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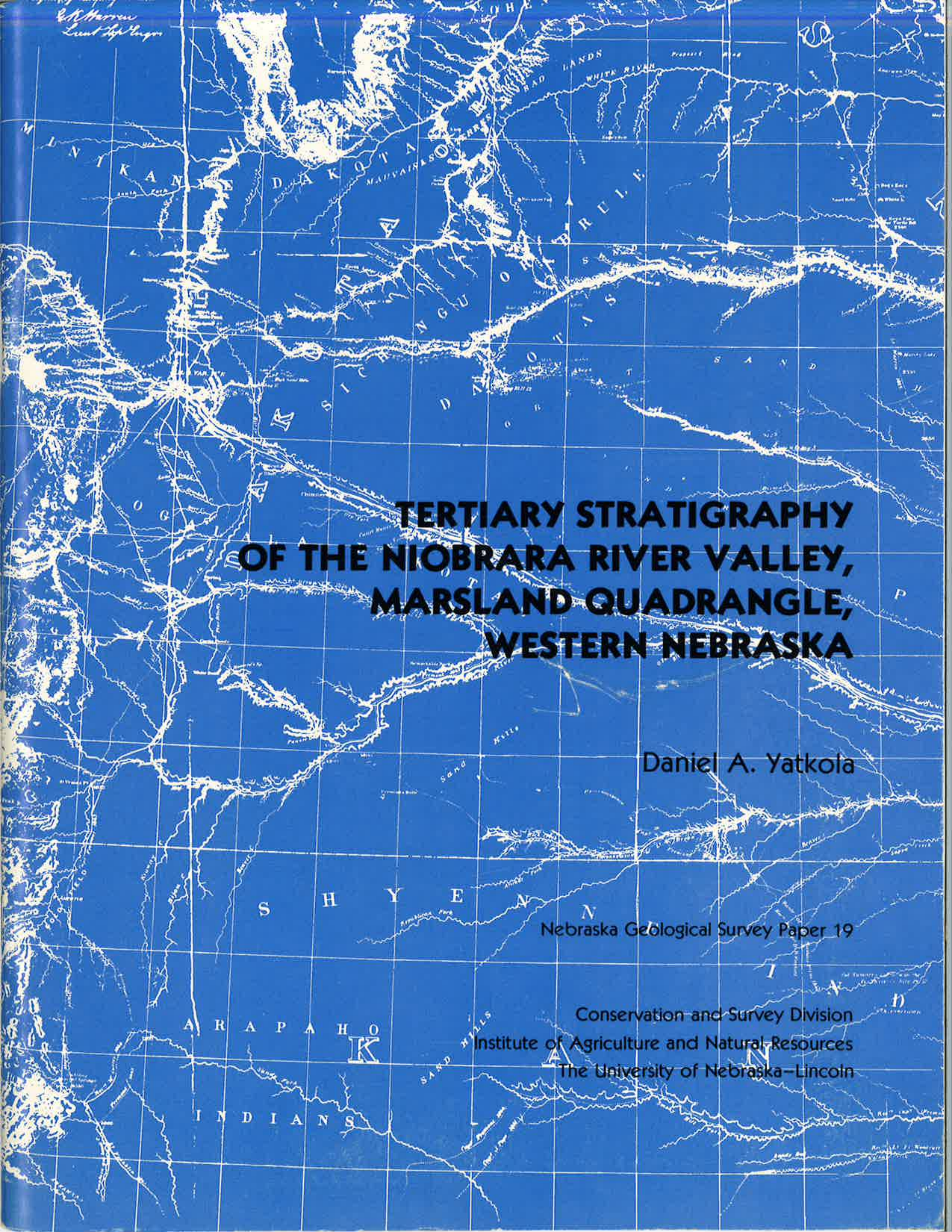
Tertiary Stratigraphy of the Niobrara River Valley, Marsland Quadrangle, Western Nebraska

Conservation and Survey Division
University of Nebraska - Lincoln



TERTIARY STRATIGRAPHY OF THE NIOBRARA RIVER VALLEY, MARSLAND QUADRANGLE, WESTERN NEBRASKA

Daniel A. Yatkola

Nebraska Geological Survey Paper 19

Conservation and Survey Division
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CONTENTS

LIST OF ILLUSTRATIONS

Plates

Figures

Tables

PREFACE

Daniel A. Yatkola (October 1, 1947 - March 12, 1976) received his Bachelor of Science degree from Waynesburg College in 1970 and his Master of Science degree from the University of Wyoming in 1972. He attended the Lutheran School of Theology in Chicago in 1972-73 and in 1973 enrolled in the doctoral program in geology at the University of Nebraska. Dan's principal interest was vertebrate paleontology, and he conducted his master's program under the direction of Dr. Paul McGrew who introduced him to the geology of northwest Nebraska, in particular the area near Marsland, Nebraska. During his program at the University of Wyoming, Dan excavated the Marsland Quarry south of Marsland, studied its fossil mammals, and developed a model for the environment of deposition of the surrounding Miocene sediments (Yatkola 1972).

This interest was continued in 1973 when Dan enrolled in a doctoral program in geology at the University of Nebraska. His dissertation proposal involved mapping the lithologic units exposed in the Niobrara River valley between Agate and Marsland and a study of the vertebrate fossils, including their biostratigraphy. Dan spent the summers of 1974 and 1975 studying the geology and fossil mammals of this area, concentrating on the area within the Marsland 15-minute Quadrangle. His dissertation was nearing completion when he was killed in an automobile accident near Lawrence, Kansas, on March 12, 1976. Dan left a typescript of the nearly complete geologic portion of his dissertation. The sections of his dissertation dealing with paleontology, however, were much less complete. Dan did publish a fine paper on Miocene lizards that included material from his study area (Yatkola 1976).

The Conservation and Survey Division of the University of Nebraska recognized the value of Dan's research and, in the fall of 1975, arranged with him to publish the geologic part of his dissertation. Most of the drafting of the geologic maps and stratigraphic profiles had been completed under Dan's supervision. It seemed appropriate to proceed with the publication by utilizing the draft text available. The editors have compiled the typescript as it was left, making only minor changes in grammar, syntax, and spelling. Where the typescript was incomplete, this is so indicated in the text by an editorial abbreviation in brackets or by a footnote. The following abbreviations were used:

[N.A.]-not available. The editors were unable to locate the item referred to (e.g., figure, plate, or literature reference).

[N.D.]-not designated by author. The editors were unable to determine the specific measured section referred to in the text.

[S.E.]-selected by editors. The editors selected the measured section based on a study of Dan's field notes and on the familiarity of Swinehart and Hunt with the area during field trips with Dan.

Any other editorial additions to the text are included in brackets. Dan left a list of photographs of outcrops he had intended to include in the dissertation. Using this list the editors have supplied new photographs of as many of the designated outcrops as possible. All figure legends were supplied by the editors.

From conversations that Dan had with the editors, it was clear that he had intended to conclude his paper with a summary of the Miocene geologic history of the study area, in particular the complex depositional history of the Runningwater Member of the Marsland Formation. Unfortunately, incomplete notes are the only record of this intention.

The nomenclature of Miocene rocks in the region from Agate to Marsland has been debated in the literature of western Nebraska for some time; it is of historical interest to note that Dan's nomenclatural terms for these Miocene rocks are his own solution to this problem, representing a compromise between the various schools of thought. Regardless of terminology, his geological study of these rocks is an important and highly significant contribution to the Miocene lithostratigraphy and biostratigraphy of western Nebraska.

It is certain that Dan would have acknowledged the following people for their help and guidance with this report: John Breyer, George Corner, the late Paul Edwards, Ted Galusha, Larry Martin, King Richey, Bill Rovnak, C. Bertrand Schultz, Morris Skinner, T. Mylan Stout, and Lloyd Tanner. Dan would have also thanked the many landowners who allowed him access to the study area.

Dan Yatkola was awarded financial support by the Geological Society of America, Sigma Xi, the Schramm Fund of the University of Nebraska, the University of Nebraska State Museum, and the Conservation and Survey Division of the University of Nebraska.

In addition to the people named above, the editors wish to acknowledge Marvin Carlson, Marie Skinner, and Dan's mother, Ellen Yatkola, for their help.

Dan's original typescript, illustrations, and field notes are preserved in the archives of the University of Nebraska State Museum.

James B. Swinehart
Conservation and Survey Division
Michael R. Voorhies
Robert M. Hunt, Jr.
University of Nebraska State Museum

HISTORICAL PERSPECTIVE AND OBJECTIVES

The earliest reports covering the geology and vertebrate paleontology near Marsland are those of Hayden (1863) and Leidy (1858, 1869). Hayden developed a generalized stratigraphic section divisible into six major units (Beds A-F) for the White River and Niobrara River basins. Beds D, E, and F were listed as occurring west of the point where the Hayden expedition joined the Niobrara from the Loup.

Stratigraphic relationships of Miocene sediments exposed in the vicinity of Marsland, Nebraska, have been accorded much discussion and debate (McKenna 1965). Vertebrate fossils collected from these sediments have played a prominent role in the development of several of the North American Cenozoic Land Mammal Ages (Wood et al. 1941). Ever since Hayden first collected vertebrate fossils in this area, interest in the abundant vertebrate remains has increased. Many fossils have been described from this immediate area, although the stratigraphy and geographic location were not always recorded.

The objectives of this investigation are: (1) to define and map the lithologic units exposed in the vicinity of Marsland, Nebraska; (2) to describe the vertebrate fossils with known stratigraphic control;* (3) to present a preliminary biostratigraphic zonation;* and (4) to discuss the bearing of the results of this study on the nomenclatorial problems associated with the classic Miocene stratigraphic terms.

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*Editors' Note: These objectives are not discussed in this report. Refer to the preface for explanation.

INTRODUCTION TO STRATIGRAPHY

The Miocene sediments exposed along the Niobrara River in Sioux, Dawes, and Box Butte counties, Nebraska, are dominantly fine-grained sandstones and siltstones (fig. ___ [N.A.]). The coarser grained sediments are geographically and stratigraphically restricted and make up only a very small percentage of the total thickness. Therefore, the author has attempted to define the rock stratigraphic units exposed in this area on the basis of their finer grained facies. The coarser grained facies of each unit were then compared. The term facies, as used in this report, is a descriptive term referring to "the sum total of all primary characteristics of a sedimentary rock" (Teichert 1958, p. 2739).

Six pre-Quaternary rock stratigraphic units crop out along the Niobrara River in the map area (fig. 1; pl. 1). These units, in order of superposition from lowest to highest, are: Monroe Creek Formation; Harrison Formation; Marsland Formation, Lower Member; Marsland Formation, Runningwater Member; Box Butte Formation; and an unnamed unit. The type section of each of the above-named units was studied during the course of this investigation. The contacts of these units were walked out and mapped as accurately as possible on an enlarged copy of the U.S. Geological Survey's Marsland Quadrangle (Nebraska, 15-minute series, 1951 edition) and checked on aerial photographs (1939 series). The Quaternary deposits that blanket much of the area have not been mapped. Stratigraphic sections were measured using a Kuker-Ranken Stadia hand level; base elevations of sections were determined using an American Paulin System altimeter and checked against the topographic map elevation. Color designations follow the Geological Society of America Rock Color chart (Goddard et al. 1970). Particle size terms follow Wentworth (1922).

Sixteen grain mount thin sections were made to check hand specimen observations. The location of these samples is given in table ___ [N.A.]. These thin sections confirm hand specimen observations and therefore form part of the basis for the differentiation of these units.* Particle size data are presented

*Editors' Note: The editors could find only an incomplete description of these thin sections and therefore cannot substantiate this statement.

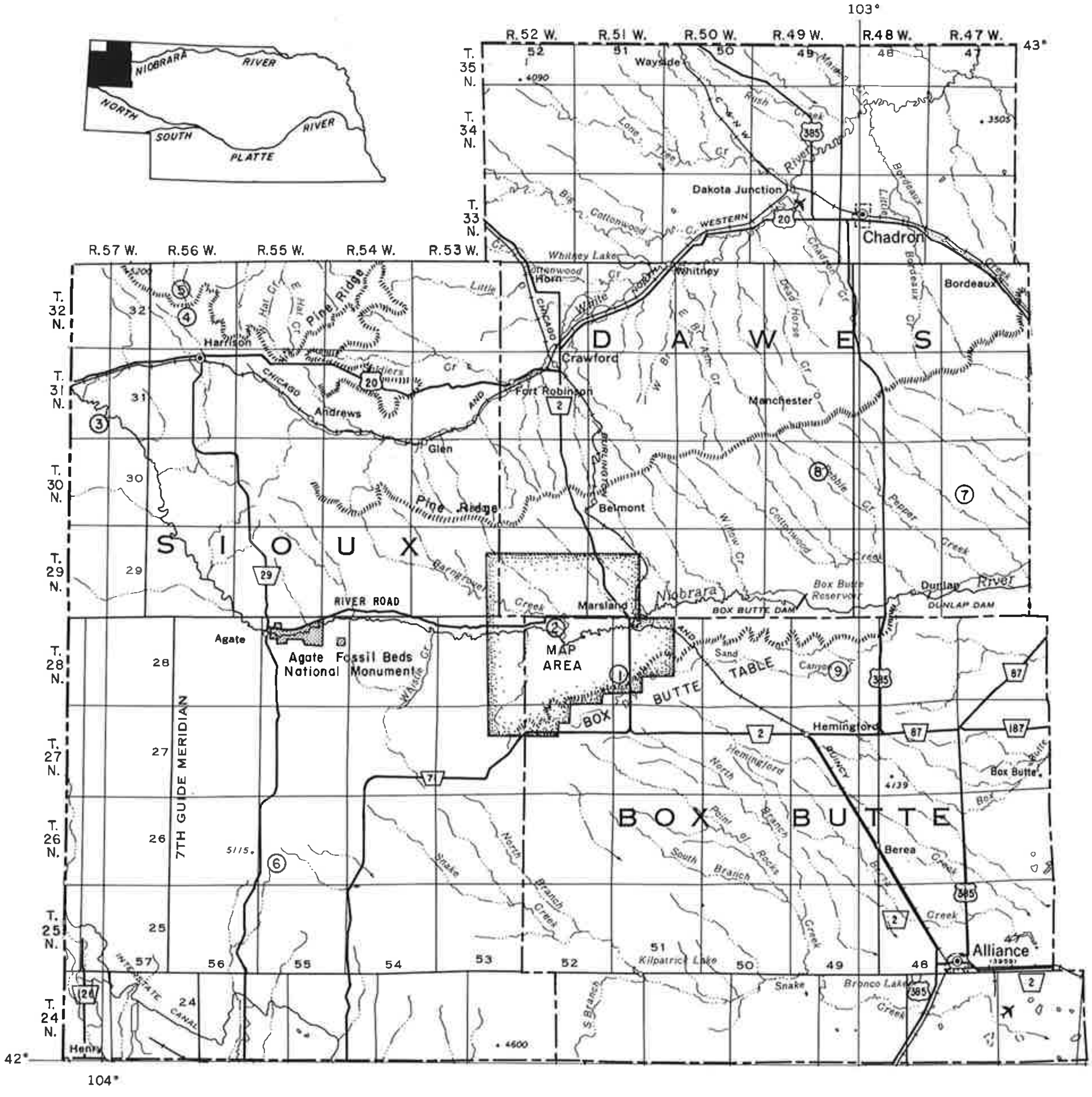

Fig. 1. Location of the map area in western Nebraska. Small numbered circles identify the following: (1) type section of Marsland Formation as defined by Cook (1965); (3) type area of the "upper Harrison beds" of Peterson (1907, 1909); (4) a reference section of the Harrison Formation; (5) type area of the Monroe Creek Formation of Hatcher (1902); (6) type locality of the Sheep Creek Formation (Matthew and Cook 1909); (7) type section of the Red Valley Member, Box Butte Formation (Galusha 1975); (8) type section of the Dawes Clay Member, Box Butte Formation (Galusha 1975); (9) type section of the Box Butte Formation as defined by Cady (1940).

two ways: (1) in a histogram [N.A.] and (2) as a cumulative log probability curve, figs. 3 and 7. Mean, sorting, and skewness values, table 1, were calculated following Folk (1974, pp. 45-48).

The following abbreviations are used in the text and on the stratigraphic sections:

ACSN	American Code Stratigraphic Nomenclature (1970)	med.	medium
		mst.	mostly
		N.	North
ag.	agatized	nod.	nodule
amp.	amplitude	org.	orange
bd.	bedded	p.	potato-shaped
bl.	blocky	pbls.	pebbles
br.	brown	pksh.	pinkish
bf.	buff	plt.	platy
cal.	calcareous	Q.	quarry
cl.	clay	R.	Range
cly.	clayey	rar.	rare
coar.	coarse	rd.	red
con.	consolidated	rdsh.	reddish
com.	compact	rwk.	reworked
conc.	concretion	S.	South
cov.	covered	sd.	sand
dk.	dark	sdy.	sandy
E.	East	sec.	section (legal description)
F:AM	Frick Collection: American Museum of Natural History	sft.	soft
		sh.	shale
		ss.	sandstone
feld.	feldspar	sty.	silty
Fm.	Formation	strat.	stratigraphic
fn.	fine	T.	Township
gr.	gray	Tb	Box Butte Fm.
gran.	granule	Th	Harrison Fm.
grn.	green	Tm	Marsland Fm.
grnsh.	greenish	Tmc	Monroe Creek Fm.
grnt.	granite	Tml	Marsland Fm. Lower Mbr.
grav.	gravel	Tmr	Marsland Fm. Runningwater Mbr.
hd.	hard	uncon.	unconsolidated or loose
horz.	horizontal	UNSM	University of Nebraska State Museum
l.	lithic		
l.f.	local fauna	v.	very
lmy.	limy	ves.	vesicular
ls.	limestone	W.	west
lt.	light	wh.	white
m.	massive	wvy.	wavy
Mbr.	Member	x-bd.	cross-bedded
		xl.	crystalline

MONROE CREEK FORMATION

Type Section

Hatcher (1902) defined the Monroe Creek Beds as the lower subdivision of Darton's (1899, 1903) Arikaree sandstones. "These are well shown in the northern face of Pine Ridge, at the mouth of the Monroe Creek cañon, five miles north of Harrison, Nebraska" (Hatcher 1902, p. 116). A reference section in the type area of the Monroe Creek Formation is exposed in roadcuts and adjacent drainage along the Monroe Creek Canyon road; secs. 8, 16, 17, and 21, T. 32 N., R. 56 W., just north of Harrison, Nebraska (fig. 1).

Name and Definition

The Monroe Creek Beds "overlie the Gering sandstones" and "are composed of some 300 feet of very light-colored, fine-grained, not very hard, but firm and massive sandstones" (Hatcher 1902). The rock stratigraphic term "Monroe Creek Formation" is provisionally applied to massive, orange brown siltstones, approximately 10 to more than 100 feet (3.05 to 30.5 m) thick (fig. 2) that extend south and east from the type area to the Niobrara valley. The Niobrara Valley Monroe Creek sediments are somewhat finer grained than sediments exposed in the type area and resemble the type sediments in color, in massive bedding, compactness, and weathering characteristics. The Niobrara Valley Monroe Creek sediments also resemble parts of the Sharps Formation of southwest South Dakota, especially in the "Potato-ball" concretions (Harkson et al. 1961, fig. 3), although "at the top of the Monroe Creek, there occurs a silty unit with small rounded and knobby "potato concretions" (Schultz and Stout 1961, p. 6). Correlation of the Niobrara Valley Monroe Creek sediments with a definite part of the type section of the Monroe Creek Formation is not possible, since the Niobrara Valley Monroe Creek Formation cannot be physically traced to the type area. However, the Niobrara Valley Monroe Creek Formation is very similar to the Monroe Creek Formation exposed high along the Pine Ridge just south of the Cochran State Wayside Area, Dawes County (sec. 10, T. 30 N., R. 52 W).

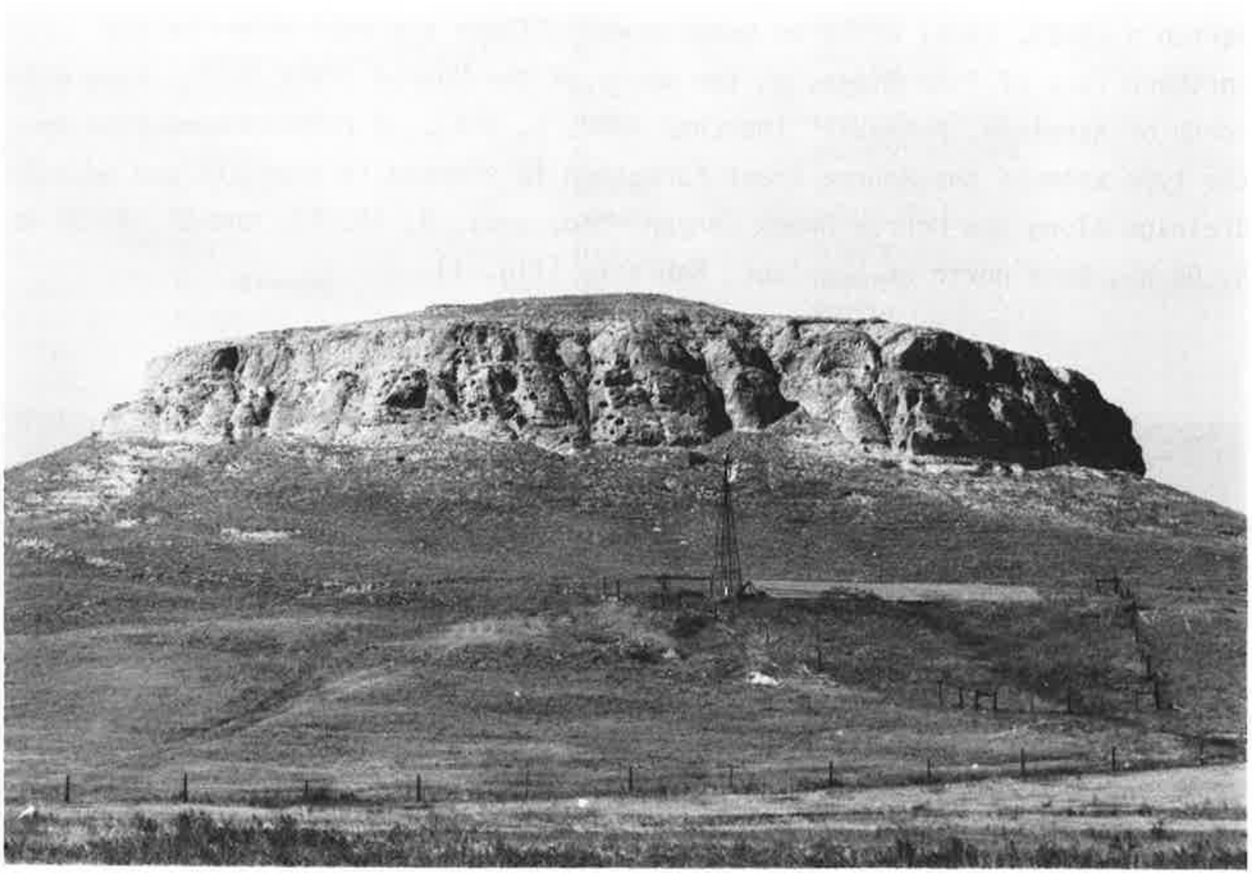

Fig. 2. Monroe Creek Formation outcrops, Ralph Morava ranch, on the south side of the Niobrara River in S½ sec. 5, T. 28 N., R. 54 W., Sioux County.

Distribution and Thickness

The Monroe Creek Formation crops out along the Niobrara River in Box Butte, Dawes, and Sioux counties, Nebraska, at lower topographic elevations (pl. 1). The thickness varies from less than 10 feet (3.05 m) at the mouth of Whistle Creek to more than 100 feet (30.5 m) in the area of the Morava Hills (pl. 6). The lithologic character and upper contact of the Niobrara Valley Monroe Creek Formation is best illustrated by section 31 (pl. 6) [SE] exposed on the south side of the Morava Hills and along a northwest-southeast trending sand wash northwest of Marsland in secs. 33, 29, 30, 19, 18, T. 29 N., R. 51 W.

Lithologic Character

The Monroe Creek Formation along the Niobrara River in Box Butte, Sioux, and Dawes counties, Nebraska, is remarkably uniform in lithologic character. These sediments are compact, massive, orange brown (5 YR, Chroma 1-4, Lightness Values 4-8) sandy siltstones. The sediments contain less than 45 percent sand-sized particles, a higher percentage of coarse silt than very fine sand and some clay (fig. 3, table 1). These siltstones are massive and locally there may be a hint of bedding. Locally there are lenses of very fine sand or very fine calcite-cemented sand ledges. Numerous, irregularly distributed, very fine-grained calcareous nodules (fig. 4) are often present (i.e., the potato concretions of Schultz 1941), but many outcrops lack these nodules. In one local exposure, located in a small north-south trending wash on the south side of the Niobrara River road in sec. 5, T. 28 N., R. 52 W., is an 8-inch-thick (0.203-m) agatized lime bed. The Monroe Creek Formation along the Niobrara River weathers to vertical smooth-faced buttes (fig. 2) similar to those of the Pine Ridge. No coarse clastic facies was observed within the Monroe Creek Formation either along the Niobrara valley or in the type area. The sediments contain volcanic glass shards but there are no ash beds. All fossil bone so far discovered is very pale orange (10 YR 8/2).

Lower Stratigraphic Contact

In the type area, the Monroe Creek Formation "overlies the Gering sandstones" (Hatcher 1902, p. 116). The correlation of the sands that Hatcher

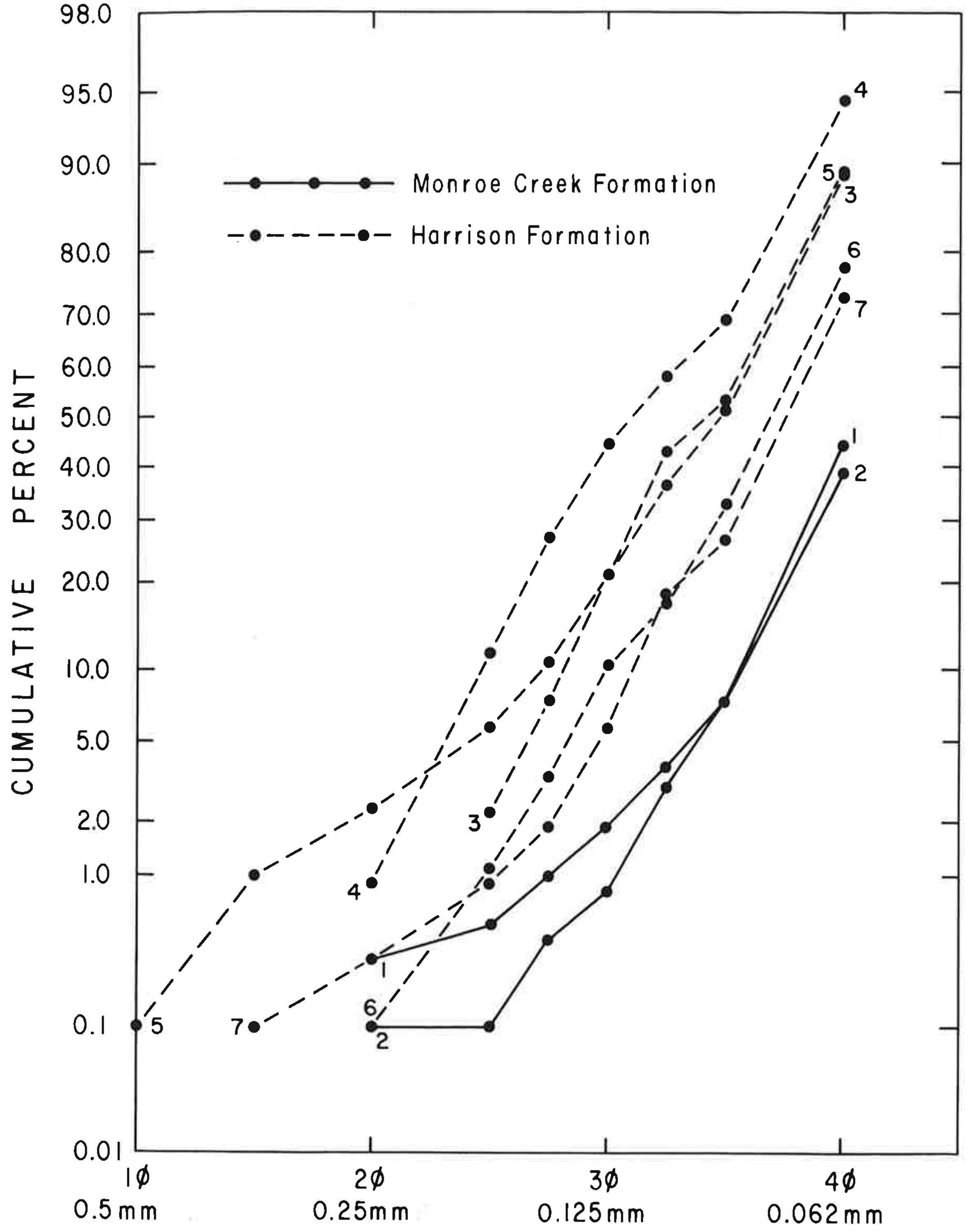

Fig. 3. Log-probability curves obtained by sieving samples of the Monroe Creek and Harrison formations from northwest Nebraska. Location of samples given in appendix A.

TABLE 1

Graphic Statistics of Selected Samples from Northwest Nebraska
(Statistics derived from curves of figures 2 and 7. Location of samples given in appendix A.)

	Monroe Creek Formation			Harrison Formation				Marsland Formation						
								Lower Member			Runningwater Member			
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Graphic Mean Size - phi (ϕ)	3.97	3.97	3.42	3.07	3.38	3.65	3.71	3.88	3.60	3.57	3.87	3.25	3.68	3.72
Sorting- Inclusive Graphic Standard Deviation	0.27	0.27	0.47	0.48	0.53	0.41	0.40	0.45	0.58	0.31	0.43	0.74	0.65	0.45
Skewness- Inclusive Graphic Skewness	-0.36	-0.51	-0.10	-0.03	-0.10	-0.24	-0.14	-0.61	-0.43	-0.56	-0.60	-0.15	-0.77	-0.31

Editors' Note: Since the author grouped silt and clay together in a pan fraction, he had to extrapolate the cumulative curve to obtain the graphic statistics. This may have introduced considerable error in the statistics for those samples with greater than 50 percent silt and clay.

Fig. 4. Calcareous nodules in the Monroe Creek Formation about 20 feet (9.1 m) below the Monroe Creek-Harrison contact at measured section 27 (Pink Schoolhouse section, pl. 5) in NE¼ SE¼ SE¼ sec. 36, T. 29 N., R. 54 W., Sioux County. The shovel is 28 inches (0.71 m) long.

designated "Gering Sands" at the base of Pine Ridge with the type section of the Gering Formation (sensu Darton 1899) has not been documented. Also the separation of Hatcher's "Gering Sandstones" from the Monroe Creek along the north rim of Pine Ridge is more a matter of imagination than lithologic difference since the sands of the "Gering" grade upward into the silts of the Monroe Creek Formation. The base of the Monroe Creek Formation along the Niobrara River is not exposed. A test hole (UNW 10-75) drilled by the Conservation and Survey Division, University of Nebraska, in NE¼ sec. 19, T. 28 N., R. 51 W., Box Butte County, Nebraska [Souders, Smith, and Swinehart, in press] penetrated at least 192 feet (59 m) from an elevation of 4,242 feet (1 290 m) to 4,050 feet (1 230 m) of Monroe Creek sediments, possibly penetrating into the White River Group from 4,050 feet (1 230 m) to the base of the test hole at 3,980 feet (1 210 m). However, this lower 70 feet (21.3 m) of section may belong in the Monroe Creek.

Vertebrate Fossil Localities

In the study area and in other areas, fossil vertebrates from Monroe Creek Formation are very rare. Fossils have been recovered from two localities along the Niobrara River: Dead Frog Locality (sec. 32, pl. 6) and UNSM BX-59A (sec. 9, pl. 3). [These localities are also indicated on pl. 2.] The stratigraphic placement of these localities is shown in figure ___ [N.A.].

Environment of Deposition

The Monroe Creek sediments along the Niobrara River represent a paleoloess. Loess, as used in this report, refers to an accumulation of windblown dust. The particle size distribution of the massive light-colored siltstones of the Monroe Creek Formation (fig. 2) are very similar to Pleistocene loess. Particle size analyses of recent windblown dust (Swineford and Frye 1945) and Pleistocene paleoloess (Lugn 1962) usually have less than 50 percent sand, a silt-sized modal class, and are very well sorted. The massive, uniform character of the Monroe Creek is characteristic of eolian deposits and not typical of fluvial sedimentation characterized by cut and fill structures, abrupt changes in particle size and textural gradations (Krumbein and Sloss 1963, p. 255). The complete lack of a coarse clastic facies is very unlikely in a fluvial environment. Even the massive siltstones and claystones of the Chadron Formation and the Orella Member of the Brule Formation, which have been interpreted as fluvial in origin but may represent in large part clay dunes, contain a coarse clastic facies. The nonlinear distribution of these sediments is not typical of fluvial environments. The high percentage of volcanic glass (Stanley 1976), which is very unstable in water, strongly suggests eolian deposition in a dry depositional environment. These factors, taken cumulatively, strongly suggest that the eolian sedimentation predominated during the time of deposition of the Monroe Creek sediments.

Loess deposition implies dry climatic conditions (___, reference N.A.). This could explain the rarity of fossil vertebrates. If conditions were dry in the area of deposition of the paleoloess of the Monroe Creek Formation, then mammals inhabiting the immediate area would probably be fewer in number; also dry conditions and slow sedimentation rates would be less favorable for preservation of bones.

The lower percentage of sand in the Monroe Creek Formation along the Niobrara River in comparison to the type area could be explained by proposing a northwest source for the sand. A similar decrease in sand content within the Peorian loess in a distance comparable to that between the two areas was described by Lugn (1962, pl. 11). There is some evidence that desert conditions existed in central Wyoming at this time. This sand could serve as the source for the sandy silts of the Monroe Creek Formation.

In summary, the following depositional model for the Monroe Creek Formation is proposed: (1) the climate was xeric; (2) the landscape was poorly vegetated; (3) eolian sedimentational processes prevailed; (4) fluvial sedimentational processes contributed a small percentage of the sediments and permanent river systems did not exist in the area; (5) the environment that existed during the deposition of the Monroe Creek Formation remained constant for some time.

HARRISON FORMATION

Type Section

Hatcher defined the Harrison Beds as the upper subdivision of Darton's (1899, 1903) Arikaree sandstones: "These are well shown in the bluffs of all the small streams that head near the summit of Pine Ridge, in the vicinity of Harrison, Nebraska . . . and conformably overlie the Monroe Creek beds" (Hatcher 1902, p. 117). A reference section of the Harrison Formation is exposed in roadcuts and adjacent outcrops along the Monroe Creek Canyon road in secs. 21 and 22, T. 32 N., R. 56 W., just north of Harrison, Nebraska (fig. 1).

Name and Definition

The Harrison Beds are "composed of about 200 feet of fine-grained, rather incoherent sandstones, permeated by great numbers of siliceous tubes arranged vertically rather than horizontally" (Hatcher 1902, p. 117). The rock-stratigraphic term "Harrison Formation" is extended south and east from the type area to the Niobrara valley for approximately 20 to 100 feet (6.1 to 30.5 m) of very fine to fine-grained, gray brown volcaniclastic, loose saudstones interbedded with numerous calcareous-cemented sandstone ledges. Individual outcrops of the Niobrara valley Harrison sediments generally contain a greater number of calcareous-cemented ledges than the type sediments. The Harrison Formation can be traced to the map area along the Niobrara River from the type area.

Distribution and Thickness

The Harrison crops out along the Niobrara River in Box Butte, Dawes, and Sioux counties, Nebraska, throughout the map area (pl. 1). The thickness varies from a few feet in sec. 9, T. 28 N., R. 51 W. to over 100 feet (30.5 m) along Barngrover Creek in secs. 25 and 36, T. 29 N., R. 53 W. The lithologic character and contacts of the Harrison Formation in the Niobrara Valley are best illustrated by sections 22 and 25 (pl. 5) and section 36 (pl. 6) exposed on the south side of Barngrover Creek; by section 27 (the Pink Schoolhouse section, pl. 5), or in a roadcut on the east side of Nebraska State Highway 2, in the southwest corner of sec. 8, T. 28 N., R. 51 W.

Lithologic Character

The Harrison Formation along the Niobrara River in Box Butte, Sioux, and Dawes counties, Nebraska, is a very fine to fine-grained, massive to bedded, gray brown, soft volcaniclastic sandstone interbedded with numerous calcareous sandstone ledges. The very fine, sand-sized, loose sediments contain more than 70 percent sand-sized particles, a greater percentage of very fine sand than coarse silt, and essentially no clay (fig. 2, table 1). The color varies from medium to very-light gray (N5 to 7), to light bluish gray (5B 7/1) to pale yellowish brown (10YR 6/2). The calcareous-cemented ledges are generally lighter in color than the massive units. The loose, massive sands contain a high percentage of bubble wall volcanic glass shards and very abundant lath-shaped dark silicates (hornblende and augite) and oxides (magnetite). The dark silicates are so abundant as to give the sand a salt and pepper appearance. The quartz grains are monocrystalline, generally angular and clear. Feldspar grains are not common.*

The sands of the Harrison Formation are primarily massive, although locally there are distinct planar and shallow trough cross-bedded units (i.e., at the base of the Harrison in section 27, pl. 5). In places there are lenses of concentration of dark heavy minerals, such as at UNSM Lizard Quarry (section 27). The calcareous-cemented beds are horizontal, randomly distributed, and somewhat coarser grained than the interbedded loose sands. These beds are laterally traceable only a few tens of feet. These ledges are very resistant to erosion and in outcrop they tend to form a very irregular profile. Even when the outcrop area is basically covered, these ledges can usually be found on sod-covered surfaces.

Also mapped as part of the Harrison Formation is a channel fill in the area of the Morava Hills (pl. 2). McKenna and Skinner (in Cook 1965, fig. 2, NE¼ sec. 6, T. 28 N., R. 52 W) also considered this channel fill a part of the Harrison Formation. Sediments within the channel fill can be traced into the

*Editors Note: The author's incomplete thin section data indicate that he had later found feldspar to be a significant component in the Harrison samples. However, no percentage data were found.

above-described sediments and are overlain by sediments of the Lower Member of the Marsland Formation (see sections 19 and 21, pl. 5 [S.E.]). A maximum relief of 45 feet (13.7 m) was observed just to the west of section 20 (pl. 5). These channels contain lithic pebbles of reworked Monroe Creek Formation nodules or intraformational debris up to 1.57 inches (40 mm) in diameter. The fill of this channel resembles the massive, gray brown volcaniclastic sands described above, although these tend to have few dark heavy minerals. The orientation of the channel axis is approximately east-west. A channel cut into the Monroe Creek Formation located in the center S½ sec. 6, T. 28 N., R. 54 W., is believed to represent the western continuation of the same channel seen in the Morava Hills area. This western channel contains granule-sized crystalline debris. This suggests an east-west Harrison drainage system.

Description of Most Complete Section

The most complete and best exposed section of the Harrison Formation along the Niobrara River is located on the south side of Barngrover Creek, in SE¼ NW¼ sec. 36, T. 29 N., R. 53 W., Sioux County, Nebraska (section 22, pls. 5 and 6). At this locality 102 feet (31.0 m) of the Harrison Formation is exposed. Approximately 16 feet (4.9 m) of the Harrison Formation occurs below the base of this section and the Monroe Creek-Harrison contact is exposed 3,000 feet (910 m) south-southeast down Barngrover Creek. This section and others in the area can be divided into three informal units: a lower massive unit, a middle ledgy unit, and an upper bedded-ledgy unit. The maximum thickness of the Harrison Formation along the Niobrara River is 118 feet (36.0 m). The lower 43 feet (13.1 m) of section 22, (pl. 5) is composed primarily of massive, gray brown, loose, volcaniclastic sandstones. Occasional light gray, calcareous-cemented sandstone ledges extend laterally a few tens of feet. Some of these ledges are distinctly pitted. The upper 59 feet (18.0 m) of section 22 is very ledgy. These ledges do not differ from those below, except they occur in greater abundance and extend laterally for greater distances. These ledges are interbedded with massive, gray brown, loose, volcaniclastic sandstones. The ledges of the upper part of the ledgy unit are slightly concave on their lower surfaces, suggesting that these upper ledges reflect small channel fills.

Near the top of the section occurs a faint indication of very broad, low-angle trough cross-bedding. The upper contact is placed at the base of a pebble conglomerate.

Lower Stratigraphic Contact

Sediments of the Harrison Formation disconformably overlie the Monroe Creek Formation. In the type area the Monroe Creek Formation "passes insensibly" into the Harrison Formation (Hatcher 1902, p. 117). It seemed useful to map the Monroe Creek-Harrison contact along the Niobrara valley at the top of the massive, orange brown siltstones of the Niobrara Valley Monroe Creek Formation (pl. 1). Usually there is no relief on the Monroe Creek-Harrison contact, although the contact varies from a deeply channeled surface with considerable relief (section 32, pl. 6 [S.E.]) to a planar eroded surface (fig. 5; section 27, pl. 5) to a paleosol with no relief (fig. 6; section 4, pl. 3). This contact is usually sharp and easily recognized in the field, although in places such as the type area the contact is less sharp.

Erosion into the deposits of the Monroe Creek Formation was limited in distribution. Small, narrow paleovalleys were filled by sediments of the Harrison Formation. Apparently most of the Monroe Creek land surface remained stable for an extensive time period.

Vertebrate Fossil Localities

In the study area, fossil vertebrates from the Harrison are a bit more common than those from the Monroe Creek Formation. The following localities occur within the unit mapped as part of the Harrison Formation: Lizard Quarry (section 27, pl. 5); Armstrong Ranch Quarry (pl. 1); BX-59B, (section 9, pl. 3); Cistern Locality (pl. 2); Morava Ranch Quarry, (section 31, pl. 6); Galusha's *Stenomylus* Quarry, (section 32, pl. 6) as well as a number of isolated specimens. The stratigraphic placement of these localities is shown in figure ___ [N.A.].

Environment of Deposition

The Harrison sedimentation patterns along the Niobrara valley represent a change from the conditions that prevailed during the deposition of the

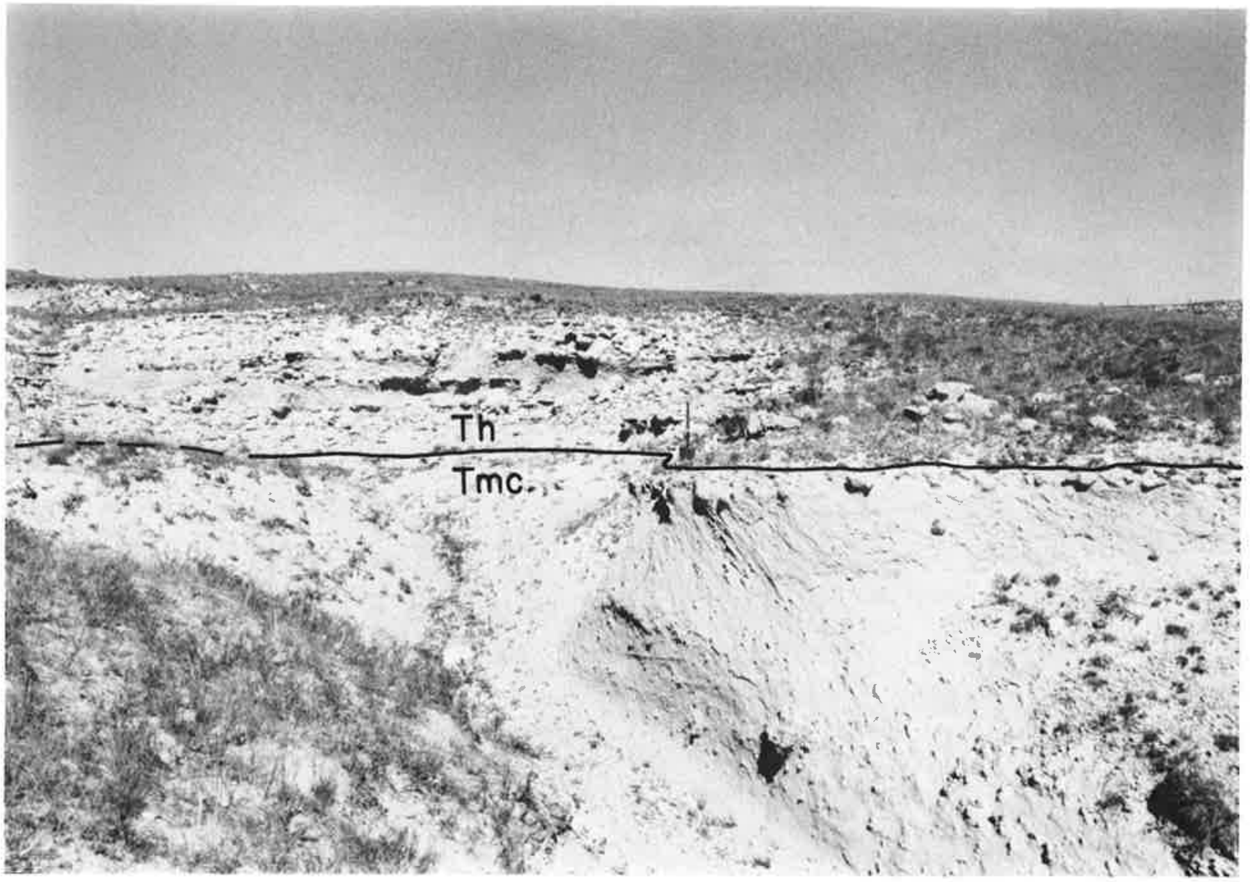

Fig. 5. Contact between the Monroe Creek and Harrison formations at measured section 27 (the Pink Schoolhouse section, pl. 5) in NE¼ SE¼ SE¼ sec. 36, T. 29 N., R. 54 W., Sioux County. Here the contact is a planar eroded surface. The shovel is 28 inches (0.71 m) long.

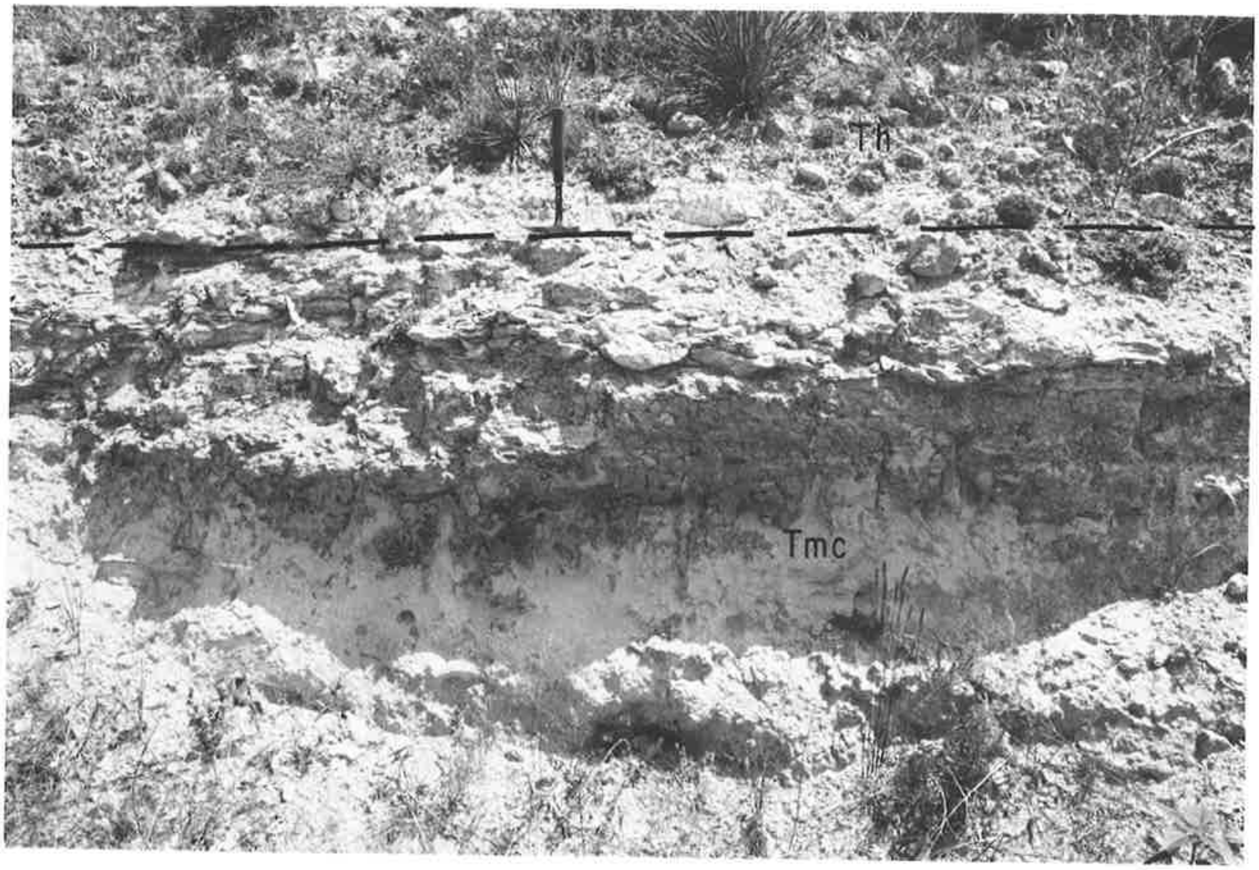

Fig. 6. Contact between the Monroe Creek and Harrison formations at section 2 (pl. 5) along Highway 2 in SW¼ SW¼ SW¼ sec. 8, T. 28 N., R. 51 W., Box Butte County.

Monroe Creek Formation. The Harrison sediments contain significantly greater percentages of sand and a greater percentage of very fine sand than coarse silt (table 1, fig. 2). The Harrison also contains a coarse clastic facies and many irregularly bedded calcareous ledges. These differences are such that the underlying Monroe Creek sediments could not have served as a source for the Harrison sands. Many of the lithic pebbles of the coarse clastic facies were reworked from the Monroe Creek Formation. The lack of discrete beds of clay; scarcity of clasts larger than coarse sand, except in the restricted areas of the channels; the abundance of volcanic glass (Stanley 1976) and very well sorted sands within most of the formation argues strongly that the sand was brought to the basin of deposition by wind (Glennie 1970, pp. 11-12). Fluvial sedimentational processes must have contributed material to the Harrison Formation in contrast to the Monroe Creek Formation. The coarser grain size and the freshness of the grains suggest that the source of the Harrison sand was closer to the areas of deposition than the source of the Monroe Creek sand.

The presence of concretion ledges suggests that the water table stood for extended periods after the deposition of the Harrison sediments. These calcareous-cemented ledges were lithified prior to the deposition of the Marsland Formation, since reworked lithic pebbles of the Harrison Formation occur within this unit.

In summary, the following depositional model is proposed for the Harrison Formation.*

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*Editors' Note: The editors could not locate the text intended for this summary.

MARSLAND FORMATION, REDEFINED

The lithologic separation of the sediments overlying the Harrison Formation in the type area has long been recognized. Hatcher (1902) used the ill-defined stratigraphic term "Nebraska Beds," a term originally used by Scott (1890), for these sediments. "These consist of a series of buff-colored sandstones of varying degrees of hardness and unknown thickness, with occasional layers of siliceous (not calcareous) grits, which protrude as hard, indurated or shelving masses from the underlying and overlying softer materials" (Hatcher 1902, p. 117). The upper limit and geographic extent of these sediments have been often debated (e.g., McKenna 1965) [see also Skinner et al. 1977] and, since Hatcher's initial recognition, the name of these sediments has gone through many changes (fig. ___ [N.A.]). At present, two concepts concerning the stratigraphic nomenclature for the sediments between the Harrison and Box Butte formations (as defined by Galusha 1975) are followed: (1) only one lithologic unit of formational rank is present (Schultz 1938); or, (2) two lithostratigraphic units of formational rank are represented (Cook 1965). As presently defined, neither viewpoint is very convincing.

Evidence from the study of these sediments demonstrates that there are two recognizable lithostratigraphic units between the Harrison and Box Butte formations: (1) The finer grained facies of the lower unit is characterized by massive, pale yellowish brown (10 YR 5-7/2-3), silty, very fine, loose sandstones. It is as typified by the sediments superimposed on the Harrison Formation in the upper portion of the Niobrara River valley in the area Peterson (1909, p. 75) designated as the type locality of the Upper Harrison (fig. 1); (2) the finer grained facies of the upper unit, as typified by the sediments superimposed on the Harrison and Monroe Creek formations in the area around Marsland, Nebraska. It is characterized by massive yellowish gray (5 Y 7/2) to pale brown-buff (10 YR 6-8/2), silty, very fine, often bimodal, loose, somewhat coarser grained sandstones in the area of the type section of the Runningwater Formation (Cook 1965). In addition, the coarser grained facies of the upper unit contains crystalline gravels* (granites, pegmatites,

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*Editors' Note: The term crystalline gravel used by the author refers to gravels composed predominantly of igneous and metamorphic clasts.

amphibolites), whereas the coarser grained facies of the lower unit contains lithic gravel,* although the author collected a few crystalline gravel pebbles at the base of the lower unit (section 21, pl. 5).

The superpositional relationship of these units is not present at either type section. However, the stratigraphic relationships of these lithostratigraphic units are exposed at a number of localities within the map area (sections 19, 21, and 28, pl. 5 [S.E.]), and also northeast of Agate and along the divide between the White and Niobrara rivers. In these sections the lower unit underlies the upper, although possibly at section ___ [N.D.] there is an interfingering relationship. At sections 21 and 28, pl. 5 [S.E.]+ the contact is rather sharp. However, at section 27 (pl. 5), and northeast of Agate, the contact is difficult to place.

In terms of stratigraphic nomenclature there are two ways of dealing with these units. First, both units could be considered members of a single formation or, alternatively, each unit could be recognized as a separate formation. Either solution to the nomenclature must take into account the following points: (1) the lithology of the finer grained facies of the two units differs only slightly; (2) in places, the contact between the two units is obscure and may even be gradational (ACSN 1970, art. 5, remark d); (3) the contact relationships of the two units do not exist at their respective type sections; and (4) in disagreement with a statement of McKenna (1965, p. 10), the age of these units or the geologic history (e.g., the number of sedimentary cycles) should not affect the stratigraphic nomenclature (ACSN 1970, art. 4, remark c).

All sediments stratigraphically above the Harrison Formation and below the Box Butte Formation are included within a single lithostratigraphic unit of formation rank. This formation, based on the dominant fine-grained facies, is characterized and unified by the following lithologic features: (1) generally less than 70 percent sand-sized particles; (2) a greater percentage coarse silt than very fine sand; (3) a small percentage of clay; (4) sediments

*Editors' Note: The term lithic gravel used by the author refers to gravel composed predominantly of sedimentary clasts.

+Editors' Note: Measured sections 21 and 28 were chosen by the editors because Yatkola personally demonstrated the superpositional relationship of the Lower Member and Runningwater Member to Hunt in the field in 1975 at these two sections.

moderately well sorted; (5) quartz grains rounded, usually frosted and polycrystalline in thin section; (6) very little, if any, bulk volcanic glass; (7) dark, heavy minerals equant to rounded; (8) mica present; (9) feldspar grains present; (10) color variable (10 R, 5 YR, 10 YR), but rarely gray. In contrast, the following lithologic features characterize the sediments of the Harrison Formation: (1) more than 70 percent sand, and usually more than 80 percent; (2) greater percentage of very fine sand than coarse silt; (3) no clay; (4) sediments well-sorted, on the average better sorted than the above unit; (5) quartz grains subangular to subrounded, not frosted, and monocrystalline in thin section; (6) bulk glass common; (7) dark, heavy minerals less equant, less rounded, and more abundant than in the above unit; (8) mica common, more abundant than in above unit; (9) feldspar grains not present;* (10) color gray (N 5-7; 5 B 7/1; 10 YR 6/2). "Formations are the basic rock-stratigraphic units used in describing and interpreting the geology of a region. The limits of a formation normally are those boundaries of lithologic change that give it the greatest practicable unity of constitution" (ACSN 1970, art. 6, remark c). The lithologic characterization given above provides the qualifications necessary for "the greatest practicable unit of constitution."

McKenna (1965) considered the possibility of containing "the lower and upper units" within the same formation, but rejected this hypothesis on the basis that "these two rock units are at least as separate and distinct from each other as are the rock units bearing the old designations Harrison and Upper Harrison beds" (McKenna 1965, pp. 9-10). My study of the lithology of this sedimentational sequence produces evidence not in agreement with McKenna. The lithostratigraphic unit directly above the Harrison Formation is decidedly different. The lithologic differences between the two lithologic units bounded by the Harrison and Box Butte formations are less obvious.

Considering the results drawn from my observations in the field and a restudy of the sediments in question, the following stratigraphic nomenclature is used in this presentation: (1) the lower and upper lithostratigraphic

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*Editors' Note: The author's incomplete thin section data indicates that he had later found feldspar to be a significant component in the Harrison samples. However, no percentage data were found.

units above the Harrison Formation and below the Box Butte Formation will be included within the same formation; (2) the sediments referred to by Peterson (1909, p. 75) near the Wyoming-Nebraska state line will serve as the original basis and type section for the lower unit; and (3) the section published in Cook (1965, pp. 4-5) in W½ sec. 5, T. 28 N., R. 52 W., Box Butte County, Nebraska, will serve as the basis and type section for the upper unit. The lithostratigraphic name Marsland Formation is retained for that "formation which lies above the Harrison and below the Sheep Creek" (Schultz 1938, p. 441),* since it is the name with priority (ACSN 1970, art. 11) and is well established in the literature (ACSN 1970, art. 11, remark b). The informal lithostratigraphic name Lower Member is applied to the lower unit of the Marsland Formation, since additional mapping to the northwest is necessary to define this unit. The lithostratigraphic designation Runningwater Member, new rank, is applied to the upper unit of the Marsland Formation.

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*Author's footnote: Note that Schultz's concept of the Sheep Creek Formation included Cady's Box Butte Formation (Schultz and Stout 1961, fig. 3).

MARSLAND FORMATION, LOWER MEMBER

Type Section

In this report, the lithostratigraphic term Lower Member is used for the lower part of the Marsland Formation, redefined, and is typified by the sediments referred to by Peterson (1909, p. 75) "immediately east of the Nebraska-Wyoming state line" as "upper Harrison beds." "The beds are exposed for four or five miles along the south side of the Runningwater or Niobrara River a few miles east of the Wyoming state line" (Peterson, 1904, p. 474). Section 30 (pl. 5) of this report was measured approximately 1.75 miles (2.80 km) east of the Nebraska-Wyoming state line on the south rim of the Niobrara River in a deep northeast-southwest trending draw in SE¼ sec. 28, T. 31 N., R. 57 W., Sioux County, Nebraska.

Name and Definition

The sediments of the Lower Member of the Marsland Formation, as here defined, unconformably overlie sediments of the Harrison Formation and are composed of a maximum of 100 feet (30.5 m) of massive, pale-yellowish brown (10 YR 5-7/2-3), silty, very fine, loose sandstones. The rock-stratigraphic term "Lower Member of the Marsland Formation" is applied to approximately 60 to 90 feet (18.3 to 27.5 m) of massive, pale-yellowish brown, silty, very fine, loose sandstones that occur south and east from the type area in the Niobrara valley of eastern Sioux, southern Dawes, and northwestern Box Butte counties. In contrast to the sediments in the type area, the sediments of the Lower Member of the Marsland Formation in the map area are restricted to narrow, steep-walled paleovalley fills and usually contain either basal or intraformational lithic conglomerates. However, the massive, pale-brown, silty sandstone filling the paleovalley is indistinguishable from sediments in the type area. The lithologic similarity of the sediments in the type area and those mapped as Lower Member of the Marsland Formation in the map area (pls. 1 and 2) indicates that they represent the same lithostratigraphic unit, even though the sediments of the Lower Member of the Marsland Formation cannot be physically traced from the type area into the map area.

Most sediments located northeast of Agate on the divide between the Niobrara and White rivers have generally been included within the Upper Harrison beds (sensu Peterson 1909, p. 75; see Cook 1915, p. 63, fig. 3). The result of this study shows that most of the sediments northeast of Agate represent part of the Runningwater Member (see section 26; measured approximately 9 miles (14.5 km) northeast of Agate [S.E.]). Sediments assignable to the Lower Member, as here defined, crop out in this area only at low topographic elevations and resemble the massive, pale-yellowish brown, silty, very fine sandstones of the type section and rest disconformably on the Harrison Formation. The upper contact of the Lower Member is not sharp in this area. Included in the Runningwater Member are all sediments characterized by orange, wavy-type beds interbedded with massive yellowish grey (5Y7/2) to pale brown-buff (10YR6-8/2) silty sandstones. These sediments may also be slightly coarser. However, even this separation is difficult to defend in the field. If the orange, wavy-bedded, indurated sandstone beds were removed, then the massive silty sandstones could not be distinguished from the sediments at the type section of the Lower Member.

Distribution and Thickness

The distribution of the Lower Member of the Marsland Formation along the Niobrara River in the map area is very limited and disjunct (pls. 1 and 2). In most cases these restricted outcrops could not be mapped at the scale used in plate 1 and were mapped within the Marsland Formation.* The contacts of the Lower Member are approximately mapped in the Morava Hills area map (pl. 2). The lithologic character and contact relationships of the sediments of the Lower Member of the Marsland Formation are best exposed and illustrated by section 34 [S.E.] exposed in the west end of the Morava Hills; section 21, exposed on the north face of Barngrover Creek; section 23, exposed on the north rim of the Niobrara River; and section 28, exposed on the south rim of the Niobrara River just south of the Pink Schoolhouse [SE¼, SE¼, sec. 36, T. 29 N., R. 54 W.]. At each of these localities the Lower Member of the Marsland Formation fills a narrow, steep-walled paleovalley and varies in thickness from 60 to 90 feet (18.3 to 27.5 m).

*Editors' Note: Since there is no undifferentiated Marsland Formation mapped on pl. 1, we assume this statement to mean that restricted outcrops of the Lower Member were mapped within the Runningwater Member of the Marsland Formation. In the case of section 21 (SW¼ sec. 30, T. 29 N., R. 52 W.), we were able to confirm this assumption and added the Tml-Tmr contact to pl. 1.

Description of the Type Section

The lithologic features of the type section of the Lower Member also form the basis for the concept of the Marsland Formation developed here. This section is 103 feet (31.5 m) thick, measured from the Harrison-Marsland contact. The base of the section is at an elevation of 4,831 feet (1 470 m) and the top at 4,934 feet (1 500 m). The Harrison-Marsland contact and the Harrison-Lower Member contact are placed at a prominent pitted topographic bench in the area and slightly below a white, ashy(?) bed that contains, in places, green agatized limestone lenses and lithic pebbles. This horizon is interpreted as an old land surface on the basis of these features. The sediments above this contact are characterized by [lithologic features given in the introductory statement (p. 21)]. In contrast the underlying sediments of the Harrison Formation are characterized [as given in the introductory statement (pp. 14-15)]. The sediments of the Lower Member also weather to steeper, vertical-faced cliffs, whereas those of the Harrison Formation weather to a rolling mound-shaped topography. Unfortunately, the contact of the Lower Member-Runningwater Member is not exposed at this section. The sediments of the type section are rather uniform from bottom to top. These sediments are characterized as massive, pale-yellowish brown (10 YR 5-7/2-3), silty, very fine sandstones [sample 8, fig. 7]. The hues of the uppermost 10 to 15 feet (3.05 to 4.55 m) are somewhat redder (5R-10R). The sediments exposed at the type section are more compact than laterally equivalent sediments exposed a few miles to the southeast.

A number of prominent topographic benches are distributed throughout the type section. These benches average 1.5 to 2 feet (0.55 to 0.61 m) in thickness and are characterized by hard, silica-cemented, dark yellowish brown (10 YR 4/2) sandstones that have a distinctive pitted surface texture. Many of these benches can be traced laterally for thousands of feet, whereas others extend only a few tens of feet.

Lithologic Character Within the Map Area

The thickest and best exposed section of the Lower Member of the Marsland Formation in the map area is located on the north side of Barngrover Creek, in NW¼ SE¼ SW¼ sec. 30, T. 29 N., R. 52 W., Dawes County, Nebraska (section 21, pl. 5; fig. 8). At this locality, the sediments of the Lower Member of the

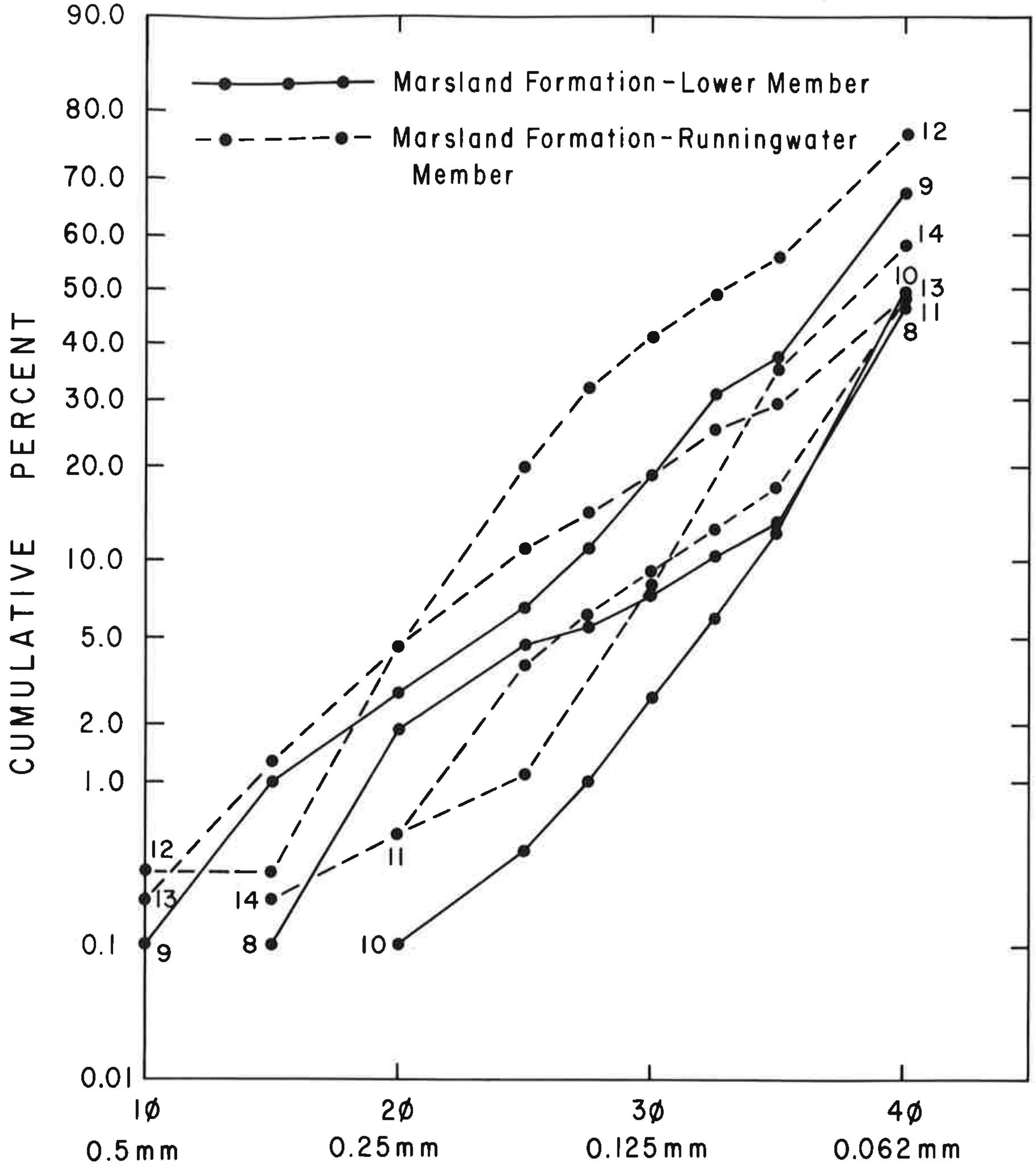

Fig. 7. Log-probability curves obtained by sieving samples of the Marsland Formation. Location of samples given in appendix A.

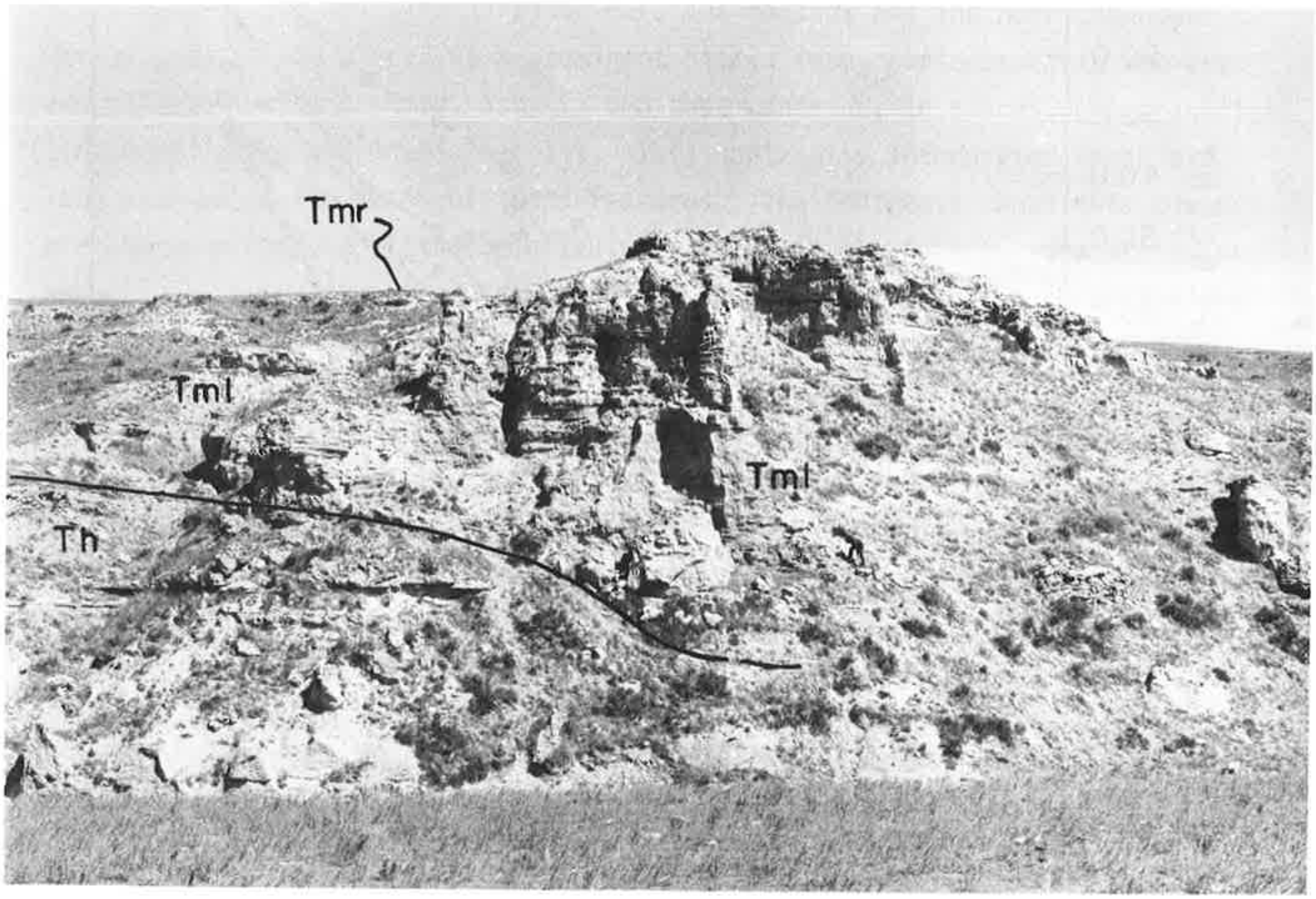

Fig. 8. Paleovalley filled with sediments of the Lower Member of the Marsland Formation that rest unconformably on the eroded surface of the Harrison Formation in NW¼ SE¼ SW¼ sec. 30, T. 29 N., R. 52 W., Dawes County. Note person near right center of photograph for scale.

Marsland Formation rest unconformably on the eroded surface of the Harrison Formation and are disconformably overlain by the Runningwater Member of the Marsland Formation. The maximum thickness of the Lower Member, measured from the base of the lowest observed point within the narrow paleovalley to the Lower Member-Runningwater Member contact, is 86 feet (26.0 m). The base elevation of this section is 4,314 feet (1 310 m) and the top elevation is 4,400 feet (1 340 m). The highest topographic and stratigraphic exposure of the Harrison Formation occurs at 4,390 feet (1 340 m). The width of the paleovalley at this point is less than 500 feet (152 m). Three hundred feet (91 m) to the east of this paleovalley is a similar paleovalley incised into the Harrison Formation to an elevation of 4,326 feet (1 320 m).

The Harrison-Lower Member contact is marked by a prominent well-indurated, 4- to 9-foot-thick (1.22- to 2.75-m) lithic pebble conglomerate (section 21, pl. 5). Sediments within this bed are poorly sorted with clasts approaching 7.9 inches (200 mm) in diameter, although the median is around 0.8 inches (20.3 mm). Most of the clasts are well rounded and composed of reworked Harrison sediments and reworked pebbles of the lithology seen at the type section of the Lower Member. Three crystalline gravel pebbles were found within this basal conglomerate.

The bulk of the sediment filling this narrow, steep-walled paleovalley is indistinguishable from that seen at the type section. However, the prominent pitted benches are not present and, at many levels within the lower 69 feet (21.0 m), there are lenses of lithic pebbles that average 0.39 inch (9.9 mm) in size. These conglomeratic lenses do not extend more than 20 to 25 feet (6.1 to 7.6 m) and are rarely more than 1.5 feet (0.47 m) in extent. These conglomerates are clearly intraformational in origin, because the composition of the lithic pebbles is similar to that of the massive silty sandstones of the channel fill.

The sediments of the next 10 feet (3.05 m) of this section are characterized by a gradual upward increase in the amount of calcium carbonate, as indicated by the grayer color of the sediments and lime lenses. The upper 2 to 3 feet (0.61 to 0.91 m) is very light gray in color and highly calcareous. The top of the Lower Member is placed at the top of a 1-foot-thick (0.305-m) gray calcite-cemented ledge. The texture of the sand of this upper 10 feet (3.05 m) of the Lower Member is the same as the browner sand below. This zone of calcium carbonate enrichment represents an old land surface. The lime was probably leached downward as a result of surface evaporation, since the calcium enrichment zone increases in calcium carbonate content near the top of the section (reference [N.A.]).

The orientation of the channel axis of section 21 [S.E.] is N-W [degrees N.A.]. This same channel can be seen cutting through the western part of the Morava Hills (pls. 2, 5, 6). The basal cut of this channel at this locality [section 34*] is not exposed. However, sections 33 and 35 (pl. 6)* show the Lower Member lying unconformably on the Niobrara Valley Monroe Creek Formation. These sections were not measured in the deepest part of the channel cut. The base of the lower member at section ___ [N.D.][+] is at an elevation of 4,333 feet (1 320 m). The sediments of the lower 35 feet (10.7 m) of this section are indistinguishable from those of the type section, although a number of platy-bedded horizons are present. The Monroe Creek-Lower Member of the Marsland Formation contact is placed at the top of a gray, hard ledge. The Monroe Creek sediments differ from those of the Lower Member in finer grain size, grayer hues, and a more even-weathered surface. A calcareous, slabby, very-fine sandstone bed occurs at 35 feet (10.7 m) above the contact. This bed grades laterally into a 1- to 1.5-foot-thick (0.305-to 0.455-m) partially agatized limestone bed. Above this limestone bed is 13 feet (4.0 m) of sand similar to the lower 35 feet (10.7 m). The upper 4 to 5 feet (1.22 to 1.52 m) of this unit resembles the upper 4 to 5 feet (1.22 to 1.52 m) feet of section ___ [N.D.]. There is an enrichment of calcium carbonate, although the amount of calcium carbonate enrichment is not as intense. The top of this unit at elevation 4,381 feet (1 340 m) is considered to be a rock-stratigraphic correlative of the calcium carbonate enrichment zone that caps section ___ [N.D.], and the Lower Member-Runningwater contact is placed at the top of this zone. Immediately above this petrocalcic horizon are a number of indurated, orange, blocky, wavy-bedded sandstone beds interbedded with massive greenish buff silty sand.

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*Editors' Note: On the author's original draft of pl. 6, the Marsland Formation was not divided into members. In Yatkola's field notes (MS: Field Book No. 3, pp. 32, 37), however, he clearly designated the members for sections 33 and 35, and these are so labeled on pl. 6.

+Editors' Note: This section was not illustrated by the author except in his field notes [Yatkola MS]. It is referred to as "the key gully section" (Field Book #2, p. 26) and is located in the W½ NW¼ NE½ sec. 1, T. 28 N., R. 52W.

In the two previous sections, the upper contact of the Lower Member and the Runningwater Member is rather sharp, and easily recognized, although difficult to trace laterally. However, at section 23 (pl. 5), which is completely exposed, the contact between these members is arbitrarily placed. The base of the Marsland is at an elevation of 4,393 feet (1 340 m). As at the previous sections, the Marsland Formation rests unconformably on the eroded surface of the Harrison Formation and fills a narrow, steep-sided paleovalley. At the base of the Marsland there is a distinct 3- to 4-foot-thick (0.91- to 1.22-m) lithic conglomerate composed mainly of reworked Harrison clasts. These pebbles are comparable to those in section ___ [N.D.], except they do not occur in an indurated ledge and are not as round. Above this contact there is 17 feet (5.2 m) of light brown sand indistinguishable from that seen in section ___ [N.D.]. A 1- to 1.5-foot-thick (0.305- to 0.455-m) brown ledge of the same material occurs above this unit. Above this indurated ledge is 6 feet (1.83 m) of massive, greenish-buff silty sandstone, the upper part of which is wavy-bedded and orange. Above this unit there are two indurated ledges composed of well-rounded, fine- to medium-grained granitic sand. These ledges grade laterally into massive, buff to greenish, silty sand. At the top of section 23 is an indurated 2- to 3-foot (0.61- to 0.91-m) ledge bearing crystalline gravels. The gravels grade laterally into cross-bedded, coarse sand, and into massive, buff, silty sandstones. The sediments of the lower 17 to 20 feet (5.2 to 6.1 m) of this section are indistinguishable from sediments of the type section and grade upward into sediments indistinguishable from those of the type section of the Runningwater Member. The contact is arbitrarily placed at the top of the brown ledge located 22 feet (6.7 m) above the base of the channel cut.

Section 28 (pl. 5) exposed in center westline, NW¼ sec. 15, T. 28 N., R. 54 W., illustrates the same gradational contact, although it is not as well exposed as the previous section. The sediments of the Lower Member fill a narrow, steep-walled paleovalley. There is a lithic conglomerate a few feet above the unexposed Harrison-Lower Member contact similar to that described in the previous section and the massive sand filling the paleovalley is indistinguishable from the lithology of the type section. Approximately 41 feet (12.5 m) of this lithology is exposed at the base of the section. The next 27 feet (8.2 m) of this section is not well exposed, although a number of small outcrops indicate that the sediments are similar to those of the type section. Above this level occurs massive, buff, silty sandstones that are coarser grained than the typical Lower Marsland sediments and lighter in color, although the lower part of this outcrop is very similar to the type sediments. Above this unit is a brown wavy-bedded sequence interbedded with a thin, gray, fine- to medium-grained indurated granitic sandstone ledge. Above this unit there is a sharp break in slope and 17.5 feet (5.3 m) of orange, blocky, wavy-bedded sandstone, interbedded with massive, pale-yellowish brown, silty sandstone. As in the previous section, the contact is placed between the Lower Member and the Runningwater Member at the top of the highest pale-yellowish brown, silty, very fine loose sandstone, although it has to be arbitrarily placed within a zone of 5 to 10 feet (1.52 to 3.05 m).

A maximum of 12 feet (3.65 m) of the Lower Member is exposed in section 20 (pl. 5) [S.E.]. However, these sediments could in all propriety be included within the Runningwater Member. The contact between the two members at this locality is gradational, both laterally and vertically.

Vertebrate Fossil Localities

No fossil vertebrates were collected from the Lower Member of the Marsland Formation within the study area. A number of collections of fossil vertebrates have been made within the area of the type section (section 30, pl. 5). These include O. A. Peterson's 1901 Carnegie Museum collection made a few miles east of Wyoming-Nebraska state line for 4 or 5 miles along the south side of the Niobrara River in beds termed "Nebraska" or "Upper Harrison" by Peterson (1904, 1907). Also included are C. H. Falkenbach's F:AM "about 9 miles SW of Harrison" collection made in the Niobrara Canyon immediately east of the Nebraska-Wyoming state line [Schultz and Falkenbach 1940, p. 291, F:AM 42494].

Environment of Deposition

The Lower Member can be divided into two distinctive facies: (1) lithic conglomeratic facies and (2) massive facies. Recent deposits similar to the lithic conglomeratic facies of the Lower Member can be seen in most gullies draining the divides of the Niobrara River. These conglomerates have the same composition as sediments exposed farther up the gully, are poorly sorted deposits, have not been transported far, are locally derived, and accumulate in gullies on slopes between the river valley and the tablelands. Sediments of the lithic conglomerate facies represent "gullywash" accumulations in response to very high energy flow conditions that last a short time.

The massive facies is the dominant lithology of the Lower Member. The following features suggest to the writer that this facies represents a paleoloess: sediments well sorted; particle size distribution similar to Pleistocene loess deposits (Lugn 1962, p. 46); bedding massive and uniform; quartz grains frosted; cut and fill structures lacking; and, color light. These sediments are not as well-sorted and as fine-grained as the Niobrara Valley Monroe Creek paleoloess, suggesting a closer proximity to the source area. Loess is eolian in origin (Lugn 1962) and requires a source that contains fine sand and silt, such as a river floodplain (Smith 1942). The loessic sediments in the map area filling the narrow, steep-sided paleovalley and associated with the lithic conglomeratic facies may represent "redeposited, valley-slope loess" (Elias 1945, p. 227).

The pitted, indurated beds associated with the massive-bedded facies at the type locality represent accumulations of loess on a stable land surface. While these sediments were accumulating, prairie grasses grew, died, and trapped dust. When the grasses decayed, a lattice network resulted. The rate of loess accumulation was relatively slower during times of accumulation of loess associated with these old land surfaces than during times of accumulation of the bulk of the Lower Member loess.

MARSLAND FORMATION, RUNNINGWATER MEMBER, NEW RANK

Type Section

In this report, the lithostratigraphic term Runningwater Member is used for the upper member of the Marsland Formation, redefined, and is typified by the section measured by Skinner (in Cook 1965, fig. 3) in the W½ sec. 5, T. 28 N., R. 52 W., Box Butte County, Nebraska (section 8, pls. 2, 3). These sediments are well exposed throughout the map area (pls. 1, 2).

Name and Definition

The sediments of the Runningwater Member of the Marsland Formation, as here defined, unconformably overlie sediments of the Monroe Creek and Harrison formations, and conformably overlie sediments of the Lower Member of the Marsland Formation. These sediments are composed of a maximum of 300 feet (91 m) of massive, yellowish gray (5Y 7/2) to pale brownish buff (10 YR 6-8/2), silty, very fine to fine, often bimodal (fig. 6), loose sandstones; wavy-bedded sandstone; and crystalline gravel lenses.

Distribution and Thickness

The sediments of the Runningwater Member of the Marsland Formation blanket and fill a 2- to 4-mile-wide (3.20- to 6.4-km) paleovalley that developed after the deposition of the sediments of the Harrison Formation (fig. 9, pls. 3 to 6). These sediments are thickest near the axis of the paleovalley and thin to the north-northwest and south-southeast. [Skinner et al. 1977 (fig. 1) show the approximate extent of the Runningwater paleovalley in western Nebraska.] The thickest and best exposed sections of the Runningwater Member in the map area are exposed northwest of Marsland (sections ___ [N.D.], pl. 4). The sediments of the Runningwater Member exposed on the south side of the Niobrara valley are approximately 150 feet (45.5 m) thick, as originally indicated by Schultz (1938, p. 441).

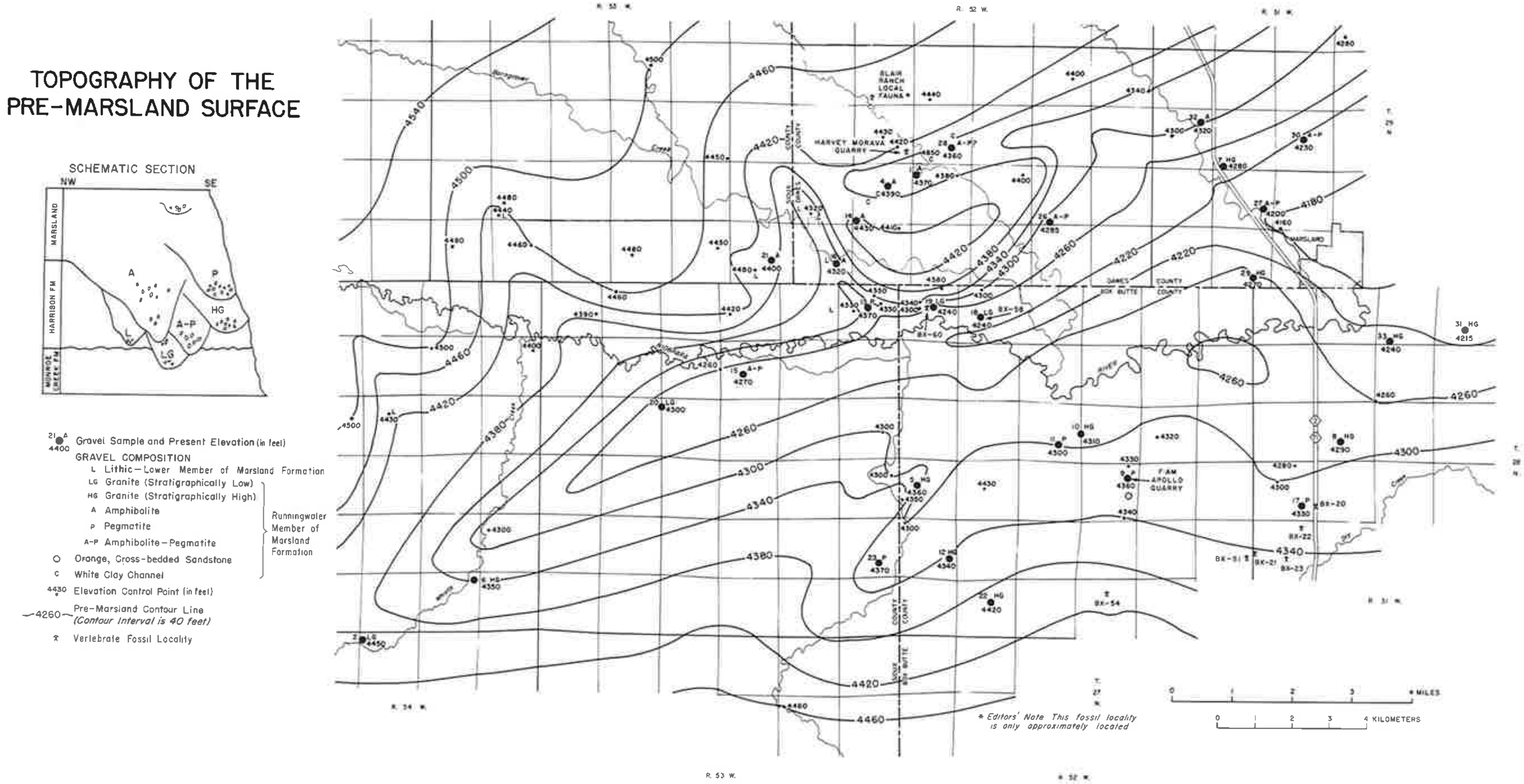

Fig. 9. Topography of the pre-Marsland surface in portions of Box Butte, Dawes, and Sioux counties. Runningwater Member fossil and gravel localities are plotted on the map.

Description of the Type Section

The type section of the Runningwater Member was well illustrated and described by Cook (1965). It is unfortunate that this section was chosen as the stratotype, since it is poorly exposed, isolated from other outcrops of the Runningwater Member, and lacks an upper stratigraphic contact. In addition, the "coarse granitic pebbles" that formed the basis for Cook's concept of the "Runningwater Formation" make up a very small percentage of the total thickness of that unit. However, this section must be maintained as the type section (ACSN 1970, art. 13, remark h).

The sediments exposed at the type section of the Runningwater Member of the Marsland Formation rest unconformably on the Niobrara River Valley Monroe Creek Formation (fig. 10). The original section published by Cook (1965, fig. 3), as measured by Skinner, represents a section of exposures in the Morava Hills. The base of the type section is exposed near a ranch dump in the first small north-south trending sand wash east of UNSM BX-58 in SW¼ NE¼ NE¼ NE¼ sec. 5, T. 28 N., R. 52 W., Box Butte County, Nebraska (section 8, pl. 3; pl. 2). At the contact a loose, feldspathic sandstone containing crystalline gravels overlies the massive, orange brown siltstones of the Niobrara Valley Monroe Creek Formation. Located a few feet above the contact and below UNSM BX-58 is an outcrop of greenish buff, silty sands containing crystalline gravels floating within the unit (i.e., the crystalline gravels are not concentrated in a lens, but are completely isolated from one another). A white platy clay occurs locally at the top of this massive unit. The sediments at the level of UNSM BX-58 are cross-bedded to planar-bedded, gravelly in part, fine- to medium-grained sandstones. A number of hard claystone lenses are interbedded with this sequence. The upper part of the section is exposed in a N 45° W trending draw just east of the north-south portion of the road along the Niobrara River. The dominant sediment in this part of the section is a loose, fine- to medium-grained feldspathic sandstone containing rare crystalline gravels. One local exposure is similar to a Platte River longitudinal bar (Smith 1970) in having parallel bedded alternation of crystalline gravel lenses and massive silty sand. A number of local, indurated, thinly bedded to low angle cross-bedded, poorly sorted, gravelly sandstones are exposed in the sequence. These often weather to a distinctive spherical shape (Schultz 1941). Near the top of the exposed sequence a hard, gray-white, clayey siltstone forms a prominent

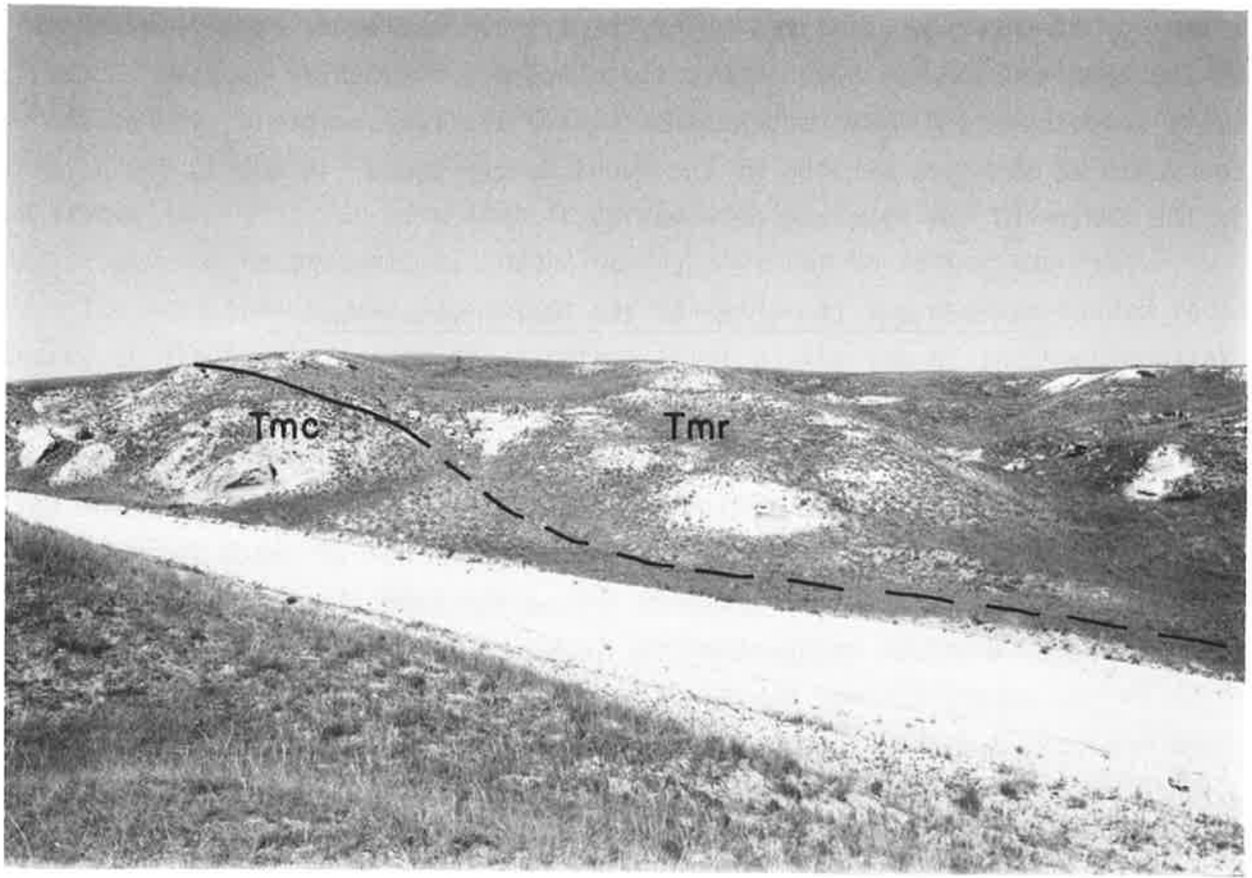

Fig. 10. Lower contact of the Runningwater Member of the Marsland Formation at the type locality of the Runningwater, section 8 (pl. 3). Here the Runningwater Member rests unconformably on the Monroe Creek Formation. Photograph was taken looking east-northeast from west side of Niobrara River road in SW¼ NE¼ SW¼ NW¼ sec. 5, T. 28 N., R. 52 W., Box Butte County.

topographic bench that can be traced around the south side of the slope. Above this bench there are only a few outcrops, primarily of loose sand and occasionally a crystalline pebble. The Runningwater Member caps the highest knoll west of the north-south portion of the road.

The type section of the Runningwater Member can be correlated with similar deposits on the north and south side of the Niobrara River (pls. 3 to 6). The lithology of these deposits resembles the overall character of the sediments at the type section, although these sediments are dominantly massive bedded, silty sandstones and wavy-bedded sandstones. The coarser grain size of the sediments at the type section of the Runningwater Member is due to its location in the center of the Marsland paleovalley.

Lithologic Character of the Runningwater Member

The sediments of the Runningwater Member exhibit greater lateral and vertical variability than do those of the Lower Member. This is a reflection of the lithogenesis of these sediments and their position relative to the axis of the Marsland paleovalley. Individual beds pinch out or grade laterally into other sediments and can rarely be traced for more than a few hundred feet. At least seven distinct sedimentary facies are recognized:

(1) massive sandstone facies
(2) wavy-bedded sandstone facies
(3) conglomeratic facies
(4) agatized limestone facies
(5) bedded clay facies
(6) gray sandstone facies
(7) cross-bedded sand facies

Massive sandstone facies.--This is the dominant facies of the Runningwater Member. An estimated 70-75 percent of the total thickness (volume) of the Runningwater Member is represented by this facies. The modal size of these sediments is less than 4 phi (0.063 mm) and the mean is very fine sand. They are moderately well to well sorted and contain some clay (table 1, fig. 7). These sediments contain common feldspars, both orthoclase and plagioclase, rounded heavy minerals, and rounded, frosted quartz grains. Heavy minerals amount to about 1 percent of the sediments (Horney 1941).

The color of these sediments is highly variable, from brown, red, light green, buff, to gray. However, the dominant colors vary between yellowish gray (5Y 7/2) to pale brownish buff (10 YR 6-8/2). Hues of brown and red (5R, 10R, 5 YR, 10YR) are more common higher in the section and to the north and west, whereas greenish tints and grays (5Y, 5GY, 5G) are more common lower in the section and near the axis of the paleovalley. The higher parts of the section tend to be primarily buff in color.

For the most part these sediments are rather soft and often compact. In places, silica and calcite cemented horizons are interbedded within the massive silty sands (Yatkola 1972, pl. 3, fig. 3). The cemented horizons can rarely be traced laterally for more than 50 to 75 feet (15.2 to 22.9 m). Root casts may or may not be present, although locally they can be rather abundant.

The most intense development of calcification of the massive-bedded facies occurs on the south side of the Niobrara River at the top of the Runningwater Member of the Marsland Formation. This calcium carbonate crust has been called the "honeycomb ledge" (Cady and Scherer 1946, p. 26) and the "Platy Bench" (Galusha 1975, p. 28). The thickness of the capping crust varies from 2 to 3 feet (0.61 to 0.91 m) and is characterized by hard, pitted lenses of calcium carbonate a few inches thick (fig. 11). Each calcareous lens has an irregular upper and lower contact and individual lenses increase in thickness near the top of the formation. The platy, calcified lenses contain inclusions of rounded clayey sandstone pebbles. These inclusions are often surrounded by concentric layers of calcium carbonate, although the individual particles are not calcified. Below the thick calcium carbonate crust is a 3- to 4-foot-thick (0.91- to 1.22-m) zone of horizontal lime stringers. The above structures are very similar to pisoliths that form as a result of the breaking up of parent material during the process of caliche formation (Swineford, Leonard, and Frye 1958). The thicker calcified lenses at the top of the unit indicate that the lime was deposited at the surface as a result of evaporation and not as a result of the upward movement of the water table (reference [N.D.]).

<u>Wavy-bedded sandstone facies</u>.--An estimated 20 percent of the total thickness (volume) of the Runningwater Member is represented by this facies. Sediments of this facies occur as single beds or, more often, as sets of beds that are interbedded with the massive sandstone facies. The contact with sediments of the massive facies is usually sharp. These sediments often grade laterally into thinly laminated beds and ultimately into the massive facies.

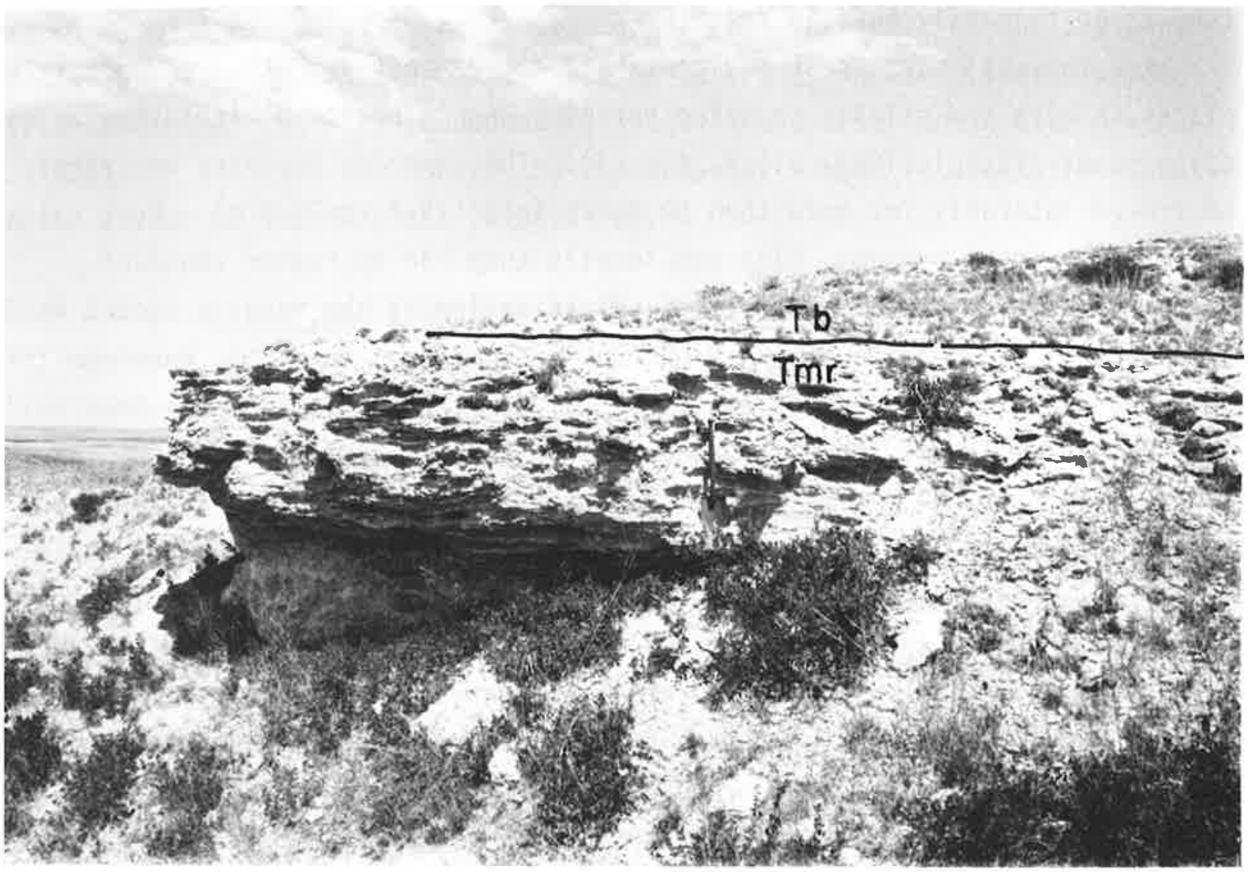

Fig. 11. The "Platy Bench" (section 1, pl. 3) at the contact of the Runningwater Member and the Box Butte Formation (SE¼ NE¼ SE¼ NE¼ sec. 30, T. 28 N., R. 51 W.) in the type area of the Marsland Formation of Schultz (1938). The shovel is 28 inches (0.71 m) long.

This facies is easily separated from the massive facies on the basis of color and hardness. The hues are similar, but the lightness values are lower (3-5) and the chroma values higher (3-6) in the wavy-bedded facies. This produces a color that is darker and more vivid than the pale colors of the massive facies. Also sediments of this facies are better indurated and more resistant to erosion than those of the massive facies, and as such weather into a distinctive blocky appearance. These sediments are slightly coarser grained than the massive facies, although the sorting is similar. Floating crystalline gravel pebbles occur in this facies, although they are very rare. The most characteristic feature of this facies is the wavy nature of the individual beds (fig. 12). The amplitude of the individual wavy beds varies from nearly flat to over 1.5 feet (0.55 m). The individual beds range in thickness from 1 to 10 inches (25.5 to 255 mm) and vary from massive to laminated. The thickness of the bed remains constant throughout the wave. There is no thickening or thinning of the bed in the troughs or at the summits. The axes of the successive waves are in line with the lower bed.

There is often a periodicity to sets of wavy beds. In such cases the lowest bed is a few inches thick, while the stratigraphically higher bed is somewhat thicker and possibly paired. The next highest bed set is also thicker and separated from the stratigraphically lower bed by less distance than were the lowest two beds. This progressive upward increase in the thickness of the beds, and decrease in the distance between superimposed wavy beds, continues until many thick beds coalesce. On rare occasions these beds are truncated.

A polygonal pattern is usually developed on the bedding plane. Individual blocks of the bed are surrounded by a very fine sand. This polygonal pattern is probably responsible for the blocky character of these sediments.

Sand volcanoes similar to those described by Burne (1970) occur at many levels. These are characterized by the abrupt ending of a wavy bed or set of wavy beds. A number of blocks of the disrupted zone are usually found above this zone. Such structures are indicative of soft sediment flow.

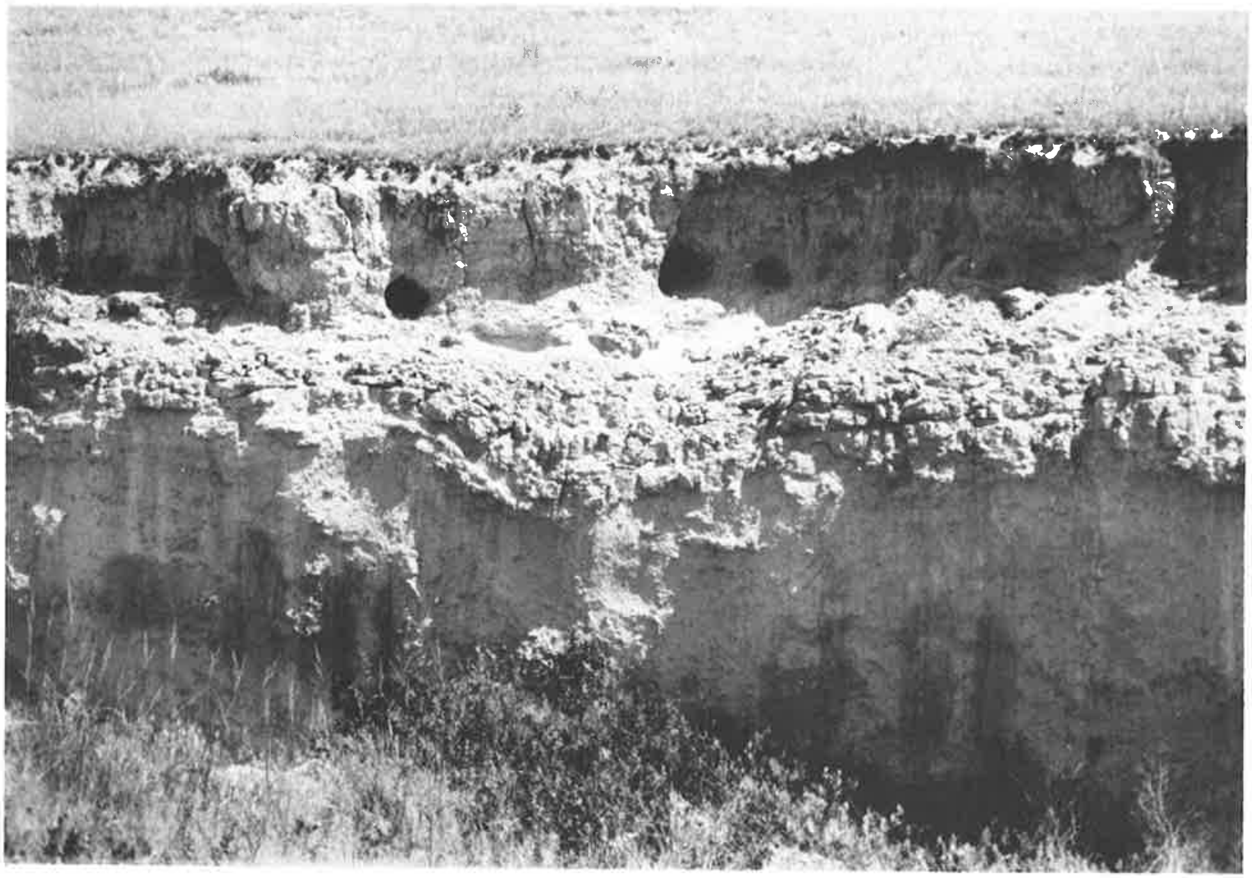

Fig. 12. Wavy-bedded sandstone of the Runningwater Member (NE¼ NE¼ sec. 30, T. 28 N., R. 51 W.) in the type area of the Marsland Formation of Schultz (1938). The outcrop is approximately 18 feet (5.5 m) high.

Conglomeratic facies.--Cook (1960, 1965) was much impressed by the occurrence of crystalline gravels in the sediments he eventually named "Runningwater Formation." The crystalline gravels that Cook mentions occur within the Runningwater Member of the Marsland Formation and represent less than 5 percent of the total thickness (volume) of the unit. The gravels are very localized and limited in distribution. However, these isolated and widely scattered gravel lenses are distributed from the bottom to the top of the section, although they are more common in the lower half of the section. They cannot be traced laterally for more than 10 feet (3.05 m). These crystalline gravels may be massive, horizontal-bedded, or cross-bedded. Concentrated pockets of crystalline gravels can be traced laterally into the massive facies. Gravel can commonly be found floating in the massive facies. Figure ___ [N.A.] illustrates that such a transition from abundant to no crystalline gravels can take place in less than 10 feet (3.05 m). Most pebbles fall within the -2 to -4 phi (4 to 16 mm) size range, although pebbles approaching -5 phi (32 mm) have been collected. On the average, the pebbles do not greatly exceed 0.4 inches (10.2 mm). The pebbles are usually rather rounded.

The composition of the crystalline pebbles varies from outcrop to outcrop. Pebble counts of three distinct pebble types for more than 200 pebbles in the size range of -2 to -3.5 phi (4 to 12 mm) were made for each of 33 gravel samples from geographically and stratigraphically separated localities (table 2, fig. 9).* Granitic pebbles are characterized by approximately equal proportions of pink orthoclase feldspar and milky plagioclase feldspar, abundant clear quartz, and a small percentage of mafic minerals (biotite, amphibolite, muscovite). Some granite pebbles have an iron oxide stain, possibly representing altered magnetite or amphibolite, or contain sericite. Graphic granite occurs in a few samples. A pebble was classified as a pegmatite if the pebble was made up of a single large crystal of quartz or plagioclase. Amphibolite pebbles are black, contain small percentages of quartz, and occasionally are bedded.

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*Editors' Note: The author also included an amorphous silica (chert) and a schist-gneiss class in the pebble counts. Not all samples contained 200 pebbles.

TABLE 2

Pebble Counts of Runningwater Gravel Samples
(Location of samples given in appendix B)

Percent of Pebble Types

Sample	Granite	Pegmatite	Amphibolite	Amorphous Silica (Chert)	Schist & Gneiss	Total Pebbles
GS - 1	59.7	10.1	29.8	0	0.4	238
2	77.8	13.9	8.3	0	0	180
3	89.7	5.9	4.4	0	0	68
4	45.4	24.4	28.5	0	1.7	291
5	87.2	12.8	0	0	0	188
6	83.1	8.1*	7.6	0	1.2	248
7	89.3	8.6	2.1	0	0	197
8	79.0	19.0	1.0	1.0	0	205
9	44.0	56.0	0	0	0	240
10	81.4	8.8	9.8	0	0	197
11	46.2	34.1*	6.1	13.6	0	132
12	91.5	7.3	1.2	0	0	164
13	71.8	28.2	0	0	0	39
14	57.2	7.9	30.7	0	4.2	215
15	59.3	23.7	14.8	0.7	1.5	135
16	55.7	10.0	33.6	0.7	0	140
17	48.4	51.1	0.5	0	0	190
18	84.1	14.0	0.6	1.3	0	157
19	74.7	19.8	5.5	0	0	182
20	79.0	15.9	5.1	0	0	182
21	47.4	13.3	39.3	0	0	135
22	84.3	13.1	2.0	0.6	0	198
23	53.1	45.5	1.4	0	0	213
24	57.9	41.3	0.8	0	0	259
25	90.7	5.8	2.2	0	1.3	225
26	70.5	12.3	16.8	0	0.4	268
27	78.6	3.3*	17.1	0	1.0	275
28	68.1	13.4	17.3+	0.8	0.4	254
29	81.4	8.1	10.5	0	0	199
30	76.2	7.0	15.4	0.7	0.7	143
31	88.0	8.6	3.0	0.4	0	232
32	58.0	14.0	26.8	0	1.2	336
33	80.7	12.0	7.3	0	0	259

*includes graphic granite
+includes 2 anorthosite pebbles

The elevation of each sample was corrected to a composite vertical section by correcting to the base level of the Runningwater Quarry and by correcting for a regional gradient of 13.5 feet per mile (2.55 m/km). A bivariate plot of the percentages of amphibolite and pegmatite separates the samples into four statistically separate clusters (fig. 13).

Five separate channel types can be recognized, based on the geographic and stratigraphic distribution of the pebble samples (fig. 9).* These are, in order of superposition: granite (stratigraphically low); amphibolite-pegmatite; granite (stratigraphically high); amphibolite; and pegmatite. The amphibolite-bearing channels are restricted to the north side of the Niobrara River, while the pegmatite-bearing channels are restricted to the south side. Apparently there is a mixing of the two channel systems at the eastern end of the map area (samples 27 and 30). The granitic channels are mainly restricted to the main axis of the drainage system.

Agatized limestone facies.--Limestone beds are not very common in the Marsland Formation. A grayish white 1-foot-thick (0.305-m) limestone bed is exposed north of Marsland (section 14, pl. 4). It cannot be traced very far laterally and it grades into a calcareous silty sand. A number of very localized marl deposits are present at various stratigraphic horizons. Sediments associated with this facies probably accumulated in small evaporating ponds.

Bedded clay facies.--This facies is very limited in distribution. The best exposures of this facies occur in secs. 21, 28, 29, T. 29 N., R. 52 W., Dawes County, Nebraska (pl. 1). At these localities sediments of the bedded clay facies fill very shallow and narrow paleovalleys, less than 15 feet (4.55 m) deep and 100 to 150 feet (30.5 to 45.5 m) wide. This facies is characterized by a thin to medium bedded, often laminated, very light gray to white (N 8 to 9), silty claystone. Sediments of the lower part of these fills are blocky, in comparison to the thinly laminated sediments higher in the section. At the base of the facies there usually occurs a gravelly sandstone or a distinct lithic conglomerate composed of white clay pebbles. Clay pebbles occur at many limited horizons within the unit, but crystalline gravels do not occur interbedded with the silty clays. Near section 17 (pl. 4), the bedded

*Editors' Note: An additional channel type characterized by lithic gravels (L) is illustrated on fig. 9. These gravels are described in the discussion of the Lower Member of the Marsland Formation.

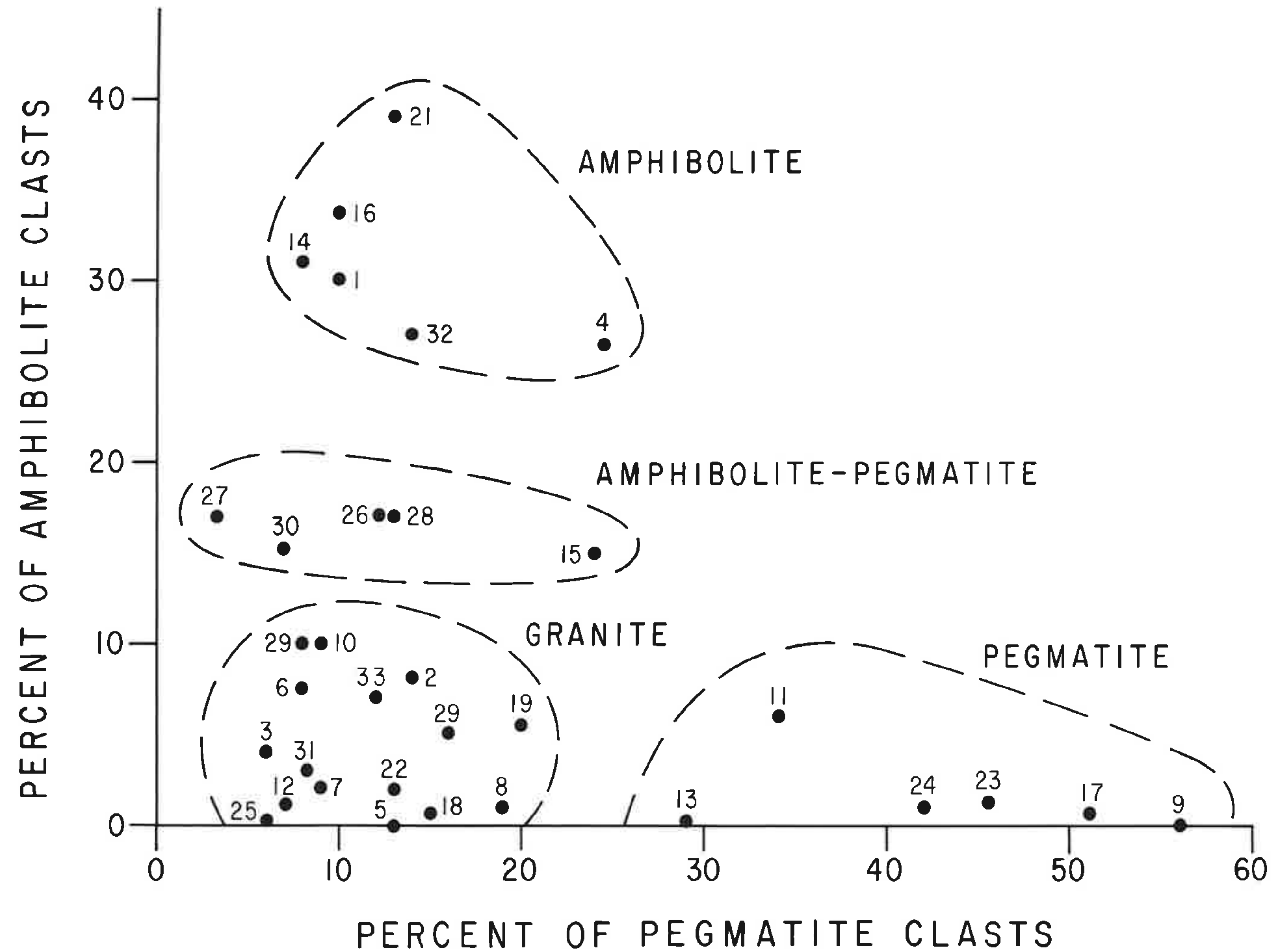

Fig. 13. Bivariate plot of percent amphibolite clasts in Runningwater Member gravel samples (4- to 12-mm size fraction). The sample number is shown beside each datum point. See appendix B and figure 9 for sample locations.

clay facies occurs stratigraphically above the crystalline gravels. The orientation of the axis of this paleovalley fill is N 45° E and the gradient on the base of the channels is 15 to 16 feet per mile (2.85 to 3.05 m/km).

Sediments associated with this facies accumulated in small, abandoned channels. These accumulations of clayey siltstones took place "in essentially a still-standing body of water when the channel was abandoned" (Meckel 1972, p. 639). Such abandoned channel deposits are part of a channel-fill sequence and are usually underlain by the coarser grained clastics of the active channel. Similar coarser grained clastic deposits occur below the bedded clay facies.

Cross-bedded sand facies.--The only exposure definitely assignable to this facies is located on the east side of the northwest-southeast trending wash in a cattle shelter in the center of sec. 32, T. 28 N., R. 52 W. The very fine sand is yellowish gray (5Y 7 to 8/1), moderately well sorted, contains no clay and a very small percentage of material less than 4 phi (0.062 mm). Larger quartz grains are rounded, uncorroded, and frosted, whereas many of the smaller grains are not frosted. Sedimentary structures associated with this facies include: contorted bedding, truncation of beds, and steep (35°) dips of foresets. These structures are very similar to the dune structure described by Bigarella (1972).

Gray sandstone facies.--This facies is very localized and occurs at many stratigraphic horizons. The sediments of this facies range in thickness from 0.5 to 4 feet (0.152 to 1.22 m) and rarely extend laterally more than 100 feet (30.5 m). They are well indurated, bedded to cross-bedded (although more than often they are simply massive), very light gray (N 8) to pinkish gray (5YR 8/1), poorly sorted, fine- to medium-grained, and calcite cemented. These beds form ledges, since they are more resistant to erosion than the surrounding sediments. The lower surface is usually convex. Gravel particles are occasionally present. Outcrops of this facies occur in sections 14, 15 (pl. 4), and the Morava Ranch key gully section [W½ NW¼ NE½ sec. 1, T. 28 N., R. 52 W.].

Lower Stratigraphic Contact

Sediments of the Runningwater Member of the Marsland Formation rest unconformably on the eroded surface of the Monroe Creek and Harrison formations, and conformably overlie sediments of the Lower Member of the Marsland Formation (pls. 3 to 6). At the type section the sediments of the Runningwater Member fill a channel cut through the Harrison Formation into the Monroe Creek Formation. The lower stratigraphic contact of the Runningwater Member is usually sharp and easily recognized in the field. The contact varies from a deeply channeled surface with considerable relief, as at the type section (section 8, pl. 3, fig. 10), to a planar eroded surface with little relief (section 9, pl. 3 [S.E.]), to a conformable contact (section 19, pl. 5 [S.E.]), to a gradational contact (sections 23 and 28, pl. 5 [S.E.]). The sediments at the contact vary from the massive facies, to the conglomeratic facies, to the bedded clay facies. The stratigraphic profiles shown on plates 3 to 6 illustrate the configuration of the lower contact of the Runningwater Member.

Description of Most Complete Section

The most complete and best exposed section illustrating the lithologic character of the Runningwater Member of the Marsland Formation in the map area is located on the south side of a high hill, known to the local ranchers as the "skull," in secs. 23, 25, and 26, T. 29 N., R. 52 W., Dawes County, Nebraska (section 15, pl. 4). The base of this section is situated on the north side of a county road in SE¼ SE¼ SW¼ sec. 25, T. 29 N., R. 52 W., Dawes County, Nebraska. The section is a composite of exposures along a small northwest-southeast trending wash. The top of the section is located at the top of a small pinnacle just east of a ranch road, near the center of the west line, SW¼ SE¼ sec. 23, T. 29 N., R. 52 W., Dawes County, Nebraska. At this locality, 273 feet (83 m) of the Runningwater Member of the Marsland Formation are exposed.

This section can be divided roughly into three informal units: a lower gravelly unit, a middle wavy-bedded unit, and an upper massive unit. The lower 60 to 70 feet (18.3 to 21.3 m) of this section is dominated by crystalline gravels. The gravels occur in association with loose sand or in association with the gray sandstone facies, with the massive facies and with the wavy-bedded facies. The stratigraphically higher beds contain few crystalline gravels and are dominated by the massive and wavy-bedded facies. The wavy-bedded facies is well exposed on the steep slopes of the "skull" near the middle part of the section. A number of calcium carbonate cemented zones of the massive facies are exposed in this part of the section. A prominent topographic bench of the gray sandstone facies occurs at 4,500 feet (1 370 m). This ledge varies from 4 to 7 feet (1.22 to 2.13 m) thick, is cross-bedded to massive-bedded, and contains crystalline gravels. Stratigraphically above this ledge, the sediments are primarily represented by the massive facies, although the wavy-bedded facies is represented. The upper 25 feet (7.6 m) of the section is characterized by a number of discontinuous zones of calcium carbonate enrichment. These "honeycomb ledges" are not as thick as the Platy Bench of Galusha (1975, p. 28) that caps the Runningwater Member on the south side of the Niobrara River [fig. 11]. The upper contact of the Runningwater Member with the Box Butte Formation is placed at the highest of these petrocalcic horizons, at the base of a red-green, silty clay.

Vertebrate Fossil Localities

Sediments of the Runningwater Member of the Marsland Formation are very fossiliferous, although most of the quarries are located near the top of the section. Only one quarry, UNSM BX-58 (=F:AM Runningwater Quarry), occurs near the base of the section. This quarry is situated within the lower part of the type section of the Runningwater Member. The following localities occur within the stratigraphic unit recognized as the Runningwater Member of the Marsland Formation: BX-58; BX-60;* BX-20; F:AM Apollo Quarry; BX-22 (=Marsland Quarry); BX-21 (=Hovorka Quarry); BX-23 (=Shimek Quarry); BX-51; BX-54; Blair Ranch Quarry;+ Harvey Morava Quarry; and many isolated specimens. The quarry locations are shown on plate 1 and figure 9. The topographic placement of these localities is shown in figure 14.

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*Editors' Note: The author originally plotted the location of BX-60 as shown on pl. 2 but also plotted it high in the Runningwater Member in section 9, pl. 3. BX-60 is indicated as being at or near the site of gravel sample 19, appendix B. The legal description (and elevation) of gravel sample 19 is essentially the same as that of BX-60 (pl. 2). Also on the basis of his original typescript which lists the Runningwater fossil localities in order based on topographic position, the editors considered BX-60 correctly located as shown on pl. 2 and fig. 12, topographically low in the Runningwater Member. UNSM field numbers 4051-74 to 4056-74 are very probably from BX-60.

+Editors' Note: The editors could not find a specific locality for the Blair Ranch Quarry and did not plot it on pl. 1. Yatkola did specify an elevation for the quarry on section 19, pl. 4, and the quarry is assumed to be in the vicinity of this measured section (SW¼ sec. 17, T. 29 N., R. 52 W.).

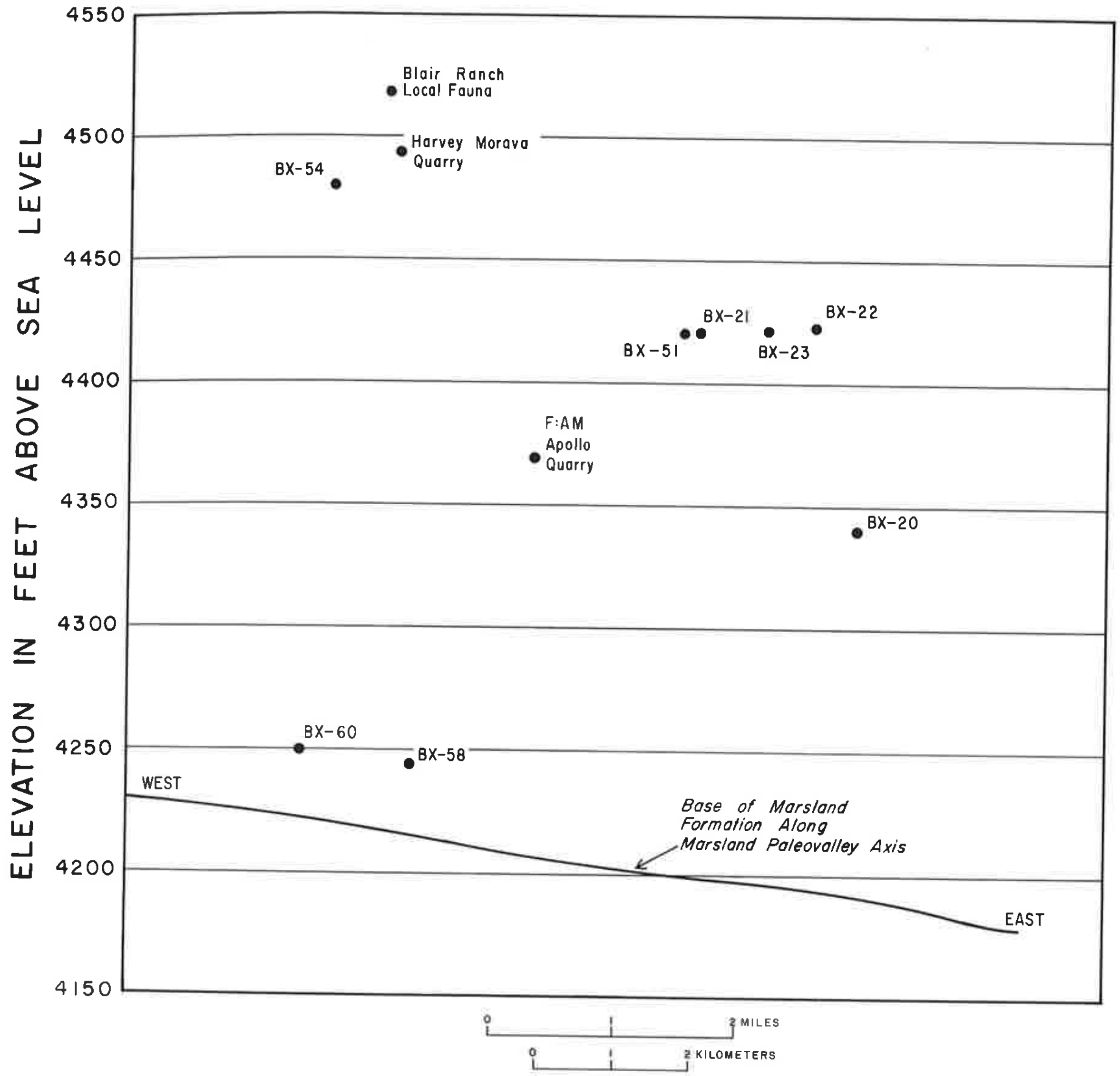

Fig. 14. Topographic placement of vertebrate fossil localities in the Running-water Member of the Marsland Formation. The base of the Marsland Formation along the Marsland paleovalley axis is taken from figure 9.

Environment of Deposition

"Environmental interpretation is the ultimate aim of facies studies" (Teichert 1958, p. 2739). Each of the described facies was produced by different sedimentological processes, representing a distinct local environment of deposition. The following depositional model is proposed to explain the origin of the sediments of the Marsland Formation.

Conglomeratic facies.--The conglomeratic facies of the Runningwater Member of the Marsland Formation defines a braided stream depositional environment. Leopold and Wolman (1957) define braiding as channel division around alluvial islands. Opinions differ, but in general braided streams are characterized by: (1) steep gradients; (2) coarse grain size; (3) wide fluctuations in discharge; (4) erodible banks; and (5) characteristic bar structures (Ore 1964, 1965; Smith 1970, 1972; Kessler 1971; Doeglas 1962; Williams and Rust 1969).

Individual channels within the Runningwater Member are difficult to trace laterally. An approximate determination of the gradient can be made on four different channels: (1) at the base of the Marsland paleovalley (fig. 9); (2) on a pegmatite channel, also characterized by orange, planar cross-bedded sandstone (fig. ___ [N.A.]); (3) on the amphibolite channel (fig. ___ [N.A.]); (4) on the white clay channel (=fill of the bedded clay facies, fig. ___ [N.A.]). The gradients are steep and vary from 8.5 to 10 feet per mile (1.61 to 1.89 m/km). These gradients are lower than the Niobrara River in the study area, 13.5 feet per mile (2.55 m/km), but compare well with gradients of rivers classified as braided (Leopold and Wolman 1957). Typical meandering rivers, such as the Mississippi have gradients of less than 0.5 foot per mile (0.095 m/km) (Leopold and Wolman 1957). The Platte River in the vicinity of Fremont, Nebraska, has a gradient of about 5.3 feet per mile (1.00 m/km) (Smith 1971, p. 3409).

The sediments of the Runningwater Member contain clasts that range in size from clay to pebbles. Gravel is transported by traction transport or saltation and requires a traction velocity of 3 to 12 feet per second (0.91 to 3.65 m/sec) to initiate movement (Sundborg 1956). Gravel occurs in the Niobrara River in the study area and in the Platte River, but is absent from most of the length of the Mississippi River (Fisk 1944, 1947).

The following features of the Runningwater Member indicate wide fluctuations in discharge: (1) the presence of abrupt lateral and vertical changes in grain size; (2) the presence of gravel lenses interbedded with massive sediments; (3) the presence of cut and fill structures; (4) the presence of irregular bedding; and (5) the presence of thin sedimentary units. Smith (1970, 1972), Ore (1963, 1965), and Kessler (1971) have reported similar features in the Platte River, Nebraska, and the South Canadian River, Texas.

Leopold and Wolman (1957) and later workers have emphasized the importance of erodible banks in the continued development of braiding. Coarser sediments accumulate in the channel as bars after high discharge when the river lacks competence to carry its load. The stream is forced laterally as sediment accumulates in the channel. Further braiding would be prevented if banks were stabilized. Bank-slump material also provides additional material for sediment braiding. The presence of large, irregular-shaped lithic clasts up to 1 foot (0.305 m) in diameter probably represent bank collapse material that has not been transported far.

Characteristic bar-types develop as a result of fluctuations in flow conditions in a braided stream system. Based on the characterizations of Smith (1970, 1972) and Ore (1963, 1965), two distinct bar types characterize braided stream systems and occur within the Runningwater Member: (1) longitudinal bars (those bars oriented parallel to the river flow direction); and (2) transverse bars (those bars oriented perpendicular to the river flow direction). The best exposure of a longitudinal bar is located just east of the north-south portion of the road in a northeast-southwest trending draw within the type section of the Runningwater Member in NE¼ SW¼ NW¼ sec. 5, T. 28 N., R. 52 W., Box Butte County, Nebraska. The best exposure of a transverse bar is located on the south side of a NW-SE trending sand wash near the center of sec. 21, T. 29 N., R. 51 W., Dawes County, Nebraska. Most outcrops within the Runningwater Member are not adequately exposed to permit differentiation of bar types, although planar cross-stratification which is characteristic of transverse bars, is more common in the Runningwater section. Longitudinal bar deposits are characterized by poorly defined, discontinuous stratification (fig. ___ [N.A.]). Transverse bar deposits are characterized by planar cross-stratification with avalanche slopes, trough cross-stratification (fig. ___ [N.A.]), and are generally finer grained than longitudinal bar deposits (fig. ___ [N.A.]). Figure ___ [N.A.] is a closeup of an avalanche face of a dissected transverse bar.

Smith (1970, p. 2993) observed that the "relative proportion of transverse to longitudinal bars increases downstream." The relative frequency of bar types within the Runningwater Member is estimated to be similar to the situation observed by Smith along the South Platte in northeastern Colorado.

The composition of the crystalline gravels transported to eastern Sioux, southwestern Dawes, and northwestern Box Butte counties by braided stream system suggests a metamorphic provenance [table 2]. Stanley (1971) and Stanley and Wayne (1972) have used the presence of distinctive pebble clasts as point source indicators. Anorthosite is the most distinctive clast-type and the source area has a restricted areal distribution in the Laramie Range (Hodge, Owen, and Smithson 1973, fig. 1). North of the Laramie anorthosite complex is a metamorphic province, and to the south is a plutonic province characterized by Sherman Granite. The absence of anorthosite (except for two pebbles) and the presence of amphibolite, rare gneissic pebbles, and a non-Sherman-type granite indicates that the provenance of these sediments was north of the Laramie anorthosite complex, probably within the metamorphic province of the Laramie Range. The east-west orientation of the Marsland paleovalley lends support to a source area in the northern parts of the Laramie Range for the braided stream that deposited the sediments of the Runningwater Member.

Gray sandstone facies.--Sediments associated with this facies accumulated in small, very shallow channels. Some of these deposits may represent longitudinal bar deposits and plane-bed deposits of the upper flow regime. Because of their poor sorting, the sediments of this facies took up calcium carbonate from the groundwater. For the most part, these deposits did not accumulate in the main channel system but represent tributary deposits.

Cross-bedded sand facies.--Sediments associated with this facies accumulated as dune deposits adjacent to the braided channel system. The skewness and mean values for these sediments (fig. ___ [N.A.]) and associated sedimentary structures are similar to recent dune deposits (Friedman 1961; Bigarella 1972). Kessler (1971) reported the occurrence of dune deposits adjacent to a number of braided river systems. These dunes represent wind transported sand from the non-vegetated parts of the channel system.*

*Editors' Note: Since the editors could not find a discussion of the other four facies of the Runningwater Member, this section must be left incomplete.

BOX BUTTE FORMATION

Type Section

Cady (1940, pp. 663, 665) defined the Box Butte as a member of the Sheep Creek Formation (Matthew and Cook 1909, p. 362), and designated a type section in sec. 27, T. 28 N., R. 49 W., Dawes County, Nebraska. Galusha (1975) redefined this lithic unit as the Box Butte Formation and discussed the apparent error in the location of the published type section. Unfortunately Cady's published section and geographic location must be considered the type locality (Code of Stratigraphic Nomenclature 1972, art. 13, remark h; Galusha 1975, p. 24). Galusha (1975) divided the Box Butte Formation into two members: the lower Red Valley Member overlain by the Dawes Clay Member. The type section of the Red Valley Member (fig. 1) is located in the NE¼ SE¼ sec. 29, T. 30 N., R. 47 W., Dawes County, Nebraska (Galusha 1975, p. 30; fig. 8, section E). The type section of the Dawes Clay Member (fig. 1) is located in the NW¼ NW¼ sec. 14, T. 30 N., R. 49 W., Dawes County, Nebraska (Galusha 1975, p. 43; fig. 13, section A).

Name and Definition

The author concurs with Galusha's definition of the Box Butte Formation. The Red Valley Member of the Box Butte Formation is composed of "reddish clayey siltstones and soft, reddish silty sandstones," and the Dawes Clay Member is composed of "reddish to greenish mottled claystones or clayey siltstones in which characteristic white, hard, heavy, nodular calcareous concretions are arranged as discrete entities" (Galusha 1975, p. 65). The rock-stratigraphic term Box Butte Formation is extended west from the type area to the map area and applied to approximately 20 to 50 feet (6.1 to 15.2 m) of red and green silty claystones with numerous white concretions (pl. 1). These sediments correlate with the Dawes Clay Member of the Box Butte Formation and were included in Galusha's concept of that unit.

Distribution and Thickness

The Box Butte Formation crops out in the map area on the upland divides of the Niobrara valley and extends into Sioux County (pl. 1; also see Galusha 1975, fig. 1). The Box Butte Formation is represented on the south rim of the Niobrara valley by approximately 29 feet (8.8 m) of the Dawes Clay Member. The western limit of the Dawes Clay Member on the south rim of the Niobrara valley is in sec. 12, T. 27 N., R. 53 W., Sioux County, Nebraska. The Dawes Clay Member crops out on the north rim of the Niobrara valley in a road cut along Nebraska State Highway 2 in the center of sec. 7, T. 29 N., R. 51 W., and extends east and west along the table. Also 30 to 70 feet (9.1 to 21.3 m) of undifferentiated Box Butte Formation crops out on a high northwest-southeast trending ridge in secs. 23, 22, 16, 15, T. 29 N., R. 52 W., Dawes County, Nebraska (pl. 1). Seventy-two feet (21.9 m) of the Box Butte Formation were measured in a north-south trending gully in the SE¼ sec. 9, T. 29 N., R. 52 W. The lithologic character and lower contact of the Box Butte Formation is best illustrated by section 1 (pl. 3), exposed in NW¼ SE¼ sec. 30, T. 28 N., R. 51 W., and section 13 (pl. 4) exposed on the east side of Nebraska State Highway 2 in sec. 7, T. 29 N., R. 51 W., Dawes County, Nebraska.

Lithologic Character

The lithology of Box Butte Formation sediments is the most distinctive lithology in the Miocene of western Nebraska. The Dawes Clay Member of the Box Butte Formation is a massive, variegated, silty claystone containing white calcareous nodules. The most distinctive lithologic feature of the Box Butte Formation is the presence of numerous, discrete, hard calcareous nodules scattered throughout the sequence. These nodules are more common near the top of the unit than at the base. The hues vary from reds (5R-10R) to greens (5GY-10GY, 5G-10G) and the lightness values generally vary from 3 to 7, depending on wetness. The upper part of these variegated silty claystones are greener than the dominantly red-colored claystones in the lower part. When wet, the clays of the Box Butte are rather plastic. The Dawes Clay Member weathers to a badlands-type topography similar to the White River Badlands of Nebraska and South Dakota. Locally there are rare, very fine to fine-grained sand lenses. Petrocalcic horizons occur locally.

A series of variegated clayey siltstones and silty claystones exposed along a high northwest-southeast trending ridge in secs. 23, 22, 16, 15, T. 29 N., R. 52 W., Dawes County, Nebraska, (section 15, pl. 4) have been mapped as part of the Box Butte Formation. These sediments differ only slightly from the stratotype sediment of the Red Valley Member, although they are not channeled into the underlying sediments. These sediments differ slightly from the stratotype of the Dawes Clay Member in that they contain more sand and in places are weakly bedded. The greatest difference is in the absence in many outcrops of the white nodular concretions. However, these nodules do occur locally but are not as abundant as in section ___, pl. ___ [N.D.]). The Box Butte Formation cannot be subdivided into members along this ridge, since these deposits combine features of both members.

Lower Stratigraphic Contact

The Box Butte Formation unconformably overlies the Marsland Formation. The Box Butte-Marsland contact on the south side of the Niobrara River was mapped at the top of the prominent, laterally traceable petrocalcic horizon at the top of the Marsland Formation (equals the Platy Bench of Galusha 1975, p. 28). This contact is sharp and easily recognized in the field (fig. 11). Locally there is 4 to 9 feet (1.22 to 2.74 m) of relief on this contact. The Box Butte-Marsland contact on the north side of the Niobrara valley is placed at the top of a clayey weathered zone that is in places calcareous. Apparently caliche formation did not proceed in this area to the degree seen on the south side of the river. The sediments above this contact are primarily red, while those below are buff in color and coarser. The elevation of the Box Butte-Marsland contact above the Marsland Quarry [UNSM BX-22] (section 1, pl. 3) is at 4,450 feet (1 360 m) above sea level, whereas this contact on the north side of the Niobrara valley in section 13 (pl. 4) [S.E.] is at 4,490 feet (1 370 m). Apparently when originally deposited, the Box Butte sediments formed a continuous blanket across what we now call the Niobrara valley. The elevation of the lower stratigraphic contact of the sediments mapped as part of the Box Butte Formation along the northwest-southeast trending ridge mentioned above is at 4,560 to 4,570 feet (1 390 to 1 393 m). Galusha (1975, p. 42) recognized this change in elevation.

Vertebrate Fossil Localities

No fossil vertebrates were collected from the Box Butte Formation in the study area. Galusha (1975) discussed the vertebrate fauna from the type area. The horse specimens described in the systematic accounts section of this report (p. ___ [N.A.]) come from UNSM BX-9, BX-40, and BX-36 of the Red Valley Member, Box Butte Formation, Box Butte County, Nebraska. The stratigraphic placement of these localities is shown in fig. ___ [N.A.].

Environment of Deposition

The sediments of the Box Butte Formation were deposited on the eroded surface of the Marsland Formation. A steep walled, narrow paleodrainage system with up to 140 feet (43 m) of relief (Galusha 1975, p. 35) was carved into the top of the Marsland Formation. A long time span prior to the deposition of the Box Butte Formation sediments is indicated by the thick and well developed petrocalcic horizon at the top of the Marsland Formation. During this dry period many gullies were carved into the Marsland surface. The process of gullying initiates during dry periods (reference [N.D.]), and associated with this gullying process is the process of dusting (i.e., loessification). The Red Valley Member represents the fill of this steep-sided gully system carved into the top of the Marsland Formation. The clasts within the fill are locally derived, indicating a drainage system similar to that draining the present-day sand hills, i.e., small, ephemeral streams originating on the plains. The bulk of the Dawes Clay Member has long been considered eolian in origin (Cady 1940). The similarity to Pleistocene loess suggests this relationship. Following Walther's law, and assuming a lithologic relationship of the named members of the Box Butte Formation, the author submits that the source of much of Dawes Clay Member is probably areas of the Red Valley sediments.

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APPENDIX A

LOCATION OF SAMPLES FOR SIEVE ANALYSIS

The following information is all that was available on the location and stratigraphy of the samples collected for sieve analysis by the author. The results of the analysis are presented in table 1 and figs. 2 and 7.

Sample Number Location

1. Monroe Creek Formation in the Niobrara Valley.

2. Monroe Creek Formation in the Niobrara Valley.

3. Type section of Harrison Formation [No type section has been formerly designated for the Harrison Formation. This sample was probably collected in Monroe Creek Canyon, secs. 15 and 16, T. 32 N., R. 56 W.].

4. Type section of Harrison Formation [This sample probably came from Monroe Creek Canyon, secs. 15 and 16, T. 32 N., R. 56 W.].

5. Harrison Formation at contact with Monroe Creek Formation-section 27 (Pink Schoolhouse section) pl. 5 [NE¼ SE¼ SE¼ sec. 36, T. 29 N., R. 54 W.].

6. Harrison Formation [No location given].

7. Harrison Formation along Highway 2.

8. Marsland Formation, Lower Member. Type area of the Upper Harrison beds (Peterson 1904), section 30, pl. 5.

9. Marsland Formation, Lower Member at contact [with Harrison Formation section 26, pl. 5, NE¼ SE¼ SE¼, sec. 36, T. 29 N., R. 54 W.].

10. Marsland Formation-Runningwater Member.

11. Marsland Formation-Runningwater Member.

12. Marsland Formation-Runningwater Member.

13. Marsland Formation-Runningwater Member [section 26, pl. 5].

14. Marsland Formation-Runningwater Member-MQ [This is probably a sample from UNSM BX-22 Quarry (= Marsland Quarry) near center NE¼ sec. 30, T. 28 N., R. 51 W., pl. 1].

APPENDIX B

LOCATION OF GRAVEL SAMPLES FROM THE RUNNINGWATER MEMBER, MARSLAND FORMATION

The elevation in feet above sea level is given in parenthesis after each sample location. (Most of the gravel samples are also located on plate 7.)

Sample Number Location

1. NW¼ NW¼ sec. 28, T. 29 N., R. 52 W., collected just east of Harvey Morava home from base of north-south trending gulley beneath pines (4,370 feet).

2. NW¼ NW¼ NW¼ sec. 3, T. 27 N., R. 54 W., from east side of road cut going down hill prior to crossing Whistle Creek (4,450 feet).

3. Center N½ sec. 17, T. 27 N., R. 54 W., from small outcrop in center of open area just north of road (4,520 feet).

4. Center SW¼ NE¼ sec. 29, T. 29 N., R. 52 W., from just west of Harvey Morava home along pasture road on north side in hollow (4,390 feet).

5. SE¼ NE¼ SW¼ sec. 19, T. 28 N., R. 52 W., from loose sand and gravel on east side of sand wash just above Harrison-Marsland contact (4,360 feet).

6. Center NE¼ NE¼ NE¼ sec. 35, T. 28 N., R. 54 W., from high hill behind abandoned house approximately 1.5 miles northeast of Murphy home (4,380 feet).

7. SW¼ SW¼ sec 20, T. 29 N., R. 51 W., from road cut on east side of road (Nebraska Highway 2) (4,280 feet).

8. SE¼ NE¼ SW¼ sec. 17, T. 28 N., R. 51 W., from just above Harrison-Marsland contact on east side of northwest-southeast drainage (4,290 feet).

9. SW¼ NE¼ NE¼ sec. 22, T. 28 N., R. 52 W., Apollo Quarry, from exposures in east-west trending wash (4,360 feet).

10. Center of east line, sec. 15, T. 28 N., R. 52 W., from loose gravels just above Harrison-Marsland contact on southeast rim of small wash (4,310 feet).

11. Center of south line, NW¼ SE¼ sec. 16, T. 28 N., R. 52 W., from loose gravelly sand outcrop in small north-south trending wash (4,300 feet).

12. Center, NE¼ SE¼ sec. 30, T. 28 N., R. 52 W., base of dune section from loose sand and gravel outcrop, just above Harrison-Marsland contact (4,340 feet).

13. Center of east line, SE½ NW½ sec. 1, T. 28 N., R. 53 W., from gravels capping small hill (4,370 feet).

14. SW¼ SW¼ SW¼ sec. 29, T. 29 N., R. 52 W., from top of high hill capped with gravels (4,430 feet).

15. Center, NE¼ SW¼ sec. 10, T. 28 N., R. 53 W., (Merychyus crabilli site), from massive, buff sandstone outcrop with isolated crystalline gravel clasts (4,270 feet).

16. Center, NW¼ SE¼ sec. 31, T. 29 N., R. 52 W., from small indurated outcrop of crystalline gravels above and on the south side of Barngrover Creek (4,320 feet).

17. Center, SE¼ sec. 19, T. 28 N., R. 51 W., type area of Marsland Formation (Schultz 1938), from small cross-bedded, gravelly sandstone outcrop located at head of small east-west trending wash (4,330 feet).

18. NE¼ NW¼ NE¼ sec. 5, T. 28 N., R. 52 W., ANMH Runningwater Quarry (UNSM BX-58), in small north-south trending wash (4,240 feet).

19. SW¼ SW¼ NE¼ sec. 6, T. 28 N., R. 52 W., UNSM BX-60, collected from very coarse grained sandstone channel outcrop along east side of small north-south trending wash (4,240 feet).

20. Near center of west line, NE¼ sec. 16, T. 28 N., R. 53 W., road cut on east side of county road heading south from Niobrara River road (4,300 feet)

21. Center, NW¼ SE¼ sec. 36, T. 29 N., R. 53 W., from very coarse channel deposit that caps the hills in the area (4,400 feet).

22. SE¼ NW¼ NE¼ sec. 32, T. 28 N., R. 52 W., on east side of major drainage, just below dune (4,420 feet).

23. NW¼ SW¼ SE¼ sec. 25, T. 28 N., R. 53 W., from small outcrop of orange, cross-bedded, gravelly sand on east side of east-west trending wash (4,370 feet).

24. Clinton site. [The author's field notes from Oct. 11, 1974, (Yatkola, MS, Field Book #4) indicate he collected this gravel sample at a "road cut on right across RR tracks" 2.5 miles west of Clinton, Nebraska, on Highway 20 and 4.1 miles east of "Rushville, Junction of highways 250 and 20." The legal description for this site is N½ SE¼ sec. 20, T. 32 N., R. 43 W., Rushville 7½-minute Quad., Sheridan Co. Elevation approximately 3,800 feet.]

25. Benchmark J-58 (1934), south of Agate. [Benchmark J-58 is located in the SE corner sec. 31, T. 28 N., R. 55 W., at an elevation of 4,571 feet.]

26. Center of south line, SE¼ SW¼ sec. 25, T. 28 N., R. 52 W., from outcrop on north side of county road (4,285 feet).

27. SW¼ NE¼ SE¼ sec. 29, T. 28 N., R. 51 W., Cephalogale site, from loose sand outcrop with ash bed (3 feet thick) on each bend of sand wash (4,200 feet).

28. Center SW¼ of north line, SE¼ sec. 21, T. 29 N., R. 52 W., collected from gravel pit in small north-south trending gully (4,360 feet).

29. Center SW¼ SE¼ sec. 32, T. 29 N., R. 51 W., white windmill section, from just east of white windmill at Marsland-Monroe Creek contact (4,270 feet).

30. Center, sec. 21, T. 29 N., R. 51 W., from cross-bedded coarse sand and gravel outcrop on south side of sand wash (4,230 feet).

31. Center S½ sec. 3, T. 28 N., R. 51 W., from gravel slope just south of railroad (4,215 feet).

32. Center, NE¼ sec. 19, T. 29 N., R. 51 W., from gravel outcrop in east-west trending gulley beneath pines (4,320 feet).

33. South line, center SW¼ sec 4, T. 28 N., R. 51 W., from just above Harrison-Marsland contact on east side of north-south trending gully (4,240 feet).

Yatkola: Tertiary Stratigraphy of the Niobrara River Valley, Marsland Quadrangle, Western Nebraska (Nebraska Geological Survey Paper 19)