The seeds were collected



in the sandstones above the quarry site. Elias gave the location erroneously as "NE ¼ sec. 13, T. 31 N., R. 47 W., Dawes County,"; the true location is in the SW. ¼, NW. ¼, sect. 14, T. 31 N., R. 47 W., Dawes County. Occurrence (3) was given as "In a thin bed of gravel and sand directly below the dark-gray volcanic ash in West Kilpatric [*sic*] and Aphelops draws, SW ¼ sec. 29, T. 26 N., R. 53 W., about 16 miles south and 1 mile east of Agate, Sioux County, Nebraska." Elias's (p. 130) correlation of the beds in the Sheep Creek-Snake Creek area of Sioux County

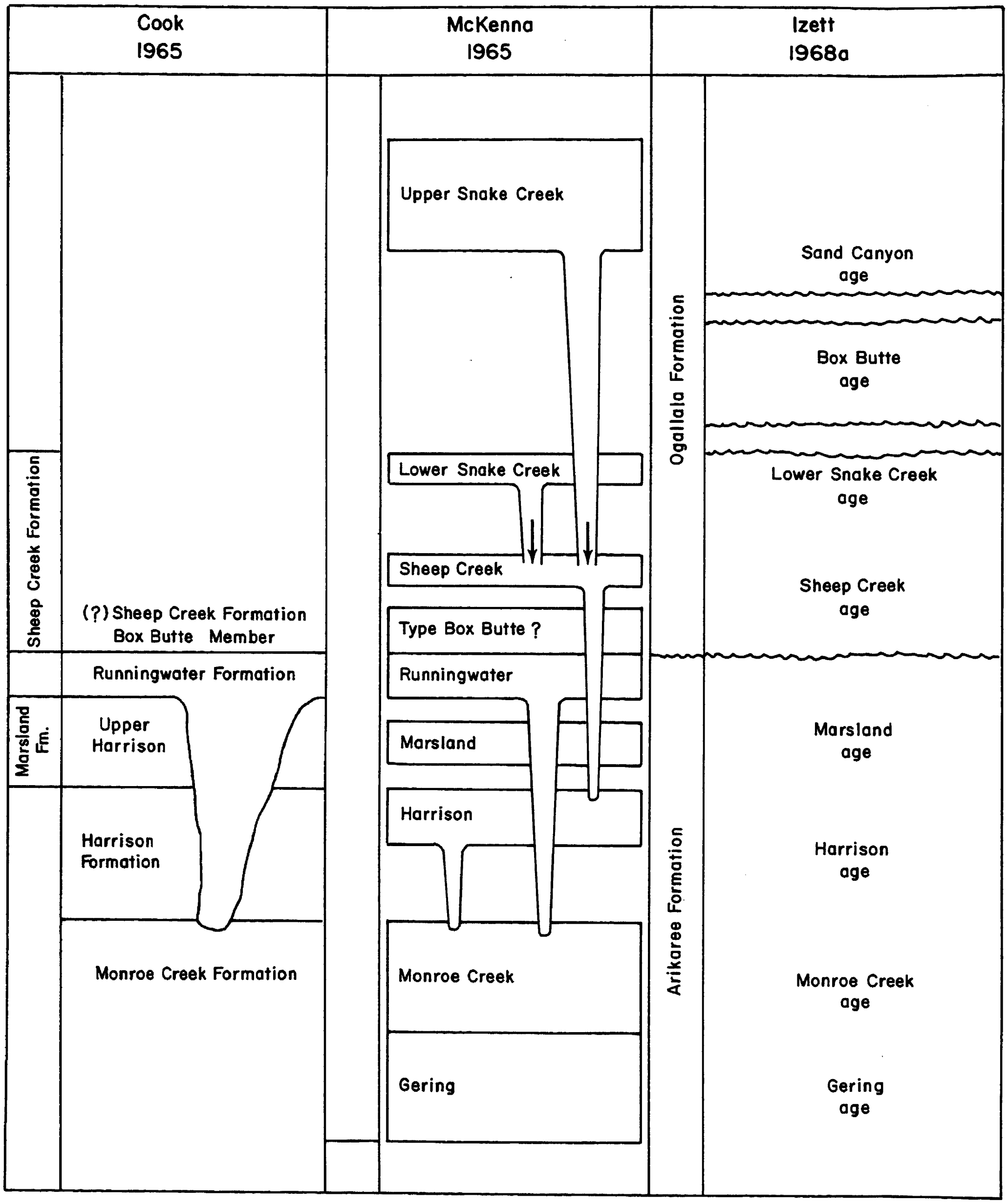


with those of the Hay Springs area rests principally on the following: "The uppermost 10 to 20 feet at the top of the section of the Sheep Creek at West Kilpatrick and Aphelops draws, which are correlated with the basal part of the Sand Canyon section on the ground of the identical fossil fruits (*S. dawesense*) and the presence of the dark-gray volcanic ash, are made of fine sand, softer than the much compressed (but not cemented) volcanic ash bed."

All the foregoing comments are required for an understanding of the tenuous nature of the

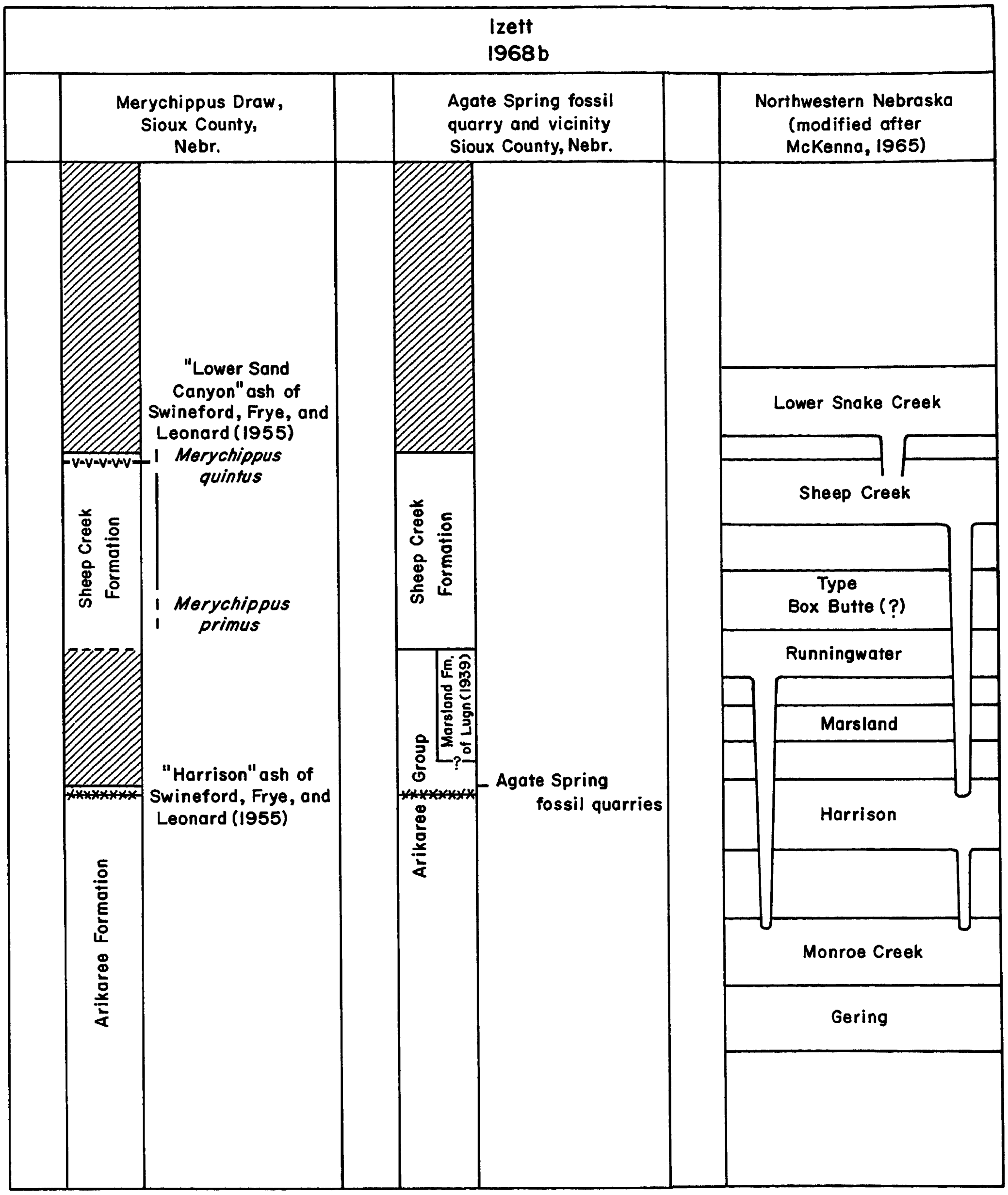
Lugn and Lugn 1956		Peckham 1961		Schultz and Stout 1961		
Ogallala Group	Kimball Formation / Sidney Gravel Fm. { Snake Creek Channels	Ogallala Group	Kimball Formation / Sidney Gravel Fm. Snake Creek Channels	Ogallala Group	Kimball Formation	UPPER MEMBER Dalton l.f.; SIDNEY MEMBER Cambridge l.f., Oshkosh l.f.
	Ash Hollow Formation		Ash Hollow Formation		Ash Hollow Formation	Upper pt., AshHollow: Feldt Ranch l.f., Xmas and Kat Quarries l.f.; Lower pt., AshHollow: Minnechaduza l.f. complex (?), CAP ROCK BED; Upper Snake Creek l.f.
	Valentine Formation		Valentine Formation		Valentine Formation	BURGE MEMBER Burge l.f.; Devil's Gulch l.f.; Fort Niobrara l.f.; Railroad Quarry l.f.; Crookston Bridge l.f.
	unconformity		unconformity			
Hemingford Group	Sheep Creek Formation (Box Butte Clay may be late Sheep Creek)	Hemingford Group	Sheep Creek Formation (Box Butte Clay may be late Sheep Creek unconformity)	Hemingford Group	Sheep Creek Formation	UPPER MEMBER (=Lower Snake Creek, = Sand Canyon, in pt.) Lower Snake Creek l.f.; LOWER MEMBER (=Sheep Creek, s.s., =Spottedtail, in part) Sheep Creek l.f.; Box Butte (?)
	unconformity					
	Marsland Formation (old "Upper Harrison")		Marsland Formation (old "Upper Harrison")		Marsland Formation	Marsland and Hemingford Quarries; Bridgeport Quarries
	unconformity		unconformity			
Arikaree Group	Harrison Formation	Arikaree Group	Harrison Formation (Unconformity—local)	Arikaree Group	Harrison Formation	Agate Spring Quarries
	unconformity, local					
	Monroe Creek Formation		Monroe Creek Formation		Monroe Creek Formation	
	Gering Formation		Gering Formation		Gering Formation	
	unconformity		unconformity			
	Brule Clay Formation		Brule Clay Formation		Brule Fm.	Whitney Member

evidence for assigning the Box Butte to the top of the Sheep Creek. The evidence is even less substantial when it is realized that the one recorded example of fossil seeds from the Box Butte was that given by Elias (1942, p. 79) as, "In greenish blocky semiconsolidated sand, of the Box Butte Member of the Sheep Creek formation of the Miocene, SW ¼ sec. 26, T. 28 N., R. 49 W., Box Butte County, Nebraska" (present report, p. 17). He also mentioned this occurrence in the part of his report dealing with the stratigraphy of late Tertiary rocks in which he (p.

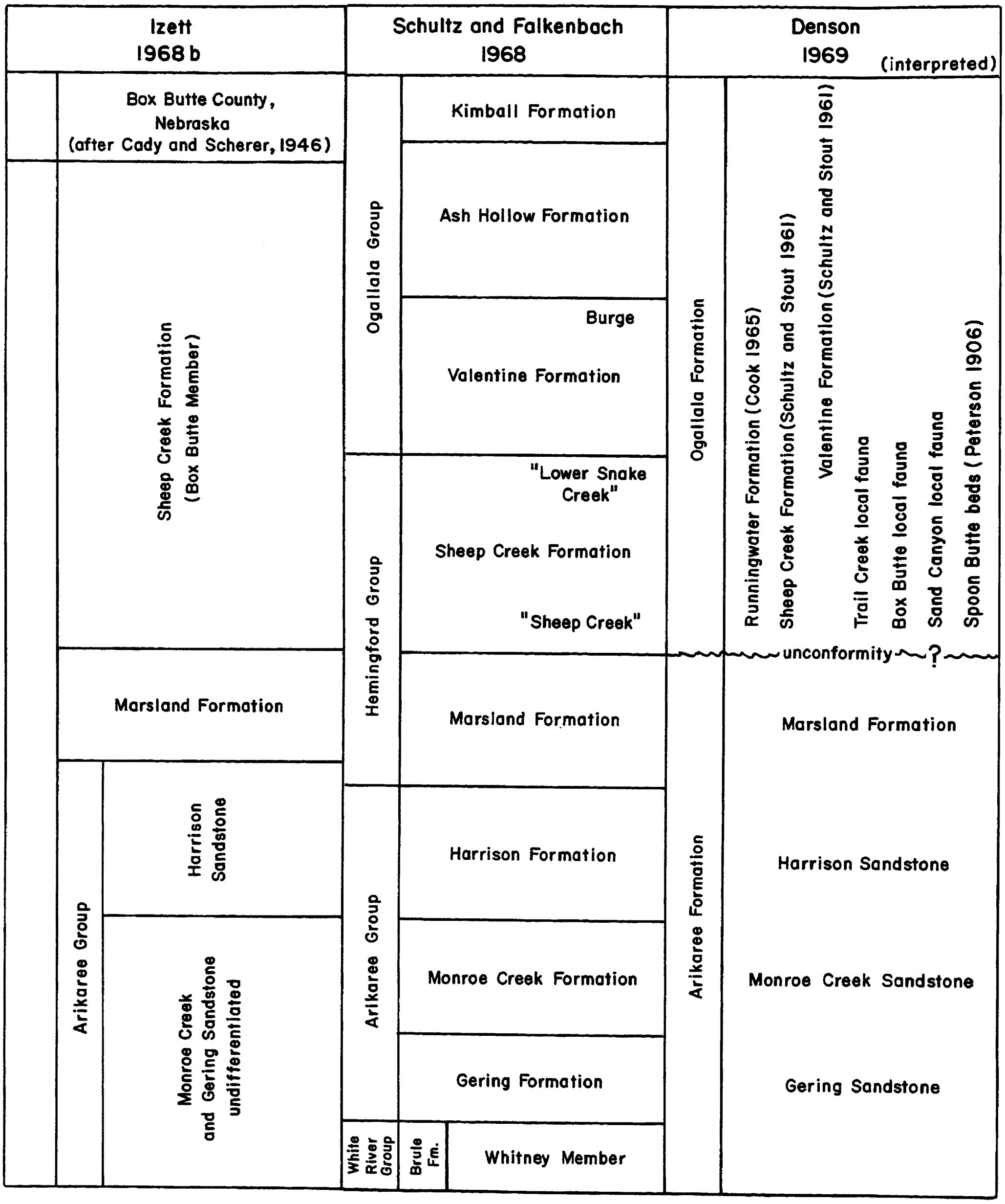


131) stated, "At a locality 3 miles east and 3 miles north of Hemingford, I measured about 35 feet of this sand, which contains a semiconsolidated 'blocky' layer in which I collected a few specimens of *Stipidium dawesense* mut. *a* and *S. commune*." It is interesting to note that Elias did not mention the above site in his original description (p. 80) of *S. commune*.

Perhaps the most significant remark by Elias (1942, p. 132) was, "Unfortunately no direct contact between the Box Butte and the Sand Canyon has been observed." He stated further:

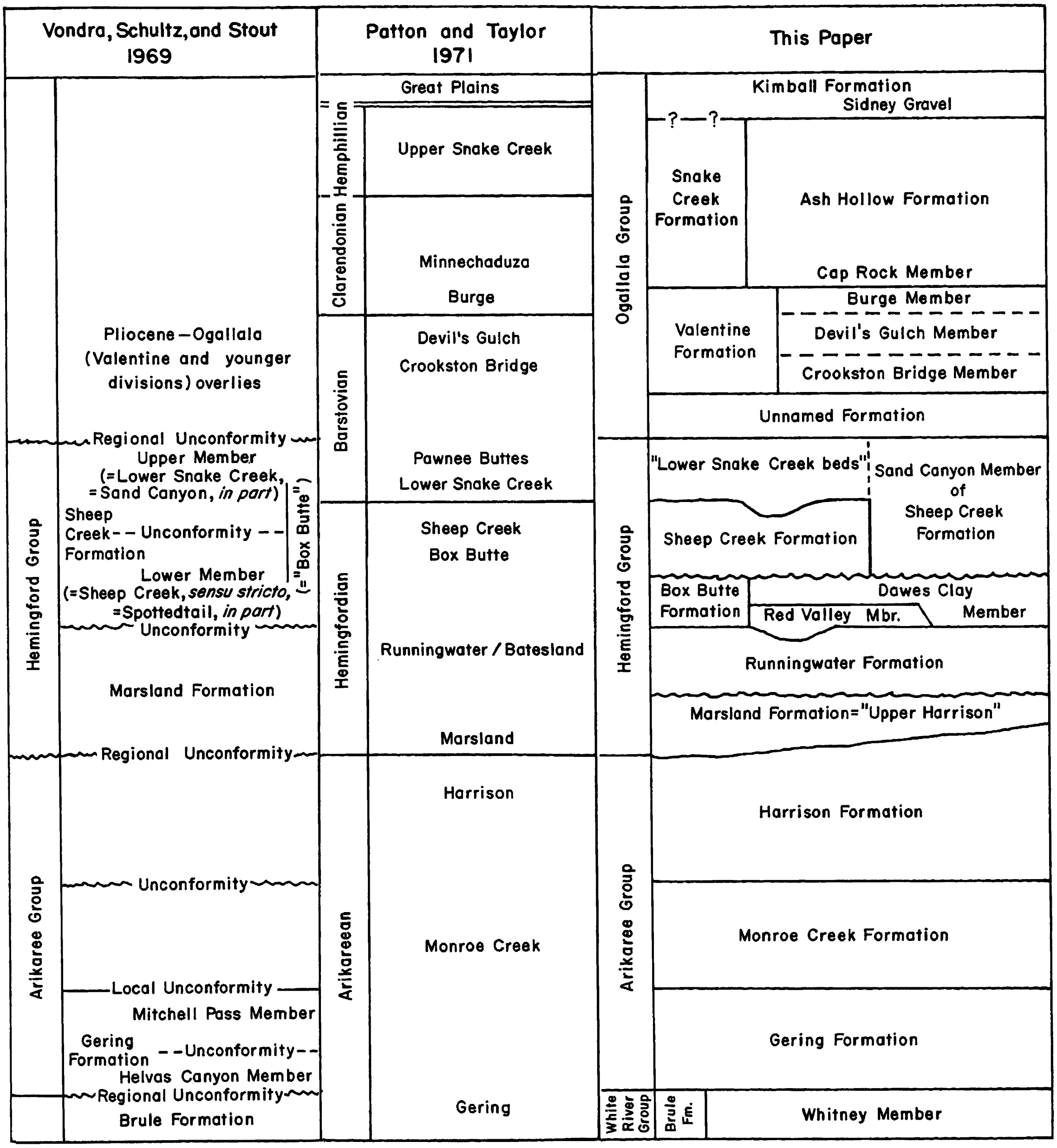


"Lugn (oral communication) considers that topographically higher outcrops of the Box Butte clays north of the outcrops of the Sand Canyon at its type locality indicate higher stratigraphic position of the former. The character of the fossil flora of the Sand Canyon seems to be in favor of this conclusion because it contains the late mutation *a* of *Stipidium dawesense*, or the typical form of the higher horizon of the Sand Canyon, and *Stipidium commune*, which is the common form of the Valentine." Alvin L. Lugn's and Elias's rationale for establishing the relative



age of the Box Butte and the Sand Canyon, as given in the above quote, seems never to have been questioned in print (fig. 2 shows the correlation concepts of several authors who have considered the Box Butte).

Further information is available regarding the supposed occurrence of fossil seeds in the Box Butte. Richard V. Lugn in his master's thesis (MS) on the heavy mineral assemblages of the Sheep Creek beds in western Nebraska, took the unusual step of reporting (p. 71) excerpts of discussions with his father, A. L. Lugn, as fol-



lows: "Further, the fossil seeds reported by Elias (1942, p. 131) as having been collected from the Box Butte, were in reality collected by Elias and Lugn together from sandy silt only a few inches below a ledge of typical Marsland 'blocky' sandstone in a small outcrop less than a quarter of a mile northeast of the southwest corner of sec. 26 (next east of sec. 27), T. 28 N., R. 49 W. He (Lugn) also at that time pointed out his conviction that these outcrops could not be Box Butte Clay, but that they were typical of Marsland lithology in every way. Apparently neither Dr. Elias nor Mr. Cady were convinced on this point."

A classification of the Tertiary system in Nebraska was published by Condra and Reed (1943, pp. 10-14) in which they relied primarily on a modification and condensation of A. L. Lugn's (1939) classification and on Elias's (1942) contributions to the revision of the Hemingford Group. Condra and Reed (1943, p. 11) showed a composite columnar section in which the Valentine Formation was depicted as unconformably overlying the Box Butte, a stratigraphic relationship I have been unable to confirm.

At the outset Cady (1940, p. 666) had difficulty in deciding whether the Box Butte belonged to the Sheep Creek Formation or to the Ogallala Formation,[1] but finally referred it to the Sheep Creek. He did, however, clearly separate the "lower zone" of his newly proposed Box Butte Member of the Sheep Creek Formation from his "middle" and "upper zones." Later Cady (then deceased) and Scherer (1946) only slightly rearranged the wording of Cady's 1940 report. In both reports they were skeptical of the age and probable correlation of the "middle" and "upper zones" and emphasized the similarity of sediments of these "zones" to those of the Sheep Creek and Marsland formations. Cady and Scherer (1946, p. 35) accentuated the uncertainty further by adding the following paragraph, which was not in Cady's 1940 original report, "Although the tentative classification of this rock unit as a member of the Sheep Creek formation is plausible, it is necessary to reserve the possibility that the Box Butte unit is a member of the Ogallala formation." No doubt existed as to the identity and persistence of the lower red clay "zone" with white concretions, and this is the "zone" that is called the Dawes Clay Member of the Box Butte Formation as recognized herein. The Dawes Clay Member, in the present report, is regarded as the upper member of the Box Butte and not the "lower zone" as Cady (1940), and Cady and Scherer (1946), assigned it.

Nine years passed before the Box Butte was considered again in a geologic report. Swineford, Frye, and Leonard (1955) included the volcanic ashes from various members of the Sheep Creek Formation in their study of the petrography of several late Tertiary volcanic ash beds in the central Great Plains. The glass shards from these ashes were compared in detail (p. 249). The "lower ash" in the type locality of the Sand Canyon Member was considered as stratigraphically equivalent to the referred "lower Sand Canyon ash" in Sioux County, Nebraska. They gave an analysis of the volcanic ash bed in sect. 26, T. 28 N., R. 52 W., Box Butte County, Nebraska. This is the ash bed shown in Cady's (1940) supplementary section of the Box Butte Member of the Sheep Creek (present report, fig. 13D); it was later mentioned by Elias (1942, p. 131) and reproduced by Cady and Scherer (1946, p. 33) in a slightly revised section. Swineford, Frye, and Leonard (1955, pp. 246, 249, 252) called it the Box Butte volcanic ash bed but did not comment on the significant differences that exist between it and the other Sheep Creek ashes used in their study. In the present report, this ash is considered a part of the Sand Canyon Member of the Sheep Creek Formation and is shown in Dawes Clay Member reference section 3 (figs. 13F, 15). On their stratigraphic chart, Swineford, Frye, and Leonard (p. 244) showed the Box Butte as the upper member of the Sheep Creek Formation and gave it and the Spottedtail equal space (present report, fig. 2).

The guidebook for the ninth field conference of the Society of Vertebrate Paleontology contained an article by Schultz and Stout (1961, p. 7) where the relationship of the Marsland and Sheep Creek formations to the Hemingford

[1]Alvin L. Lugn (1938, p. 225) redefined the Ogallala Formation as the Ogallala Group, which consisted of four formations: (1) Valentine Formation, (2) Ash Hollow Formation, (3) Sidney Gravel Formation, and (4) Kimball Formation.

Group was discussed, and in which they stated: "The Hemingford includes the Marsland and Sheep Creek formations, but the latter is now considered to include only two rather poorly-named members, the restricted 'Sheep Creek' below and the 'Lower Snake Creek' above. The divisions proposed by Elias (1942) are at least partly preoccupied by these two earlier names, and the name 'Box Butte' (Cady, 1940; Elias, 1942; Lugn, 1939b) appears also to be invalid." On the next page, however, in their Nebraska correlation chart, Schultz and Stout (1961, fig. 3) showed the Box Butte(?) as equivalent to nearly all, if not all, the Sheep Creek Formation, and, moreover, the Marsland Formation was depicted as including all beds immediately underlying the Sheep Creek Formation. To the geochron of the Marsland Formation they applied their newly coined term Marslandian provincial age, which, as McKenna (1965, p. 17) pointed out, was inadequately defined and not equivalent to the Marslandian of Wilson (1960, p. 16), which also was inadequately defined. It should be noted, however, that Stout (Schultz and Stout, 1961, fig. 2), on his rock-stratigraphic chart of the Great Plains sedimentational patterns, showed a missing set of beds between the Upper Marsland and the Sheep Creek in his Hemingford section C. Although no discussion of the "Red Fill" appears in the text, that unit was shown as equivalent to a large part of the "Sheep Creek," which in turn was depicted as the lower part of the Sheep Creek Formation. It is not clear whether Stout considered the "Red Fill" equivalent to, or the same as, the Box Butte of Cady (1940), Elias (1942), and A. L. Lugn (1939), but, since Schultz and Stout (1961, fig. 3) showed the Box Butte(?) as equivalent to their Lower Member and perhaps part or all of their Upper Member, it is reasonable to assume that their "Red Fill" can be, and was, equated to the Box Butte.

Cook (1965) described the Runningwater Formation, stating (p. 6), "The principal exposures of the Runningwater Formation occur in the drainage breaks of the Niobrara River (locally known as the Runningwater), in eastern Sioux, northern Box Butte, and southern Dawes counties, Nebraska, where it locally underlies sediments correlated with the Box Butte Member of the (?) Sheep Creek Formation and overlies the (restricted) Marsland and older formations." It is clear that Cook recognized that the Box Butte overlies the Runningwater Formation, but it is also clear that he questioned that it was a member of the Sheep Creek.

BOX BUTTE IN RELATION TO THE HEMINGFORD GROUP

In his original description of the Hemingford Group, A. L. Lugn (1938, p. 226), said: "The Hemingford group is a new division suggested by C. Bertrand Schultz, Assistant Director, Nebraska State Museum, and concurred in by this survey. This is the first publication of the new term. The Hemingford group includes the Marsland and Sheep Creek formations. The Marsland formation is a recent term given by Schultz." McKenna (1965), in an exhaustive synthesis of and commentary on the stratigraphic nomenclature of the Miocene Hemingford Group in Nebraska, dealt with various aspects of the confusion that has evolved concerning the limits of the Sheep Creek Formation and stated (p. 15): "The lower and upper limits of the Hemingford Group as defined depend upon the lower limit of the Marsland and the upper limit of the Sheep Creek. The former is the base of the old Upper Harrison beds of Peterson (1906), but the position of the latter is subject to various interpretations. If Lugn's concept of the Sheep Creek is utilized, then the upper limit of the Sheep Creek is at the top of the Lower Snake Creek (Lugn, 1938, p. 225), because Lugn regarded the Lower Snake Creek as part of the Sheep Creek at the time he was proposing the Hemingford Group." Alvin L. Lugn (1939, p. 1256) amplified and refined his description of the Sheep Creek Formation in a report entitled "Classification of the Tertiary System in Nebraska" and described and defined (p. 1258) these beds (Box Butte) as, "The lower part of this upper clay member of the Sheep Creek formation . . ." and "This upper member of the Sheep Creek . . . ." Cady (1940) described the same beds as the Box Butte Member of the Sheep Creek Formation. It is clear that A. L. Lugn regarded the Box Butte as the uppermost member of the Sheep Creek and therefore as the top of the Hemingford Group by definition. McKenna (1965, fig. 1) was the first to show the

"Type Box Butte?" as questionably occupying a position in the stratigraphic interval below the Sheep Creek and immediately above the Runningwater. Although A. L. Lugn (1939, p. 1258) recognized that the Box Butte "generally has been included with and measured as a part of the Marsland formation, on which it rests unconformably at most places, where no separating Sheep Creek valley fill deposits occur to reveal the true relationship," his interpretation of the stratigraphy caused him to place the beds at the top of the Sheep Creek section rather than below as depicted by McKenna. As shown in the present report, the Box Butte beds actually occupy a stratigraphic position below any previously recognized Sheep Creek beds. Elias (1942, p. 131) also quoted A. L. Lugn to the effect that the Box Butte formerly had been included with and measured as a part of the Marsland Formation, and added, "Indeed, even now, when the Box Butte is differentiated from the latter, it is somewhat difficult to find its contact with the Marsland in those exposures where the latter is not capped by its highest hard calcareous zone." Elias (p. 128) described the Box Butte as the uppermost member of the Sheep Creek and thus further crystallized the concept.

Additional confusion concerning the age of the Box Butte was introduced by Izett (1968a) in an open-file report of the United States Geological Survey in which he compared many volcanic ash samples collected from Miocene rocks in western Nebraska and southern Wyoming. One of these samples, DN5-46 (p. 19), was from the volcanic ash shown in Cady's (1940, p. 665) supplementary section in sect. 26, T. 27 N., R. 52 W., Box Butte County, Nebraska (present report, Dawes Clay Member reference section 3), and the ash bed therefore is part of the original description of the Box Butte Member of the Sheep Creek Formation. Izett (1968a, p. 35) grouped this volcanic ash bed (DN5-46) with the silver-gray ash beds of the Troublesome Formation and this led him to show "Box Butte age," on his generalized stratigraphic sections of Miocene rocks in western Nebraska and near Kremmling, Colorado (p. 28), as not only younger than "Sheep Creek age," but also younger than "Lower Snake Creek age"; moreover, he showed "Box Butte age" as older than "Sand Canyon age" (Sand Canyon Member of the Sheep Creek Formation, present paper, fig. 2), which is surprising inasmuch as the Sand Canyon beds in the Hay Springs area contain a fauna equivalent to that from the type area of the Lower Snake Creek beds in Sioux County, Nebraska. Izett (p. 9) followed Sato and Denson (1967) in suggesting a twofold stratigraphic division of the Miocene with "the top of the lower division placed at the top of the Marsland Formation of Lugn (1939)." This twofold scheme was shown by Izett (1968a, fig. 7; present report, fig. 2) as the Arikaree Formation for the lower division and the Ogallala Formation for the upper division. Little resolution of stratigraphic problems can result from grouping recognized smaller formations into large amorphous formations.

Considerable modification of the earlier open-file report appeared in Izett's report (1968b) on the Hot Sulphur Springs Quadrangle, Colorado, in which less direct references were made of the Box Butte and comparisons with the volcanic ash from the Box Butte were eliminated. Most of Izett's (pp. 48, 49) tentative interpretations of the correlation of Miocene rocks in Colorado, Nebraska, and Wyoming were included in a diagram, and it was in this diagram that his interpretation of the Box Butte was shown. This was particularly noticeable in his modification of McKenna's stratigraphic section of northwestern Nebraska in which Izett showed the top of the Runningwater Formation as definitely higher in the section than the top of the Marsland Formation. McKenna (1965, fig. 1) depicted the top of the Runningwater to be the same as the top of the Marsland Formation as used by a series of writers dating back to A. L. Lugn (1938). In Izett's (1968b, p. 49) modification of Cady and Scherer (1946), he considered the Box Butte to be equal to the Sheep Creek Formation in Box Butte County, Nebraska.

Schultz and Falkenbach (1968, p. 414) stated that they followed A. L. Lugn's redefinition of the Sheep Creek Formation throughout the several reports of their revision of the oreodonts "but have retained 'Sheep Creek' and 'Lower Snake Creek' in quotation marks as signifying the lower and upper members of the Sheep Creek Formation for the convenience of the readers, since much of the paleontological literature of western Nebraska refers to these terms. Hence 'Sheep Creek' (in quotes) is used in the restricted sense by the present writers. Schultz and Stout[15] [1961, p. 8] also considered the Sheep Creek, as redefined by Lugn, as a formation with two members." They apparently considered the Box Butte Member of Cady (1940), Elias (1942), Cady and Scherer (1946), and others as a part of the Sheep Creek Formation and hence did not show it separately on their ideal geologic section (Schultz and Falkenbach, 1968, p. 411) of Oligocene, Miocene, and Pliocene deposits of the central Great Plains region.

A twofold rock-stratigraphic division of the Miocene of Wyoming and adjacent states was suggested by Sato and Denson (1967, p. C42), and this concept was expanded further to provide for lumping of many formations of the middle Rocky Mountains and northern High Plains into two largely amorphous formations, the Arikaree Formation below and the Ogallala Formation above. These distinctions were based primarily on assemblages of nonopaque heavy minerals. A volcanic assemblage was recognized as characteristic of the Arikaree and a plutonic assemblage was recognized for the Ogallala.

Denson (1969, p. C28) attempted to demonstrate that several of the recognized formational units in south-central South Dakota and northwestern Nebraska including the Box Butte "are differentiated largely on faunal rather than lithologic criteria." Yet the examples and generalized data that he presented were inconclusive and confusing. He failed to provide sufficient documentation for the source of the samples on which he based sweeping correlations of several critical formations; moreover, some of his correlations, either expressed or implied, were based on his inability to distinguish between nonopaque heavy-mineral assemblages in certain groups of formations. This was particularly critical in his handling of the Marsland Formation, which he placed, on lithologic criteria, in his Arikaree Formation, which also included the Harrison, Monroe Creek, and Gering Sandstones. (In the present report, each of the three last-mentioned sandstones is considered to be a formation of the Arikaree Group.) The Runningwater Formation of Cook (1965) was lumped with the Sheep Creek and the Valentine formations by Denson (1969, p. C28) as follows: "Similarly, lithologic samples from the Miocene Runningwater Formation of Cook (1965) and Sheep Creek Formation and the Pliocene Valentine Formation of Schultz and Stout (1961) cannot be distinguished from one another on the basis of nonopaque heavy-mineral assemblages. Locally, however, slight color differences and bedding characteristics permit these units to be recognized individually and mapped separately."

Denson failed to recognize that the Runningwater Formation of Cook (1965) was equal to the Upper Marsland of Schultz and Falkenbach (1947) and also included the Upper Marsland of Schultz and Stout (1961, fig. 2); by assigning the Runningwater to the Ogallala Formation and the Marsland to the Arikaree, he actually directed attention to the flimsy basis of his concept of a twofold subdivision of the Miocene and Pliocene rocks of south-central South Dakota and northwestern Nebraska. This emphasizes a statement by Denson (1969, p. C31) that should be of particular concern to all investigators dealing with beds usually assigned to the Hemingford Group: "The term 'middle Miocene' or Hemingford Group of Lugn (1938) has no rock-stratigraphic meaning in the twofold lithic subdivision of Miocene rocks emphasized by this study. Similarily, faunas designated only as Hemingford or of Hemingfordian provincial age of Wood, Chaney, Clark, Colbert, Jepsen, Reeside, and Stock (1941) cannot be fixed with respect to the unconformity between Ogallala and Arikaree Formations or their equivalents, because the rocks containing the Sheep Creek fauna are lithologically allied to the Ogallala, whereas those containing the Marsland fauna are lithologically allied to the Arikaree."

Denson apparently confused rocks and time in the above quote. There is nothing wrong with the time term "Hemingfordian" provided it is usefully based on the succession of fossil mammals. The utilization of stratigraphically collected fossil mammals may eventually provide the control necessary to insure with high probability that the investigator is actually sampling the rocks of a specific formation; furthermore, these fossil mammals may be used as a tool in determining where to look in the geologic section of the Great Plains for significant unconformities. A reexamination of the occurrence of nonopaque heavy minerals in the Runningwater Formation sequence is in order, for a decided influx of plutonic debris has been observed in these deposits. This is in sharp contrast to the absence of such debris in the Lower Marsland=Upper Harrison. Any program of reexamination should maintain a strict stratigraphic control to ensure against misidentification of beds, formations, and faunas.

PROPOSALS FOR NEW NAMES AND RANKS

Owing to the altered stratigraphic position that should be accorded the Box Butte as the result of new information, and because of the distinctive lithologic characteristics of the beds that are consistently and easily recognizable on widely separated outcrops in Sioux, Dawes, Box Butte, and Sheridan counties, Nebraska, and because the Box Butte sediments are readily mappable, I formally propose that the Box Butte Member be removed from the Sheep Creek Formation and raised in rank to Box Butte Formation. I further propose that the Box Butte Formation be divided into two members, an upper division to be called the Dawes Clay Member and a lower division to be termed the Red Valley Member. The name combination for the lower member, admittedly, is not geographic, but it is suggested in an effort to conserve a useful concept and a series of informal names that express it, such as "Red Fill," "Red Valley Fill," "brick-red channel fill," and others, used by several authors during the past 40 years. These proposals require redefinition of the rock-stratigraphic unit for the Box Butte and require that the members be formally established. An attempt is made in the following paragraphs to provide the documentation necessary to fulfill the regulations and recommendations of the Code of Stratigraphic Nomenclature (Amer. Comm. Strat. Nomenclature, 1970).

BOX BUTTE FORMATION, NEW RANK

Several changes in the stratigraphic nomenclature of the Box Butte Member of the Sheep Creek Formation, as originally described by Cady (1940, p. 663), are proposed in the present report. These proposals, formally stated above are as follows: (1) The Box Butte Member is changed in rank and raised to Box Butte Formation and thus removed entirely from the Sheep Creek Formation. (2) The lithologic content of the Box Butte Formation is redescribed. Only the "lower zone" of Cady's (1940, p. 665) Box Butte Member is retained in the Box Butte Formation, and it is redefined and formally designated herein as the Dawes Clay Member of the Box Butte Formation. (3) The "middle" and "upper zones" of Cady's (p. 665) Box Butte Member are removed and temporarily assigned to the Sand Canyon Member of the Sheep Creek Formation (see footnote 2, p. 5). (4) The channels filled with "brick-red silt and sand" that Cady (p. 666), and Cady and Scherer (1946, pp. 32, 34, pl. 1), recognized as underlying the Box Butte Member, and which they regarded as Sheep Creek in age and not a part of the Box Butte, are shown to be pre-Sheep Creek in age; they are part of the same depositional cycle as the Dawes Clay Member and are designated formally as the Red Valley Member of the Box Butte Formation.

In succeeding pages the reasons for these changes are discussed and many data are supplied to substantiate them. The two new members are defined, with a type section and reference sections figured and described for each; this procedure is designed to provide detailed lithologic and stratigraphic information concerning the members. Significant features or stratigraphic relations in areas adjacent to the figured sections are also provided.

Deposits of the two members, which together comprise the Box Butte Formation, have been recognized only in four counties in northwest Nebraska: (1) Box Butte County, for which the formation was named by Cady (1940, p. 663); (2) Dawes County, in which the formation is best exposed; (3) Sioux County; and (4) Sheridan County. In Sioux and Sheridan counties outcrops are few and small.

The Box Butte Formation crops out high on the rims and ridges of the tablelands being dissected by the Niobrara River and its tributaries and by a few largely ephemeral streams that occupy original courses on the plains that antedate the Niobrara River system (fig. 1). Because the geographic and topographic setting of the area is important in understanding the outcrop pattern of the Box Butte, and in fixing the limits of the formation, several of the following paragraphs are concerned with a general description of some of the more important features of the geomorphology of the area.

The Pine Ridge escarpment marks the northern edge of the High Plains in this region, and, in the area covered by this report, Pine Ridge also marks the drainage divide between the White River system to the north and the Niobrara River system to the south. The part of the High Plains north of the Niobrara River ending along Pine Ridge from the vicinity of Squaw Mound east to Antelope Valley near the eastern border of Dawes County is known simply as the Table; the part of the High Plains south of the Niobrara River valley is called the Box Butte Table (fig. 1). Because of the similarity of the stratigraphy of both tables and because of the NW-SE orientation of the tributary streams crossing them, it is clear that these two tablelands were once continuous before the Niobrara River drainage system was established across the area in an easterly to northeasterly direction. Dry Creek and Box Butte Creek are tributaries of the Niobrara that pirated some of the original NW-SE trending drainages. Several of these original tributaries south of the Niobrara (notably Hemingford, Berea, and Point of Rocks creeks, fig. 1) still maintain their directional trend, eventually ending in low swampy areas along the west edge of the Sand Hills, which are of Pleistocene and Holocene age and which obstructed the older drainage system, in two townships east and north of Alliance, Nebraska. The Niobrara River is a young stream (Skinner, Hibbard et al., 1972, pp. 15, 18), for it is superimposed on the northern edge of the High Plains and crosses it in an east-west direction. Along the eastern edge of Sioux County, at the Sioux County-Dawes County line, the Pine Ridge escarpment stands at an elevation of 4800 feet and is situated about the same distance from the White River as from the Niobrara River, yet the White River has an elevation of 3800 feet at the line, whereas straight south along the Sioux County-Dawes County line the Niobrara River has an elevation of 4200 feet. Thus the Niobrara River is 400 feet higher than the White River and runs in a valley 600 feet deeper than the north rim along Pine Ridge and 300 feet below the edge of the Box Butte Table (elevation 4500 feet) that forms the south rim of the Niobrara valley at this point. The Niobrara valley is only about 14 miles wide at the eastern Sioux County line. At the eastern edge of Dawes County along the Dawes County-Sheridan County line the Niobrara valley drainage system is about 20 miles wide with the Pine Ridge escarpment much subdued and at an elevation of 4000 feet. The Niobrara crosses the Dawes County-Sheridan County line at 3800 feet, and the rim of the tableland south of the Niobrara is only 3900 feet and has been greatly affected by the piracy of Box Butte Creek that worked southward along the edge of the Sand Hills closely paralleling the Box Butte County-Sheridan County line. Therefore, the Niobrara River valley here, although broader, is much shallower than it is at the western edge of Dawes County. It is only 200 feet deeper than Pine Ridge and 100 feet deeper than the ill-defined and modified southern rim. This is in sharp contrast to the vigorous White River at an elevation of 3000 feet at a point in South Dakota a few miles north of the Dawes County-Sheridan County line, but which is still about the same distance north of the Pine Ridge divide as the Niobrara River is south of the divide. The Niobrara River at the east line of Dawes County is 800 feet higher than the White River; thus, in crossing Dawes County the Niobrara River drops 800 feet in about 40 miles or 20 feet per mile.

Deposits of the two members of the Box Butte Formation do not underlie continuously great areas of the four counties mentioned above, but rather, owing to the formation's topographic position high along the tablelands in the area, the deposits have been subjected to extensive erosion and now crop out in irregular exposures, some of which are restricted to well-defined paleochannels that can be traced for several miles but are not continuous across the basins of tributaries draining the area. The outcrop area of the formation (fig. 1) is nearly quadrilateral. The east-west dimension is about 36 miles and the north-south dimension is about 24 miles. Thus the area within which deposits of the formation may be exposed totals about 865 square miles.

As an aid to continuity and stability, the type section of the Box Butte will remain, as originally designated by Cady (1940, p. 665), in sect. 27, T. 28 N., R. 49 W., Box Butte County, Nebraska (present report, figs. 1, site 1; 3; 4). One of the main objections to Cady's type section is that the heavily grass-covered slopes in sect. 27, T. 28 N., R. 49 W. do not provide good expo-

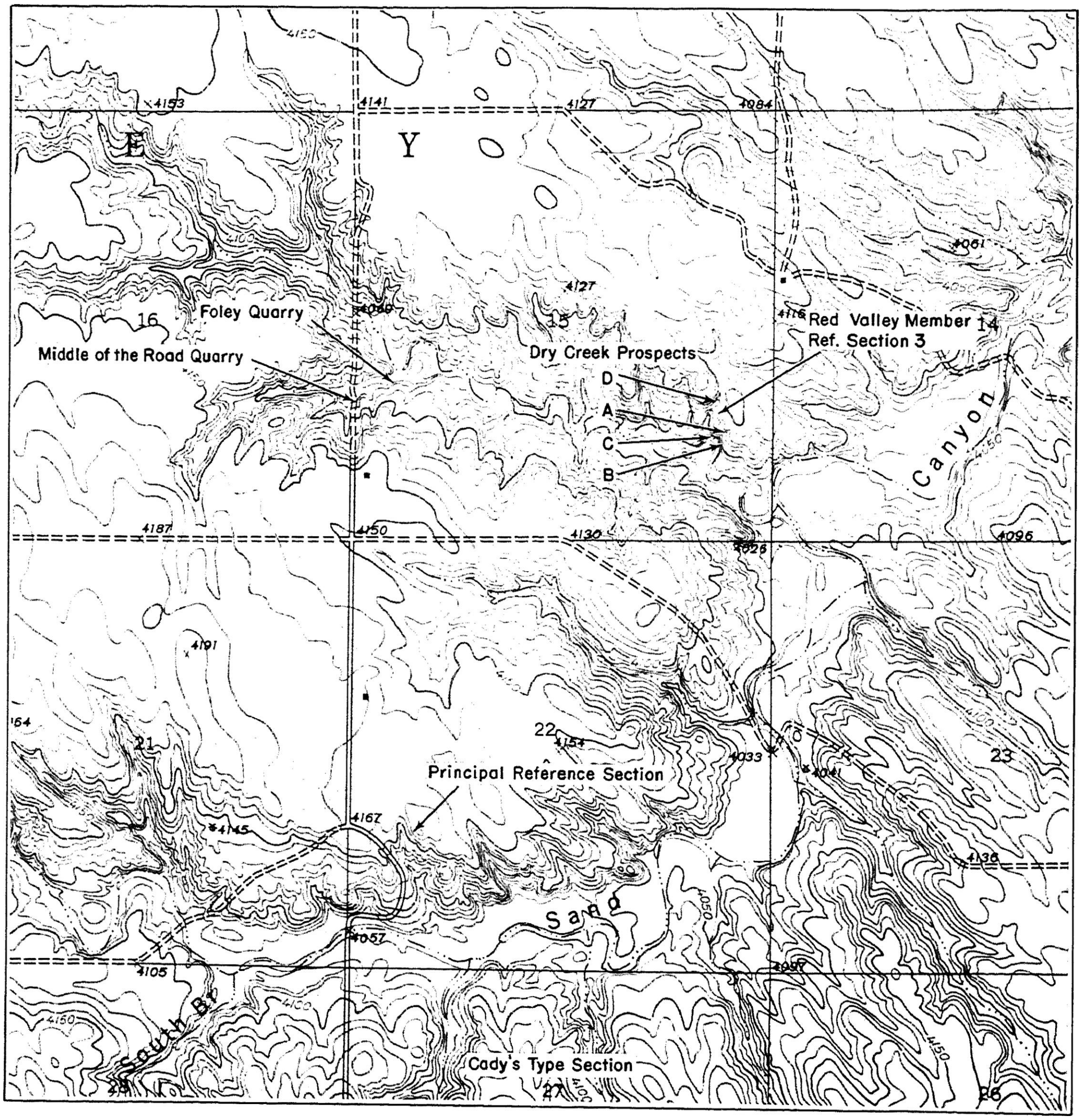


FIG. 3. Map of type and principal reference section of Box Butte Formation. Topographic base is enlarged from USGS Box Butte Reservoir East, Nebraska 7.5 minute Quadrangle, 1948.

FIG. 4. Two views across Dry Creek valley of type locality of Box Butte as established by Cady (1940). *Left*: Looking southeasterly across east half of type section. *Right*: Looking southerly across west half of type section.

sures of the "middle" and "upper zones" of his Box Butte Member; furthermore, concerning the "middle zone," he stated (p. 664), "As in the Marsland, these sandstones are impregnated with calcareous material, weather into honey-comb ledges, and are similar to those in the Marsland in all other respects." His "upper zone" was also given in the type section (p. 665) as, "Upper zone—40 feet—Covered slope, at the top of which the top zone of the Box Butte member can be found by digging through the turf." Despite the obvious shortcomings of the type locality and the type section as set by Cady, they, nevertheless, cannot be changed. Luckily, the "lower zone," as he recognized it, is exposed in the type section, and this is the same "zone" that is proposed as the Dawes Clay Member in the present report and now is considered the upper member of the Box Butte Formation.

I have specifically avoided retaining Box Butte as the name for Cady's (1940) "middle" and "upper zones" because he (p. 666) considered the "middle zone" to be local, and, moreover, stated (p. 664) that the sandstones of the "middle zone" were "similar to those in the Marsland in all other respects." The thickness and content of his "upper zone" was indefinite. His concept of the Box Butte was based primarily on the lithologic characteristics displayed by the beds of his "lowest zone," which is consistently recognizable throughout the area. A cogent case might be made for proposing a new name for the middle and upper "zones," but I believe that the term Box Butte appropriately should be continued to be applied to beds included in Cady's "lowest zone," and to the new underlying Red Valley Member, rather than have the term discarded as a synonym of Sand Canyon Member and/or Sheep Creek Formation, forcing the use of a new formation name for the "lower zone" and the underlying Red Valley Member, which would add one more level of complexity to an already complex stratigraphic nomenclature.

For reasons set forth in the chapter on "History of the Name Box Butte," I designate the beds in the SW. ¼, sect. 22, T. 28 N., R. 49 W., Box Butte County, Nebraska, on the north side of Dry Creek as the principal reference section of the Box Butte Formation (figs. 1, site 2; 5; 8D). Dry Creek, unfortunately, is shown as Sand Canyon on the USGS Box Butte Reservoir East, Nebraska 7.5 minute Quadrangle, 1948, thereby causing confusion with the Sand Canyon in Dawes County, which is a few miles to the northeast and has been known by that name since the 1880's. The principal reference section is shown in a measured section (fig. 8D), in a photograph (fig. 5), and on ASCS aerial photograph CAK-4AA-68.

The lithology of the Box Butte Formation as restricted in this report is distinctive and readily recognizable in the field. The deposits are red or green siltstone or clayey siltstone with an occasional lens of sandstone or admixture of sand. All beds may show a mottled red and green effect especially on fresh exposures. On dry weathered outcrops, the colors often are subdued reddish, brownish, or pinkish tones. On damp exposures the colors are vivid and particularly intense. White to gray, hard, heavy, mostly rounded, nodular calcareous concretions appear as discrete entities that occur throughout the upper part of the formation. These concretions may be scattered, or concentrated in distinct bands, but they still retain their discrete characteristic. They commonly are covered with a very thin to a quarter-inch thick film of powdery calcium carbonate when lying undisturbed in the matrix. Upon weathering, these resistant nodules tend to concentrate on low slopes in sufficient quantities to give the outcrop a white appearance, especially from a distance.

The contrast between the Box Butte Formation and the overlying Sand Canyon Member of the Sheep Creek Formation is striking both in color and lithology. The Sand Canyon Member displays a dull grayish hue owing to the presence of volcanic ash beds and to the predominantly tuffaceous content of the mixture of tuff, quartz grains, and intraformational granule and pebble-sized clasts that comprise the member. The superposition of the Sand Canyon Member on the Box Butte is best exposed in the northwestern part of the area.

Rocks of the Box Butte Formation lie unconformably on the Runningwater Formation. Both of the new members, the Dawes Clay and the Red Valley, are in contact extensively with the Runningwater. The contact varies greatly from place to place; in some places it is at the base and

FIG. 5. Principal reference section of Box Butte Formation. A. North part. B. South part.

along the sides of distinct and fairly broad paleovalleys, at other places it is along the boundaries of narrow, steep-walled paleovalleys, and at other sites the contact is with a major topographic bench that is herein informally called the Platy Bench. Because the Platy Bench is important in interpreting the climatic, sedimentary, and stratigraphic history of the Box Butte Formation, and because it is one of the principal contact units with the overlying Box Butte, the following description of it is provided.

The Platy Bench is a geomorphic feature of the Runningwater Formation composed of sandstone ledges that are typically more calcareous and whiter toward the top; they tend to weather in platy slabs as much as 2 feet long but rarely more than 3 inches thick. These platy slabs may contain included angular sandstone pebbles or particles scattered throughout, many of which are surrounded or outlined by calcareous material that seems to anastomose around the pebbles or in seams in the sandstone. On weathered surfaces the small sandstone particles or pebbles are commonly eroded, leaving pits that are outlined by the more resistant calcareous material. This results in a boxwork or fretwork appearance to the surface or, as Cady and Scherer (1946, p. 26) called it, a "honeycomb ledge."

The individual sandstone particles are not impregnated by the limy materials for they do not effervesce with dilute hydrochloric acid, although the calcareous anastomosing material that surrounds them effervesces freely. In road cuts, such as that between sects. 7 and 8, T. 28 N., R. 49 W., in Box Butte County north of Hemingford, the unweathered sediments forming the Platy Bench can be observed. This shows the Platy Bench to be composed of a mixture of greenish and brownish sandstone and also brownish sandstone particles, all permeated or anastomosed by stringers or seams of calcareous material with the main accumulation occurring horizontally, thus accounting for the tendency to weather in plates. The concentration of limy material is greater near the top of the bench. This is obviously a response to a process akin to calichification but differs mainly in that the entire zone is not solidified to hard rock as in some of the caliche beds of the arid southwestern United States. In general, the Platy Bench may be as much as 10 feet thick with the uppermost 5 feet being most heavily impregnated by the limy material, but significant amounts also may occur in the remaining 5 feet; this strongly suggests that calichification was effective during a long period of time.

The Platy Bench is a response to a static period of little or no deposition, or of little erosion, in which whitish, limy material was concentrated at or near the paleosurface regardless of the stratigraphic level of the exposed bed. It occurs at several stratigraphic horizons in the Runningwater Formation, and one of the several horizons contained within it is the stratigraphic marker bed at the "top" of the Marsland (Runningwater Formation) as stated by Cady (1940, p. 664), "The top of the Marsland is a white, limy, slabby caprock as much as five feet thick. It is resistant to erosion. In most exposures the Box Butte member rests upon this caprock." This was restated by Cady and Scherer (1946, p. 34), "The 4-foot limy cap rock at the top of the Marsland implies an extended interval of subaerial weathering and calcification of a calichelike nature." Again it should be emphasized that the "caprock" is only one of the beds included in the Platy Bench.

Lugn and Wenzel (1938), Cady (1940), Elias (1942), and Cady and Scherer (1946) all speculated that the Box Butte Member of the Sheep Creek Formation, as they recognized it, was a loess. Cady and Scherer (1946, p. 34) stated: "The Box Butte member, composed chiefly of clay and silt and blanketing as it does the rolling pre-Ogallala topography, is probably a loess. The concretions are of the kind that might form in a loess." This observation cannot be verified readily, for concretions rarely are mentioned in descriptions of measured sections of loess deposits. Loess deposits are commonly so nearly homogeneous lithologically that the presence of any unusual lithologic inclusion would warrant special attention. Obviously calcareous concretions normally are not found in loess deposits or they would be mentioned more often. Lugn and Wenzel (1938, p. 54), however, described one site in the Loveland Formation in south-central Nebraska in which large calcareous concretions occurred. How closely these would compare with those of the Box Butte only can be conjectured.

Recently another site in central Nebraska in which calcareous concretions were collected has been reported. Thus it is apparent that concretions do occur in loess deposits, but they are extremely rare. In a study of the Quaternary stratigraphy of the northern Shansi and eastern Kansu loess district in the Peoples Republic of China, Wang et al. (1966, translated in 1969, p. 800) said: "in the lower part of the loess section, can be found closely spaced, thin-bedded, densely disseminated concretion beds, at more than ten locations. These concretion beds are diagenetically altered reddish brown paleosoils, formed in two stages: first, the reddish brown paleosoil; then, after burial, mineralized by the carbonate salts carried into the horizon by groundwater circulation. Calcareous concretions (precipitated by carbonates over the original paleosoil) were continuously enlarged and subsequently cemented together; in the meantime mineralization of the paleosoil bleached the color of the horizon and cemented the clastics into lithic loess." It is interesting to contemplate the special sedimentation or soil-forming regimens that would be required to provide the untold numbers of discrete calcareous nodules that are a conspicuous and diagnostic lithologic feature of the Dawes Clay Member. One inescapable conclusion is, if the silt and clay of the Dawes Clay Member were formed as a loess, then the method of accumulation and the sedimentary and climatic conditions that were operative at the time of deposition would be radically different from those that were involved in forming the widespread deposits of the Mississippi River Valley, the Pacific Northwest, and China.

Speculation concerning the origin of the beds of the Box Butte Formation must also include the following heretofore insufficiently appreciated considerations: (1) It must be recognized that a significant period of time is represented by the nondeposition of beds during the forming of the Platy Bench. (2) Interpretation of new fossil mammalian evidence shows that the interval represented by subaerial weathering in post-Runningwater time was considerably longer than had been suspected. (3) Some steep-walled, narrow paleochannels were eroded in the calichified deposits of the Platy Bench. (4) These narrow channels were cut without forming discernible terraces or flood plains in the trench, or without building recognizable overbank deposits. (5) The special process of degradation required to incise channels, and then to aggrade them, compels the recognition that relations of the beds involved are considerably more complex than previously believed. (6) The topographic expression of the Platy Bench emphasizes that the surface had little relief for a period of time, during which the calichification process was active. Such calichification implies, but does not prove, that a period of aridity existed in northwestern Nebraska during the interval between the deposition of the latest Runningwater beds and the deposition of the sediments from which fossils were collected in the Red Valley Member of the Box Butte Formation.

RED VALLEY MEMBER, NEW NAME

A formal statement of intent to establish the Red Valley Member as the lowermost member of the Box Butte Formation is made on page 22. Deposits of the newly recognized member (description of type section, p. 30) are confined primarily to well-defined paleochannels or paleovalleys, many of which have steep-sided walls and are only a few yards or, at most, a few hundred yards wide. The sediments of the member are reddish or pinkish. If the sediments are wet they can be described as brick red, but if they are dry, paler hues of red or pink are typical. The lithology of the deposits is surprisingly uniform wherever observed, for they consist predominantly of reddish or pinkish fine sand, silt, clayey silt, and minor amounts of clay. Coarser clasts are mostly reworked sandstone concretions, no more than 4 inches in diameter, from the underlying beds of the Runningwater Formation. They are numerous and are confined essentially to the bottom and along the walls of the narrow paleovalleys. No igneous, volcanic, or metamorphic clasts have been found in these Red Valley deposits, thus indicating that the provenance was not in mountains to the west or in the Black Hills to the north-northwest. This, of course, is in sharp contrast to the underlying Runningwater Formation in which granitic and other igneous rocks are conspicuous in the coarser fluvial sediments of the paleovalleys. Small sandstone concretions of intraformational origin are rare, and a few limy sandstone concretions may crop out at some sites. Intraformational pebbles also occur, but these are rare, and intraformational clasts, along with minor sandstone lenses, were observed in some places to lie on ill-defined bedding planes in the main body of the Red Valley deposits. These are arranged occasionally in discernible horizontal bands extending laterally from the walls into the deposits. Along the walls, some of the included bodies are as much as 2 feet in diameter, but the size of the particles decreases abruptly, and 50 feet laterally from the walls they are few and no more than small pebble size. Indeed, in many places intraformational pebbles or clasts of more than granule size are entirely lacking in the sediments filling the paleochannels.

Observed differences in sediments are great at those spots where the base of the Red Valley Member is exposed. At some of these sites the basal sediments are conglomerates as much as 3 feet thick where individual clasts consisting of concretions and included bodies from underlying formations are rarely more than 3 inches in diameter and large numbers of the clasts are about 1 inch in diameter. These clasts are set in a matrix of smaller pebbles, granules, and sand of the same lithology as the larger fragments; all may be cemented locally and form ledges. At other sites the basal sediments are clay or silt-sized particles, and moreover, the finer grained particles commonly are associated with the narrower and deeper paleochannels, providing somewhat perplexing problems relating to the origin of these channels. No flood plain or overbank deposits have been recognized in or along these paleochannels. Cross-bedding of any kind is rare, and cross-bedding certainly would be expected to be prominent in the deposits if the mode of deposition had been by streams carrying a large volume of water regularly or intermittently. Cross-bedding also should be an important feature if the deposition had been primarily of eolian origin. A special set of erosional and depositional conditions must have been operating to account for the excavation of the narrow, steep-walled paleochannels and the unusual lack of primary and secondary depositional structures observed in the deposits of the Red Valley Member.

Beds assigned to the Red Valley Member lie with marked unconformity on deposits of the Runningwater Formation, and so far they have been observed to be in contact only with beds of the upper part of that formation. A comprehensive discussion of the contact and boundary relationships between the Red Valley Member and the underlying Runningwater Formation necessarily must include consideration of some of the upper beds of the latter.

The outcrop area of the Red Valley Member is small, both absolutely and relatively, when compared with the outcrop area of the Dawes Clay Member. An analysis of the sedimentation of the beds immediately underlying these two members shows that a major topographic bench, which I have informally called the Platy Bench (p. 28), crops out at most localities where the Dawes Clay Member is well exposed in Dawes and Box Butte counties. The Platy Bench is also recognized laterally at several exposures of the Red Valley Member, and the relationship of it to Red Valley deposits and to the overlying Dawes Clay Member is treated below (p. 35).

Exposures of the Red Valley Member of the Box Butte Formation crop out in a discontinuous belt from near the western edge of sect. 30 eastward through sects. 29, 28, and 27, all in T. 30 N., R. 47 W., Dawes County (fig. 6B). These exposures are in the Sand Canyon drainage system and include the type section of the Red Valley Member situated in the NE. ¼, SW. ¼, sect. 29, T. 30 N., R. 47 W., Dawes County, Nebraska, at the site of Sand Canyon Quarry (figs. 1, site 3; 7) of the former Frick Laboratory of the American Museum of Natural History. The type section is on the north side of a sharp bend in Sand Canyon and is shown on USGS Chadron 3 SE, Nebraska 7.5 minute Quadrangle, 1966, and also on ASCS aerial photograph CAO-1BB-165. The continuity of the deposits is obscured owing to the grassed-over hills in the area that commonly form low divides between tributaries of Sand Canyon in which the exposures of the Red Valley Member occur. On a few of these exposures the Dawes Clay Member, up to 25 feet thick, overlies the Red Valley deposits and affords an excellent opportunity to observe the relationship of these two members in a constricted incised channel environment instead of the broader environment in which the channels are incised only

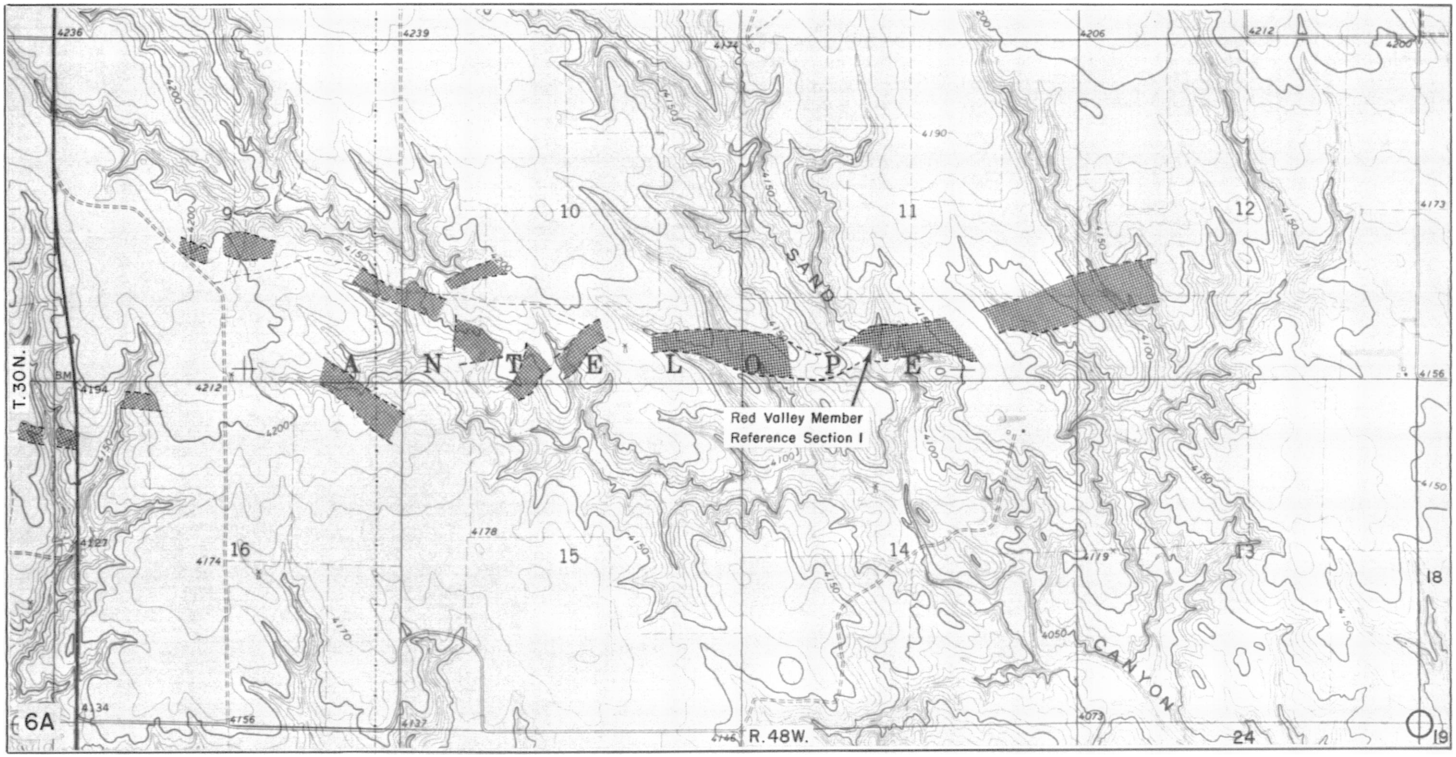
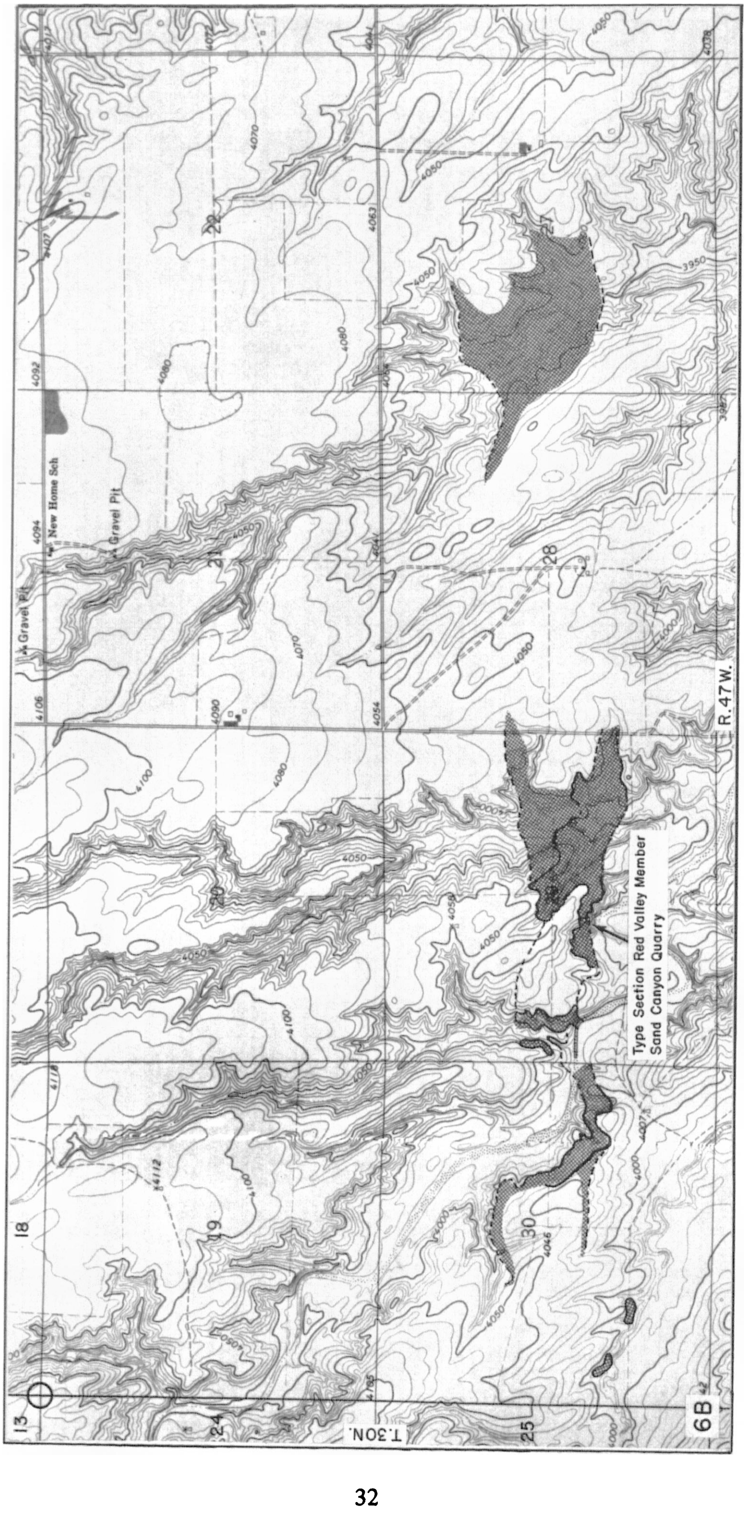
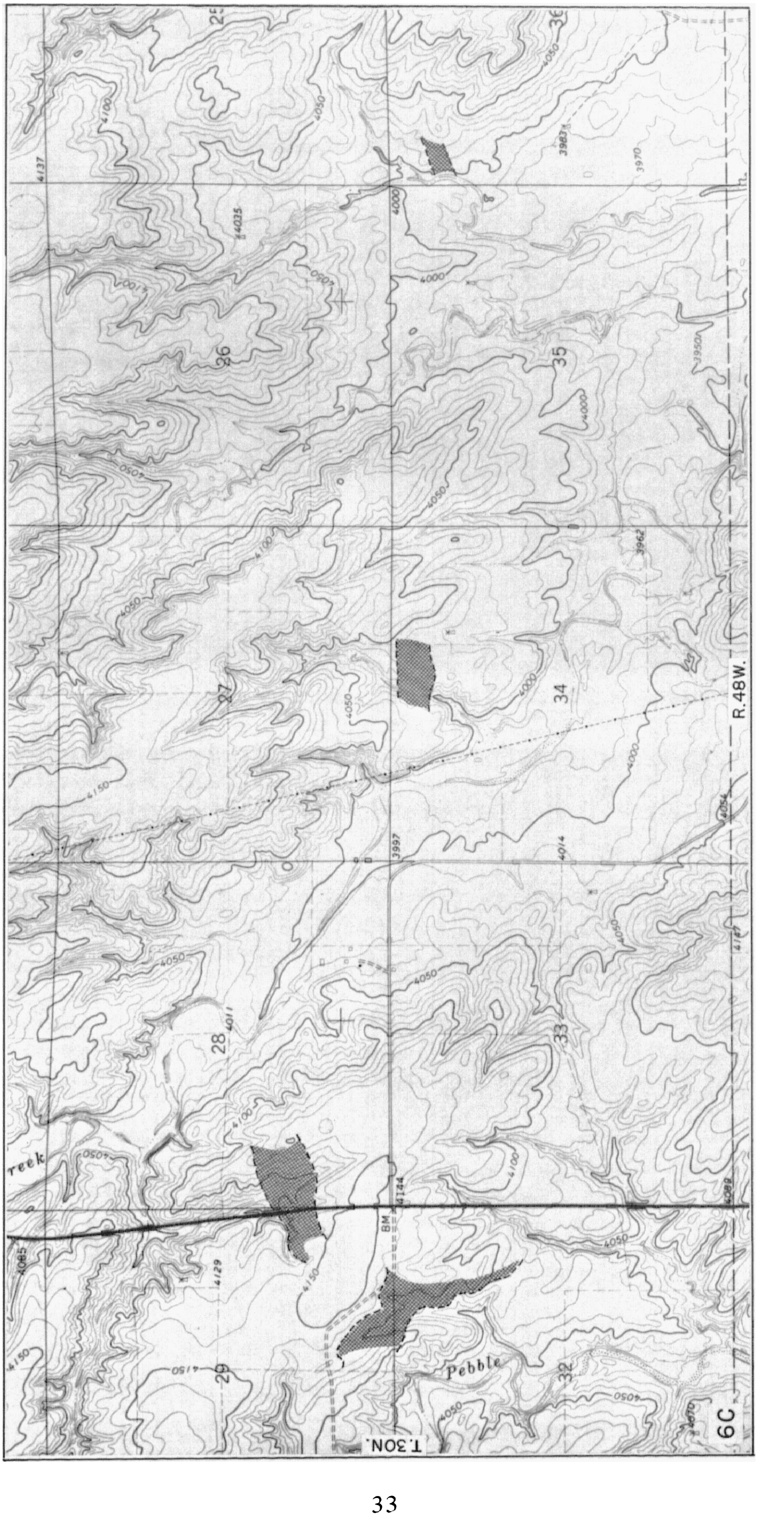


FIG. 6. Three maps (on consecutive pages) of some Red Valley Member channels north of the Niobrara River. Map A and Map B join at common corner, marked with circle, of sections 13, 18, 19, and 24. Map B and Map C join along east side of section 25. Topographic bases are enlarged from USGS Chadron 3 SW and Chadron 3 SE, Nebraska 7.5 minute Quadrangles, 1966.


Type Section Red Valley Member
Sand Canyon Quarry
Gravel Pit
New Home Sch
Gravel Pit
R.47W.
T.30N.
6B


6C
R. 48W.
T. 30N.
Pebble
reek
25
26
27
28
29
32
33
34
35
36

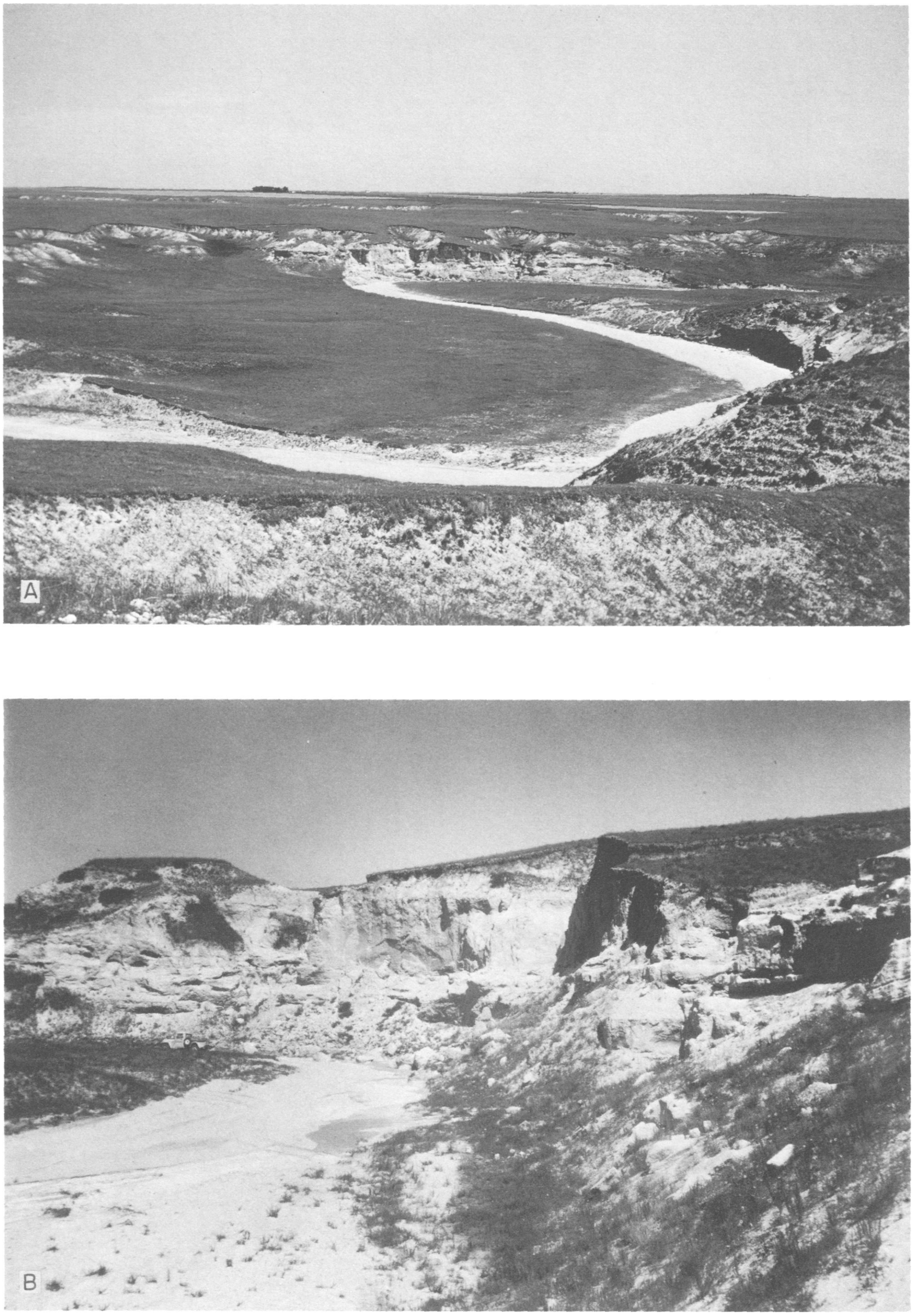


FIG. 7. Type section of Red Valley Member of Box Butte Formation, site of Sand Canyon Quarry of former Frick Laboratory. A. Red Valley Member deposits at left center are underlain by Runningwater Formation. B. Near view of type section at Sand Canyon Quarry.

slightly below the level of the Platy Bench as observed at several localities farther west in western Dawes County and in northwestern Box Butte County.

The elevation at the base of the Red Valley Member at Sand Canyon Quarry is about 3970 feet and the top of the exposed Box Butte Formation (Dawes Clay Member) is at an elevation of more than 4020 feet, although grassed-over hills at the site as much as 4060 feet in height might be underlain by Box Butte, but this cannot be demonstrated. On a line of section to the south, the Runningwater Formation rises abruptly to a remnant of tableland forming a ridge a few hundred yards wide that diagonally crosses sect. 32, T. 30 N., R. 47 W. from a point slightly east of the northwest corner to slightly north of the southeast corner. The summit of this ridge is at 4090 feet, or about 120 feet higher than the base of the Red Valley Member at Sand Canyon Quarry; the valley that contains the deposits of the member was cut down at least 120 feet at this point and very likely more. A high ridge of Runningwater deposits about a quarter of a mile wide terminates just north of Sand Canyon Quarry at a distance of less than a quarter of a mile. This ridge angles northwest from near the middle of sect. 29, T. 30 N., R. 47 W. across the west edge of sect. 20 to the northwest corner of sect. 20 and the northeast corner of sect. 19, T. 30 N., R. 47 W., Dawes County. The elevation of the common corner of sections 19 and 20, as mentioned, is 4118 feet. Thus the incision of the valley that now contains the Red Valley sediments was more than 140 feet as shown by the outcrops of the Runningwater Formation on the north side of Sand Canyon in a distance of one and a half miles along an unbroken ridge. Fortunately, a good collection of fossil mammals has been obtained from the Runningwater Formation at many sites underlying the Red Valley Member as well as lateral to it on both sides of the valley of Sand Canyon. These, combined with the fossil collection from the Red Valley and Dawes Clay members, give firm paleobiologic support to the stratigraphic framework.

The Dawes Clay Member lies disconformably on the Red Valley deposits at the type section of the Red Valley Member; this relationship can be observed at many sites and several of these are mentioned elsewhere in the present report. The contact is best described as a paraconformity in which no erosion surface is discernible, with beds above and below essentially parallel, but in which a wafer-like or boxwork-like zone of calichification about 2 feet thick includes the contact of the two members. This is considered to be more than a diastem and is interpreted as being a response of the fine-grained sediments of the Red Valley Member paleochannels to a depositional process operating through a short time as contrasted with the long-term calichification that formed the Platy Bench in Runningwater sediments.

At the type section of the Red Valley Member, the two members are in normal stratigraphic position, but they are incised in a deeper, broader valley than is commonly observed farther west in Dawes, Box Butte, and Sioux counties where several narrow, steep-walled paleocanyons or paleovalleys were cut through the Platy Bench. These paleovalleys invariably contain the deposits of the Red Valley Member and the locations of a few of them north of the Niobrara River in Dawes County are shown in figure 6. At each site in the western part of the area, the Dawes Clay Member also overlies the Red Valley Member. In addition, the Dawes Clay Member crops out at widely spaced intervals over several hundred square miles. Where it is not underlain by the Red Valley Member it commonly lies on the Platy Bench, and the topographic expression of the relationship often aids in tracing these deposits.

At many sites the Red Valley Member fills the narrow paleovalleys that were eroded into the Platy Bench, but it should be emphasized that no overbank deposits have been detected at these sites. The zone of calichification described above as wafer-like or boxwork-like includes a few inches of sediments above and below the paraconformity and is at the same topographic level as the surface of the Platy Bench. This indicates a close relationship between the two members, and furthermore suggests an enrichment of the zone by ground water subsequent to the deposition of the Dawes Clay Member across the area underlain by the Platy Bench. This may have been associated with a leveling process in the western part of the region that brought to an end the deposition of sediments typical of the Red Valley Member. The enrichment suggested by the wafer-like zone also may have provided secondary calcareous material to the Platy Bench. This calcareous material seems to have invaded the interstices between the sandstone particles or clasts forcing them apart. A local ground water concentration at the base of the Dawes Clay Member where the Red Valley deposits are involved could produce, under proper conditions, the wafer-like calichification that includes the paraconformity, both at the level of the Platy Bench in some areas and much below it in the deeper, broader paleovalley containing the type section of the Red Valley Member where the Platy Bench is not present.

Red Valley Member reference section 1: Reference section 1 in the SE. ¼, SE. ¼, SW. ¼, sect. 11, T. 30 N., R. 48 W., Dawes County, is a part of the northernmost Red Valley deposit yet recognized (figs. 1, site 4; 8F; 9). The locality appears on USGS Chadron 3 SW, Nebraska 7.5 minute Quadrangle, 1966, and on ASCS aerial photograph CAO-5BB-293. It is particularly interesting because a section of the member 30 feet thick (the base of the Red Valley Member lies below the bed of Sand Canyon) is well exposed along the south wall of the paleovalley, and its stratigraphic relation to the blocky, convoluted or wavy-bedded, coarse, green to gray sandstone of the upper part of the Runningwater Formation is shown. A zone of sandstone slump blocks or boulders 18 feet wide (figs. 8F, 9B) derived from the adjoining Runningwater intervenes between the typical Red Valley Member and the Runningwater. The individual clasts may be as much as 2 feet in diameter, but most are 1 foot or less and are in a gray sand matrix. The face of the exposure of the Red Valley Member is 90 feet wide in the bend of Sand Canyon, but the Red Valley deposits can be traced north in a short side gully for a distance of 180 to 200 feet and yet the north edge of the Red Valley channel is not reached. The slope of the bedding planes, however, is southerly along the northerly exposed beds, so obviously the north edge of the paleovalley is being approached.

Along the contact of the Red Valley Member with the zone of slumped blocks 18 feet wide (fig. 8F), the Red Valley deposits incorporate green, sandy blocks of adjacent Runningwater Formation. These are concentrated along the contact and also in lenses that extend laterally into the main body of the Red Valley deposits. The size of the clasts and frequency of occurrence decrease sharply away from the contact. One silty clay layer about 6 feet from the bottom of the exposure produced several mammalian fossils.

Red Valley Member reference section 2: A reference section in the Pebble Creek drainage system in the NW. ¼, SW. ¼, SE. ¼, sect. 25, T. 30 N., R. 49 W., Dawes County (fig. 1, site 5) gives a basis for comparison of the Pebble Creek and Pepper Creek remnants of the Red Valley Member with those described in Sand Canyon and in the Dry Creek locality of the Hemingford area. The reference section shown in figure 8G, and the photograph in figure 10A, illustrate the general agreement of the occurrence of these widely separated paleochannel fill deposits. Both members of the Box Butte Formation crop out at this site. The exposed portion of the paleochannel is 550 feet wide, but at the south end there is a lateral extension 180 feet wide toward the east. A small buried hill of sediments of the Runningwater Formation is being exposed on the floor of the paleovalley at the south end. The basal conglomerate is best exposed on and around this buried hill and along the south and southeast side of the Red Valley deposits. The maximum thickness of the conglomerate is 4 feet, but the usual thickness is about 1 foot. It is composed of rounded concretions and intraformational conglomerates. The individual clasts are 1 inch in diameter and these are set in a matrix of smaller pebbles and granules of the same lithology as the larger fragments. Sand also forms a part of the matrix, and all may be locally cemented to form ledges. At these outcrops an extended search produced an occasional grain of granitic sand or granule, and these are regarded as having been redeposited from the Runningwater Formation. An occasional minute fragment of fossil bone was seen among the clasts of the basal conglomerate. The specimens collected occurred in the finer grained sediments higher in the section.

At one point across the small canyon or gully at the southeast corner of the exposure, a bed of pinkish buff silt 2 feet thick separates two 4-feet thick lenses of basal conglomerate. Only about 11 feet of the Red Valley Member is exposed here, with the balance of the 44 feet of section belonging to the Dawes Clay Member, which is in its normal position in relation to the Red Valley Member. Both members are shown in the cross

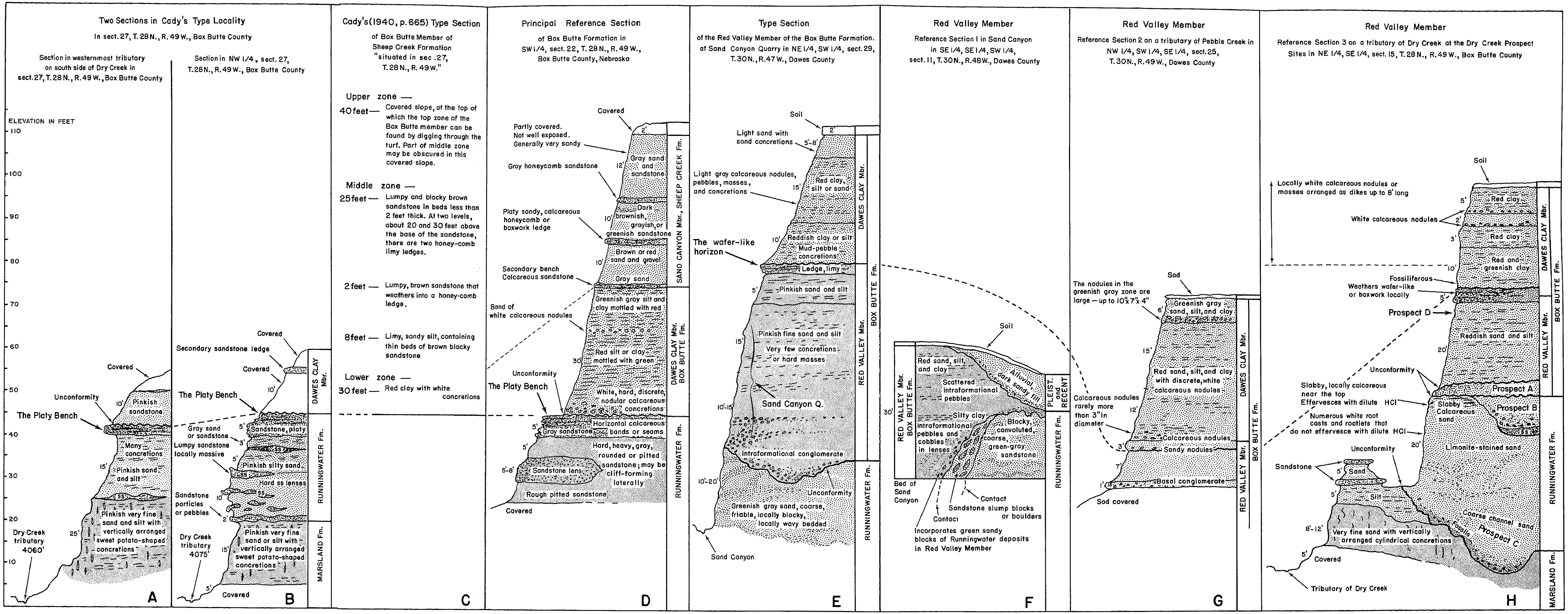


FIG. 8. Cross sections in Cady's (1940) type locality and newly proposed principal reference section of Box Butte Formation. Type and reference sections of Red Valley Member of Box Butte Formation. A. Cross section in Cady's type locality of Box Butte Formation. B. Cross section in Cady's type locality of Box Butte Formation. C. Type section as published by Cady (1940). D. Principal reference section of Box Butte Formation. E. Type section of Red Valley Member. F. Red Valley Member reference section 1. G. Red Valley Member reference section 2. H. Red Valley Member reference section 3.

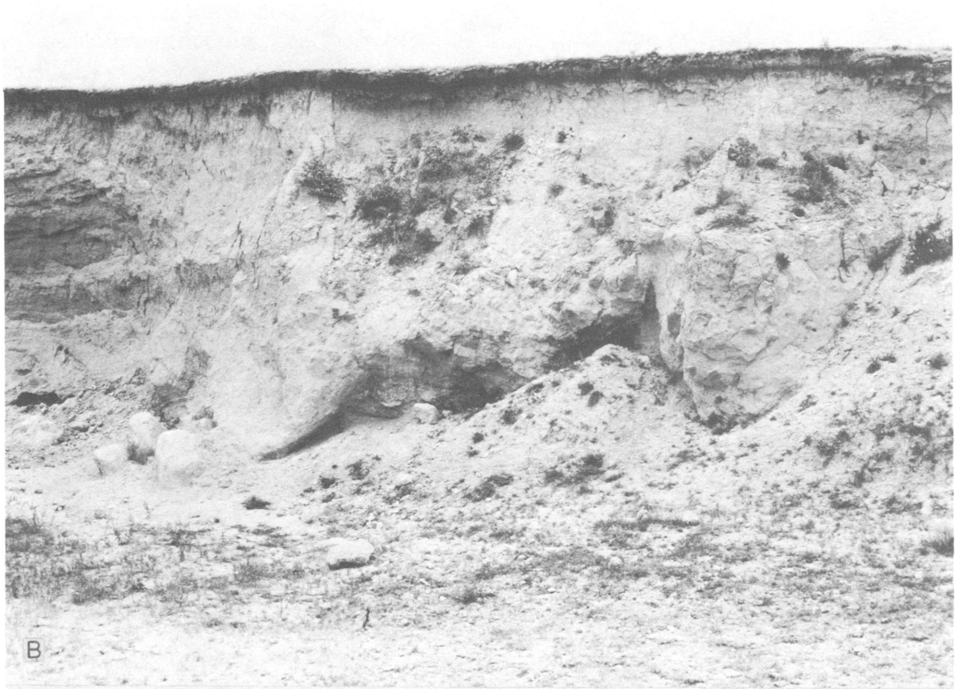


FIG. 9. A. Red Valley Member reference section 1. B. Detail of contact area of Red Valley Member with Runningwater Formation shown at the extreme right in A. (See fig. 8F and p. 36 in text.)

FIG. 10. A. View of Red Valley Member reference section 2. B. View of Red Valley Member reference section 3 at Dry Creek Prospects, Box Butte County.

section in figure 8G. This reference section crops out in an area that has not been topographically surveyed by the USGS, but the site is shown on ASCS aerial photograph CAO-1HH-147.

Red Valley Member reference section 3: This reference section is at the site of the Dry Creek Prospects in the Hemingford area (figs. 1, site 6; 10B). These prospects are unusually important in that they have provided a collection of four closely spaced but stratigraphically distinct suites of mammalian fossils. This reference section is in the NE. ¼, SE. ¼, sect. 15, T. 28 N., R. 49 W., Box Butte County, and the locality is on USGS Box Butte East, Nebraska 7.5 minute Quadrangle, 1948. ASCS aerial photograph CAK-4AA-68 shows the site.

The diagrammatic cross section in figure 8H is designed to show the relative stratigraphic positions of the various prospects and of the deposits that contain them. About 25 feet of deposits of the Red Valley Member crop out. These are overlain by about 22 feet of the Dawes Clay Member at the line of section, but laterally (in the next draw to the west of that containing the Dry Creek Prospects) there is exposed another 12 feet of Dawes Clay, and these upper beds contain the large irregular calcareous nodules. The lower 8 to 12 feet (fig. 8H) is composed of the pinkish, very fine sand and silt that contain elongated, vertically arranged, cylindrical, spindle-shaped concretions. Most are smaller than 4 inches in diameter although some that are irregularly shaped are larger. They tend to weather in relief on cliffs and appear as small knobs or cylinders scattered over the outcrops. Some groups or cylinders seem to be arranged discontinuously but essentially vertically for several feet. Some, but not all, of these concretions, upon weathering, tend to split horizontally in thin layers at right angles to the long axis of the concretion. Some have pitted surfaces. These deposits underlie the Runningwater Formation channels in the area and are earlier deposits of the Marsland Formation. Grayish silt or sand 8 to 20 feet thick, containing at least two sandstone lenses, conformably overlies the pink, very fine sand and silt with the vertically arranged concretions. It is on this grayish silt and sand that the cut and fill channel deposits containing Dry Creek Prospect C lie with strong unconformity. More than 20 feet of sediments above Prospect C, which is Runningwater Formation, range from greenish very fine sand to gray coarse sand with limonite stained zones. The upper part (10 feet) tends to be gray sand with hard, slabby weathering lenses of whitish calcareous sandstone. Prospect B with its Runningwater Formation fauna occurs at the level of the sandstone that caps this 10 feet of sediments. Prospect B in turn is overlain unconformably by the deposits containing Prospect A in the conglomerate at the base of the Red Valley Member. Prospect D occurs about 20 feet higher in the Red Valley Member than Prospect A, indeed it is about 5 feet below the zone of wafer-like calichification at the contact with the overlying Dawes Clay Member. A few specimens of fossil mammals were obtained from the Dawes Clay at this site. Typical white, hard, heavy, calcareous nodules of the Dawes Clay Member occur in two layers in this section, and the larger, irregular nodular concretions of the higher zones appear on the grassed slopes. These also are found in place in the next draw west of that containing the Dry Creek Prospects.

DAWES CLAY MEMBER, NEW NAME

A type section (p. 43) and four reference sections (pp. 43, 45, 46, 48) are herein designated for the newly proposed Dawes Clay Member of the Box Butte Formation; this supplements the formal statement of intent to establish the Box Butte Formation, the Red Valley Member, and the Dawes Clay Member. The type section of the Box Butte, as designated by Cady (1940), is reluctantly retained (present report, p. 8 and p. 24); moreover, in both the type and principal reference sections (p. 26), only the Dawes Clay Member is exposed.

At the principal reference section of the Box Butte (figs. 1, site 2; 5; 8D), the Dawes Clay Member is 30 feet thick. The upper 10 feet consists of greenish gray clayey siltstone mottled with reddish siltstone. A calcareous sandstone that may be as much as 2 feet thick marks the base of the overlying deposits, serves as a local cap for the Dawes Clay, and forms a conspicuous secondary topographic bench. The Platy Bench, described on page 28, forms the primary topographic bench at this and adjacent sites. About a mile north in a tributary of Dry Creek in sect. 15, T. 28 N., R. 49 W., Box Butte County, the secondary bench is formed in the Dawes Clay Member by a bed of sandy calcareous concretionary masses 35 to 40 feet above the base of the member. These calcareous masses are larger and less pure than the calcareous nodules in the lower red part of the member, and they commonly break up into angular particles that tend to mantle slopes. At some sites they form lag concentrations on slopes or accumulate in shallow depressions on the slopes and are not disrupted appreciably. The large sandy calcareous masses that mark the top of the Dawes Clay Member on most outcrops, unfortunately, are not well developed or exposed either in the principal reference section or in the type section, although in sections measured at other places in the general locality these large nodules are a noticeable and important part of the lithology. This last observation is particularly true of the beds in western Box Butte, western Dawes, and eastern Sioux counties.

A type section and four reference sections for the Dawes Clay Member, designated at widely separated localities, demonstrate the lithologic consistency of the member over parts of four counties in northwestern Nebraska. The Dawes Clay Member, at the various reference sections, ranges from 24 to about 40 feet in thickness. The sediments are red or green siltstones or clayey siltstones with a distinct tendency to be mottled red and green on fresh outcrops. Weathered outcrops are reddish, brownish, or pinkish commonly with the red color more predominant in the lower part of the member. Green silts and clays are more numerous in the upper part. White to gray, hard, heavy, rounded, nodular calcareous concretions occur as discrete entities throughout the member, but at some sites they are concentrated sufficiently in horizontal bands to give the appearance of forming distinct layers. Many of these nodular calcareous concretions are 3 to 4 inches in diameter, some are spindle-shaped, and in the lower part of the section they are rarely more than 3 inches in diameter (fig. 11B), but in the higher, greenish gray, silty clay zones they may range up to 10 inches by 7 inches by 4 inches with an average size nearer 7 inches by 4 inches by 3 inches (fig. 11A). These red and green silty clays with the gray to white calcareous nodules are distinctive and can be identified readily on outcrops in parts of Sioux, Box Butte, Dawes, and Sheridan counties. The nodules are unusually resistant to erosion, and on outcrops with low slopes they may be concentrated in sufficient numbers to give the outcrops a white color, especially from a distance. The numerous nodules upon weathering often show through sod or through the top soil of plowed fields in the area, and as a result have led to the discovery of remnants of the Dawes Clay Member that otherwise would have remained unrecognized. Exploratory holes dug on these problematical sites have greatly extended the known distribution of the member. In Sioux, Dawes, and Box Butte counties, on most outcrops where the red silty clay with the distinctive white nodules of the Dawes Clay Member is well exposed, the member lies on beds that weather to a major topographic bench that is described (p. 28) as the Platy Bench and is part of the Runningwater Formation; however, at a few sites it lies on beds of the Red Valley Member.

General geographic, topographic, and geologic relations of the Dawes Clay Member are discussed under the Box Butte Formation (p. 22), but certain salient features should be repeated to emphasize their importance in explaining the outcrop pattern of the member. The Dawes Clay Member in western Dawes, northern Box Butte, and eastern Sioux counties commonly crops out at or near the top of the tablelands between the crest of Pine Ridge and the "breaks" along the north side of the Niobrara River valley and again high along the northern edge of the Box Butte Table south of the Niobrara River. It also crops out high along the sides of the Dry Creek valley. Only in eastern Dawes and eastern Box Butte counties were the valleys containing sediments of the Box Butte entrenched deeply enough into sediments of the Runningwater Formation to demonstrate that the Dawes Clay Member was deposited more than 100 feet below the level of the tablelands. This also shows that the high lands in eastern Sioux, western Box Butte, and western Dawes counties were fairly uniform and not greatly dissected, and that the main trunk streams were essentially straight water courses that sharply incised the edge of the High Plains in

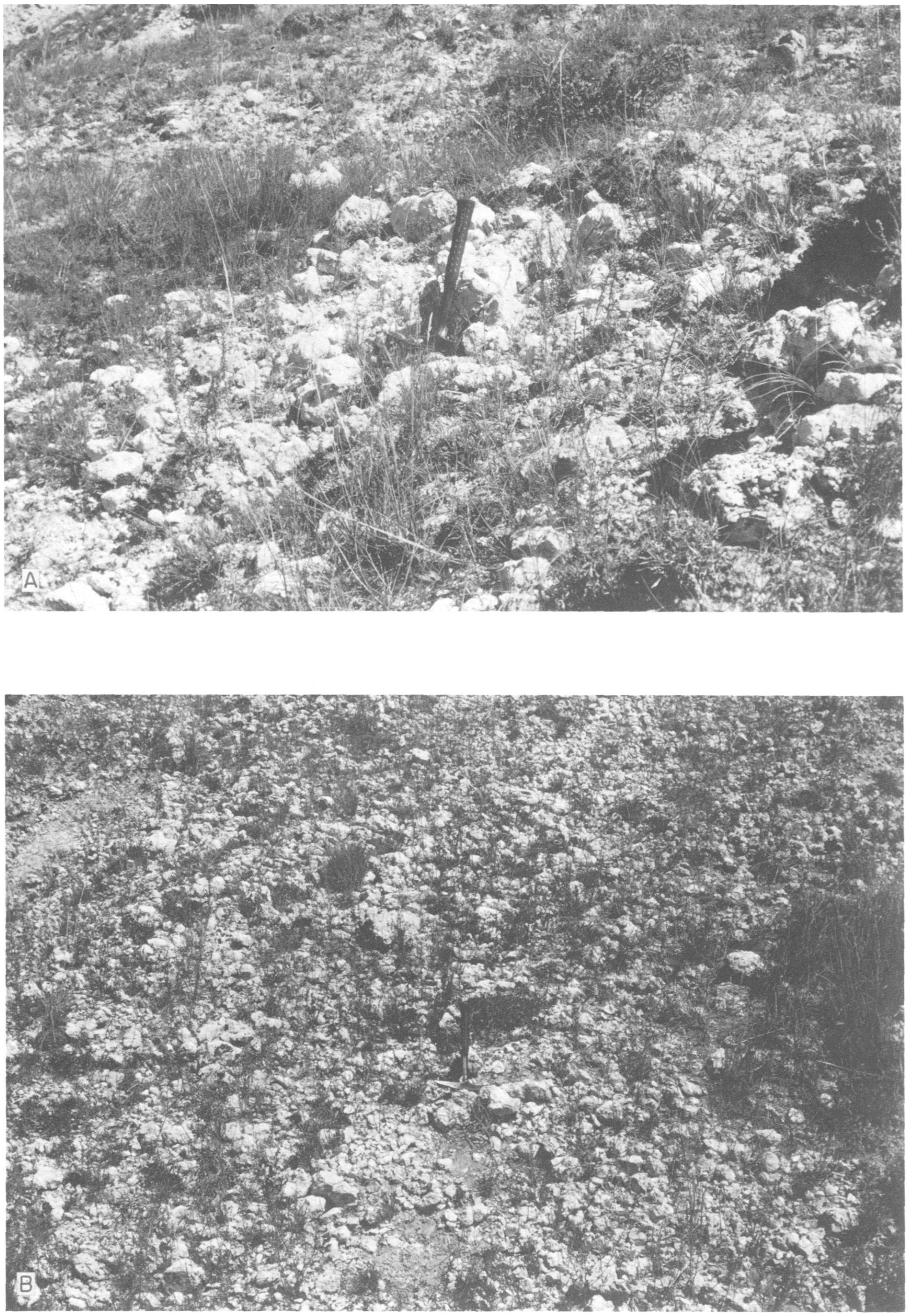


FIG. 11. Views of typical calcareous nodules eroding from Dawes Clay Member. A. Upper nodules at Dawes Clay Member reference section 3. B. Lower nodules at Dawes Clay Member reference section 2.

the eastern edge of what is now Box Butte and Dawes counties and the western edge of Sheridan County. It should be recalled that the present topographic relief did not then exist.

An outlying exposure of the Dawes Clay Member crops out on the shoulder of a high narrow ridge that is capped by beds equivalent to the Sand Canyon Member of the Sheep Creek Formation, as shown by lithology and mammalian fossils. This ridge forms a conspicuous highland that starts about 10 miles west of Belmont, Nebraska, in the SE. corner of T. 30 N., R. 53 W., Sioux County, and trends southeasterly across the northern part of T. 29 N., R. 52 W., in Dawes County. In this locality the unconformable superposition of beds of the Sand Canyon Member on the Dawes Clay Member disposes of Cady and Scherer's (1946, p. 35) reservation concerning the possibility of the Box Butte unit being a member of the Ogallala Formation (at least in the sense that they used Ogallala Formation). Deposits of the Dawes Clay Member cap some of the hills, ridges, and divides in a northeasterly direction through the southwestern part of T. 30 N., R. 52 W., in Dawes County, but in that area none of the beds overlying the Dawes Clay are readily recognizable, if, indeed, they exist. The Dawes Clay Member covers a much larger area than the beds that overlie it, for many of the hills in the locality that show white spots on the aerial photographs prove, on inspection, to be Dawes Clay. A distinctive set of pinkish to reddish, friable, sandy to silty beds underlies the Dawes Clay Member on this ridge and on adjacent areas. These sediments are sparsely fossiliferous and have been the locus of an intensive and moderately successful search to obtain diagnostic fossils. Deposits that conformably underlie the distinctive pinkish or reddish beds contain fossils that are suggestive of those that occur in the Runningwater Formation.

One of the important stratigraphic problems is the fact that Dawes Clay beds crop out at an elevation of about 4800 feet in the area along the ridge as described above; a few miles to the east and northeast the beds lie between 4700 and 4800 feet. At this elevation deposits of the Dawes Clay are all exposed west of Nebraska State Highway 2. No deposits of the member have been observed along Pine Ridge between Nebraska State Highway 2 and Squaw Mound (fig. 1). The northern edge of the outcrop belt of the Dawes Clay is not exposed along the crest of Pine Ridge from Squaw Mound in the northeast corner of T. 30 N., R. 51 W., Dawes County, to United States Highway 385 south of Chadron, in T. 31 N., R. 48 W. It is important to note, however, that the Platy Bench crops out along the Pine Ridge crest from Squaw Mound to United States Highway 385, but at no place are beds of either member of the Box Butte Formation exposed. If the Box Butte beds were ever deposited along the crest they were completely removed by erosion, and late surficial sediments, including soils, have been deposited in their place.

A few hundred yards south of the junction of the Ridge Road with the Squaw Creek Road, on the east side of the Squaw Mound Road, which leads south to the Niobrara River, is an outcrop of the Dawes Clay Member. This is in sect. 12, T. 30 N., R. 51 W., Dawes County, and represents the northernmost exposure of the member observed to date. About 2 miles farther south, another exposure of the Dawes Clay crops out; this is on the west side of the Squaw Mound Road in the NE. ¼, sect. 23, T. 30 N., R. 51 W., and is important in showing the discontinuous pattern of the Box Butte Formation. Only in a few places can the Dawes Clay Member be traced for more than 2 or 3 miles without some ravine or draw, grassed-over area, or cultivated field breaking the continuity of the outcrops. The largest unbroken exposure of the member is along the north facing escarpment of the Niobrara River valley at the edge of the Box Butte Table in and near T. 28 N., R. 52 W., in the extreme northwest corner of Box Butte County.

Cady and Scherer (1946, pl. 1) mapped the Sheep Creek Formation, which included their Box Butte Member, as underlying a belt about 1 mile wide in the northwest part of Box Butte County and 10 miles wide in the northeast part of the county. The broadest belt of Sheep Creek exposures was shown midway between Alliance and Berea, thence north for about 18 miles. When the discontinuous nature of the deposits of the Box Butte is considered, along with the great expanse of soil on the Box Butte Table that is now in cultivated farms or unbroken land, mapping the Box Butte deposits as underlying the above area, was, and is, extremely conjectural. It is more accurate to map the actual outcrops, then outline hypothetical areas in which the members of the Box Butte may be exposed or may once have been present. Much field evidence shows that the land surface on which the Dawes Clay Member was deposited was not uniformly level, but neither was it manifestly a rolling topography. It was merely uneven enough to preclude the possibility of uniform distribution across the entire area of the member as shown and therefore should not be mapped where completely covered. The eastern limits of the Box Butte Formation are difficult to establish despite the 10-mile broad outcrop belt of the Sheep Creek Formation shown on Cady and Scherer's (1946, pl. 1) map. Only test well No. 10 (Cady and Scherer, pl. 8) was drilled in the northeastern corner of Box Butte County in the NE. corner of sect. 25, T. 27 N., R. 47 W. It is just west of the Box Butte County-Sheridan County line at an elevation of about 3860 feet. This test well is not likely to have penetrated the Box Butte Formation, since it is located on the valley floor of Box Butte Creek. Test wells elsewhere in the area appear to have been used to establish the presence of the Sheep Creek Formation; it is strange that only one such well was drilled in the northeastern sector of the mapped area.

In accordance with the procedure followed in my discussion of the Red Valley Member, the type section and each of the newly proposed reference sections of the Dawes Clay Member are treated in sufficient detail to provide more information concerning the lithology and stratigraphic relations than would be feasible or possible in a generalized statement. The type section of the Dawes Clay Member is designated as the deposits that are well exposed on the east side of Pebble Creek, on C. W. "Buster" Moody's Pebble Creek Ranch, in the NW. ¼, NW. ¼, sect. 14, T. 30 N., R. 49 W., Dawes County (figs. 1, site 7; 12A; 13A). No topographic maps exist for the locality but it is shown on ASCS aerial photograph CAO-5BB-301. Although sediments of the Dawes Clay Member appear at the original type section of the Box Butte (Cady, 1940, p. 665) as the "lower zone" and also in the principal reference section as proposed in the present report, the newly selected type section of the member on the Pebble Creek Ranch is better exposed and more typical of the sediments of the member wherever they crop out. The Dawes Clay Member is 31 feet thick at this section and unconformably overlies the Runningwater Formation. The beds beneath the unconformable contact are cemented by calcium carbonate and weather to form the distinctive Platy Bench. A key bed, which I have called the Datum sandstone in the Runningwater Formation, occurs 20 feet below the top of the Platy Bench in the section and serves as a point of comparison with other sections in northwest Nebraska to show that the Platy Bench does not always occur at the same horizon in the Runningwater Formation.

The basal 4 feet of the Dawes Clay Member in the type section is composed of green and red clayey siltstone with numerous white, heavy calcareous nodules; this zone shows a tendency to be somewhat slabby in appearance with a waferlike concentration of calcium carbonate occurring in the lower part of the bed. A bed of red silt or clay mottled with green, 12 feet thick, containing a few scattered, discrete, white calcareous nodules overlies the basal zone. At the top of the 12-foot bed is the first layer of larger, white, calcareous nodules; a local change in sediments separates this first layer of nodules from the overlying pinkish sand, 3 feet thick, at the top of which is the second layer of larger calcareous nodules. Above this is another 12-feet thick bed, of pinkish sand with sandy calcareous nodules or concretions. The top 5 feet of this bed contains a greater concentration of these sandy calcareous concretions, which upon weathering tend to fall to pieces. The remaining 15 feet of section is sod-covered and unassigned.

The type section of the Dawes Clay Member, and adjacent exposures, are particularly useful in demonstrating the contact relationships to the underlying beds.

Dawes Clay Member reference section 1: Deposits that are well exposed in a road cut about 6.5 miles due north of Hemingford, on the Box Butte Reservoir road, were selected as Dawes Clay Member reference section 1 (figs. 1, site 8; 12B; 13B). The site is on the west side of the new road in the SE. ¼, NE. ¼, sect. 7, T. 28 N., R. 49 W., Box Butte County. The road has been straightened since the USGS issued the Box

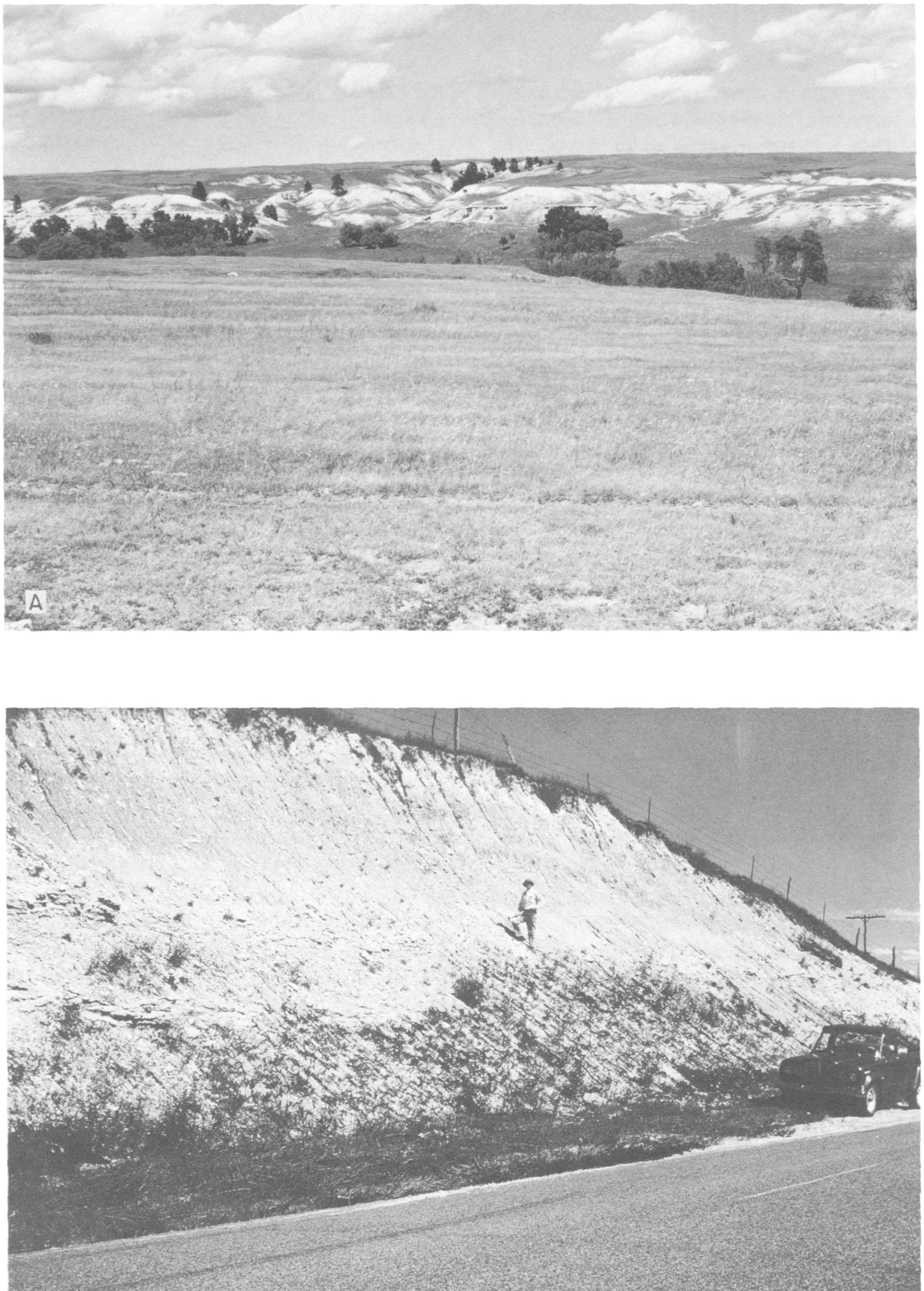


FIG. 12. A. Type section of Dawes Clay Member of Box Butte Formation on Pebble Creek Ranch, Dawes County. B. Dawes Clay Member reference section 1, Box Butte County.

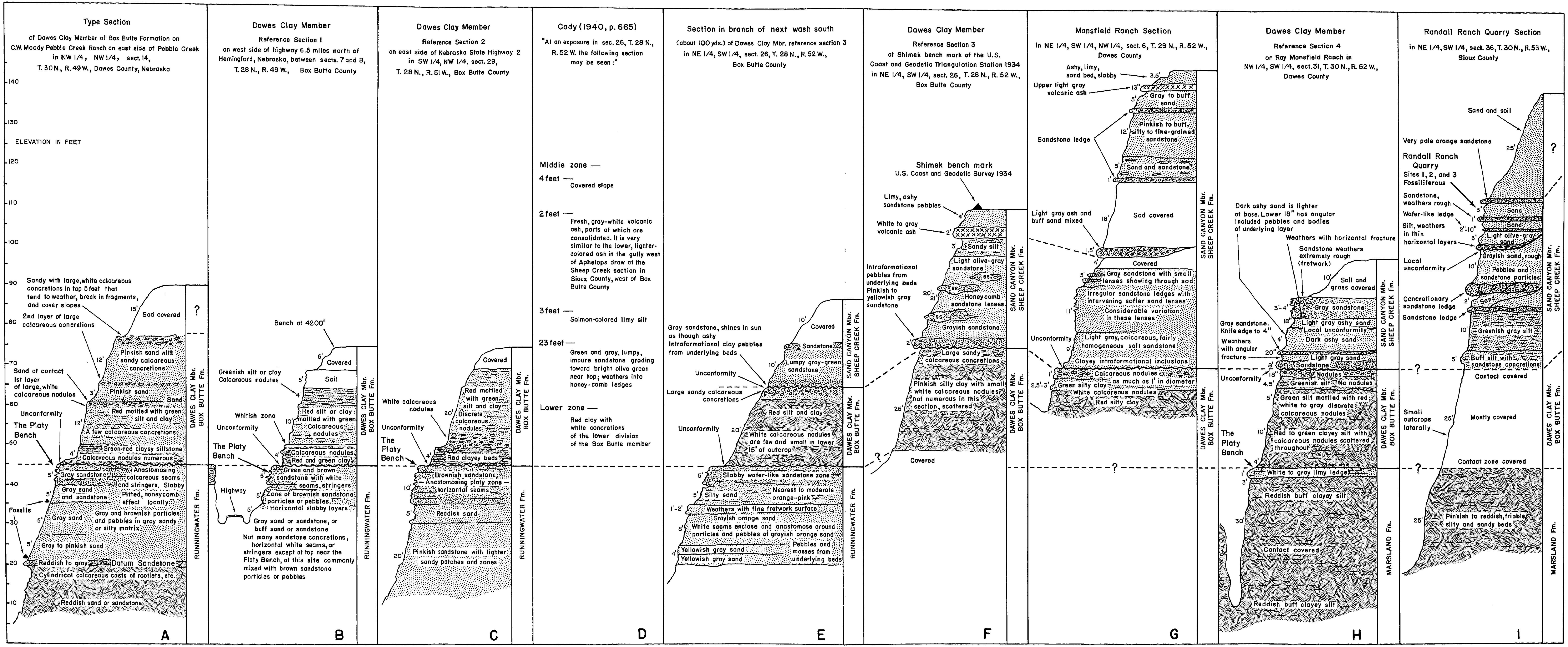


FIG. 13. Cross sections of type, reference, and supplemental sections of Dawes Clay Member of Box Butte Formation. A. Type section of Dawes Clay Member. B. Dawes Clay Member reference section 1. C. Dawes Clay Member reference section 2. D. Section published by Cady (1940) in sect. 26, T. 28 N., R. 52 W., Box Butte County. E. Section 100 yards south of Dawes Clay Member reference section 3 (supplemental). F. Dawes Clay Member reference section 3. G. Mansfield Ranch section (supplemental). H. Dawes Clay Member reference section 4. I. Randall Ranch Quarry section (supplemental).

Butte Reservoir East, Nebraska 7.5 minute Quadrangle, 1948. The locality also is shown on ASCS aerial photograph CAK-4AA-19. This reference section was chosen because it is an easily accessible exposure of the lower 18 feet of the Dawes Clay Member in a setting that should provide a relatively fresh outcrop for many years. The lower 4 feet of red silt and clay, with a mottling of green silt and clay, is densely packed with the discrete calcareous nodules typical of the member. Indeed, the nodules are so numerous that they appear as a whitish zone on the outcrop. In the next 10 feet of section the calcareous nodules are less numerous and scattered throughout the red and green mottled silt and clay, although more of them are concentrated on certain levels and tend to show as indistinct bands upon weathering. The upper 4 feet of exposed section is composed of greenish silt and clay with fewer calcareous concretions. The uppermost 10 feet of the section is soil- and grass-covered slope leading up to a topographic bench at an elevation of 4200 feet. This reference section also provides the best available fresh exposures of the Platy Bench, which represents the top of the Runningwater Formation at this point. The contact relationships between the Platy Bench and the Dawes Clay Member are remarkably well exposed.

Dawes Clay Member reference section 2: Dawes Clay Member reference section 2 is herein established as those beds of the member that are exposed in a road cut on the east side of Nebraska State Highway 2 in the SW. ¼, NW. ¼, sect. 29, T. 28 N., R. 51 W., Box Butte County (figs. 1, site 9; 13C; 14). It appears on USGS Marsland, Nebraska 15 minute Quadrangle, 1951, and on ASCS aerial photograph CAK-1AA-75. This reference section was selected for several reasons: (1) It is easily accessible. (2) The Dawes Clay Member disconformably overlies the Marsland Formation, as the Marsland is recognized by University of Nebraska field men. This section, in fact, is adjacent to the type section of the Marsland Formation as designated by the University of Nebraska (Schultz, MS; Toohey, MS; Folsom,

FIG. 14. Dawes Clay Member reference section 2.

MS).[1] (3) This section shows the points of similarity and difference that can be expected in lateral variation of the Dawes Clay Member in about 3 miles by comparing it with the Shimek reference section (Dawes Clay Member reference section 3).

Overlying beds, which are prominent but not thick along the escarpment toward the west, crop out on only three small hills east of the highway, and two of these are at and near reference section 2 in section 29; the third is very small and occupies the crest of a promontory in sect. 20, T. 28 N., R. 51 W. The upper beds, if present, underlie, and are obscured by, sod of pasture lands or soil of tilled fields elsewhere in the general area east of Nebraska State Highway 2. In a southerly direction across the valley of Dry Creek, which is not incised in this locality, the elevation of the hills suggest that the upper beds could be present below the soil of the tilled fields. Light spots on the slopes indicate the possible presence of buried Dawes Clay, but owing to lack of exposures the beds represented by these light spots cannot be ascertained precisely.

At reference section 2 the upper part of the Dawes Clay Member consists of 8 to 10 feet of greenish, silty and sandy clay containing the usual irregular calcareous concretions that are consistently and very noticeably larger than those that are typical of the middle, mottled greenish and reddish or the lower, reddish, silty and sandy clay parts of the member.

Dawes Clay Member reference section 3: Dawes Clay Member reference section 3 is at the Shimek bench mark of the United States Coast and Geodetic Triangulation Station, 1934, in the NE. ¼, SW. ¼, sect. 26, T. 28 N., R. 52 W., Box Butte County (figs. 1, site 10; 13F; 15). The bench mark is shown on USGS Marsland, Nebraska 15 minute Quadrangle, 1951. ASCS aerial photograph CAK-1AA-75 shows the site. This reference section was selected because Cady (1940, p. 665), in his original description of the Box Butte, published a type section and also stated, "At an exposure in sec. 26, T. 28 N., R. 52 W. the following section may be seen: . . . " This was measured at the Shimek bench mark, and although Cady did not specifically call it a reference section it should serve as such, since it was the only other section he gave for comparison purposes. Cady's section (p. 665) is reproduced herewith (fig. 13D), and owing to differences in interpretation of parts of the section, and of the units to which they should be allocated, I have provided my section (fig. 13F) of the Shimek bench mark exposure and an accompanying section (fig. 13E) taken in the branch of the canyon about 100 feet south of the Shimek bench mark exposure to give the stratigraphic relationship to the underlying beds.

Beds overlying the Dawes Clay Member in the Shimek section (Dawes Clay Member reference section 3, fig. 13F) are correlated in the present report as an equivalent to the Sand Canyon Member of the Sheep Creek Formation.[2] Cady (1940) and Cady and Scherer (1946, p. 33) assigned these deposits to the "middle zone" of their Box Butte Member and they regarded beds now included in the Dawes Clay Member of the present report as the "lower zone" of their Box Butte Member. It should be emphasized that in the present report the top of the deposits included in the Dawes Clay Member is the top of the Box Butte Formation. In this and other sections in the locality, the top of the Dawes Clay Member is placed at the distinctive band of large, white to gray, calcareous, or sandy calcareous nodules whose dimensions may be as much as, or more than, 8 inches by 12 inches by 4 inches (fig. 11A). These nodules are resistant to erosion and often mantle slopes. They are much larger than the nodules typical of the lower 20 feet of the Dawes Clay Member (fig. 11B). Throughout this area rocks of the Sand Canyon Member lie unconformably on this band of large calcareous nodules. The lower few inches of the basal bed of the Sand Canyon Member typically contain light

[1]No type section of the Marsland Formation has been published, although Schultz (MS), Toohey (MS), and Folson (MS) each designated the same section as the type in unpublished theses. Many workers in Tertiary stratigraphy insist that the type section of the Upper Harrison, as illustrated by Peterson (1906, p. 23), automatically became the type section of the Marsland Formation when Schultz (1938, p. 441) stated, "The name Marsland is proposed for the formation (until now incorrectly called 'upper Harrison') which lies above the Harrison and below the Sheep Creek."

[2]Radiometric dating of the ash beds by fission track or K-Ar methods at the Shimek bench mark, the Sand Canyon Member type locality, and the Mansfield and Randall ranch localities would add greatly to the understanding of the stratigraphy of these areas.

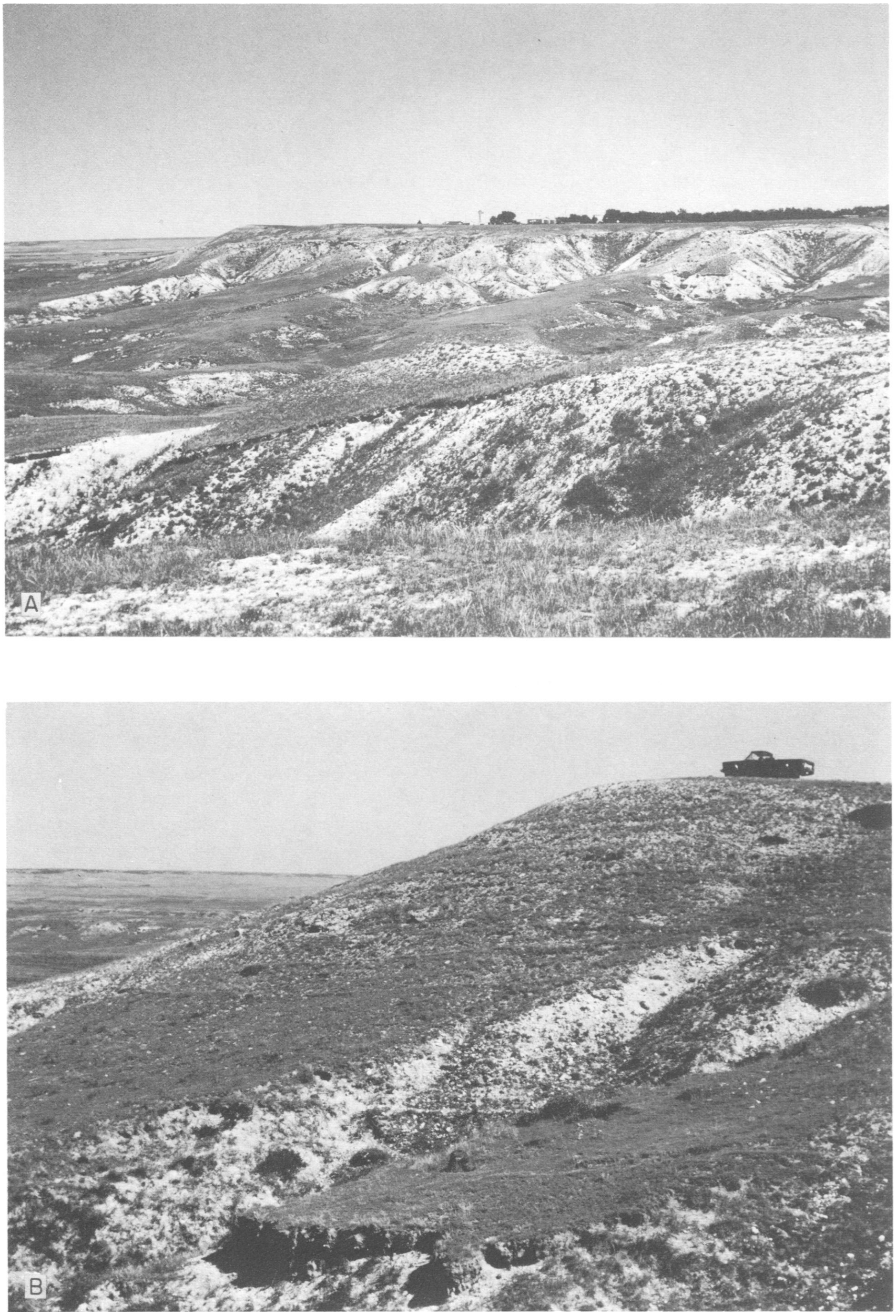


FIG. 15. Dawes Clay Member reference section 3, Shimek bench mark locality. A. Looking northeast across the SW. ¼, sect. 26, T. 28 N., R. 52 W., Box Butte County. B. Close-up of Shimek bench mark section.

colored clay pebbles derived from the underlying Dawes Clay Member. The 20 to 21 feet of sediments above the basal sandstone are a light olive gray sandstone with grayish sandstone honeycomb ledges. A layer 3 feet thick of pinkish sandy silt underlies a bed of white to gray volcanic ash 2 feet thick near the top of the section. Strata 3 to 4 feet thick, composed of limy, ashy, flattened to rounded chunks or pebbles of gray sandstone, overlie the ash bed at the Shimek site and also overlie the ash bed on small hills west of the Havorka Ranch buildings.

Along the edge of the escarpment overlooking the Niobrara River through sections 25 and 26 and parts of sects. 27, 34, and 35, T. 28 N., R. 52 W., in Box Butte County, a gray sandstone ledge crops out about 10 feet above the uppermost contact of the Dawes Clay Member. This ledge forms a rimrock around the heads of the canyons that ramify into the edge of the uplands, and only about 10 to 20 feet of beds, whose topographic expression is one of low slopes, commonly overlie this rimrock. Most of these slopes are sod-covered except for a narrow band of exposed beds along the rim. About the middle of section 34 the sandstone 10 feet above the upper contact of the Dawes Clay Member disappears and its position is taken by softer sediments. These sediments appear to have been rather easily removed and to have been replaced by blown sand and soil. In the west half of sect. 34 and a corner of sect. 33, T. 28 N., R. 52 W., the upper contact is eroded or passes beneath the sod; the identity of the contact is lost but many of the larger white calcareous concretions that mark the upper limit of the Dawes Clay Member are scattered down some of the slopes in the heads of the canyons. The lower contact can still be traced, but in this area the beds underlying the Dawes Clay are soft, pink sands, in many ways similar to those of the Red Valley Member, and as such show the wafer-like, boxwork calichification at the base instead of the distinctive Platy Bench type of sedimentation that is characteristic of the basal contact farther east along the rimrock.

The bold escarpment of the Box Butte Table ends in the E. ½, sect. 33, T. 28 N., R. 52 W., Box Butte County, and gives way to grass-covered hills that show few exposures. A dry tributary system that drains about 30 square miles and enters the Niobrara River south of the Don Morava Ranch in sect. 6, T. 28 N., R. 52 W., Box Butte County, heads against the drainage divide that marks the edge of the Box Butte Table in a southwesterly direction. Some exposures of the Runningwater Formation crop out here and there in the headwaters of the tributaries, but Box Butte exposures are few and far between; the formation is mostly completely covered by grass slopes or by the soil of tilled fields.

The westernmost exposures of the Dawes Clay Member of the Box Butte Formation south of the Niobrara River, so far observed, are in Sioux County, 19 miles west and a little more than a half-mile north of Hemingford, Nebraska, in the NE. ¼, sect. 12, T. 27 N., R. 53 W., just west of the Sioux County-Box Butte County line. The exposures are small; one lies north of the road and the other crops out in the ditch along the road. The elevation of the base of the member at these exposures is 4600 feet; the base of the member in the type and the principal reference sections of the Box Butte Formation, which are 22 miles east and 4 and 5 miles north, respectively, of the Sioux County exposures, stands at about 4100 feet. This indicates a drop in elevation of 500 feet in approximately 22 miles, or 24½ feet per mile in an easterly direction. This is remarkable in view of the fine-grained nature of the Dawes Clay Member.

Dawes Clay Member reference section 4: North of the Niobrara River along the crest of Pine Ridge, the westernmost exposure of the Dawes Clay Member crops out at and near the common corner of sects. 27, 28, 33, and 34, T. 30 N., R. 53 W., in Sioux County. This is, in fact, the westernmost exposure of the member recognized to date. In the same general area, but in Dawes County just east of the Sioux County-Dawes County line, a set of beds north of the Mansfield Ranch building site was selected as Dawes Clay Member reference section 4 (figs. 1, site 11; 13H; 16). At this site 24 feet of the Dawes Clay Member crops out above a white to gray, limy ledge 1 foot thick correlated as the Platy Bench, which in turn overlies about 36 feet of the exposed Marsland Formation. The typical white to gray, hard, heavy, calcareous nodules of the Dawes Clay are scattered throughout this ref-

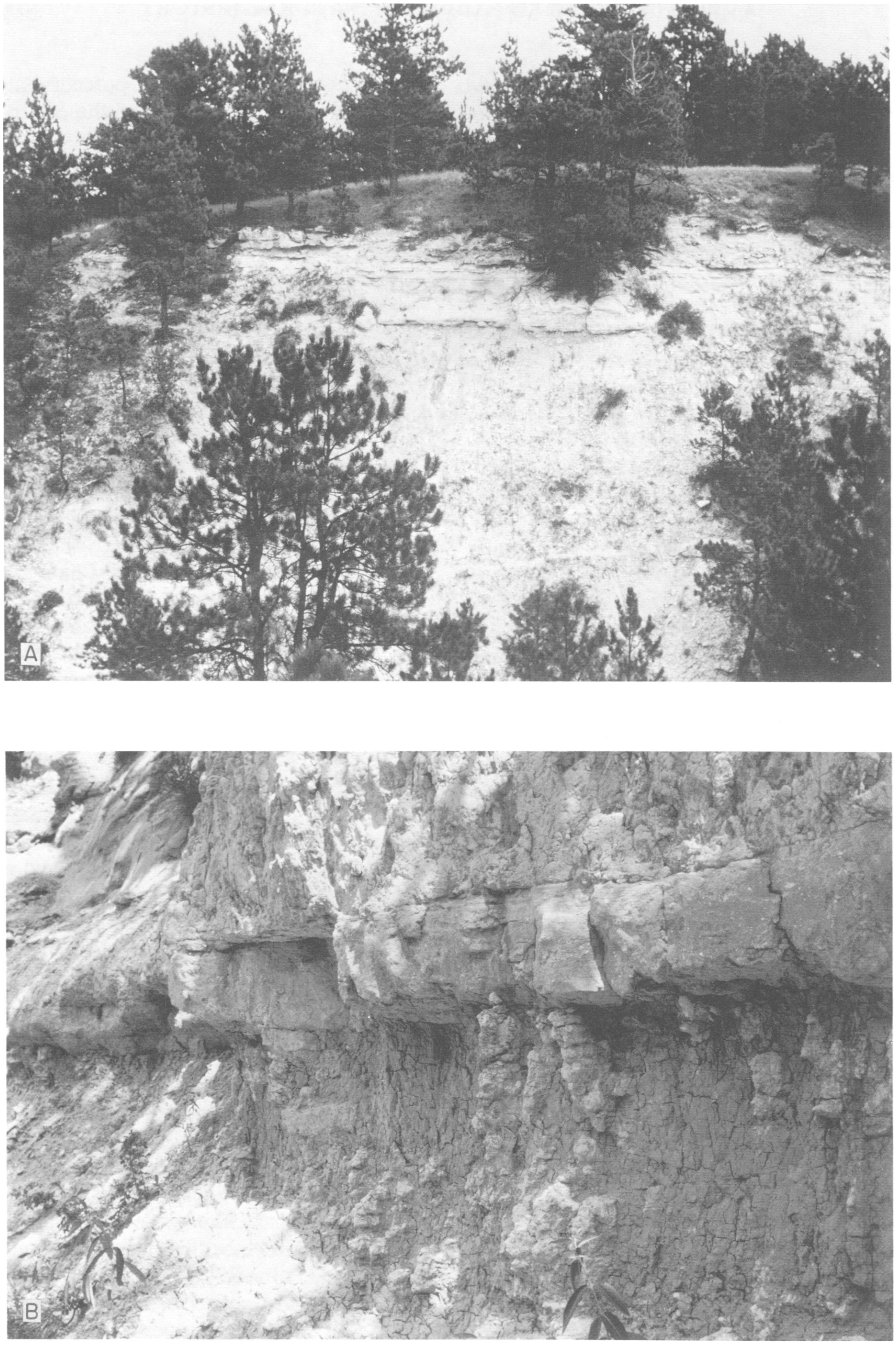


FIG. 16. Dawes Clay Member reference section 4, Mansfield Ranch locality. A. View across canyon looking east. B. Close-up of contact of overlying Sand Canyon Member of Sheep Creek Formation with Dawes Clay Member.

erence section, and some of these discrete nodules are concentrated and arranged in recognizable horizontal layers. The matrix is red and green mottled clayey silt, which, together with the distinctive white to gray calcareous nodules, makes the Dawes Clay Member recognizable wherever exposed. At Dawes Clay Member reference section 4, only 12 feet of well-exposed sediments of the Sand Canyon Member of the Sheep Creek unconformably overlies the member. Ten feet of soil and grass cover completes the section. The area is covered by ASCS aerial photograph CBE-4BB-30 and by the USGS Alliance, Nebraska, Transverse Mercator Projection Map, 1955.

SAND CANYON MEMBER OF THE SHEEP CREEK FORMATION

The geologic age and correlation of deposits overlying the Dawes Clay Member have been uncertain in the past. Distinctive lithologic characters that are useful for correlations on adjacent outcrops often prove unsatisfactory for identifying stratigraphic sections taken several miles apart, particularly where intervening outcrops are missing or covered and do not permit evaluation of facies changes. On most outcrops, however, the strata overlying the Dawes Clay Member contain volcanic ash beds and a strong component of volcanic ash mixed in the sediments, which consist predominantly of fine-grained to moderately coarse grayish or greenish sand or sandstone. These volcanic rich deposits contrast markedly with sediments of the underlying Dawes Clay and also with those of the Red Valley Member, both of which are virtually free of volcanic rocks and are primarily intermixtures of clay, silt, and very fine-grained sand that commonly display a reddish to pinkish color. Lithologically, the beds overlying the Dawes Clay Member are more compatible with those described by Elias (1942, p. 129) as the Sand Canyon Member of the Sheep Creek Formation from the southeastern corner of Dawes County than they are like those from the type locality of the Sheep Creek Formation in southern Sioux County. Elias (p. 130) established the type locality and type section of his Sand Canyon Member as occurring "on the southwest side of the canyon, at and around the junction of sections 11, 13, and 14, T. 29 N., R. 47 W., Dawes County, Nebraska."

The large collection of mammalian fossils that I obtained from Elias's type locality of his Sand Canyon Member, both prior to and subsequent to his work demonstrates that the taxa are those typical of the Lower Snake Creek beds of Sioux County and not those of the Sheep Creek beds. This, of course, emphasizes the severe complications that exist in interpreting the stratigraphy of northwestern Nebraska and particularly that of the Sheep Creek-Snake Creek locality in Sioux County. Stratigraphic relations of the Sheep Creek-Snake Creek type locality have been exhaustively described and revised by Skinner, Skinner, and Gooris (MS), and, in view of the imminent publication of their report, I am purposefully avoiding discussion of the intricate details of the interrelations of the various members that in the past have been assigned to the Sheep Creek Formation. They suggest a replacement name for the Lower Snake Creek beds (see footnote, p. 5) which are primarily a succession of stream channel deposits that were preserved in a late Miocene (Barstovian) paleovalley system. The lithology of the Lower Snake Creek beds in the type locality in Sioux County differs from that of the type area of the Sand Canyon Member, and, although the fossils from the two sites are manifestly equivalent, it is difficult to justify correlating them as the same formation on purely rock-stratigraphic criteria, despite the presence in each of similar appearing volcanic ash beds.

Correlated exposures of the Sand Canyon Member of the Sheep Creek Formation overlie some of the outcrops of the Dawes Clay Member along the crest of Pine Ridge west of Nebraska State Highway 2. The western terminus of the Sand Canyon Member is on land presently controlled (1973) by Roy Mansfield, and the terminus forms a distinctive pine-covered highland at and about the common corner of sects. 27, 28, 33, and 34, T. 30 N., R. 53 W., in Sioux County. The trend of the main part of the highland is eastward and southeastward through sects. 34

and 35, T. 30 N., R. 53 W., Sioux County, and lies mostly on the Ralph Stamen Ranch. The ridge formed by the highland has a somewhat sinuous outline owing to the spurs and promontories that occupy the divide area between the heads of the larger tributaries of the Niobrara River and the White River drainage systems that abut against it. The width of the crest of the ridge ranges from a few yards to no more than half a mile. On the Roy Randall Ranch, in the southern half of section 36, the trend is strongly southeastward with the main crest lying in the northeast corner of sect. 1, T. 29 N., R. 53 W., Sioux County, and in the northwest corner of sect. 6, T. 29 N., R. 52 W., Dawes County. From there it curves eastward to slightly northeastward through the northern parts of sections 6 and 5. This is on the Reynoldson Ranch. At the northeastern corner of sect. 5, T. 29 N., R. 52 W., the continuity of the ridge becomes less pronounced and spurs are traceable in a southerly or southeasterly direction between the larger of the Niobrara River tributaries heading in the area. These beds of the Sand Canyon Member cover a small area not more than a part of 4 or 5 square miles in the southeast corner of T. 30 N., R. 53 W. and in the northeast corner of T. 29 N., R. 52 W., Dawes County. The Dawes Clay Member of the Box Butte Formation crops out at many localities on both sides of this ridge near the crest.

A consolidated limy ash bed 5 inches to 2 feet thick caps several, small, flat-topped hills on the summit of the divide. These are grouped on either side of the Sioux County-Dawes County line, but the larger outcrops are in the NW. ¼, sect. 6, T. 29 N., R. 52 W., Dawes County. The Federal Aviation Agency Remote Control Air Ground Facility situated at latitude 40° 31′ 18″ N, longitude 103° 28′ 48″ W, elevation 4861.8 feet, is on one of these isolated hills. The base of the towers is 4 feet above the ash and therefore the ash can be placed confidently at about 4858 feet at this point. Three additional outcrops of the ash cap small hills northwest of the Remote Control Towers in the NE. ¼, sect. 1, T. 29 N., R. 53 W., Sioux County. The easternmost of the ash-capped hills in the area is about a half mile due east of the Remote Control Air Ground Facility. This easternmost bed is 75 feet above the top of the Dawes Clay Member and, since it is the highest bed in the sequence, it indicates that the Sand Canyon Member is 75 feet thick in this area. This light gray ash bed is commonly limy, very resistant, and appears dark gray owing to a partial covering of black lichen. Rusty orange spots of lichen also are present. It may grade locally to pockets of vitric tuff, which, although small, provide the definitive answer to questions concerning the nature and color of the original ash fall. The upper part of the ash or ashy zone tends to break up in plates and the true maximum thickness cannot be ascertained with assurance.

A good topographic map for this area is not available, although the area is covered by the 1955 USGS Alliance, Nebraska, Transverse Mercator Projection Map with a contour interval of 100 feet. The beds range in elevation from about 4700 feet on the east to 4880 feet at the highest point on the western end of the high ridge. Fossils have been found at a few places in the beds overlying the Box Butte, notably in the three adjacent Randall Ranch quarries (fig. 13 I) and at two other sites in the SW. ¼, sect. 36, T. 30 N., R. 53 W., Sioux County. In addition, Pine Ridge Quarry and some nearby prospects were found in deposits filling a channel that had been cut into the Dawes Clay Member and hence are not necessarily the unit that directly overlies the member. Fossils from this site differ in preservation and slightly in taxonomy from those obtained from the Randall Ranch quarries.

A light gray ash bed 1½ feet thick crops out at one point on the east side of a small canyon in the SW. ¼, NW. ¼, sect. 6, T. 29 N., R. 52 W., Dawes County. This ash bed is 29 feet above the top of the Dawes Clay Member of the Box Butte Formation. Its lithology and stratigraphic relations suggest that it correlates with the ash bed at the Shimek section (Dawes Clay Member reference section 3). It is about 40 feet below the ash bed recognized above as the top of the Sand Canyon Member in the Randall Ranch-Mansfield Ranch locality. Although beds overlying the Dawes Clay Member in this locality can be correlated with those in the Shimek and Havorka Ranch sections south of the Niobrara River in T. 28 N., R. 52 W., Box Butte County, the beds at both of these sites cannot be correlated lithologically at the same level of confidence with the deposits overlying the Dawes Clay Member in the Dry Creek area at the original type locality of the Box Butte (Cady, 1940, p. 665), or with those of the principal reference section (fig. 8D), or with other exposures in the Dry Creek drainage system. Unfortunately, diagnostic fossils have not been found in the deposits overlying the Dawes Clay Member at any of the exposures on Dry Creek.

Cady (1940, p. 665) and Cady and Scherer (1946, p. 33) stated that the gray-white ash in their published section in sect. 26, T. 28 N., R. 52 W., Box Butte County (Dawes Clay Member reference section 3), was similar to the lower, lighter colored ash in the gully west of Aphelops draw at the Sheep Creek section in Sioux County, and it appears to have influenced them in their decision to refer these upper beds, which they considered the "middle zone" of the Box Butte Member, to the Sheep Creek Formation. With greater certainty the small exposures at the Shimek bench mark, and those west of the Havorka Ranch house, can be correlated with the exposures along the Pine Ridge escarpment north of the Niobrara River at the Randall Ranch quarries (fig. 13 I), the Mansfield Ranch section (fig. 13G), and Dawes Clay Member reference section 4 (fig. 13H). Fossils from the Randall Ranch quarries firmly establish that the beds overlying the Dawes Clay Member in this locality are equivalent in age to those of the Sand Canyon Member of the Sheep Creek Formation in the type locality.

Owing to the significance that has been attributed to it in the past and probably will be afforded it in the future, it is important to direct attention to the stratigraphic position of the white to gray volcanic ash in the Shimek section. This ash crops out at an elevation of 4570 feet at the Shimek bench mark, and at only one other site was this ash observed in the area west of Nebraska State Highway 2 south of the Niobrara River. This second site is immediately west of the Havorka Ranch buildings in the SW. ¼, sect. 30, T. 28 N., R. 51 W., Box Butte County, where three small exposures of the white to gray ash crop out at an elevation of 4520 to 4540 feet, indicating a differential in elevation of 30 to 50 feet in one and a half miles toward the east.

The sections at the Havorka Ranch and Shimek localities are essentially the same, at least as far as the Dawes Clay Member of the Box Butte Formation and the overlying beds containing the volcanic ash are concerned. East of the Havorka Ranch, however, the upper beds that overlie the Dawes Clay Member are commonly very thin or missing along the escarpment, and the sandstone that holds up the rim of the escarpment in sects. 25, 26, 27, 34, and 35, T. 28 N., R. 52 W. and part of sect. 30, T. 28 N., R. 51 W. is conspicuously missing in the section. This does not seem to be entirely a function of lower elevation of the rim, which decreases in elevation from 4500 feet at Havorka's Ranch buildings to 4400 feet 4 miles to the northeast, but reflects a lateral change in sedimentation within the Sand Canyon Member.

At Dawes Clay Member reference section 4 (figs. 13H, 16A, 16B) the basal bed of the Sand Canyon Member is a gray sandstone 8 inches thick with white to gray angular particles of Dawes Clay sediments scattered throughout. The bottom of the 8-inch bed is irregular but the top is relatively regular. A dark, sooty, ashy sand stratum 4 feet thick is a conspicuous feature of this outcrop. It is correlated with a similar appearing sooty ash bed in the type locality of the Sand Canyon Member. Several local unconformities were observed in this section, but, because adjacent outcrops are covered, the extent or significance of the local unconformities cannot be determined. A gray sandstone ledge 3 to 4 feet thick that weathers to an extremely rough fretwork surface forms a distinct rimrock at this site. Elsewhere in the locality this sandstone crops out on the pine-covered, soil-mantled, north-facing slopes and few good exposures occur.

BIOSTRATIGRAPHY OF THE BOX BUTTE FORMATION

Interpretation of the biostratigraphy of the Box Butte Formation now can be based on more than 400 fossil mammalian specimens, most of which are identifiable and sufficiently complete, or well enough preserved, to be referable to genera and in many cases to species. Only three fossil mammalian specimens have been described previously from the Box Butte. The first of these, the type of *Ticholeptus tooheyi*, was collected near the center of the SE. ¼, sect. 13, T. 28 N., R. 49 W., Box Butte County, and was reported by Schultz and Falkenbach (1941, p. 84). The other two, an insectivore skull from Foley Quarry, Box Butte County, and an insectivore ramus from the Red Valley Member in Sand Canyon, Dawes County [mislocated by Rich and Rich (1971, p. 15) as having been collected in Box Butte County], were referred by Rich and Rich (1971, pp. 14, 15, 46) to *Brachyerix macrotis*. Cady (1940, pp. 666, 667) and Cady and Scherer (1946, pp. 34, 35) reported vertebrate fossils from the Box Butte, presumably collected from several localities, but gave no indication of the number or kinds represented. Elias (1942, pp. 79, 131) collected a few specimens of grass seeds (*Stipidium dawesense* mut. *a* and *S. commune*) from beds that he believed to be the Box Butte Member of the Sheep Creek Formation, but which are considered to belong in the Marsland Formation by some workers and in the Runningwater Formation by others.

Five fossil quarries in beds that are herein assigned to the Red Valley Member of the Box Butte Formation have produced most of the 400 specimens recovered from the formation, but other sites have provided fossil concentrations, which, although small, have been exceptionally useful for comparisons with material from the underlying Runningwater Formation, from the Marsland Formation, and from the overlying Sand Canyon Member of the Sheep Creek Formation. Isolated finds on several widely separated exposures of the Red Valley Member also have proved helpful. Fossil mammals from the Dawes Clay Member number only 10 biostratigraphically useful specimens, and the great difference in total specimens between the two members reflects in a realistic way the abundance of fossils in each; it is not just an artifact of collecting.

Four of the five known fossil quarries in the Red Valley Member are in Box Butte County: Foley Quarry has produced 210 specimens; Dry Creek Prospect A, 53; Middle of the Road Quarry, 36; and Dry Creek Prospect D, 32. In contrast, the most prolific site in Dawes County, Sand Canyon Quarry, has produced only 40 specimens. The remaining specimens that have been collected were from small concentrations or were from single isolated occurrences.

Foley Quarry, as indicated above, is the largest and most productive of the Red Valley quarries; it is situated in the area northeast of Hemingford, Nebraska, on a tributary of Dry Creek in the SW. ¼, NW. ¼, SW. ¼, sect. 15, T. 28 N., R. 49 W., Box Butte County, and has been the source of most of the fossils that have been collected in the Box Butte Formation. This quarry was named for Mr. Hugh Foley, owner of the land on which it was found.

Middle of the Road Quarry, as its name implies, was found in the road, in a road cut, on the south side of a tributary of Dry Creek about midway between the SW. ¼, sect. 15 and the SE. ¼, sect. 16, T. 28 N., R. 49 W., Box Butte County. Middle of the Road Quarry and Foley Quarry are approximately on the same horizon, and only slight differences are seen in their taxa.

Fossils from Dry Creek Prospect A show minor differences from fossils collected in Foley and Middle of the Road quarries. Dry Creek Prospect D is in the same Red Valley Member paleochannel as Dry Creek Prospect A but it is stratigraphically higher in the section (fig. 8H); the assemblages from these two prospects also show some differences.

Preliminary identifications of the taxa from the Box Butte Formation were made by specialists in the various mammalian families that are represented, and I have supplemented their determinations with close point by point comparisons of the fauna from the Box Butte with the large collections of mammalian fossils in the American Museum of Natural History from the underlying Runningwater Formation, from the Marsland Formation, from the overlying Sand Canyon Member of the Sheep Creek Formation, and also from the type locality of the Sheep Creek Formation. Recognizable differences exist among these fossil mammal assemblages, but owing to the sensitive degree of resolution required to document the observed differences, I am convinced that a sophisticated faunal study of the assemblage from the Box Butte should be made by a coterie of specialists. A consensus by a select group of specialists should provide a new and useful measure of order to a part of the late Tertiary geologic section that has become notorious for controversial interpretations of the stratigraphic positions of the named formations and the ages assigned to them (McKenna, 1965).

The following preliminary analysis suggests that the fauna of the Box Butte Formation is slightly earlier than that of the Sheep Creek Formation, as exemplified by the collections from the type locality of the Sheep Creek in Sioux County, Nebraska, and is later than that of the Runningwater Formation.

Many taxa that are included in the preliminary faunal list that follow are deleted from discussion because they are new; because they are not well known; or because they are not complete, not diagnostic, and not amenable to comparison with older or younger taxa. Omission of a taxon from the discussion under biostratigraphy, then, is not necessarily a criterion of the importance of the taxon; rather it is a gauge of its usefulness in determining how the members of the Box Butte Formation fit in the stratigraphic sequence in the Great Plains.

PRELIMINARY FAUNAL LIST OF THE BOX BUTTE FORMATION

- Class Osteichthyes
  - Order Siluriformes
    - Family Ictaluridae
      - *Ictalurus* sp.
  - Order Amiiformes
    - Family Amiidae
      - *Amia* sp.
- Class Amphibia
  - Order Salientia
    - Family Bufonidae
      - *Bufo* sp.
- Class Reptilia
  - Order Testudines
    - Family Testudinidae
      - *Testudo* sp.
- Class Aves
  - Order Strigiformes
  - Order Falconiformes
    - Family Accipitridae
      - Subfamily Aquilinae
- Class Mammalia
  - Order Insectivora
    - Family Erinaceidae
      - *Brachyerix macrotis* ref.
  - Order Lagomorpha
    - Family Leporidae
  - Order Rodentia
    - Family Mylagaulidae
      - *Mesogaulus* sp.
      - *Mylagaulus* sp.
  - Order Carnivora
    - Family Canidae
      - *Leptocyon* sp.
      - *Tomarctus* cf. *T. optatus*
      - *Tomarctus* sp.
      - *Cynarctoides* cf. *C. acridens*
    - Family Amphicyonidae
      - *Amphicyon* sp.
    - Family Mustelidae
      - *Miomustela* sp.
  - Order Perissodactyla
    - Family Equidae
      - *Archaeohippus* sp.
      - *Anchitherium* sp.
      - *Hypohippus* cf. *H. pertinax*
      - *Parahippus* cf. *P. nebraskensis*
      - *Parahippus* cf. *P. vellicans*
      - *Merychippus* cf. *M. primus*
      - *Merychippus* cf. *M. isonesus*
      - *Merychippus* sp.
    - Family Rhinocerotidae
      - *Aphelops* sp.
      - ?New caenopine genus
  - Order Artiodactyla
    - Family Tayassuidae
      - *Hesperhys* sp.
    - Family Merycoidodontidae
      - *Brachycrus* sp.
      - *Merychyus* sp.
      - *Ticholeptus tooheyi*
    - Family Camelidae
      - *Miolabis* cf. *M. princetonianus*
      - *Miolabis tenuis* aff.
      - *Protolabis* cf. *P. saxeus*
      - *Aepycamelus* cf. *A. priscus*
      - *Oxydactylus* cf. *O. longirostris*
      - *Michenia* sp.
      - New genus and species
    - Family Cervidae
      - *Barbouromeryx* sp.
      - *Bouromeryx* cf. *B. submilleri*
      - *Bouromeryx milleri*

?*Dromomeryx* sp.
Sinclairomeryx cf. *S. tedi*
Sinclairomeryx sp.
?*Rakomeryx* sp.
Family Antilocapridae
Merycodus sp. indet.
Cosoryx (*Paracosoryx*) cf. *C.* (*P*) *wilsoni*
Cosoryx (*Paracosoryx*) *wilsoni*
New genus and species

Although of minimal use in solving correlation problems, a brief comment on some of the taxa that are merely mentioned in the above faunal list may be of interest to those readers dealing with late Tertiary stratigraphy.

In the small collection of fish material from Foley Quarry two genera are recognized: *Amia*, the bowfin, is represented by a portion of one premaxilla; and *Ictalurus*, a catfish, is known from two pectoral spines. Nine fish vertebrae of several sizes were also collected.

Amphibians are represented by a good skeleton of a toad, which has not been fully prepared or described. A small collection of amphibian bones has not been prepared.

The only reptile remains so far recovered from the Box Butte are fragments of plastra of a large and a small turtle, both of which are referred to the genus *Testudo*.

A partial skeleton of an owl is listed under Strigiformes for it has not been studied sufficiently to allocate it to family and genus. A short robust hallux of an eagle-like bird from Foley Quarry (F:AM 8824) has been referred to the Accipitridae and to the subfamily Aquilinae as recognized by Howard (1932, p. 3). This hallux is similar to the type of *Spizaëtus pliogryps* (Shufeldt) Wetmore (Wetmore, 1956, p. 46) from Silver Lake, Oregon, except that the specimen from the Box Butte is shorter and heavier with more pronounced ridges for the attachment of tendons on the ventral proximal two-thirds of the phalanx. These ridges are arranged along the internal and external edges of the ventral side of the bone and limit a smooth but distinct groove between them. The proximal ends are almost identical in the two fossils. Compared with the recent golden eagle (*Aquila chrysaëtos*) and the bald eagle (*Haliaeëtus leucocephalus*), the shaft of the specimen from the Box Butte is slightly smaller and the proximal end also is less expanded transversely; otherwise the hallux is similar to that of the golden eagle, to which it is probably related. Species of fossil eagles and eagle-like birds from the Miocene and Pliocene have been founded mostly on tarsometatarsi and parts of skeletons other than the hallux. Reference of this hallux to a fossil genus and species would require more than a little conjecture.

The two insectivore specimens from the Red Valley Member were mentioned above (p. 53). These specimens were referred by Rich and Rich (1971, pp. 14, 15) to the hedgehog genus and species *Brachyerix macrotis* Matthew, 1933. They stated (p. 44) that "Specimens of *Brachyerix* range in age from late Arikareean or Hemingfordian to late Barstovian and possibly later" and showed (p. 46, table 4) that the species *B. macrotis* ranged from the ?Marsland (= Upper Harrison) or Harrison into the Sheep Creek. Of five known specimens of *B. macrotis* from western Nebraska, only one, F:AM 76693, a left mandible with M_2 (p. 45), was collected from the Sheep Creek Formation (Greenside Quarry in Sioux County); the rest were from the Box Butte or earlier formations.

Only two isolated teeth and one edentulous lower jaw with a fragment of a P_4 and an incisor attest to the presence of lagomorphs in the fauna. These are assigned to the Leporidae.

Rodents are surprisingly rare in the Box Butte Formation despite several attempts to recover microfauna by washing matrix. Several tons of worked matrix from Foley Quarry were washed in the summer of 1967 with disappointing results. The only identifiable rodent bones are two mylagaulid rami (F:AM 95282, F:AM 95283) and three mylagaulid teeth (F:AM 95284-95286) from Foley Quarry and three additional mylagaulid teeth (F:AM 95280, F:AM 95281, F:AM 95287) from other sites in the Red Valley Member. These specimens are interesting because they represent a stage intermediate between *Mesogaulus* and *Mylagaulus*. P_4 in one ramus from Foley Quarry exhibits the customary five-lake arrangement of *Mesogaulus* with the addition of one tiny round accessory lake that lies between the internal posterior corner of the hypofossettid and the external posterior corner of the metafossettid. This small accessory lake likely would have disappeared with a small amount of additional wear, and the tooth then would have exhibited the typical *Mesogaulus* pattern. The other ramus and additional molars from Foley Quarry show a sufficient number of lakes in an appropriate arrangement to warrant reference to the genus *Mylagaulus*, although both rami retained a functional but small M_1 wedged between P_4 and M_2. The crown of M_1 has no lakes or pattern and is set transversely in the jaw with the outer loop directed posteriorly and closely appressed to the anteroexternal edge of M_2. M_1 has two roots, one on the lingual and one on the buccal side. In general, the mylagaulid rami from Foley Quarry appear to be more nearly allied to *Mesogaulus* from the Runningwater Formation than they are to *Mylagaulus* from the Sheep Creek quarries.

As mentioned above, the fauna from the Box Butte is closer to Sheep Creek in age than it is to Runningwater, but nevertheless certain of the taxa are sufficiently long ranging to be common to both formations. This is particularly true of *Tomarctus* cf. *T. optatus*, which is represented by a fine palate and mandible (F:AM 95279) collected with a small concentration of fossils from an outcrop in the northern channel system of the Red Valley Member, a system that can be traced across parts of 6 square miles in the Esther Canyon branch and in the main branch of Sand Canyon. The exposure that produced the *Tomarctus* cf. *T. optatus*, as well as bones of several individuals of *Sinclairomeryx* cf. *S. tedi* (Frick, 1937, p. 168) and *Merycodus* sp., is situated in the NE. ¼, SW. ¼, SW. ¼, sect. 10, T. 30 N., R. 48 W., Dawes County. Specimens from the Runningwater Formation collected at Ahren's Prospect on the main branch of Cottonwood Creek, and on the Elder Ranch branch of Cottonwood Creek, are stratigraphically earlier but very close in physical characteristics to the specimens from the Red Valley Member; the *Tomarctus* cf. *T. optatus* from the Red Valley is intermediate in size and cusp arrangement between the examples from the Runningwater and similar remains from Ginn Quarry, which is situated in the NE. ¼, NW. ¼, sect. 24, T. 31 N., R. 47 W., Dawes County, and has provided a surprisingly early Sheep Creek-like fauna. Indeed, the specimens from Ginn Quarry appear to occupy an intermediate position between the fauna from the Box Butte and the earliest fauna (Long, Greenside, and Thomson quarries) from the type area of the Sheep Creek Formation. These comparisons permit a preliminary evaluation of the microevolution of not only the fossils from the Box Butte but of those from Ginn Quarry and of those from the Sheep Creek age quarries in the type locality of the Sheep Creek Formation as well.

Specimens from Ginn Quarry, as stated above, are intermediate in aspect between those from the Red Valley Member and those from the type area of the Sheep Creek, which includes the type of *Tomarctus optatus* (Matthew, 1924, p. 98) from the Sheep Creek beds in Stonehouse Draw, Sioux County. The type is larger than any of the earlier specimens mentioned here. Despite the difference in size, sufficiently diagnostic characters are lacking to justify erecting a new species to receive the forms from either the Red Valley Member or the Runningwater Formation; rather they are so nearly, if not, conspecific that they can be referred best to *Tomarctus* cf. *T. optatus*. This emphasizes their close relationship to later forms. They all appear to be excellent candidates for inclusion in an ancestral line leading to *T. optatus*.

Only a few other carnivore specimens have been collected from the Box Butte Formation, but, although too few to serve as a statistical sample, they nevertheless are useful for direct comparisons with similar carnivores from other formations.

A fragment of a right lower jaw (F:AM 96688) with a small slender M_1 and P_4 is referred to *Leptocyon* sp. The Box Butte specimen is from Middle of the Road Quarry and is most closely matched by the smaller specimens from Dunlap Camel Quarry in the Runningwater Formation. *Leptocyon* in the Frick Collection from Dunlap Camel Quarry show a wide variation ranging from small forms similar to that from Middle of the Road Quarry to individuals with large teeth approaching the type of *Leptocyon vafer*. All examples from the Sheep Creek have larger, heavier teeth. In contrast, earlier forms of *Leptocyon* from the Rosebud Formation and also from the Harrison Formation have both the larger, heavier, more robust teeth and the smaller, slender variety. Individual and specific variation appear to be too great in *Leptocyon* for a single partial jaw to be of importance in relative age determinations. Similarly, a partial lower jaw (F:AM 95277) of *Cynarctoides* cf. *C. acridens* from Dry Creek Prospect A and a fragment of a lower jaw (F:AM 95278) of *Miomustela* sp. from Sand Canyon Quarry, although useful and interesting as additions to the faunal record, add little to the resolution of correlation problems.

An immature right maxilla (F:AM 95276) of an amphicyonid with dP^3 and dP^4 in place, but with a fully formed P^4 and M^1 in position to erupt, and a mature left lower canine, were collected in Foley Quarry. The maxilla is larger than the type of *Amphicyon idoneus* (AMNH 18912) from Stonehouse Draw in the Sheep Creek area and is only slightly larger than a referred specimen (F:AM 54395) of *A. idoneus* in the Frick Collection from Thomson Quarry. Certain of the features of P^4 and M^1 suggest that this immature maxilla could be compared with *Amphicyon sinapius* with a greater chance of matching characters. Although the teeth of *A. sinapius* from the Lower Snake Creek beds are much larger than those of the specimen from the Box Butte, a similar robustness can be detected; this is especially noticeable in the substantial anteroposterior length of M^1 measured across the paracone and metacone compared with the marked shortness of the transverse width. The paracone is large and robust relative to the metacone. P^4 also is robust, with a significantly greater transverse distance measured through the protocone than is characteristic of *A. idoneus*.

Although the maxilla from the Box Butte Formation is much smaller than the type of *Amphicyon frendens* (AMNH 18913) from Stonehouse Draw in the Sheep Creek area, the general configuration of M^1 and P^4 is similar; this is particularly true of a specimen referred to *A. frendens* (F:AM 54390) in the Frick Collection from Thomson Quarry. The internal half of M^1 of the maxilla from the Box Butte is short transversely instead of expanded as in *A. idoneus*, and its shape approximates that of an equilateral triangle. The internal cingulum is distinct and surrounds the protocone anteriorly, medially, and posteriorly. Posteriorly the cingulum is only slightly expanded and even if worn would not display the pronounced shelf observed in *A. idoneus*. Until the amphicyonids are revised and the status of *A. sinapius*, *A. frendens*, and *A. idoneus* clarified, this specimen can be listed as *Amphicyon* sp. and provisionally considered to be in or near the lineage or lineages leading to *A. sinapius* or *A. frendens*.

Four genera of horses are well represented in the Box Butte fauna and they far outnumber all other mammals combined. More horse genera may yet be recognized when criteria for certain unnamed forms are published.

Rare and diminutive specimens of *Archaeohippus* were collected at three localities in the Red Valley Member. Sand Canyon Quarry, which is in the type section of the Red Valley Member, has produced 15 specimens as follows: a right maxilla (F:AM 71679) with P^1-M^1; three associated upper molars and premolars (F:AM 71680); parts of a worn right ramus (F:AM 95273) with P_4-M_2 and a part of a left ramus (F:AM 95274) with P_4-M_1 that were associated; four isolated upper molars and premolars; and five isolated lower molars. Dry Creek Prospect A, which is in Red Valley Member reference section 3, has provided eight examples: two partial lower jaws (F:AM 95275, F:AM 95537); and three upper and three lower molars. One right P^3 was found on the north side of a tributary of Dry Creek about a quarter of a mile east of Foley Quarry.

These 24 available specimens vary among themselves in the fine details of the teeth patterns, but with only two exceptions they are noticeably lower crowned than the 45 examples of *Archaeohippus* in the Frick Collection from the quarries in the Sheep Creek Formation in Sioux County. The teeth from the Box Butte either have no crochet, or have only a slight swelling or change of alignment of the enamel border on the metaloph that could be interpreted as suggesting a crochet. Many of the specimens from the Sheep Creek, and particularly those from the later Lower Snake Creek beds, have incipient to distinct crochets on some of the molars and premolars, but not on all of them. *Archaeohippus blackbergi* from the Garvin Gully local fauna of Texas, according to the original description (Hay, 1924, pp. 4, 5), showed no trace of a crochet on the type molar. Small horses from the Thomas Farm in Florida were referred to the species *blackbergi* by White (1942, p. 15), but he transferred the species to the genus *Parahippus* and included in it an unspecified number of teeth, jaws, and maxillae that covered a wide range of characters. Prominent among the features listed by White (p. 19) for this form was a "well developed crochet."

The upper molars from the Box Butte Formation have little or no cingula at the internal base of the protocone and the hypocone, and the swelling in the basal area is here regarded as the incipient stage of the weak to strong cingulum that is a characteristic feature of most, but not all, of the specimens of *Archaeohippus* from the Sheep Creek. The hypoloph and hypostyle are less complex in the Box Butte forms, and except in much worn teeth, the hypoloph tends to be distinctly separated from the metaloph. In the Sheep Creek forms the hypoloph is commonly joined with the metaloph or at least tightly appressed against it. In the specimens from the Box Butte, the external cingula on the lower molars are weak or missing; in those from the Sheep Creek, the external cingula are moderately strong to very strong and the length of the crown is perceptibly longer. These enumerated differences suggest that the specimens from the Box Butte have simpler shorter-crowned teeth, and that they represent an earlier stage of *Archaeohippus* development at the time when they had not yet attained the distinctive cingula so characteristic of later members of the genus.

Two other kinds of anchitheriine horses occur in Foley Quarry. One of these (F:AM 95538, F:AM 95539) has large molars and large unreduced M^3_3s, the other (F:AM 95540) has small molars and markedly reduced M^3_3s. A mature right lower jaw (F:AM 95541) from Dry Creek Prospect A and a left immature lower jaw (F:AM 95542) from Dry Creek Prospect D also display the small molars and small M_3s.

A horse skull (F:AM 95543) and a few associated limb and partial limb elements were collected near the base of the Red Valley Member deposits in the NE. ¼, SW. ¼, sect. 9, T. 30 N., R. 48 W., Dawes County, in a short tributary of Esther Canyon, which in turn is a tributary of Sand Canyon. This partial skeleton has been identified by Morris F. Skinner as a large male specimen of *Parahippus* cf. *P. vellicans*. The teeth are brachydont but have a fairly strong covering of cement on both the premolars and the molars. They are larger and carry more cement than similar teeth from Thomas Farm in Florida, or those from Garvin Gully in Texas from which Hay (1924, p. 7) selected the type of the species from "about a dozen upper molars." On the following page (p. 8) Hay mentioned 50 molars and premolars as belonging to *Merychippus vellicans* (the species has since been transferred to the genus *Parahippus*); these were sent by Dr. Mark Francis to Hay for identification and were from several sites in the vicinity of Navasota, Texas, including some from the Jesse Garvin farm about 2¼ miles directly north of Navasota. This particular specimen of *Parahippus* from the Box Butte shows a closer relationship to horses from the Runningwater than to any horse from the Sheep Creek in Sioux County. *Parahippus* has not been collected from the Sheep Creek Formation.

Several examples of *Merychippus* sp. near *M. primus* have been identified from deposits of the Red Valley Member in the paleochannel system north of the Niobrara River (fig. 6). These do not exactly duplicate *M. primus* but belong in a mélange of specimens in the American Museum and Frick collections that display an astounding array of characters that suggest that this particular group of horses was changing rapidly, especially during the interval in which the Sheep Creek Formation was deposited. Unfortunately, no complete skull of *Merychippus* has yet been collected in the Box Butte south of the Niobrara River, but a few maxillae and palates with parts of the facial region preserved have provided hints of diagnostic skull features and have been useful in preliminary allocations. Most of the fossil horse remains from Foley Quarry, Middle of the Road Quarry, and other sites in the Red Valley Member south of the Niobrara River belong to one species. This group of animals is nearer in dental features to *Merychippus isonesus secundus* (Osborn, 1918, p. 105) from the Sheep Creek than to any other taxon, and here again, the poor preservation of facial and malar fossae makes reference uncertain; until better specimens are available, the bulk of the collection of fossil horse bones from the Red Valley Member south of the Niobrara must be referred to *M. isonesus secundus*.

A species of *Merychippus* with larger teeth than those referred to *M. isonesus secundus* occurs in both Foley and Middle of the Road quarries. Examples are rare in each quarry, but in the few specimens that are available several of the following characters are consistently present: (1) The grinding teeth are subhypsodont with strong parastyles on the premolars, but the parastyles are slightly less robust on the molars. (2) The mesostyles are very strong on the premolars and strong on the molars. (3) On the premolars the parastyle distinctly overlaps the metastyle of the preceding tooth, and on the molars there is little or no overlap. (4) The crochet is not confluent with the protoconule except on M^1, and that union takes place only after considerable wear. (5) M^3 is distinctly larger than in the other two species of *Merychippus* recognized in the collections from the Box Butte Formation. (6) The metaloph is confluent with the ectoloph. (7) The protocone is separated from the protoconule except after extensive wear. (8) The protoconule is rounded to lophid and blends to a confluent protoloph which is also confluent with the anterior end of the ectoloph. (9) The infraorbital foramen is situated above the P^4-M^1. (10) The shapes of the lachrymal and malar fossae are indeterminate on all specimens. This species with larger teeth does not closely match any described species, and for that reason it is assigned to *Merychippus* sp.

In the two members of the Box Butte Formation, the genus *Merychippus* is represented by at least three species and the genus *Parahippus* by two species. This is remarkable, for *Merychippus* has not been recognized in the Runningwater Formation and *Parahippus* has not been collected in the type locality of the Sheep Creek Formation. The presence of both *Merychippus* and *Parahippus* in Box Butte deposits lends strong support to the premise that the Box Butte is intermediate in age between the Runningwater and the Sheep Creek formations.

The occurrence of numerous specimens of *Merychippus* in Box Butte deposits can be explained in either of two ways: (1) by the hypothesis of dispersal of the genus from peripheral areas, such as the Texas Coastal Plains or Florida; or (2) by recognition of a sufficiently long period of time between the end of the Runningwater and the beginning of the Sheep Creek for the development of the significant evolutionary changes necessary for indigenous *Parahippus* of the Great Plains to become recognizable *Merychippus* taxa. For either of these alternatives the necessary interval may be largely accounted for by the length of time that would have been required to establish and maintain a probable arid regime in the outcrop area of the Box Butte. This would have permitted the deposition of the thick calichified layer, informally designated as the Platy Bench in the present report (p. 28), that marks the homotaxial uppermost beds of the Runningwater Formation. Furthermore, a significant span of time would have been required to enable special erosional processes to carve narrow steep-walled gullies or channels in the resistant calichified beds and then later fill them with deposits of the Red Valley Member. Regardless of how the introduction of *Merychippus* to the beds of the Box Butte was accomplished, the genus was already well established and at least three species had been differentiated. These three species had diverged sufficiently so that differential evolutionary change can be detected in the premolars compared with the molars, in the size and shape of facial fossae, in the position of the infraorbital foramen on the face, in the shape or presence of the malar fossa, and in the relative size of M^3 compared with M^2. The dental patterns of the teeth are useful and are occasionally diagnostic, but differences in the amount of wear often serve to eliminate some of the more intricate patterns. This was convincingly demonstrated by Skinner and Taylor (1967, p. 31).

Rhinoceros specimens from the Box Butte Formation are confined primarily to the collections from Dry Creek Prospect A and from Foley Quarry, although an occasional unidentified, or unidentifiable, fragment of rhinoceros bone or tooth has been obtained from other sites. Apparently the better specimens in the collection belong in the subfamily Caenopinae, but, despite a reasonably close fit with the diagnostic features of the genus *Aphelops*, certain of the salient characters of the fossils are sufficiently different to present serious problems of generic allocation.

No counterpart of a rhinoceros skull (F:AM 95544) from Dry Creek Prospect A has been recognized in the extremely large number of rhinoceros remains in the American Museum and

Frick collections; in the latter, such matching would be expected owing to the great collection amassed from deposits of Sheep Creek age and from beds regarded as slightly older than Sheep Creek and from those slightly younger. This particular skull is outstanding because of the extreme retraction of the narrow, but long, narial notch to a point above the anterior end of M^1. The nasals are long, narrow, and pointed with a slight rugose area at the extreme tip indicating the presence of a small nasal horn. The skull is small (only 485 mm. from occipital crest to tip of nasals) but long (dolichocephalic) with a narrow occiput that is not elevated. The result is a gently undulating dorsal outline for the skull with a slight swelling noticeable above the posterior end of the narial notch. The paroccipital processes are essentially three-sided, slender, and pointed; the postglenoid processes also are slender with a flattened, beveled anterior surface. The teeth are brachydont and surprisingly small, and the molars, although well worn, show evidence of having had a crochet and an antecrochet.

Another partial skull (F:AM 95545) from Dry Creek Prospect A had the top of the skull and occiput eroded, and only the palate and basicranial region are well preserved back to and including the thick, stubby postglenoid processes. This partial skull is much larger than F:AM 95544; the teeth are moderately worn, subbrachydont, and all have strong cingula including the premolars (in contrast, the cingula are weak on all teeth in F:AM 95544). M^1 and M^2 have moderately developed crochets and antecrochets, and P^4 has a tiny crochet but no antecrochet. P^3 and P^2 have neither crochet nor antecrochet and the same is true of M^3. M^3 has a small cylindrical tubercle 7.8 mm. long and 4.7 mm. in diameter in the middle of the valley between the protocone and the hypocone. It is situated just externally of the pillar or column that occupies the position of the antecrochet; if this tooth were well worn, the pillar or column probably would appear as an antecrochet fold. Many of the generic characters of *Aphelops* cannot be verified on this incomplete skull, but in general the specimen seems to possess distinguishing characteristics that would indicate that it is an advanced species of *Aphelops*, perhaps foreshadowing *Aphelops megalodus* or *Aphelops ceratorhinus*, which come from much later beds.

One isolated M^3 (F:AM 95550) from Dry Creek Prospect A has a small crochet and an incipient antecrochet.

The distinguishing features given for these three rhinoceros specimens are provided to show the interesting and contradictory combinations of characters that exist at this one site. How many of these combinations represent merely individual variation or how many of them indicate intermediate stages of interbreeding populations must wait for additional discoveries. They are provisionally referred to *Aphelops* sp. despite the supposed hornless condition of the genus. Not much can be said about their relative age except that they are smaller and display less development of certain of the derived characters, such as antecrochet and crochet, than any of the rhinoceroses from the Sheep Creek Formation or from the Lower Snake Creek beds.

A complete rhinoceros mandible with well-worn teeth (F:AM 95551) from Foley Quarry has a molar-premolar series about equal in length to the molar-premolar series of the small skull (F:AM 95544) from Dry Creek Prospect A. Despite this seeming accordance in size of the tooth row, the greater distance from M_3 to the posterior plane of the condyle and the much greater height of the surface of the condyle above the plane of the molar-premolar grinding surface would make the reference of the mandible to the same species as that of the skull highly unlikely. The length of the lower molar-premolar series is 219.3 mm. compared with 268 mm. for the type of *Aphelops montanus*, and that difference effectively eliminates reference of the Box Butte form to that species. The mandible from Foley Quarry has two peglike vestigial I_1s. The left I_1 is larger than the right I_1, a rather unusual arrangement that is seen occasionally in mandibles from later deposits.

These caenopine rhinoceroses, if they are here correctly referred to *Aphelops* sp., probably represent one of the earliest, if not the earliest, occurrences of *Aphelops* in North America. *Floridaceras whitei* (Wood, 1964) from the Thomas Farm local fauna in Florida appears also to belong in a pre-*Aphelops* category, but it is even further removed from the latter genus than the Box Butte genera and species.

Oreodonts, surprisingly, are not numerous in the Box Butte Formation. This is particularly noticeable, for the underlying upper beds of the Runningwater Formation have produced large collections of *Merycochoerus proprius* (Schultz and Falkenbach, 1940) and *Merychyus elegans* (Schultz and Falkenbach, 1947). The Sheep Creek Formation and Lower Snake Creek beds have provided a startling array of oreodont genera and species remarkably different from those of the Runningwater.

One important specimen (F:AM 24504) is a crushed skull, left ramus, and some associated fragments of limb bones, metapodials, and phalanges of an oreodont referred to *Ticholeptus tooheyi*. Schultz and Falkenbach (1941, p. 84) described the type of *T. tooheyi* and stated that the beds from which it was collected were "Correlated with the Lower Part of the 'Sheep Creek' Formation." This specimen (F:AM 24504) came from the type locality of *Ticholeptus tooheyi* and was collected near the center of the SE. ¼, sect. 13, T. 28 N., R. 49 W., Box Butte County. Although *T. tooheyi* was stated at that time to be the smallest known species of the genus, this new skull is noticeably smaller. The pattern of the teeth in F:AM 24504 is equally as complicated as that of the type, but the length of P^1-M^3 inclusive is only 79.6 mm. and the same measurement for the type is 86 mm. Other teeth measurements are: length of P^1-P^4 inclusive in F:AM 24504, 35.6 mm., in the type, 38.5 mm.; length of M^1-M^3 inclusive in F:AM 24504, 45.7 mm., in the type, 48.5 mm.; width of M^3 (maximum) in F:AM 24504, 15.1 mm., in the type, 16.5 mm.; and depth of malar below orbit in F:AM 24504, 17.7 mm., in the type, 22 mm. These smaller measurements may indicate that the specimen was female or may indicate a greater size range in the species than was known previously.

Another oreodont skull, mandible, and associated partial elements of a forelimb (F:AM 25502), which were collected in red silt at Sand Canyon Quarry (fig. 8E) about 25 feet above the base of the intraformational conglomerate, are of unusual interest. The small immature skull has P^4, P^3, and M^3 just erupting. The bullae are not greatly inflated, as in *Merychyus arenarum* or *M. elegans*, but are semidepressed; the paroccipital processes, although slender distally, flare or expand laterally, suggesting a tendency to form a fan-shaped occipital region. Most unfortunately, the occipital region was eroded and the extent to which this specimen foreshadows *Ustatochoerus* in this feature cannot be determined. The upper and lower premolars are complicated, approaching or even surpassing *T. tooheyi* in complexity, except that F:AM 25502 does not have cingula on either upper or lower teeth as in *T. tooheyi*. This specimen is nearest to *Merychyus relictus taylori* (Schultz and Falkenbach, 1947) from the Sheep Creek but differs from it, and from *Merychyus relictus* from the Lower Snake Creek beds, in having larger P^4_4s and P^3_3s. This is interpreted as possibly indicative of size reduction in premolars in this subgenus.

A right lower jaw (F:AM 95552) of an oreodont with P_3-M_3 was collected from light-colored pinkish to gray beds that underlie the main body of the Red Valley Member and crop out along the walls and in the bottom of the narrow paleovalleys in which the Red Valley sediments accumulated in the NE. ¼, SW. ¼, SW. ¼, sect. 10, T. 30 N., R. 48 W., Dawes County. This ramus is referred to *Merychyus* (*Metoredon*) cf. *relictus taylori*. It is, however, a much smaller jaw than F:AM 25502 with a decidedly smaller P_4 and P_3; the cusp patterns in the two specimens are identical.

A partial left maxilla (F:AM 95553) of a *Brachycrus* from Dry Creek Prospect A is the only recognized specimen of that genus in the collection from the Box Butte Formation. It is noticeably smaller than any example from Ginn Quarry in Dawes County, or from Long, Greenside, and Hilltop quarries in Sioux County, or from the Sweetwater locality in Wyoming that produced *Brachycrus rusticus* and *B. sweetwaterensis*. It is not readily assignable to any known species and can best be listed as *Brachycrus* sp.

Some small to medium-sized oreodont metapodials, phalanges, and isolated teeth were collected from four sites in the Red Valley Member in addition to those mentioned above. These specimens are not diagnostic, consequently they cannot be allocated more than provisionally and therefore do not add to the known fauna from the Box Butte.

Camelidae from the Box Butte Formation can be assigned to five known genera, namely, *Miolabis*, *Protolabis*, *Aepycamelus*, *Oxydactylus*, and *Michenia*. An unnamed genus, for obvious nomenclatural reasons, must remain unnamed until formally proposed and described.

Camels range in considerable diversity throughout the Marsland Formation (=Upper Harrison Formation of Peterson, 1906), although in the literature many different species and genera are referred mostly to *Oxydactylus*. Some of these range, with modifications, through the Runningwater, and only when the Sheep Creek Formation is reached are significant changes apparent. Other lines of camels suddenly appear in Great Plains deposits in Sheep Creek time; they not only flourish but diverge sharply, and by Lower Snake Creek time they are much advanced over their Sheep Creek counterparts.

Camels from Foley Quarry are represented by many immature specimens, but a few mature examples aid in referring the material to genera and in judging the relative stage of evolution. Some specimens from Foley Quarry, except for having almost imperceptibly smaller and slightly more trenchant premolars, can be matched closely in an unnamed species from the University of Nebraska's Hemingford Quarry 12D belonging to the genus *Michenia* Frick and Taylor, 1971 (Frick and Taylor, 1971, p. 5). Two other specimens can be referred to *Oxydactylus* sp. near *longirostris*, and although they do not match Peterson's (1911) type, they fall within the range of specimens referred to that species in the Frick Collection. These specimens are so close in stage of evolution to forms from the Runningwater Formation that no basis for separation at the species level can be detected.

Surprisingly, with the exception of one lower jaw, which is referred to *Protolabis* cf. *saxeus*, Middle of the Road Quarry produced only camels of the genus *Miolabis*. The *Miolabis* specimens are significantly smaller than the type of *Miolabis tenuis* described by Matthew (1924) from Sheep Creek beds in Stonehouse Draw. The single jaw of *Protolabis*, mentioned above, also is much smaller and has more reduced and more trenchant premolars than any known referred specimen of *Protolabis saxeus* from the Sheep Creek Formation. Despite these differences, this jaw is closely allied to that taxon.

A small species of *Aepycamelus* is represented in the Box Butte collection by a referred immature ramus, several partial maxillae, a partial humerus, a metacarpus, and a proximal phalanx. These are not enough specimens of this genus to draw a definite conclusion concerning the stage of evolution to which they should be assigned. In my opinion, however, all the camel specimens from the Box Butte, except possibly those referred to *Aepycamelus*, show a definite pre-Sheep Creek stage of development; indeed, the *Michenia* and *Oxydactylus* show strong affinities with the forms from the Runningwater Formation.

Cervids from the Red Valley Member are predominantly forms referable to the genera *Sinclairomeryx* and *Bouromeryx*. *Sinclairomeryx* bones have been recognized in the collection from eight sites in the Red Valley Member, but no specimens of it are known to have been collected from the Runningwater Formation; neither has the genus been reported from any of the faunas from the Texas Coastal Plain or Florida. The individuals from the Box Butte may represent the earliest known remains of *Sinclairomeryx*, and this hypothesis is further supported by the consistently smaller size of the rami and greater reduction of premolars in the specimens from the Red Valley Member when compared with *Sinclairomeryx tedi* (Frick, 1937, p. 168) from Ginn Quarry, the species with which they compare most favorably. The species from the type locality of the Sheep Creek Formation, (?)*Sinclairomeryx riparius* (Matthew) (p. 165) and *Sinclairomeryx sinclairi* (p. 164), have larger less reduced premolars. Details of the dental pattern of the Red Valley specimens suggest that *Sinclairomeryx* was derived from *Aletomeryx*. Unfortunately, no horn cores or crania have been recovered from the Box Butte. Future discoveries may provide the needed information to establish firmly the taxonomic position of the Red Valley specimens, but until such data are available they will be referred to *Sinclairomeryx* *tedi*. Since the previously known range of *Sinclairomeryx* was from Sheep Creek beds only, the usefulness of the genus is limited for stage of evolution and for comparative age determinations; it is of interest, however, to extend the range of the genus and record additional occurrences.

A right maxilla with P^3-M^3 (F:AM 95554) of a brachydont dromomerycid was collected at Sand Canyon Quarry from a point 4 inches above the contact of the basal conglomerate of the Red Valley Member with the underlying Runningwater Formation. This specimen is remarkable for its unusually large premolars, particularly P^3, when they are compared with the molars, which are relatively small. The teeth look surprisingly like those of the large later dromomerycids despite their small size; however the intricate details of the tooth pattern compare closely with *Bouromeryx*, which Frick (1937, p. 127) placed in the Barbouromerycinae with the following qualifications, "The subgenus, perhaps, might be referred better to the Cranioceratinae than to the Barbouromerycinae." His observation is supported by the examples currently available in the collections. This specimen probably represents a new species although, owing to the lack of good comparative upper dentitions, its relationship to *Bouromeryx submilleri* (p. 131) from the Sheep Creek can be inferred only. It is here interpreted as indicating a slightly earlier stage of evolution than any displayed by *Bouromeryx*-like specimens from the Sheep Creek.

Foley Quarry has provided a sample of *Bouromeryx* cf. *B. submilleri* consisting of four mature and five immature mandibular rami and also one metapodial referred to the species. Other large limb elements of appropriate size in the collection might be tentatively referred to the genus and species; however the limb elements of this and closely related cervids are too poorly known to warrant such allocation. These specimens are similar in size and dental characteristics to the type (F:AM 33729) from Greenside Quarry. From other sites in the Box Butte a single lower molar from the NW. ¼, SE. ¼, sect. 13, T. 28 N., R. 49 W., Box Butte County, is referred to *B. submilleri*; also a left M_3 and a left M_2, found together and regarded as belonging to the same individual, are referred to *B. submilleri*. This M_3 and M_2 are from a high channel on the Marshall Ranch in the NE. ¼, sect. 31, T. 30 N., R. 49 W., Dawes County.

Only two specimens referable to *Bouromeryx* cf. *B. milleri* are in the collection; one of these is a fine mandible (F:AM 95555) from the Dawes Clay Member in the SE. ¼, NE. ¼, SE. ¼, sect. 24, T. 30 N., R. 48 W., Dawes County. This mandible is much smaller than the type of *Bouromeryx milleri* (Frick, 1937, p. 130) from Aphelops Draw, or questionably referred material from other localities in Sioux County, or from unpublished rami from Greenside Quarry. It is significantly smaller than any jaws referred to the species from Long or Hilltop quarries. When compared with the rami from the Sheep Creek, the reduction of the premolars and the slender shape of the molars in the specimen from the Dawes Clay Member indicate that the mandible is an early example of *B. milleri* and properly should be called *Bouromeryx* aff. *B. milleri*.

An immature left ramus (F:AM 95556) and a mature right partial ramus (F:AM 95557) from Foley Quarry have been identified as ?*Barbouromeryx*. If the reference is correct, then these specimens suggest that another Runningwater genus survived into Box Butte time.

Three genera of antilocaprids have been recovered from the Box Butte Formation. They are in order of abundance, (1) *Cosoryx* (*Paracosoryx*), (2) *Merycodus*, and (3) a new genus, which, for nomenclatural reasons, must await formal description before being named or discussed.

Although merycodonts are not numerous in the Box Butte, they nevertheless were obtained from three sites that have produced important collections. Two of these are in the Red Valley Member and one is in the Dawes Clay. The small collection of mammalian fossils from Sand Canyon in the NE. ¼, SW. ¼, SW. ¼, sect. 10, T. 30 N., R. 48 W., Dawes County, that included the fine palate and associated mandible of *Tomarctus* cf. *T. optatus* and several specimens of *Sinclairomeryx* cf. *S. tedi* discussed above, also contained three merycodont specimens as follows: a fragment of a right maxilla with P^3 and P^4, a left ramus, and a small fragment of a right ramus with P_2. Regrettably these examples, as well as two lower jaws recovered from Foley Quarry, are not sufficiently diagnostic to permit generic allocation.

The merycodont specimen from the Dawes Clay Member consisting of the pelvis and most of both articulated hind legs came from a site 4 feet above the contact with the Red Valley Member on the south side of Sand Canyon in the NE. ¼, SE. ¼, sect. 30, T. 30 N., R. 47 W., Dawes County.

A diminutive, mature, hornless merycodont skull (F:AM 95561) from Foley Quarry appears to represent a new genus and species and necessarily will require extended study to establish its true taxonomic position.

Seven specimens of *Cosoryx* (*Paracosoryx*) from six different sites are in the collection. Two of these have numerous associated skeletal elements, including some articulation. Two individuals collected together from near the top of the type section of the Red Valley Member at Sand Canyon Quarry display a surprising difference in size. One of these, an articulated partial skull and mandible (F:AM 95558), approaches in size the type of *Cosoryx* (*Paracosoryx*) *wilsoni* (F:AM 32470) from Long Quarry in the Sheep Creek Formation (Frick, 1937, p. 351). The other, an associated left maxilla and left ramus (F:AM 95559) with worn dentition, however, is noticeably shorter and smaller than the type (F:AM 32470). Indeed, the length of P^2-M^3 dental series in specimen F:AM 95559 from the Red Valley Member is equal only to P^3-M^3 series in the type. The second and third premolars of F:AM 95559 are much reduced over those in the type or in the larger individual collected in the same block. Thus, in general, specimens of *C.* (*Paracosoryx*) *wilsoni*, although relatively numerous, do not provide a sure guide to the age of the deposits that contain them. They are, obviously, closer to Sheep Creek in age than to the Runningwater Formation. To date only one horn core of *C.* (*Paracosoryx*) sp. is known from Runningwater deposits, and it is tiny compared with horn cores of *C.* (*Paracosoryx*) from the Sheep Creek. One partial horn (F:AM 95560) from the SW. ¼, SW. ¼, sect. 11, T. 30 N., R. 48 W., in Dawes County, has a shorter shaft than the Sheep Creek forms and it is flattened below the forks to a greater extent. It is not so slender as a horn from Ginn Quarry [*C.* (*Paracosoryx*) *dawesensis* (Frick, 1937, p. 354)], although it has a noticeably shorter shaft.

As mentioned above, bones of *C.* (*Paracosoryx*) were collected at six sites in the Red Valley Member of the Box Butte Formation, and bones of *Sinclairomeryx* were obtained at eight, but only at Dry Creek Prospect D have the two occurred together. It must be recognized, however, that indeterminate phalanges and fragments of cervid-like and merycodont-like bones from several places suggest that the association of several genera may have been more prevalent than the identifiable specimens indicate.

Comparisons of the fauna from the Box Butte Formation as listed above (p. 54) with that from the Marsland Formation and that from the Sheep Creek Formation demonstrate that a startling divergence exists between the fossils from the Marsland Formation and those from the Sheep Creek Formation. The projected unknown time gap is great, indeed, when the basis for comparison consists of fossils collected in the area northeast of Agate, Nebraska, from beds originally called Upper Harrison by Peterson (1906, p. 22) and given the replacement name of Marsland Formation by Schultz (1938, p. 443). The unknown time spread, as indicated by the fossils, is narrowed dramatically when fossils from the Sheep Creek are compared with fossils from the Runningwater Formation (Cook, 1965), and with those collected from beds considered equivalent to Cook's Runningwater Formation and, in fact, designated as Runningwater Formation in the present report. The equivalent beds are well exposed in the Dawes County-Hay Springs-Hemingford areas where extensive collections have been made since 1932. The mammalian fauna from the Box Butte, furthermore, represents a segment of time that previously has not been recognized as distinct in the Nebraska biostratigraphic section, and occupies a position intermediate between the fauna from the Runningwater Formation and that from the type locality of the Sheep Creek Formation. The Box Butte fauna, however, does seem more closely allied to the fauna from the Sheep Creek than to that from the Runningwater, and consequently these apparent skewed affinities compel evaluation of the hypothesis that the Box Butte Formation contains merely the earliest known Sheep

Creek deposits that hitherto were unrecognized. To accept the above hypothesis would entail setting up arbitrary formational boundaries for the Sheep Creek that rely solely on interpretation of faunas and virtually disregard the observable lithologic and stratigraphic differences. A greater understanding of the extent of the hiatus between the Marsland and Runningwater formations on the one hand and the Sheep Creek Formation on the other can be attained by recognizing the Box Butte Formation as an intermediate entity, both stratigraphically and biostratigraphically, and by directing future research toward refining and recording the bases on which separations among the various formations can be made with the greatest accuracy.

SUMMARY

Sedimentary deposits of soft, reddish to greenish mottled claystones, clayey siltstones, and silty sandstones in northwestern Nebraska that were formerly assigned to the Box Butte Member of the Sheep Creek Formation are formally redefined as the Box Butte Formation, which, upon redefinition, is composed of two members. The lower, or Red Valley Member, is mainly confined to narrow steep-walled valleys that were incised into the Runningwater Formation (see footnote, p. 5) and filled chiefly with reddish clayey siltstones and soft, reddish silty sandstones. The upper, or Dawes Clay Member, commonly consists of reddish to greenish mottled claystones or clayey siltstones in which characteristic white, hard, heavy, nodular calcareous concretions are arranged as discrete entities. On some outcrops the concretions are numerous and weather as distinct light colored bands, on others they tend to concentrate as a residual accumulation on low slopes.

Outcrops of the Dawes Clay Member are numerous and extensive compared with those of the Red Valley Member. In some places the Dawes Clay paraconformably overlies the Red Valley, and the two members display an essentially lithologic homogeneity although many superficial differences exist that permit easy identification and separation of them. On most exposures, however, the Dawes Clay lies disconformably on a zone of calichified sediments of the Runningwater Formation that commonly weathers as platy slabs of limy sandstone that forms a distinctive topographic bench. Formerly this topographic bench was regarded as the capping, or highest, bed of the Marsland Formation (Cady, 1940, p. 664; Elias, 1942, p. 131; Cady and Scherer, 1946, p. 34), but the present study of the field relations of the "white, limy, slabby caprock" permits the suggestion that the sandstone is a reponse to a calichification process and occurs at several different stratigraphic horizons.

An attempt is made to retain Cady's (1940) type locality for the Box Butte by establishing a principal reference section in an adjoining surveyed section. A type section and three reference sections for the newly proposed Red Valley Member are designated, measured, and illustrated. The same procedure is followed for the Dawes Clay Member, for which a type section and four reference sections are proposed. These type sections and reference sections are established to show the lithologic consistency of the Box Butte Formation at widely separated and discontinuous exposures in an area of more than 1000 square miles in northwestern Nebraska.

More than 400 fossil mammalian specimens collected since 1962 from exposures of the Box Butte Formation, when compared with several hundred specimens from the type locality of the Sheep Creek Formation in Sioux County, Nebraska, show that the Box Butte Formation contains fossils that are earlier than the earliest fossils from the Sheep Creek. Similar direct comparisons with the known fauna from the underlying Runningwater Formation show that the Box Butte specimens are younger and tend to reinforce the concept that a significant segment of time existed between the end of deposition of the uppermost beds of the Runningwater Formation and the start of deposition of the lowest beds of the Sheep Creek Formation in its type area. The Box Butte Formation was deposited in the later part of this segment of time, which has not been recognized previously as being represented by any set of rocks in Nebraska.

Local faunas that are assigned to Hemingfordian age in other parts of North America have been few and, moreover, commonly have included elements that show a strong Arikareean affinity. A few local faunas, however, that are assigned to the Hemingfordian contain elements that suggest a better fit with early Barstovian assemblages. Only a few sites have produced faunas that are approximately equivalent to that from the Runningwater Formation, and still fewer can be equated with the Box Butte; even less can be construed to fit in the time segment between the Runningwater and the Box Butte.

The fauna from the Runningwater Formation is unique in many ways and records the almost explosive spread of *Aletomeryx* into the Great Plains. *Aletomeryx* remains in the restricted Marsland Formation (= Upper Harrison Formation of Peterson, 1906) are rare. Some teeth of *Parahippus* species have a light coating of cement; most do not. *Cephalogale*, *Amphicyon*, and other presumable European immigrant mammals made an appearance in the fauna. No undoubted species of *Merychippus* have been identified in the Runningwater, but specimens of *Merychippus* appear in large numbers and represent two or more species in the Red Valley Member of the Box Butte Formation, where the few species only serve to presage the spectacular divergence of forms that characterize the equid fauna of the Sheep Creek Formation and the still later Lower Snake Creek deposits. Several cervid and merycodont genera that were unknown in the Marsland and Runningwater faunas also became major elements in the Box Butte and later faunas, for example *Sinclairomeryx*, *Bouromeryx*, and *Paracosoryx*.

The concept of the stratigraphic position of the Box Butte Formation has fluctuated markedly in the years since 1939 (fig. 2). It was thought to be the uppermost member of the Sheep Creek Formation, which, also by original definition, made it the top of the Hemingford Group. By 1961, and as late as 1969, the position of the Box Butte was depicted as equivalent to the lower part, or even equivalent to a large part, of the Sheep Creek. In the present report, the stratigraphic correlation of the Box Butte Formation shows its age to be post-Runningwater and pre-Sheep Creek. Its lithologic correlation demonstrates its homogeneity and emphasizes marked differences from the underlying Runningwater Formation and the overlying Sheep Creek Formation.

LITERATURE CITED

American Commission on Stratigraphic Nomenclature
1970. Code of stratigraphic nomenclature. Tulsa, Oklahoma, U. S. A., Amer. Assoc. Petrol. Geol., Inc., 22 pp.

Cady, Robert C.
1940. The Box Butte Member of the Sheep Creek Formation, Nebraska. Amer. Jour. Sci., vol. 238, no. 9, pp. 663-667.

Cady, Robert C., and O. J. Scherer
1946. Geology and ground-water resources of Box Butte County, Nebraska. U. S. Geol. Surv. Water-Supply Paper 969, vi+102 pp., 4 figs., 9 pls.

Condra, George E., and E. C. Reed
1943. The geological section of Nebraska. Nebraska Geol. Surv. Bull., no. 14, viii+82 pp., 25 figs.

Cook, Harold J.
1965. Runningwater Formation, middle Miocene of Nebraska. Amer. Mus. Novitates, no. 2227, 8 pp., 3 figs.

Cook, Harold J., and Margaret C. Cook
1933. Faunal lists of the Tertiary Vertebrata of Nebraska and adjacent areas. Nebraska Geol. Surv., Paper no. 5, pp. 9-58.

Denson, Norman M.
1969. Distribution of nonopaque heavy minerals in Miocene and Pliocene rocks of central Wyoming and parts of adjacent states. U. S. Geol. Surv. Prof. Paper 650-C, pp. C25-C32, 3 figs., 1 table.

Elias, Maxim K.
1941. Late Tertiary prairie vegetation in Nebraska. *In* Schultz, C. Bertrand, and Thompson M. Stout, Guide for a field conference on the Tertiary and Pleistocene of Nebraska. Special Publ. Univ. Nebraska State Mus., pp. 19-20.

1942. Tertiary prairie grasses and other herbs from the High Plains. Geol. Soc. Amer., Special Papers, no. 41, 176 pp., 17 pls.

Folsom, Jerry R.
[MS.] The field stratigraphy and mapping of the Marsland Formation in Sioux County, Nebraska. Master's thesis for Univ. of Nebraska, 1954.

Frick, Childs
1937. Horned ruminants of North America. Bull. Amer. Mus. Nat. Hist., vol. 69, xxviii+669 pp., 103 figs.

Frick, Childs, and Beryl E. Taylor
1971. *Michenia*, a new protolabine (Mammalia, Camelidae) and a brief review of the early taxonomic history of the genus *Protolabis*. Amer. Mus. Novitates, no. 2444, 24 pp., 4 figs., 3 tables.

Hay, Oliver P.
1924. Description of some fossil vertebrates from the upper Miocene of Texas. Proc. Biol. Soc. Washington, vol. 37, 19 pp., 6 pls.

Howard, Hildegarde
1932. Eagles and eagle-like vultures of the Pleistocene of Rancho La Brea. Contrib. Palaeont., Carnegie Inst. Washington, no. 429, 82 pp., 3 figs., 29 pls.

Izett, Glen A.
1968a. The Miocene Troublesome Formation in Middle Park, northwestern Colorado. U. S. Geol. Surv. Open-file Rept. *In* Robinson, Peter, Craig C. Black, and Malcolm C. McKenna (conf. committee), Field conference guidebook for the high altitude and mountain basin deposits of Miocene age in Wyoming and Colorado. Univ. Colorado Mus., 42 pp., 7 figs., 4 tables.
1968b. Geology of the Hot Sulphur Springs Quadrangle, Grand County, Colorado. U. S. Geol. Surv. Prof. Paper 586, 79 pp., 25 figs., 1 pl., 10 tables.

Lugn, Alvin L.
1938. The Nebraska State Geological Survey and the "Valentine Problem." Amer. Jour. Sci., ser. 5, vol. 36, no. 213, pp. 220-227.
1939. Classification of the Tertiary system in Nebraska. Bull. Geol. Soc. Amer., vol. 50, pt. 3, pp. 1245-1275, 1 pl., 2 tables.

Lugn, Alvin L., and Richard V. Lugn
1956. The general Tertiary geomorphology in Nebraska and the northern Great Plains. Compass, Sigma Gamma Epsilon, vol. 33, no. 2, pp. 98-114, 10 figs.

Lugn, Alvin L., and L. K. Wenzel
1938. Geology and ground-water resources of south-central Nebraska. U. S. Geol. Surv. Water-Supply Paper 779, vii+242 pp., 19 figs., 16 pls.

Lugn, Richard V.
[MS.] The heavy mineral assemblages of the Sheep Creek beds in western Nebraska compared with similar assemblages in other formations in the same region. Master's thesis for Univ. of Nebraska, 1955.

McKenna, Malcolm C.
1965. Stratigraphic nomenclature of the Miocene Hemingford Group, Nebraska. Amer. Mus. Novitates, no. 2228, 21 pp., 1 fig.

Matthew, William D.
1924. Third contribution to the Snake Creek fauna. Bull. Amer. Mus. Nat. Hist., vol. 50, art. 2, pp. 59-210, 63 figs.

Osborn, Henry F.
1918. Equidae of the Oligocene, Miocene, and Pliocene of North America, iconographic type revision. Mem. Amer. Mus. Nat. Hist., new ser., vol. 2, pt. 1, 217 pp., 173 figs., 54 pls.

Patton, Thomas H., and Beryl E. Taylor
1971. The Synthetoceratinae (Mammalia, Tylopoda, Protoceratidae). Bull. Amer. Mus. Nat. Hist., vol. 145, art 2, pp. 119-218, 37 figs., 15 tables.

Peckham, Alan E.
1961. Heavy minerals of the Miocene Harrison Formation in northwestern Nebraska. Jour. Sediment. Petrology, vol. 31, no. 1, pp. 52-62, 2 figs.

Peterson, Olof A.
1906. The Miocene beds of western Nebraska and eastern Wyoming and their vertebrate faunae. Ann. Carnegie Mus., vol. 4, no. 1, pp. 21-72, 20 figs., pls. 9-19.
1911. A new camel from the Miocene of western Nebraska. *Ibid.*, vol. 7, no. 2, pp. 260-266, pls. 37-40.

Rich, Thomas H. V., and Pat V. Rich
1971. *Brachyerix*, a Miocene hedgehog from western North America, with a description of the tympanic regions of *Paraechinus* and *Podogymnura*. Amer. Mus. Novitates, no. 2477, 58 pp., 22 figs., 4 tables.

Sato, Yoshiaki, and Norman M. Denson
1967. Volcanism and tectonism as reflected by the distribution of nonopaque heavy minerals in some Tertiary rocks of Wyoming and adjacent states. U. S. Geol. Surv. Prof. Paper 575-C, pp. C42-C54, 5 figs., 1 table.

Schultz, C. Bertrand
1938. The Miocene of western Nebraska. Amer. Jour. Sci., vol. 35, pp. 441-444.
[MS.] Oreodonts from the Marsland and Sheep Creek formations, with notes on the Miocene stratigraphy of Nebraska. Doctoral thesis for Univ. of Nebraska, 1941.

Schultz, C. Bertrand, and Charles H. Falkenbach
1940. Merycochoerinae, a new subfamily of oreodonts. Bull. Amer. Mus. Nat. Hist., vol. 77, art. 5, pp. 213-306, 18 figs.
1941. Ticholeptinae, a new subfamily of oreodonts. *Ibid.*, vol. 79, art. 1, 105 pp., 17 figs.
1947. Merychyinae, a subfamily of oreodonts. *Ibid.*, vol. 88, art. 4, pp. 157-286, 7 figs.
1968. The phylogeny of the oreodonts. *Ibid.* vol. 139, 498 pp., 56 figs., 19 tables, 26 charts.

Schultz, C. Bertrand, and Thompson M. Stout
1941. Guide for a field conference on the Tertiary and Pleistocene of Nebraska. Special Publ. Univ. Nebraska State Mus., 51 pp., 16 figs., 1 pl.
1961. Field conference on the Tertiary and Pleistocene of western Nebraska. Guidebook, Ninth Field Conf., Soc. Vertebrate Paleont., Special Publ. Univ. Nebraska State Mus., no. 2, 55 pp., 47 figs.

Skinner, Morris F., Claude W. Hibbard, et al.
1972. Early Pleistocene pre-glacial and glacial rocks and faunas of north-central Nebraska. Bull. Amer. Mus. Nat. Hist., vol. 148, art. 1, 148 pp., 60 figs.

Skinner, Morris F., Shirley M. Skinner, and Raymond J. Gooris
[MS.] Stratigraphy and biostratigraphy of late Cenozoic deposits in Sioux County, Nebraska.

Skinner, Morris F., and Beryl E. Taylor
1967. A revision of the geology and paleontology of the Bijou Hills, South Dakota. Amer. Mus. Novitates, no. 2300, 53 pp., 12 figs., 5 tables.

Swineford, Ada, John C. Frye, and A. Byron Leonard
1955. Petrography of the late Tertiary volcanic ash falls in the central Great Plains. Jour. Sediment. Petrology, vol. 25, no. 4, pp. 243-261, 3 figs., 2 pls.

Toohey, Loren
[MS.] Equidae of the upper part of the Marsland Formation. Master's thesis for Univ. of Nebraska, 1950.

Vondra, Carl F., C. Bertrand Schultz, and Thompson M. Stout
1969. New members of the Gering Formation (Miocene) in western Nebraska *including* a geologic map of Wildcat Ridge and related outliers. Nebraska Geol. Surv. Paper, no. 18, 18 pp., 8 figs.

Wang Yung-yen, Hsueh Hsiang-hsi, Ho Ju-ch'ang, and Chang Kuo-wei
1966. Quaternary stratigraphy of northern Shansi and eastern Kansu loess district. Acta Geol. Sinica, vol. 46, no. 1, pp. 102-117. (Translated in Internatl. Geol. Rev., vol. 11, no. 7, pp. 787-802, July, 1969.)

Wetmore, Alexander
1956. A check-list of the fossil and prehistoric birds of North America and the West Indies. Smithsonian Misc. Coll., vol. 131, no. 5, publ. 4228, 105 pp.

White, Theodore E.
1942. The lower Miocene mammals of Florida. Bull. Mus. Comp. Zool., vol. 92, no. 1, 49 pp., 10 figs., 14 pls.

Wilson, Robert W.
1960. Early Miocene rodents and insectivores from northeastern Colorado. Univ. Kansas Paleont. Contrib., Vertebrata, art. 7, 92 pp., 311 figs.

Wood, Horace E., 2nd
1964. Rhinoceroses from the Thomas Farm Miocene of Florida. Bull. Mus. Comp. Zool., vol. 130, no. 5, pp. 361-386, 2 figs., 5 tables.

Wood, Horace E., 2nd, et al.
1941. Nomenclature and correlation of the North American continental Tertiary. Bull. Geol. Soc. Amer., vol. 52, 48 pp., 1 pl.