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Past and Present Molluscan Fauna, Sheyenne River, North Dakota

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PAST AND PRESENT MOLLUSCAN FAUNA, SHEYENNE RIVER, NORTH DAKOTA

by

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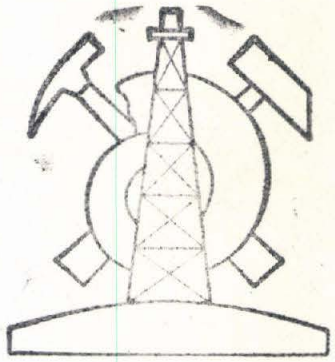

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ABSTRACT

Mollusks of the Sheyenne River in eastern North Dakota were studied during the summer of 1966. Both living mollusks from the river and fossil forms from the exposed terrace sediments were collected.

Nine species of mussels presently occur in the Sheyenne River: Fusconaia flava (Rafinesque), Amblema costata Rafinesque, Lasmigona compressa (Lea), L. complanata (Barnes), Anodonta grandis Say, Anodontoides ferussacianus (Lea), Strophitus rugosus (Swainson), Lampsilis siliquoidea (Barnes), and L. ventricosa (Barnes). Three other species, Quadrula quadrula Rafinesque, Proptera alata (Say) and Ligumia recta latissima (Rafinesque) occur only as fossils in terrace sediments.

Nine genera of gastropods and fingernail clams (sphaeriids) now exist in the river. These same nine genera have also been collected from river terrace sediments.

Long periods of no flow, high alkalinity, high turbidity, unavailability of the proper fish host, and small low-water check dams may be possible factors limiting the mussel distribution in the Sheyenne River. Some of these factors may also limit the gastropod and sphaeriid distribution. Long periods of no flow is perhaps a limiting factor in the upper reaches of the river. High alkalinity may also be another limiting factor

in the upper reaches. High turbidity in the lower reaches appears to be a limiting factor here. The absence of particular fish hosts for mussels and small low-water check dams may be significant limiting factors in the upper reaches above Baldhill Dam.

A comparison between the present and fossil gastropods and sphaeriids suggest that no appreciable faunal change has occurred. In comparing the present and fossil mussel fauna, three species, Quadrula quadrula, Proptera alata, and Ligumia recta latissima, were found only as fossils. These three species presently occur in the Red River Valley only in rivers of significantly greater discharge. This suggests that the Sheyenne River had a greater discharge at times in the past.

INTRODUCTION

During two months of the summer of 1966, a field study was made of the past and present molluscan fauna of the Sheyenne River in eastern North Dakota.

One purpose of this paper is to report on those species of mollusks living in the Sheyenne River at present. The distribution and general ecology of these mollusks were observed and described. The fossil mollusks were collected from the terraces and identified. The other purpose is to make a comparison between the present fauna and the fossil fauna to determine if a change in the species composition or a change in the distribution of the two faunas has occurred.

Previous to the time of this study, comparatively little has been known of the molluscan fauna of the Sheyenne River. Coker and Southall (1915, p. 15) reported 4 species of mussels from the Sheyenne River at Lisbon. Winslow (1921) listed 2 species of mussels, 4 species of sphaeriids and 11 species of gastropods inclusive in 6 genera.

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The writer expresses thanks to Dr. Alan M. Cvancara, Assistant

Professor of Geology, University of North Dakota, who proposed the project, supervised the field work and advised throughout the study. The writer is also indebted to him for giving permission to use some of his observations and data. This information was collected by Dr. Cvancara during the summer of 1966 in conjunction with his project on distribution and ecology of mussels in North Dakota. The use of parts of his work is necessary in order to make a complete report for the Sheyenne River. The writer acknowledges Dr. John A. Brophy, Professor of Geology, North Dakota State University, for showing the writer one of the fossil sites and for providing a carbon-14 date, with a C^{12}/C^{13} isotopic analysis, on the mussel shells at this site. The writer also expresses thanks to Dr. John R. Reid, who gave assistance in the writing; to Dr. Lee Clayton for his fruitful discussions; to John Tinker, Jr., who compiled the discharge data and to numerous other individuals in the Department of Geology who assisted me in various phases of this study.

METHODS

Field Methods.--Approximately twenty, equally spaced stations were selected for a meaningful research of the upper and middle reaches of the Sheyenne River. Tentative stations for the collection of the living mollusks were marked on county highway maps. The final selection of the stations, however, was determined by field investigation. Stations at bridges were selected because of their stability as reference points

and easy accessibility. Some tentative stations were rejected because of deep water or ponding by nearby dams.

Some potential fossil sites were selected from aerial photos of the study area. Most sites were discovered in the field, however.

The living mussels were hand picked with the aid of a Turtox Fishscope, a 60 cm aluminum alloy cylinder with a glass plate 15 cm in diameter fitted in one end. The sphaeriids and gastropods were collected from the stream bottom at periodic intervals or gathered from aquatic plants with the aid of a food strainer 15 cm in diameter.

Fossil mollusks were collected with some of the enclosing sediment. The position of the specimens above the river and the stratigraphic sections were measured with a hand level. Each section profile was sketched and the section described while in the field. Approximately 1 to 2-quart samples were taken from each unit.

A Hach Chemical Company Portable Water Engineer's Laboratory, Model DR-EL, was used for the chemical analyses. Procedures used were those outlined by the Hach Chemical Company. Water samples were taken with a 1200 cc Kemmerer water sampler, at a depth of 6 cm below the water surface in the swiftest part of the stream. Water was allowed to run through the sampler for about a minute during which time the sampler was tilted to allow trapped air bubbles to escape.

Laboratory Methods.--Partial particle size analyses were made of some bottom samples at selected stations and of samples from the

stratigraphic sections. These analyses were made according to an unpublished procedure for particle size analysis of wet sediments devised by Dr. Alan M. Cvancara and A. Kirth Erickson. This procedure involves wet sieving to determine the sand and gravel fractions and pipette analysis to determine the silt and clay fractions. The exact procedure is on file at the Department of Geology, University of North Dakota.

Mussel shells were measured to the nearest one-half millimeter with vernier calipers. Figure 1 shows how a sample mussel shell was oriented for length, height and width measurements. Length is the greatest length measured parallel to the hinge line. Height is the greatest

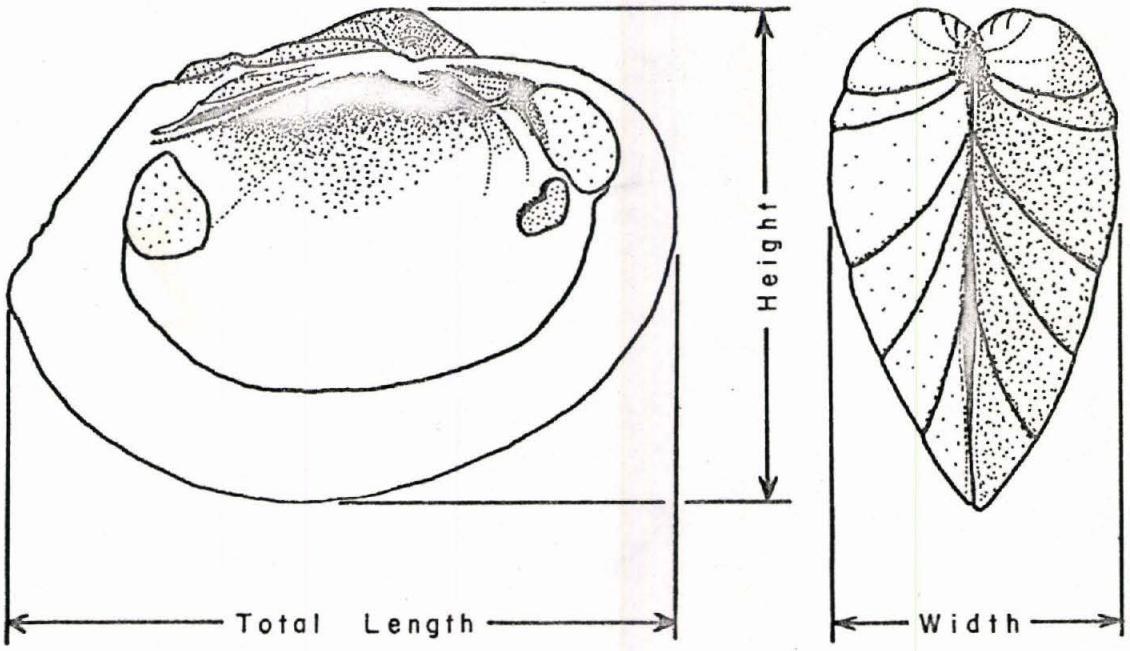

Fig. 1.--Orientation of Lampsilis ventricosa for length, height and width measurements (Orientation similar for other species).

height measured at right angles to the hinge line and at the highest part of the umbo. With the valves closed, the width was measured across the widest part.

GEOLOGIC SETTING

The Sheyenne River, originating in Sheridan County in north-central North Dakota, flows eastward, southward and northeastward before intersecting the Red River approximately 10 miles north of Fargo (Plate 1). From the headward reaches in the vicinity of Sheyenne Lake and for 170 miles eastward, the river is ephemeral. In this area, the river flows through a glaciated region consisting of gently rolling ground moraine. In places, the river cuts into Cretaceous shales underlying the glacial till. The river has formed a valley a quarter of a mile to three-quarters of a mile wide, generally increasing in width toward the east.

Near McVille, the Sheyenne River makes a broad turn toward the south and becomes a permanent stream. The geology here is similar to that in the upper reaches.

Fifteen miles southeast of Cooperstown, the Sheyenne River enters Lake Ashtabula which is a large river-lake. Continuing from Baldhill Dam at the south end of Lake Ashtabula, the Sheyenne River flows south-southeast to a point 10 miles southeast of Lisbon where it reaches the Sheyenne Delta. The river crosses the delta, flows north for 15 river miles and then swings to the east and crosses the remainder of the delta

in 50 meandering river miles. Leaving the delta, the river enters the plain of glacial Lake Agassiz and flows northeastward to its intersection with the Red River.

The region where the Sheyenne River flows from the Drift Prairie of glacial deposits onto the Sheyenne Delta and through the flat Lake Agassiz plain is strikingly portrayed by the bottom sediments in the river. At station 22, which is the last station before the river enters the delta (Plate 1), the bottom sediment is pebble gravel sand, a reflection of the glacial till. Within the delta (stations 23, 24 and 25), the bottom sediment is generally clean, medium sand which reflects the delta sediments. On the plain of Lake Agassiz, the bottom sediment of the river is very fine muddy sand with mud almost as abundant as sand. Again, the bottom sediment reflects the silts and clays of glacial Lake Agassiz.

Discharge also increases significantly where the river crosses the delta (Paulson, 1964). The source of water above the delta is primarily runoff and this increases regularly along the course of the river. As the river flows through the delta, the discharge increases about 2 1/2 times, due primarily to ground water discharge from the deltaic deposits into which the river is cut. The discharge remains stable or decreases slightly in crossing the Lake Agassiz plain. A slight decrease in discharge may be due to both impermeable clays and silts acting as a shield against any ground water inflow, as well as to evaporation of the water along the course of the river.

STREAM CHARACTERISTICS

Physical.--The Sheyenne River, from its mouth to Sheyenne Lake, is 493 miles long. Its drainage basin upstream from water gage station 595 (Plate 1) encompasses an area of approximately 9,270 square miles, including 3,940 square miles of the closed Devils Lake basin (United States Geological Survey, 1960, Surface Water Supply of the United States, pt. 5, p. 53). The average gradient of the river is 1.5 feet per river mile. Data from gage station 595 shows an average discharge for the Sheyenne River for the 10-year period, 1956-1965, of 134 cfs (Plate 1). Six other gaging stations also measure discharge along the river (Plate 1).

A bottom primarily of sandy mud exists from station 2 to station 5. This type of bottom was soft and aquatic vegetation was common to abundant here. At station 6, sandy mud began to change to medium to coarse sand downstream. From station 7 to station 15, the bottom consisted of either sand, gravelly sand or sandy gravel with the particle size generally increasing downstream toward station 15. Over this same zone, the aquatic vegetation generally decreased from common to rare. In Lake Ashtabula (station 16) the grain size decreased to medium and coarse sand with some small cobbles. Algae were also common in the lake. From station 17 to station 22, the bottom was variable but it was generally of medium to very coarse sand with some pebbles up to 1 to 3 cm in diameter. The aquatic vegetation was generally uncommon or rare.

Between stations 23 and 25, the bottom was primarily sand with aquatic vegetation occurring rarely. Stations 26 and 27 had bottoms consisting of fine to very fine sandy mud. No aquatic vegetation was found at these last two stations.

Particle size analyses were completed on 7 selected stations and are shown on Plate 1 by pie diagrams. Percentages for each sample are given under the description of stations in Appendix A.

Chemical.--At each station, 13 chemical properties were analyzed. These chemical analyses were made over as short a time interval as possible and under similar weather conditions. This was done to minimize some of the variables in order that the analyses could be compared with a greater confidence. The complete chemical data for each station are shown on Table 1.

The oxygen values generally ranged from 7 to 10 ppm with a low of 3 and a high of 11 ppm. The low value of 3 ppm occurred at station 5 and may be due to pollution; upstream from station 5 was a pasture and one specific area about 200 yds. upstream appeared to be frequented often by cattle. Here, the water was a reddish brown due to organic pollution. Reid (1961, p. 163) stated that oxygen in streams varies with time of day, season, current velocity, stream morphology, temperature and biological characteristics. In light of this, the range in values is not very marked.

Free carbon dioxide was found to be present at only 5 stations with values ranging from 2 to 14 ppm. The pH was usually slightly greater

TABLE 1

Chemical Data for the Sheyenne River

Station	Date of analysis in 1966	O_2	Free CO_2	pH	Chloride	Nitrate	Nitrite	Alkalinity Phen.	Alkalinity Total	Hardness Cal.	Hardness Total	Iron	Phosphate	Turbidity
		ppm	ppm		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	JTU
1	8/10	5.5	14	9.3	45	0	0	65	445	75	190	0	1.4	80
2	8/10	10.0	0	9.3	20	0	0	50	520	60	180	0	0.5	0
3	8/11	5.0	0	9.5	30.5	0.7	0.12	60	630	65	225	0	1.2	30
4	8/11	11.0	0	9.1	27.5	0.7	0.03	70	720	95	270	0.15	2.1	100
5	8/18	3.0	0	9.2	25.0	0.4	0.03	0	725	90	290	0.05	1.6	40
6	8/16	7.5	0	9.0	25.0	0.6	0.03	80	695	100	300	0.30	2.8	80
7	8/17	7.0	0	9.0	25.0	0.6	0.06	0	750	90	335	0.25	2.5	35
8	8/17	9.0	0	8.8	22.5	0.4	0.03	50	600	120	375	0.15	2.0	30
9	8/18	8.0	0	8.6	24.0	0.4	0.02	25	525	130	325	0.10	1.8	30
10	8/23	10.0	0	8.8	21.0	0.3	0.04	0	475	130	290	0.05	1.5	15
11	8/23	9.0	0	8.6	20.0	0.4	0.03	25	425	135	275	0.25	1.1	35
12	8/24	10.0	0	8.5	25.0	0.4	0.03	25	450	125	300	0.10	1.1	30
13	8/25	8.0	4	8.3	20.0	0.8	0.03	25	450	150	275	0.30	1.2	70
14	8/27	7.0	8	8.2	20.0	1.4	0.05	50	425	170	325	0.45	1.1	110
15	9/5	9.0	8	8.1	21.0	1.4	0.07	0	400	170	300	0.25	1.0	65
16	9/2	10.0	0	9.0	15.0	0.3	0.03	50	300	110	250	0.10	0.7	15
17	9/2	7.0	0	8.8	15.0	0.2	0.02	25	250	120	225	0.05	0.7	0
18	8/31	7.0	0	8.5	22.5	0.3	0.03	50	275	110	225	0.20	0.4	40
19	8/31	7.0	0	8.3	25.0	0.6	0.02	50	325	120	225	0.25	0.6	55
20	8/30	8.0	2	8.4	27.5	0.8	0.07	50	300	140	250	0.20	0.6	40
21	8/30	8.0	0	8.4	25.0	0.6	0.04	75	300	130	250	0.20	0.2	45
*22	7/22	6.9	8.0	8.0	30	1.0	0	0	300	125	240	0.50	0.7	75
*23	7/25	7.0	5.2	8.1	23	0.6	0	0	270	140	260	0.40	0.7	65
24	9/9	9.0	4	8.4	32.5	0.3	0	50	350	170	300	0.15	0.4	20
*25	7/25	8.1	10.8	8.1	22	1.6	0	0	260	150	250	0.60	0.8	105
*26	7/26	7.3	5.6	8.1	21	1.3	0	0	260	170	250	0.70	0.8	140
*27	7/23	7.6	9.2	8.1	31	2.3	0	0	260	130	250	0.90	1.0	180

* - Chemical data taken by A. M. Cvancara and A. C. F. Hung.

than 8 at these stations. According to Reid (1961, p. 172), free carbon dioxide is usually absent where the pH is above 8.

The pH varied from a low of 8.0 in the lower reaches to a high of 9.5 in the upper reaches. There was a gradual decrease from 9.5 at Sheyenne Lake to 8.1 at station 15. At Lake Ashtabula (station 16), the pH increased abruptly to 9.0 and then decreased gradually to 8.1 near the mouth of the Sheyenne River (Figure 2).

Chloride content varied from 15 to 45 ppm with no apparent trend for the river.

Nitrates varied from 0.2 to 2.3 ppm with no apparent trends. Although the range was relatively great, no value appeared to be above normal limits. Higher values in the Lake Agassiz plain and elsewhere may be due to concentrations of fertilizer washed from adjacent fields into the river. The nitrites ranged from 0 to 0.12 ppm.

Phenolphthalein alkalinity ranged from 0 to 80 ppm, whereas the total alkalinity ranged from 250 to 750 ppm. The total alkalinity showed a general decrease downstream (Figure 2).

The calcium hardness ranged between 60 and 170 ppm. A few low values occurred in the upper reaches of the river, but otherwise it was fairly consistent. The total hardness ranged from values of 180 to 375 ppm with no apparent trends.

The iron content ranged from 0 to 0.88 ppm. Some variance was noted, with 0 ppm recorded for the extreme upper reaches and the high

Fig. 2.--Graph showing the variation of pH, phosphate, and alkalinity with each station on the Sheyenne River.

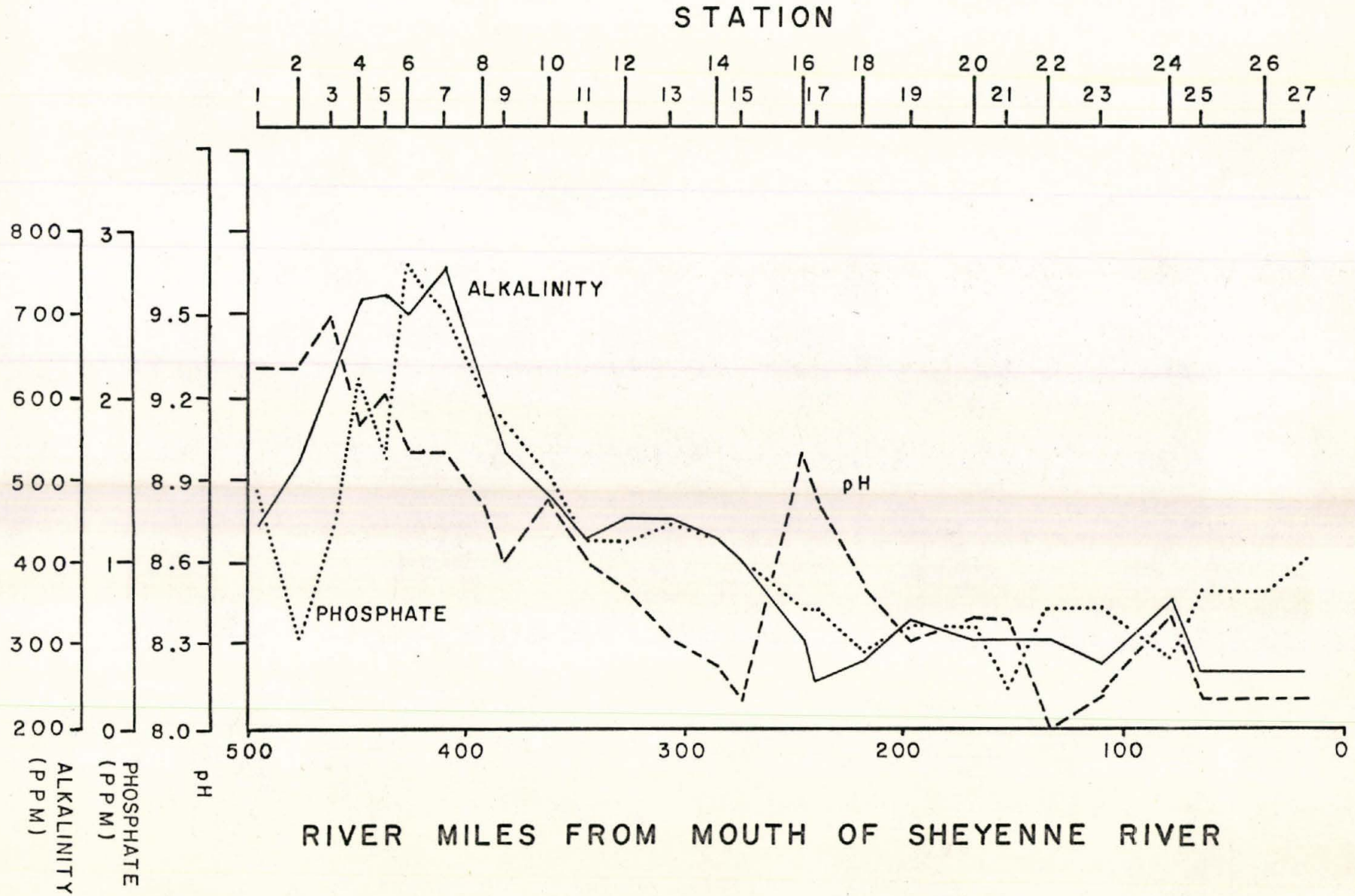
STATION
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
800 700 600 500 400 300 200
ALKALINITY (PPM)
3 2 1 0
PHOSPHATE (PPM)
9.5 9.2 8.9 8.6 8.3 8.0
pH
ALKALINITY
PHOSPHATE
pH
500 400 300 200 100 0
RIVER MILES FROM MOUTH OF SHEYENNE RIVER

Figure 2

values recorded for the extreme lower reaches of the river.

Phosphates ranged from 0.2 to 2.8 ppm with a slight downstream trend (Figure 2). Turbidity ranged from 0 at station 17 below Baldhill Dam to 180 (Jackson Turbidity Units) near the mouth. No apparent trends downstream but higher values near the mouth are probably a reflection of the finer bottom sediments.

LIVING MOLLUSKS

Phylum Mollusca

Class Gastropoda

General.--Seven genera of gastropods were found in the Sheyenne River. Succinea sp. was found only on the banks of the river. These seven genera were generally restricted to Lake Ashtabula and that reach of the river above it (Table 2). Gastropods occur only rarely below Baldhill Dam. Many genera were found at stations 1, 2, 3, 8, 9, 10 and 16. Also stations 4 through 7 have a paucity of gastropods as do stations 11 through 15. These latter stations, however, have common sphaeriids and mussels. The water at stations 11 through 15 was swifter and fewer ponded conditions existed. Below the dam the water flow was generally strong whereas aquatic vegetation was rare, adding another factor to limit some genera.

TABLE 2

Distribution of Live Species of Mollusks in the Sheyenne River

The relative abundance of each species is indicated by the symbols: A = abundant(>25 specimens), C = common(11-25 specimens), U = uncommon(3-10 specimens), R = rare(1-2 specimens).

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Valvata tricarinata (Say)		A							C	U						C	R										
Amnicola cf. A. limosa (Say)		U							U	R	U					C		R									
Amnicola sp.									U	U																	
Lymnaea (Stagnicola) palustris (Say)	C		C							R																	
Helisoma trivolvis		U	U						U	U	R																
H. anceps (Menke)																U											
Gyraulus sp.			R																								
Ferrissia cf. F. parallela (Haldeman)									R	U																	
Physa sp.	R		C		R				U	R	U			R	R			R	R								
Sphaerium sp.		R							C	C	C		A	A	C	C	U				C	C	U			P	
Pisidium sp.		A							R	R	C	C						R	R								

Subclass Prosobranchia

Order Mesogastropoda

Family Valvatidae

Valvata tricarinata (Say)

Diagnosis.--Shell generally pale green, low, turbinate; dextral, with 3 carinae; multispiralled operculum.

Remarks.--This species occurred alive at stations 2, 9, 10, 16 and 17 in the Sheyenne River (Table 2). It does not seem to favor any particular type of bottom, as was noted earlier by Baker (1928, p. 14). The highest turbidity of the five stations where V. tricarinata occurred was 35 JTU, thus indicating it prefers clearer waters, which would be natural for a gill breather.

Family Amnicolidae

Amnicola cf. A. limosa (Say)

Diagnosis.--Shell generally yellowish brown, small, high, turbinate; dextral, aperture about one-half of total length, pauci-spiralled operculum.

Remarks.--This species occurred at 6 stations in the river, at 4 of these stations with Valvata tricarinata (Table 2). This is perhaps an indication of similar ecology. Amnicola, like Valvata, is a gill breather and probably prefers water with less turbidity. It occurs over a variety of bottom conditions. The length of the shell generally ranged from 2.5 to 5 mm.

Amnicola sp.

Diagnosis.--Like Amnicola cf. A. limosa, but shell thinner, translucent and first few whorls coiled in the same plane.

Remarks.--It occurred uncommonly at stations 9 and 10. The length of the shell was generally between 2.5 and 4 mm.

Order Pulmonata

Family Lymnaeidae

Lymnaea cf. L. (Stagnicola) palustris (Say)

Diagnosis.--Shell elongate, thin and brittle; spire acute; last whorl expanded, tear-drop shaped aperture.

Remarks.--This species was common at 2 stations in the upper reaches and rare at station 10 (Table 2). According to Baker (1928, p. 215, 216) this species has a wide variety of habitats from ponds to rivers, in both clear and stagnant water. But it does prefer a habitat in which the water is not in motion. The largest specimen was about 26 mm in length.

Family Planorbidae

Helisoma anceps (Menke)

Diagnosis.--Shell, ultra-sinistral, discoidal, flat; carinate above, subcarinate below; spire forms a funicular depression.

Remarks.--H. anceps was found only (uncommonly) at station 15 (Lake Ashtabula). It is rather out of place here since it is generally

considered to be a river or creek species (Baker, 1928, p. 319). The diameter of the shell ranged from about 8 to 11 mm.

Helisoma trivolvis (Say)

Diagnosis.--Like H. anceps, but spire is flat and only slightly sunken below last whorl.

Remarks.--This species was uncommon to rare at 5 stations in the upper reaches. The water here, was flowing slightly or was stagnant. The shell ranged in diameter from 10 to 20 mm.

Gyraulus sp.

Diagnosis.--Shell, ultra-dextral, small, with few rapidly increasing whorls; discoidal.

Remarks.--Gyraulus occurred commonly at station 3 and it was the only station where it was found alive. Empty shells were found at many other stations. It is generally found in stagnant water areas (Baker, 1928, pp. 376, 378, 380 and 381). The shell diameters were about 3 mm.

Family Ancylidae

Ferrissia cf. F. parallela (Haldeman)

Diagnosis.--Shell, narrow, elongated; lateral margins nearly straight; conate, elevated.

Remarks.--This species was found uncommonly to rarely at two stations in the upper reaches. Ferrissia was generally found on plants in the quieter waters. The length ranged from 3.5 to 4 mm.

Family Physidae

Physa sp.

Diagnosis.--Shell, sinistral, spiral, thin, translucent; spire short, aperture generally longer than spire.

Remarks.--*Physa* was usually a rare genus at each station, but for the river as a whole, it occurred at more stations (10) than any other gastropod. *Physa* is found in many different habitats but usually occurred more abundantly in relatively stagnant water areas. The largest specimen was about 16 mm in length.

Class Bivalvia

Order Eulamellibranchiata

Family Unionidae

General.--Nine species of mussels were found to presently inhabit the Sheyenne River: *Fusconaia flava* (Rafinesque), *Amblema costata* Rafinesque, *Lasmigona compressa* (Lea), *L. complanata* (Barnes), *Anodonta grandis* Say, *Anodontoides ferussacianus* (Lea), *Strophitus rugosus* (Swainson), *Lampsilis siliquoidea* (Barnes) and *L. ventricosa* (Barnes) (Table 3).

Coker and Southall (1915, p. 15) reported "*Quadrula coccinea*" [=*Pleurobema coccineum*] from a millpond just above the city of Lisbon. *Pleurobema coccineum* is quite similar to *Fusconaia flava* except the umbonal region is somewhat higher in *P. coccineum*. Therefore, it is

TABLE 3

Distribution of Live Species of Mussels in The Sheyenne River

The numbers indicate the number of specimens of each species noted per station, x indicates empty shells and x* indicates shells which are presumably fossils.

Species \ Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Fusconaia flava (Rafinesque)												2			x		x		9	13	13	x*	20				
Amblema costata Rafinesque												1	1	x			1	x	15	12	63	29	43				
Lasmigona compressa (Lea)										2		2			1					3							
L. complanata (Barnes)							x	x	x	x	3	3	5		1		48	2	94	2	30	4	17	1	3		
Anodonta grandis Say		1		x	x	x	82	4	13	10	15	13	32	6	15		12	22	13	16	14	1	4	1		2	x
Anodontoides ferussacianus (Lea)		x	x							x	x	33	1	1	x				2	3	2	x	1	x			
Strophitus rugosus (Swainson)										x		x			2			x		8	1	x*	1				
Lampsilis siliquoidea (Barnes)		x				x	5	50	17	x	16	44	15	9	22		23	3	86	24	16	x	x	7	1	2	10
L. ventricosa (Barnes)												x						x	2	3	1	x*	x	1	1		

possible that Coker and Southal misidentified this species. This possibility is strengthened by the fact that they did not report finding Fusconaia flava, which at present is a common mussel in this part of the Sheyenne River.

The relative abundance of these nine species varies from station to station (Table 3), but two species, Anodonta grandis and Lampsilis siliquoidea, are more widely distributed than any of the other species. In the upper reaches, these are the only two species found above station 10. In the lower reaches, these are the only species found at the last two stations. No mussels were found in either Sheyenne Lake or Lake Ashtabula. They may exist there, but time did not permit an extensive search.

Between stations 3 and 6 no live mussels were found (Plate 1), although empty shells of Anodonta grandis were common at three of these stations (Table 3). Some possible reasons why mussels were not found in this part of the river are high alkalinity, long periods of no flow, the unavailability of the proper fish host, and the presence of small check dams. Quite likely, the absence of mussels may be a combination of these factors.

The total alkalinity in the upper reaches is quite high with a maximum found at station 7 (Figure 3). At this station, incidentally, two species of mussels exist and one of these was very abundant (82 specimens). Preliminary soil maps do not seem to indicate that the soil here

Fig. 3.--Graph showing the variation of alkalinity and number of mussel species with each station on the Sheyenne River.

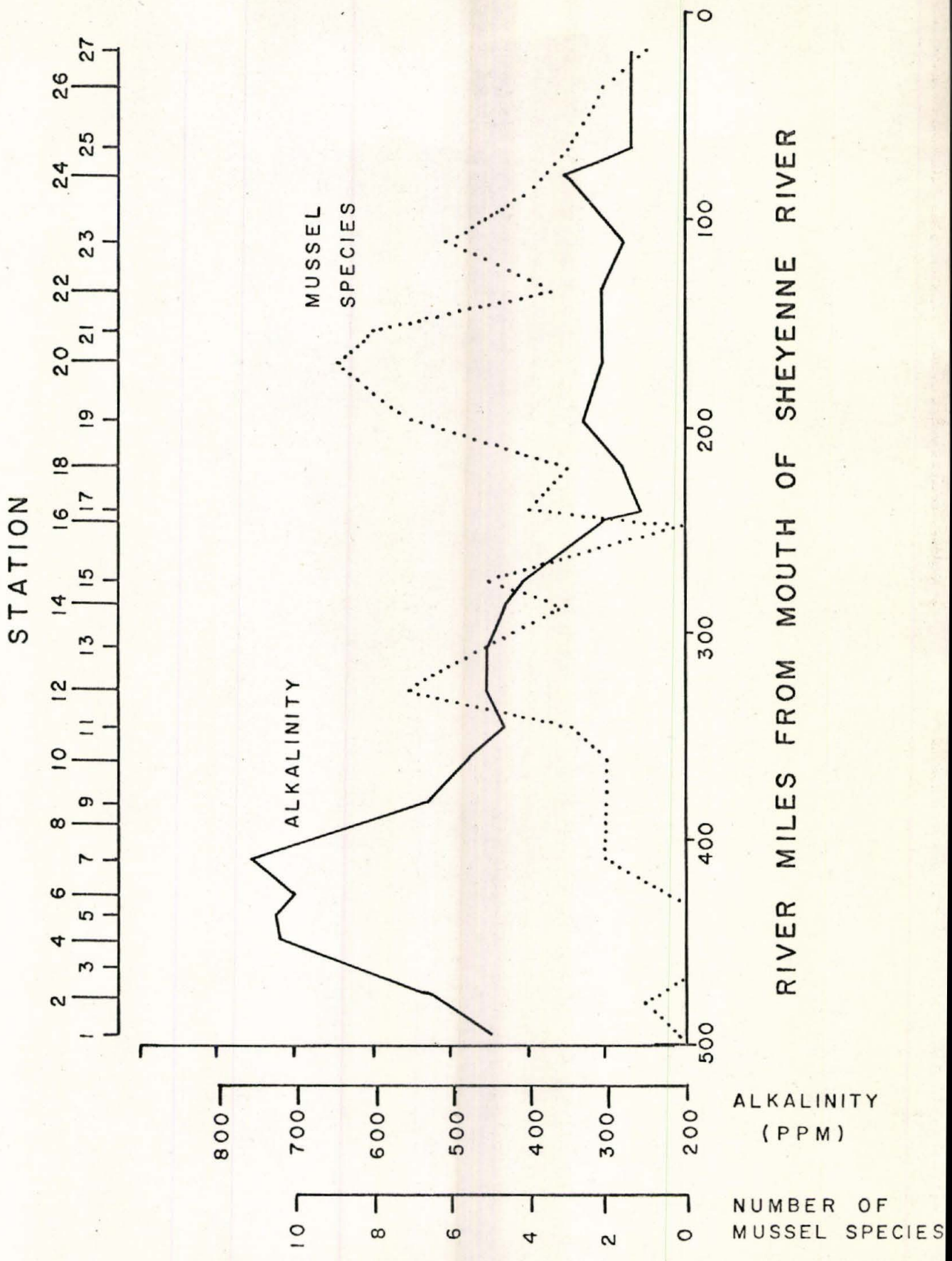
STATION
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
ALKALINITY
MUSSEL SPECIES
0
100
200
300
400
500
RIVER MILES FROM MOUTH OF SHEYENNE RIVER
800
700
600
500
400
300
200
ALKALINITY (PPM)
10
8
6
4
2
0
NUMBER OF MUSSEL SPECIES

Figure 3

is any more alkaline than elsewhere along the river (General Soil Maps, North Dakota Agricultural Experiment Station). Therefore, if mussels can exist under a condition of high alkalinity, then perhaps it is not alkalinity per se which restricts occurrence. This high alkalinity may be a result of stagnant water conditions or an actual drying up of parts of the stream channel with a resulting concentration of compounds containing the carbonate, bicarbonate or hydroxide radical. Such stagnant or dry water conditions undoubtedly exist at times in this area. At gage station 545 (Plate 1), no flow was reported for 21% of the time indicating a dry or stagnant water condition. However, in other parts of the stream, there is probably a much longer period of no flow. At one place, a few miles downstream from this gage station, the stream bed was dry, whereas water was flowing at the gage station. Mussels can live under stagnant water conditions even if the water level is low, or they can exist in deep pools if parts of the stream become dry. However, since mussels are relatively stationary, they may not be able to move to areas of deeper water if parts of the stream become dry. Between stations 3 and 6, the empty mussel shells were found in a part of the stream which was fairly shallow. These mussels had probably established themselves during wet years and were "wiped out" during one dry year.

Fish hosts are very important to the life of a mussel. Each mussel species must have a fish present on which the larval mussel (glochida stage) can attach itself to a fin or gill. It then encysts for a time

before dropping to the bottom and taking up the normal life cycle. Moreover, each mussel species encysts on only certain species of fish. Some mussels may have only one known fish host, while others may have many. Lampsilis siliquoidea, for example, has nine possible fish hosts (Coker, et al., 1922, p. 153). It seems probable that the more common species of mussels have more species of host fish, which may be another factor why some mussels are more common and widespread than others.

The fish also seem to have definite distribution patterns in the rivers. Shelford (1913) has noted this trend in his work on animal communities, and Tubb, et al. (1965) have outlined the fish distribution for the Sheyenne River. They listed 43 species of fish for the Sheyenne River, but only 14 of these species are able to maintain a population above Lake Ashtabula. The fish which occur above Baldhill Dam are due to planned or indiscriminate stocking and naturally this dam prevents any species which occur in the lower reaches from migrating into the upper reaches. One species, Perca flavescens or the yellow perch, is a known host for Lampsilis siliquoidea and L. ventricosa (artificially) (Coker, et al., 1922, p. 153). Some of the other species probably are host fish, but they are presently unknown. It is quite likely therefore that certain mussel species occurring in the lower reaches of the river do not occur in the upper reaches because of the unavailability of a proper fish host. Small check dams over much of the upper reaches may also limit the fish distribution. During most of the year it is doubtful if the fish

can migrate upstream due to these check dams.

In the lower reaches of the river, especially at stations 26 and 27, few species of mussels occurred and few specimens were found (Table 2). One possible explanation for this may be high turbidity (Figure 4). Churchill and Lewis (1924) have compiled some notes on the feeding of mussels in turbid waters. They indicated that some researchers believe that in very turbid waters the suspended particles affect the feeding mechanism. All the particles, including food, pass off the palps if the amount of suspended particles is great enough. The result is that the mussel may be actually starving even though food may be abundant. Churchill and Lewis said that others felt the mussel could still feed in turbid waters. The answer may lie in the degree of turbidity; no turbidity values were given by Churchill and Lewis. Some species of mussels may be more tolerant of turbidity than others. Turbidity, in addition to its effect on mussel feeding, may also indirectly limit the fish distribution. Turbidity would cut down the light penetration, thereby decreasing the amount of vegetation and thereby limit those fish which frequent vegetated habitats from appearing here.

Height/length and width/height shell ratios were computed for all specimens of each species. In none of the species was any apparent downstream trend of shell ratios evident.

Fig. 4.--Graph showing the variation of number of mussel species, number of mussels noted per hour and turbidity with each station on the Sheyenne River.

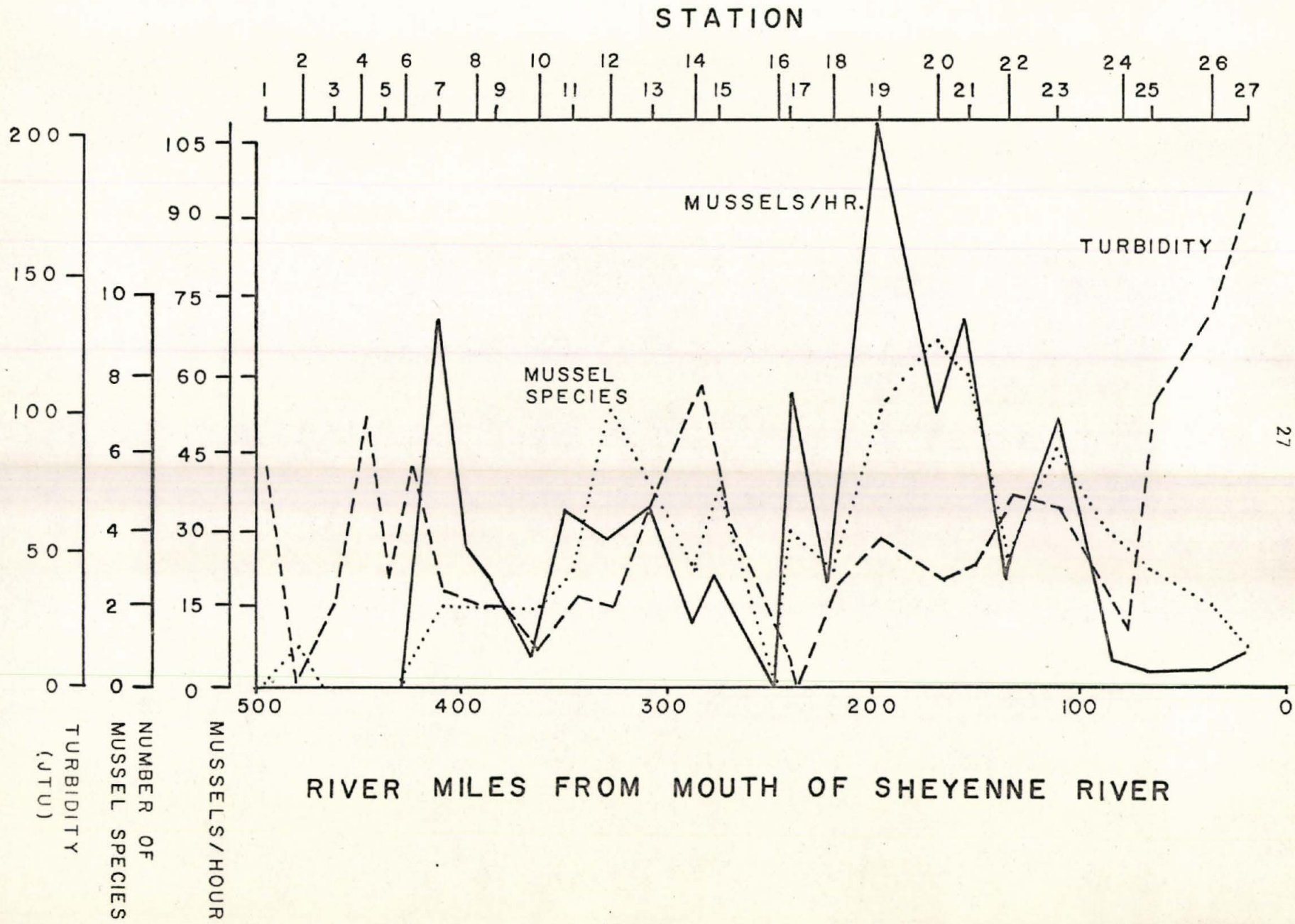
STATION
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
MUSSELS/HR.
TURBIDITY
MUSSEL SPECIES
200 150 100 50 0
10 8 6 4 2 0
105 90 75 60 45 30 15 0
500 400 300 200 100 0
RIVER MILES FROM MOUTH OF SHEYENNE RIVER
TURBIDITY (JTU)
NUMBER OF MUSSEL SPECIES
MUSSELS/HOUR

Figure 4

Subfamily Unioninae

Fusconaia flava (Rafinesque)

"Wabash Pig-toe"

Diagnosis.--Shell medium-sized, thick, sub-quadrate to sub-triangulate shell with low posterior ridge; strong pseudocardinal and lateral teeth. Beak sculpture of few, low ridges.

Remarks.--This species was common in the upper part of the lower reaches. The occurrence here would be expected of this medium to large river species. A preference for a bottom of a sandy gravel or a gravelly sand was observed.

The periostracum is usually satiny, and brownish yellow with a white nacre occasionally tinged with salmon.

Height/length ratios varied from 0.74 to 0.84 (N=19) and width/height ratios varied from 0.48 to 0.55 (N=19). The largest specimen was found at station 19 and measured: length, 76.5 mm; height, 60.5 mm; and width, 30.5 mm.

Amblema costata (Rafinesque)

"Three Ridge"

Diagnosis.--Shell large, thick, with commonly distinct diagonal ridges; massive pseudocardinal and lateral teeth present; beak sculpture of few distinct concentric ridges.

Remarks.--This species was common to abundant in the upper part

of the lower reaches of the river. It was generally found in the swiftest part of the stream where the bottom was a sandy gravel. Usually one-half to two-thirds of the shell was exposed above the bottom.

The periostracum is generally dark brown, becoming darker in older specimens. The nacre is white with a purplish tinge in the posterior portion. A few specimens were tinged with a peach color on the ventral margins. At a few stations, a majority of the shells had irregular yellowish-brown splotches.

Height/length ratios varied from 0.72 to 0.78 and the width/height ratio varied from 0.45 to 0.56. The largest specimen was found at station 19 and measured: length, 135 mm; height, 98.5 mm; and width, 55.0 mm.

Subfamily Anodontinae

Lasmigona compressa (Lea)

Diagnosis.--Shell usually small, with long delicate pseudo-cardinal and lateral teeth; beak sculpture of several irregular double-looped ridges.

Remarks.--This species was present at 4 stations in the middle reaches of the Sheyenne River. The occurrence of the mussel at these stations was uncommon to rare. This species, when noted, seemed to prefer a sandy type of bottom.

The periostracum is usually yellowish green and lightly rayed.

The nacre grades from a salmon color under the umbonal areas to a white near the margins of the shells.

Height/length ratios varied from 0.56 to 0.57 (N=5) and width/height ratios varied from 0.45 to 0.54 (N=5). The largest specimen was found at station 12 and measured: length, 86.0 mm; height, 48.0 mm; and width, 22.5 mm.

Lasmigona complanata (Barnes)

"White Heel Splitter"

Diagnosis.--Shell large, thick with massive pseudocardinal teeth; lateral teeth lacking or represented by a thickening along hinge line; beak sculpture of strong double-looped ridges.

Remarks.--This species occurred at 13 stations throughout most of the middle and lower reaches. It was usually uncommon in the middle reaches whereas it was common to abundant in the upper part of the lower reaches. It was found on a variety of bottoms but seemed to be most abundant on sandy gravel or gravelly sand. Usually one-half to two-thirds of the shell was exposed above the bottom.

The periostracum is generally brown to dark brown with white nacre.

Height/length ratios varied from 0.64 to 0.80 (N=50) and the width/height ratio varied from 0.37 to 0.58 (N=50). The largest specimen was found at station 22 and measured: length, 166.5 mm; height, 114.5 mm; and width, 61.5 mm.

Anodonta grandis (Say)

"Floater"

Diagnosis.--Shell thin, medium-sized, with no hinge teeth; beak sculpture of several distinct double-looped ridges.

Remarks.--This species was found at more stations than any other species in the Sheyenne River, occurring at 19 stations with empty shells found at 4 other stations. It was common throughout the middle reaches of the river but it was found at only one station in the extreme upper part and uncommon to rarely in the extreme lower parts. Anodonta grandis seemed to have no real bottom preference.

The periostracum exhibited grays, browns, yellows, greens and all shades in between. Many individual shells may exhibit this entire color range. The nacre was white with tinges of yellow, pink, salmon or orange.

Height/length shell ratios varied from 0.51 to 0.64 (N=89) and width/height shell ratios varied from 0.51 to 0.72 (N=89). The largest specimen was found at station 23 and measured: length, 124.5 mm; height, 68.0 mm; and width, 45.0 mm.

Height/length and width/height shell ratios were computed for 89 specimens. Each of these two ratios was plotted separately against the length of each specimen and against the number of river miles above the mouth at which each specimen occurred. The length of shell compared to the height/length ratio gave a regression coefficient of -0.00073.

The length of shell compared to the width/height ratio gave a regression coefficient of 0.00066. The length of river compared to the height/length ratio gave a regression coefficient of 0.00006. The length of river compared to the width/height ratio gave a regression coefficient of -0.00008. These analyses show that there is no real change in shell ratios with age as indicated by length of shell and that there is no real downstream trend in shell ratios.

Anodontoides ferussacianus (Lea)

"Cylindrical Paper Shell"

Diagnosis.--Shell small, thin, lacking hinge teeth; beak sculpture of few, low concentric ridges.

Remarks.--This species was abundant at station 12 but at the 6 other stations where it was found, it was uncommon to rare. In all cases this species seemed to prefer a bottom of firm sand or pebble gravel sand and usually was positioned with its siphons flush with the bottom.

The periostracum is either brownish tan, yellowish brown or yellowish green. A few specimens were lightly rayed. The nacre is usually bluish white.

Height/length ratios varied from 0.49 to 0.57 (N=17) whereas width/height ratios varied from 0.58 to 0.76 (N=17). The largest specimen was found at station 18 and measured: length, 87.5 mm; height, 42.5 mm; and width, 32.5 mm.

Strophitus rugosus (Swainson)

"Squaw Foot"

Diagnosis.--Shell usually small with pseudocardinal teeth represented by swellings or tubercles, lateral teeth absent; beak sculpture of heavy, roughly concentric ridges.

Remarks.--This species occurred at 4 stations in the middle and lower reaches of the river. Its occurrence was uncommon to rare. The greatest number of specimens found was 8 at station 20 near Fort Ransom. No particular bottom preference was noted.

The periostracum is brown and commonly with light rays. The nacre is usually salmon or cream colored under the umbonal areas varying to white near the margins.

Height/length ratios varied from 0.54 to 0.61 (N=11) and width/height varied from 0.53 to 0.63 (N=11). The largest specimen occurred at station 21 and measured: length, 67.5 mm; height, 36.5 mm; and width, 23.0 mm.

Subfamily Lampsilinae

Lampsilis siliquoidea (Barnes)

"Fat Mucket"

Diagnosis.--Shell medium to large in size and sexually dimorphic. Pseudocardinal and lateral teeth present; beak sculpture of low wavy chevron-like ridges.

Remarks.--This is a species which occurred throughout the Sheyenne River. It was common to abundant in the middle reaches from station 8 to station 21. In the extreme lower reaches, the species was uncommon. However most species were rare or unexistent in this stretch of the river. Lampsilis siliquoidea seemed to prefer a muddy bottom rather than a sandy bottom, but this did not always hold true. It may occur with its siphons flush with the bottom when the substrate is sandy while it usually exposes about half of its shell if the bottom is very muddy.

The periostracum is generally greenish yellow to brownish yellow and commonly with green rays. The nacre is white.

Height/length ratios for the male varied from 0.47 to 0.60 (N=68) while width/height ratios varied from 0.50 to 0.75 (N=68). The largest specimen was found at station 17 and measured: length, 115.5 mm; height, 61.0 mm; and width, 40.5 mm.

Lampsilis ventricosa (Barnes)

"Pocketbook"

Diagnosis.--Shell usually large, sexually dimorphic with good pseudocardinal and lateral teeth present; beak sculpture of a few coarse wavy ridges. Height/length ratio usually greater than for Lampsilis siliquoidea.

Remarks.--This species occurred rarely at 5 stations in the lower

reaches. The greatest number found (3 specimens) was at station 20. No apparent bottom preference was noted.

The periostracum is brownish yellow to yellow, commonly with green rays. The nacre is white.

Height/length ratios for the male varied from 0.59 to 0.67 (N=4) and width/height ratios varied from 0.61 to 0.75 (N=4). The largest specimen was found at station 19 and measured: length, 76.5 mm; height, 60.5 mm; and width, 30.5 mm.

Family Sphaeriidae

General.--Both Sphaerium and Pisidium are present in the Sheyenne River. More than one species of each genera are present but time did not permit specific identification.

The sphaeriids were generally absent from the extreme upper reaches and from the extreme lower reaches. Again some of the factors affecting the mussel distribution seem to affect the sphaeriid distribution as well.

Sphaerium sp.

Diagnosis.--Fingernail-size clam with beaks located centrally or if subcentral, on the anterior side of center.

Remarks.--This genus was generally common to abundant throughout the middle reaches of the river, but was absent or found only rarely in the extreme upper and lower reaches (Table 2). The shells generally

ranged in length from 5 to 15 mm.

Pisidium sp.

Diagnosis.--Generally smaller than Sphaerium, with the beaks posterior or, if subcentral, on the posterior side of center.

Remarks.--This genus was abundant at station 2 and common at stations 9 and 10. It occurred at five other stations only rarely. Pisidium was absent from part of the upper reaches, part of the middle reaches and all of the lower reaches of the river (Table 2). The shells generally ranged in length from 2 to 4 mm.

FOSSIL MOLLUSKS

General

The word fossil, as used in this section, pertains to any mollusks which have been found buried in sediment.

The relative abundance of each fossil species is indicated by: A = abundant, C = common, U = uncommon and R = rare.

The aquatic fossils found at each site (Plate 2) will be listed for each unit with remarks following. A full description of each site and descriptions of the sections are given in Appendix B.

Fossil Sites

Fossil Site A.--near Kathyrn

Unit 8--Amnicola cf. A. limosa (R) and Ferrissia sp. (R).

Unit 6--Amnicola cf. A. limosa (U-R), Ferrissia sp. (R), and Sphaerium sp. (U-R).

Unit 4--Lampsilis ventricosa (R).

Unit 2--Amnicola cf. A. limosa (C), Ferrissia sp. (R), Physa sp. (R), Anodonta grandis (R), Anodontoides ferussacianus (R), and Sphaerium sp. (A-C).

All of the 4 units, which contained fossils, consisted of sandy mud of approximately the same composition (Figure 5). Apparently, there was little change in the environment throughout the time when these units were deposited. The species composition does not change significantly, except for the fact that the mussel species were found only in the bottom two units. This is probably due not to a restriction of the mussels to the earlier deposited units but to the scarcity of specimens.

Fossil Site B.--near Anselm

Unit 2--Amnicola cf. A. limosa (R), Lampsilis siliquoidea (C), and Sphaerium sp. (U).

These fossils were found presumably in sand of the Sheyenne Delta and apparently are river forms. A carbon-14 date, with a C^{12}/C^{13} isotopic analysis was made on the mussel shells and a date of approximately 12,000 years B. P. was determined (fide Dr. J. A. Brophy, March 17, 1967).

Fossil Site C.--near Lisbon

Unit 3--Amnicola cf. A. limosa (A), Helisoma anceps (R),

Fig. 5.--Graph showing the measured sections A and B in which fossils occurred along the Sheyenne River. The letter above each section refers to the location on Plate 1. The relative abundance of the mollusks are given by the terms: A = abundant, C = common, U = uncommon, and R = rare.

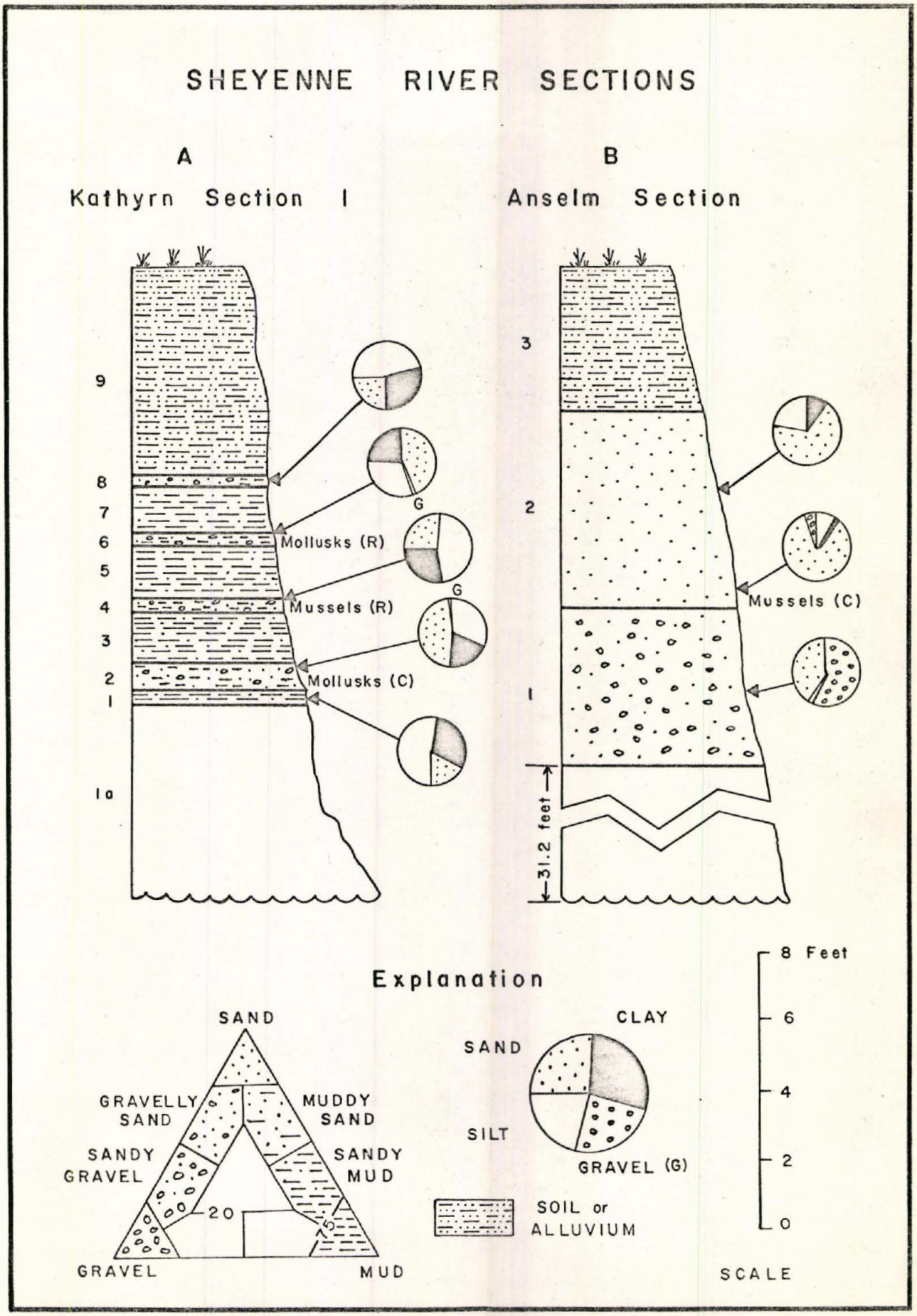
SHEYENNE RIVER SECTIONS
A
Kathyrn Section I
B
Anselm Section
9
8
7
6
5
4
3
2
1
1a
Mollusks (R)
Mussels (R)
Mollusks (C)
G
G
3
2
1
Mussels (C)
31.2 feet
Explanation
SAND
GRAVELLY SAND
MUDDY SAND
SANDY GRAVEL
SANDY MUD
20
5
GRAVEL
MUD
CLAY
SAND
SILT
GRAVEL (G)
SOIL or ALLUVIUM
8 Feet
6
4
2
0
SCALE

Figure 5

H. trivolvis (R), Menetus ? sp. (R), Gyraulus sp. (R), Physa sp. (R), Fusconaia flava (U-C), Amblema costata (R), Quadrula quadrula (R), Anodonta grandis (R), Strophitus rugosus (U), Ligumia recta latissima (U), Lampsilis siliquoidea (U), L. ventricosa (R), Sphaerium sp. (A), and Pisidium sp. (U).

Unit 2--Amnicola cf. A. limosa (C), Quadrula quadrula (R), Ligumia recta latissima (R), Sphaerium sp. (C), and Psidium sp. (U).

Both of these units are of sand. Quadrula quadrula and Ligumia recta latissima are found in both of these units. However, they are not found in the river at present.

Fossil Site D.--150 yds. from fossil site C

Unit 3--Amnicola cf. A. limosa (R), Fusconaia flava (R), Amblema costata (R), Lasmigona complanata (R), Strophitus rugosus (R), Ligumia recta latissima (U), Lampsilis siliquoidea (U), and L. ventricosa (R).

Unit 2--Amnicola cf. A. limosa (A), Helisoma anceps (U), H. trivolvis (R), Physa sp. (R), Fusconaia flava (U), Amblema costa (U), Quadrula quadrula (R), Lasmigona complanata (R), Anodonta grandis (U), Strophitus rugosus (C), Lampsilis siliquoidea (C),

L. ventricosa (C), Sphaerium sp. (A), and Pisidium sp. (U).

As at fossil site C, both of these two units are of sand (Figure 6). Again, the total faunal assemblages are similar. In fact there is a very remarkable similarity of the fauna between unit 2 of this fossil site (D) and unit 3 of fossil site C. Considering a stratigraphic difference of 1.5 feet which may be due to an irregular river bottom, these two units are probably of the same age.

Fossil Site E.--near Kathryn

Unit 2--Lasmigona complanata (R).

A poor cutbank section in which only one fragmented specimen was found. This species was found in a coarse sand unit (Figure 6).

Fossil Site F.--near Cooperstown

Unit 8--Amnicola cf. A. limosa (U), Helisoma trivolvis (R), Lampsilis siliquoidea (R), and Sphaerium sp. (U).

Unit 4--Amnicola cf. A. limosa (A), Anodonta grandis (R), Anodontoides ferussacianus (R), Strophitus rugosus (U), Lampsilis siliquoidea (R), L. ventricosa (R), Sphaerium sp. (A), and Pisidium sp. (R).

Unit 2--Amnicola cf. A. limosa (C), Lymnaea sp. (R), Ferrissia sp. (R), Anodonta grandis (U), Anodontoides ferussacianus (R), Strophitus rugosus (U), Lampsilis

Fig. 6.--Graph showing measured sections C through F. An explanation appears in Figure 5.

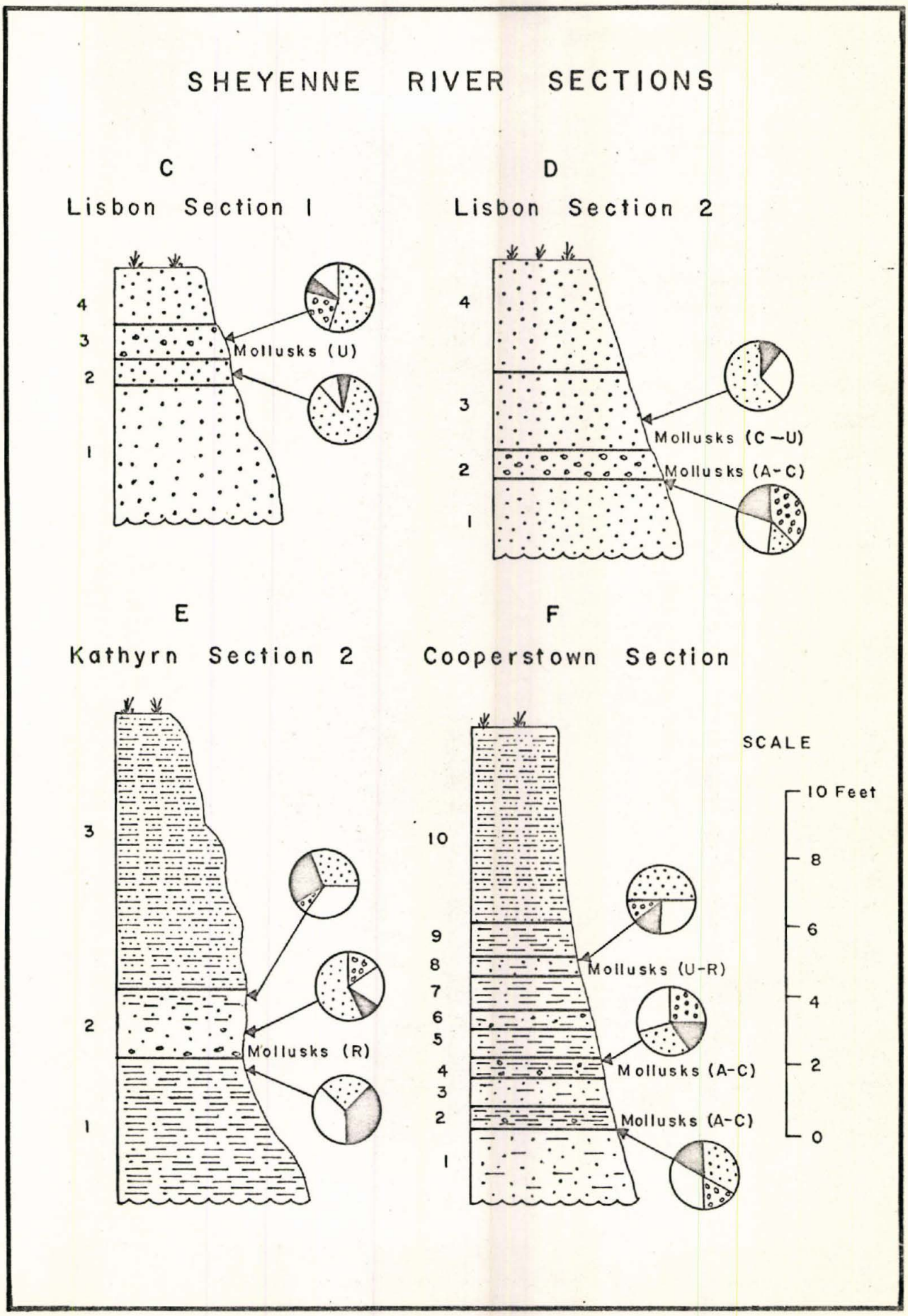
SHEYENNE RIVER SECTIONS
C
Lisbon Section 1
4
3
2
1
Mollusks (U)
D
Lisbon Section 2
4
3
2
1
Mollusks (C—U)
Mollusks (A-C)
E
Kathyrn Section 2
3
2
1
Mollusks (R)
F
Cooperstown Section
10
9
8
7
6
5
4
3
2
1
Mollusks (U-R)
Mollusks (A-C)
Mollusks (A-C)
SCALE
10 Feet
8
6
4
2
0

Figure 6

siliquoidea (C), L. ventricosa (U), Sphaerium sp. (A), and Pisidium sp. (R).

The fossils were found in either muddy sand or sandy mud. The species composition is similar to that found at other sites although the number of specimens found here was less.

Discussion

Any attempt at correlation of any of the units between the fossil sites usually met with failure. One exception is the probable correlation between unit 2 of fossil site D and unit 3 of fossil site C.

Amnicola cf. A. limosa is well represented in most sand units. This species, since it is a gill breather, may indicate that the water was clear with little turbidity. Although Amnicola was found in a few sandy mud units, which might indicate turbidity, this need not be the case. Although sandy mud units are presently found near the banks of most of the stations, the general bottom may still be sand and the water may be quite clear.

The age of the fossils at fossil site B (approximately 12,000 years B. P.) is known from a radiocarbon date as indicated earlier. This fossil unit was about 36 feet above the river level. The ages of the fossils at the other sites, where the fossil units vary from 2 to 10 feet above water level are not known with any certainty. However, Tuthill (1964, p. 154) found a shell of Lampsilis siliquoidea near the water level along the

Sheyenne River. Some wood associated with the mussel shell has been radiocarbon dated at 2,540 ± 300 years B. P. That location is about 35 river miles downstream from fossil site B and about 50 miles downstream from sites C and D. Therefore, the age of the fossils found at fossil sites A, C, D, E, and F may be in this order of magnitude.

COMPARISON OF PAST AND PRESENT MOLLUSCAN FAUNA

In general the species composition of the two faunas, fossil and present, is quite similar. Among the fossil gastropods, the same living genera were found in the river now. Amnicola cf. A. limosa, however, was found at nearly all of the fossil sites and usually quite abundantly. But at the 6 stations where it was found alive on the river, it was rare to common (Table 2). This suggests, perhaps, that the river was generally clearer (less turbid) in the past.

Three mussel species, which do not occur in the river at present, were found at the fossil sites. Quadrula quadrula and Ligumia recta latissima were found in place at fossil sites C and D. Proptera alata was found on the river bottom near sites C and D and was presumed to be a fossil. Quadrula and Ligumia occur only in the larger rivers of the Red River Valley area (oral communication, Dr. A. M. Cvancara, University of North Dakota, September, 1966). Ligumia was found in the Otter Tail River in Minnesota where the average discharge was about 372

cfs downstream from Fergus Falls (1956-1965 water calendar year period, United States Geological Survey Surface Water Branch, Grand Forks and Bismarck, North Dakota and St. Paul, Minnesota). Ligumia was also found in the Red Lake River, near Crookston, Minnesota where the average discharge was about 937 cfs and in the Red River downstream from Grand Forks where the average discharge was about 2191 cfs. Quadrula was only found in the Red Lake and Red Rivers. The fossil forms were found in the Sheyenne River near station 22 where the average discharge was about 115 cfs (at Lisbon). Considering where these two species are found in the valley area at present and the discharge (size) of the rivers in which they now occur, it is apparent that the Sheyenne River probably had a discharge of 3 to 9 times greater in the past.

In comparing the fossil and present forms of Strophitus rugosus and Lampsilis ventricosa, it is obvious that these were more abundant in the past as evidenced by a greater abundance of these two species at the fossil sites.

One specimen of Lampsilis ventricosa was found at fossil site F above Lake Ashtabula (Plate 1). At present L. ventricosa does not appear in the river above station 19, which is located below Baldhill Dam (Table 3). In the past this species occurred further upstream. The Baldhill Dam may be affecting the present distribution however.

Approximately one week was spent searching for fossil sites among the upper terraces. About three dozen prospective fossil sites were

examined, but no mollusks were found with the exception of Lampsilis siliquoidea and two other mollusks in the Sheyenne Delta. However, the fossils appear to be common in the lower terraces. This indicates that most of the molluscan fauna did not appear in the Sheyenne River until the time of deposition of these lower terraces (2,000 + years ago?). More fossil sites will probably prove or disprove this hypothesis.

CONCLUSIONS

Nine species of mussels and nine genera of gastropods and sphaeriids were found to inhabit the Sheyenne River at present. Five species of mussels, Fusconaia flava, Lasmigona complanata, Anodontoides ferussacianus, Strophitus rugosus and Lampsilis ventricosa are reported for the river for the first time. Valvata tricarinata and Helisoma anceps, two gastropods, are also reported for the first time.

The present molluscan fauna appears to be limited to certain parts of the river. The factors limiting mussels in parts of the upper reaches may be high alkalinity, long periods of no flow, the unavailability of the proper fish host and small, low-water check dams. In the lower reaches of the river, mussels may be limited by high turbidity. The gastropods and sphaeriids were also absent from parts of the upper and lower reaches of the river. Some of the limiting factors which applied to mussels may also apply to the gastropods and sphaeriids.

Fossils were not found in the upper reaches of the river. In the

lower reaches, some low terraces were found in which the fossils were usually common with numerous species present. Only one high terrace was found which contained mollusks and it contained only three species of mollusks. Since fossils are apparently rare from the upper terraces but common in the lower terraces, the indication is that most of the molluscan species entered the river rather late in post-glacial time.

A comparison between the fossil and the present fauna reveals that the two are nearly the same. The same nine genera of gastropods and sphaeriids found living now also appeared as fossils in the terraces. Eight of the presently occurring nine species of mussels were found as fossils. In addition, three more species of fossil mussels were found in the terraces. These three species, Quadrula quadrula, Proptera alata, and Ligumia recta latissima, occur in the Red River Valley area only in those rivers with higher average discharges than the Sheyenne River. Therefore, these three fossil species, which occur in the lower terraces, indicate that the average discharge of the Sheyenne River was probably three to nine times greater when these lower terraces were deposited.

FUTURE WORK

At present, the mussel distribution and the fish distribution are known for the river. However, one link remains which could tie the two together. That link is the glochidial or larval clam stage. The question is, which mussel species encysts on which fish host. If the answer to

this question could be found; the present distribution of mussels might be better understood.

Various shell ratios were measured for the mussel species but no downstream trend for the river was noted. However, a weight of shell/shell length ratio versus river length might show a downstream trend which perhaps could be related to some chemical factor.

More work needs to be done on the fossil fauna. Probably many more low terraces can be found which might contain fossils. Few exposures of the higher terraces exist; however, those which are exposed seem devoid of fossils. Along with a few select radiocarbon dates, the time of appearance of each fossil species in the Sheyenne River could perhaps be worked out. Later, upon finding a certain species or faunal assemblage in a terrace, the age of that terrace could probably be found by knowing when that species or assemblage first appeared in the river. However, many problems result considering the relatively short time span of post-glacial time with which one has to work.

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APPENDIX A

DESCRIPTION OF STATIONS

(University of North Dakota, Department of Geology, accession numbers follow station numbers; mollusk species for each station are given in Tables 2 and 3).

General.--Bottom firmness is designated by the relative terms soft, firm and very firm:

Soft - a 160 pound man will sink into the bottom 15 cm or more.

Firm - a 160 pound man will sink into the bottom from 5 to 15 cm.

Very firm - a 160 pound man will sink into the bottom from 0 to 5 cm.

Water velocity is designated by the relative terms stagnant, low, moderate and strong:

Stagnant - no flow is evident.

Low - flow is barely perceptible.

Moderate - velocity is great enough to cause noticeable pressure against the side of the fishscope.

Strong - velocity is great enough to make the fishscope extremely difficult to handle.

Particle size is designated by the Wentworth grade scale.

Station 1 (A 151).--Sheyenne Lake, SE1/4SE1/4 sec. 33, T. 149 N., R. 74 W., 11 miles south of Martin, Sheridan Co., N. Dak.; August 10, 1966. Station, 493 river miles above mouth. Lake bottom at depth of 0.7 m along shore primarily medium sand ranging to pebbles 2-3 cm in diameter; generally very firm. Lake bottom examined for 100 m along extreme southeast shore, out to 15 m from shore for one-half hour. Maximum depth of area covered, 1 m. Some trees on banks, but shading negligible.

Station 2 (A 143).--Sheyenne River where crossed by east-west gravel road, SE1/4 sec. 24 and NE1/4 sec. 25, T. 149 N., R. 73 W., about 4 miles south of Harvey, Wells Co., N. Dak.; July 19 and August 10, 1966. Station, 476 river miles above mouth. Stream bottom primarily dark gray to black sandy mud, with gravel particles up to 3 mm in diameter; generally soft. Stream 3.2 m wide on immediate downstream side of culverts, but usual width about 3.7 m. Depth generally 0.6 to 1 m with maximum depth of 1.6 m about 3 m downstream from culverts. Water flow low. Bottom examined from 239 m below culverts to 14 m above it for 3 hours. Banks open and grassed over. Bottom covered entirely with vegetation above culverts and about one-half of bottom covered below it.

Station 3 (A 144).--Sheyenne River where crossed by north-south gravel road, NE1/4 sec. 20, T. 150 N., R. 71 W., about 2 1/2 miles south of Wellsburg, Wells Co., N. Dak.; July 20 and August 11, 1966. Station, 461 river miles above mouth. Stream bottom primarily sandy

mud below bridge and above it, bottom primarily boulders approximately 0.3 to 0.8 m in diameter. Smaller particles from very coarse sand size to 5 cm. Bottom soft below bridge to firm above it. Stream 2 m wide at bridge but usual width about 4 m. Depth varied from maximum of 1 m below bridge to maximum of 0.5 m above it. Water flow low. Stream bottom examined from 27 m above bridge to 36 m below it for 1 hour. Banks open and grassed over. Bottom almost covered with vegetation below bridge but little vegetation above it.

Station 4 (A 152).--Sheyenne River where crossed by north-south gravel road, NE1/4 sec. 30, NW1/4 sec. 29, T. 151 N., R. 70 W., 9 miles southwest of Maddock, Benson Co., N. Dak.; August 11, 1966. Station, 448 river miles above mouth. Stream bottom primarily sandy mud. Bottom soft to firm (firm after sinking through 0.3 m of mud). Stream 8 m wide at bridge with maximum depth 0 to .8 m. Water flow low. Stream bottom examined from 70 m below bridge to 44 m above it for 1 1/2 hours. Banks open and grassed over. Vegetation uncommon.

Station 5 (A 160).--Sheyenne River where crossed by north-south asphalt road (ND 30), SE1/4 sec. 18, SW1/4 sec. 17, T. 151 N., R. 69 W., 5 miles south of Maddock, Benson Co., N. Dak.; August 18, 1966. Station, 435 river miles above mouth. Stream bottom primarily sandy mud with medium sand the coarsest particle size; bottom relatively soft. Stream 10.5 m wide at bridge with maximum depth of 1 m. Water stagnant. Stream bottom examined from 309 m below bridge to 274 m

above it for 1 1/2 hours. Banks open and grassed over. Aquatic vegetation common.

Station 6 (A 153).--Sheyenne River where crossed by north-south gravel road, S1/2 sec. 7, T. 151 N., R. 68 W., about 6 1/2 miles southeast of Maddock, Benson Co., N. Dak.; August 12 and August 16, 1966. Station, 426 river miles above mouth. Stream bottom primarily medium to coarse sand with thin layer of fine sandy silt covering bottom in most places. In thalweg, pebbles up to 2.5 cm in diameter common. Cobbles and boulders up to 0.6 m in diameter uncommon. Bottom generally firm. Stream 7 m wide with maximum depth of 1 m. Water low. Stream bottom examined from 176 m below bridge to 79 m above it for 2 hours. Banks open and grassed over. Aquatics common along edge of stream bottom.

Station 7 (A 159).--Sheyenne River where crossed by east-west gravel road, SW1/4 sec. 2 and NW1/4 sec. 11, T. 150 N., R. 67 W., 4 miles west-northwest of Sheyenne, Eddy Co., N. Dak.; August 16 and 17, 1966. Station, 408 river miles above mouth. Stream bottom primarily very coarse sand and pebbles up to 6 mm in diameter. Some fine to medium sand and pebbles up to 12 mm in diameter noted. Stream bottom generally very firm; bottom near bridge soft. Stream 12 m wide at bridge. Average depth 1 to 1.3 m but about 8 m below bridge to it, depths probably greater than 2 m. Stream bottom examined from 172 m below bridge to 17 m above bridge for 1 1/4 hours. Banks open and grassed

over. Aquatic vegetation uncommon to common near edge of banks. About 70 mussels collected per hour.

Station 8 (A 148).--Sheyenne River where crossed by east-west gravel road, SE1/4 sec. 2, T. 150 N., R. 65 W., 8 1/2 miles east of Sheyenne, Eddy Co., N. Dak.; August 4 and 17, 1966. Station, 392 river miles above mouth. Stream bottom primarily medium sand with abundant cobbles up to 5 cm in diameter. Cobbles up to 25 cm in diameter in thalweg. Stream bottom generally very firm. Stream 14 m wide at bridge. Maximum depth 1.2 m with average depth of 0.8 m. Stream bottom examined from 106 m below bridge to 4 m above it for 2 hours. Channel partially shaded by trees. Aquatic vegetation uncommon. About 27 mussels collected per hour.

Station 9 (A 161).--Sheyenne River where crossed by north-south gravel road, SW1/4 sec. 3, T. 149 N., R. 64 W., 9 1/4 miles southwest of Warwick, Eddy Co., N. Dak.; August 18 and September 6, 1966. Station, 380 river miles above mouth. Stream bottom primarily angular cobbles from 5 to 18 cm in diameter with sandy silt; generally very firm. Near bridge, cobbles uncommon. Stream 21 m wide at bridge with depth of 0.8 m. Water flow low. Stream bottom examined from 123 m below bridge to 26 m above it for 1 1/2 hours. Channel generally well shaded by trees. Aquatic vegetation common. About 20 mussels collected per hour.

Station 10 (A 149).--Sheyenne River where crossed by north-south

asphalt road (ND No. 15 and 20), W1/2 sec. 22, T. 150 N., R. 62 W., 3 1/2 miles south-southwest of Hamar, Eddy Co., N. Dak.; August 5 and 23, 1966. Station, 360 river miles above mouth. Stream bottom primarily gray, medium to coarse sand with pebbles up to 2.5 cm in diameter; generally firm. Stream 34 m wide at bridge; with maximum depth of 1 m. Water flow low. Stream bottom examined from 140 m below bridge to 17 m above it for 1 1/2 hours. Banks open and grassed over. Aquatic vegetation common. About 7 mussels collected per hour.

Station 11 (A 142).--Sheyenne River where crossed by east-west gravel road, SE1/4 sec. 30, T. 150 N., R. 60 W., about 2 1/2 miles west-southwest of Pekin, Nelson Co., N. Dak.; June 6 and August 23, 1966. Station, 344 river miles above mouth. Stream bottom primarily fine to coarse pebbly sand with light grayish-brown sandy silt cover in places; generally firm. Stream 20 m wide at bridge with maximum depth about 1.3 m. Water flow moderate. Stream bottom examined from 115 m below bridge to 35 m above it for 1 hour. Channel generally well shaded by trees. Aquatic vegetation uncommon to common. About 17 mussels collected per hour.

Station 12 (A 150).--Sheyenne River where crossed by north-south gravel road, NW1/4 sec. 24, T. 149 N., R. 59 W., about 3 1/2 miles south of McVille, Nelson Co., N. Dak.; August 5 and 24, 1966. Station, 323 river miles above mouth. Stream bottom primarily gray sandy pebble gravel with medium to coarse sand and shale pebbles from 2 mm to 20 mm

in diameter; generally firm. Stream 14 m wide at bridge with general depth of 1 m and maximum depth of 1.7 to 2 m. Water flow moderate. Stream examined from 316 m below bridge to 44 m below and from bridge to 53 m above it for 3 1/2 hours. Channel well shaded by trees. Aquatic vegetation uncommon. About 28 mussels collected per hour.

Station 13 (A 162).--Sheyenne River where crossed by northeast-southwest gravel road, NW1/4 sec. 36, T. 148 N., R. 59 W., 10 1/2 miles north of Cooperstown, Griggs Co., N. Dak.; August 25, 1966. Station, 305 river miles above mouth. Stream bottom primarily gray sandy gravel with particles, mainly shale, ranging from very coarse sand size to 16 mm. In thalweg, cobbles up to 25 cm in diameter common and boulders up to 50 cm in diameter uncommon. Near edges, a sandy mud prevalent. Stream bottom very firm. Stream 19 m wide at bridge with maximum depth of 1 m. Water flow moderate. Stream bottom examined from 105 m below bridge to 35 m above it for 1 1/2 hours. Channel well shaded by trees. Aquatics rare. About 35 mussels collected per hour.

Station 14 (A 163).--Sheyenne River where crossed by east-west gravel road, NE1/4 sec. 1, T. 146 N., R. 58 W. and SE1/4 sec. 36, T. 147 N., R. 58 W., 7 1/2 miles northeast of Cooperstown, Griggs Co., N. Dak.; August 27, 1966. Station, 286 river miles above mouth. Stream bottom primarily gray sandy pebble gravel with particles, some of them shale, ranging from very coarse sand size to 6 mm in diameter;

generally firm. Edges of stream consisted of a sandy mud; generally soft. Stream 15.5 m wide at bridge with a maximum depth of 1 m. Water flow moderate. Stream bottom examined from 35 m below bridge to it and from 265 m above bridge to 350 m above it for 1 1/2 hours. Channel well shaded by trees. Aquatics rare. About 11 mussels collected per hour.

Station 15 (A 167).--Sheyenne River where crossed by northwest-southeast gravel road, SW1/4 sec. 3 and NW1/4 sec. 10, T. 145 N., R. 58 W., 5 miles southeast of Cooperstown, Griggs Co., N. Dak.; September 5, 1966. Station, 273 river miles above mouth. Stream bottom primarily a gray sandy pebble gravel with particles, predominantly shale, ranging from very coarse sand size to 25 mm in diameter. Cobbles and boulders uncommon. Stream bottom very firm. Bottom sample taken 15 m below bridge, 3 m from left bank at depth of 0.5 m on September 30, 1966. Particle size analysis, as follows: gravel, 67%; sand, 24%; silt, 6%; clay, 3%. Stream wide at bridge with maximum depth of 1 m. Water flow moderate. Stream bottom examined from 80 m below bridge to 53 m above it for 2 hours. Channel well shaded by trees. Aquatics uncommon to rare. About 20 mussels collected per hour.

Station 16 (A 166).--Lake Ashtabula, along east shore, SW1/4 sec. 27, T. 142 N., R. 58 W., 11 miles north of Valley City, Barnes Co., N. Dak.; September 2, 1966. Station, 243 river miles above mouth. Lake bottom primarily gray brown to white. Medium to very

coarse sand with pebbles 6 to 12 mm in diameter. Cobbles uncommon. Lake bottom very firm. Lake bottom examined for about 36 m along east shore and out for a distance of 15 m from shore for 3/4 of an hour. Depth at 15 m about 1 m. Water stagnant. Algae and moss were common. No mussels noted.

Station 17 (A 165).--Sheyenne River where crossed by east-west gravel road, W1/2 sec. 24, T. 141 N., R. 59 W., 6 miles southeast of Rogers, Barnes Co., N. Dak.; September 2, 1966. Station, 237 river miles above mouth. Stream bottom primarily sandy pebble gravel with particles ranging from very coarse sand size to 16 mm. Cobbles abundant and boulders up to 0.7 m in diameter uncommon. Bottom sample taken 7 m below bridge, 5 m from left bank at depth of 0.6 m on September 30, 1966. Particle size analysis, as follows: gravel, 89%; sand, 10%; silt and clay, 1%. Stream bottom very firm. Stream 14 m wide at bridge with maximum depth of 1 m. Water flow moderate. Stream bottom examined from 70 m below bridge to 53 m above it for 1 1/2 hours. Channel partially shaded by trees. Aquatics uncommon to common. About 55 mussels collected per hour.

Station 18 (A 147).--Sheyenne River where crossed by north-south asphalt road, SE1/4SE1/4 sec. 9, and SW1/4SW1/4 sec. 10, T. 139 N., R. 58 W., 4 miles south of Valley City, Barnes Co., N. Dak.; July 28 and August 31, 1966. Station, 218 river miles above mouth. Stream bottom primarily gray medium to fine sand; generally firm. Sandy mud

near edges; cobbles abundant in thalweg. Stream 12 m wide at bridge with maximum depth of 1.3 m. Water flow moderate. Stream bottom examined from 114 m below bridge to 52 m above it for 1 1/2 hours. Channel partially shaded by trees. Rooted aquatics rare and mosses common. About 18 mussels collected per hour.

Station 19 (A 145).--Sheyenne River where crossed by north-south gravel road, SE1/4SE1/4 sec. 3 and NW1/4NW1/4 sec. 11, T. 137 N., R. 58 W., about 1 1/2 miles north of Kathyrn, Barnes Co., N. Dak.; July 25 and August 31, 1966. Station, 196 river miles above mouth. Stream bottom below bridge generally firm and consists of gray-brown medium sand varying to sandy mud near banks. About 320 m above bridge bottom sandy pebble gravel with cobbles uncommon. Stream 10.5 m wide at bridge with maximum depth of 1 m. Water flow low. Stream bottom examined from 106 m below bridge to 35 m above it and from 310 m to 330 m above bridge for 2 hours. Channel well shaded by trees. About 109 mussels collected per hour.

Station 20 (A 164).--Sheyenne River where crossed by northwest-southeast gravel road, E1/2 sec. 19, T. 136 N., R. 57 W., about 4 miles north of Fort Ransom, Ransom Co., N. Dak.; August 30, 1966. Station, 178 river miles above mouth. Stream bottom primarily pebbly sand with particles from medium sand size to 16 mm in diameter; generally very firm. Bottom sample taken under bridge, 3 m from left bank at 0.6 m on September 30, 1966. Particle size analysis as follows:

gravel, 27%; sand, 58%; silt, 10%; clay, 5%. Stream 17.5 m wide at bridge with maximum depth of 1.3 m. General depth between 0.7 and 1 m. Water flow strong. Stream bottom examined from 140 m below bridge to 44 m above it for 1 3/4 hours. Channel well shaded by trees. No aquatics noted. About 52 mussels collected per hour.

Station 21 (A 146).--Sheyenne River where crossed by east-west gravel road, S1/2 sec. 18, T. 135 N., R. 56W., 6 miles northwest of Lisbon, Ransom Co., N. Dak.; July 26 and August 30, 1966. Station, 154 river miles above mouth. Stream bottom primarily coarse sand with particles ranging from medium sand size to 16 mm in diameter; generally very firm. In thalweg, cobbles uncommon. Sandy mud noted along banks. Stream 15.5 m wide at bridge with maximum depth of 1 m. Water flow strong. Stream bottom examined from 96 m below bridge to 70 m above it for 2 hours. Channel well shaded by trees. No aquatics noted. About 70 mussels collected per hour.

Station 22 (A 107).--Sheyenne River where crossed by east-west gravel road, NW1/4 sec. 32, T. 134 N., R. 55 W., about 4 3/4 miles southeast of Lisbon, Ransom Co., N. Dak.; July 22, 1966. Station, 134 river miles above mouth. Station described and collecting of mollusks by A. M. Cvancara and A. C. F. Hung. Stream bottom primarily sandy pebble gravel with boulders to about 0.5 m at rapids. Muddy in places; along banks primarily fine to medium muddy sand. Bottom sample taken 3 m above bridge, 6 m from left bank at depth of 0.7 m on September 30,

1966 by R. D. Norby. Particle size analysis, as follows: gravel, 23%; sand, 65%; silt, 8%; clay, 4%. Stream 21 m average width. Maximum depth probably 1.7 m with average depth of 1 to 1.3 m. Stream bottom examined from small boulder rapids, 87 m above bridge to 276 m above it for 1 hour. Mussels collected by feeling bottom with feet. Channel well shaded by trees. No rooted aquatics or algae noted. About 34 mussels collected per hour.

Station 23 (A 109).--Sheyenne River where crossed by north-south gravel road along section line common to sections 16 and 17, T. 135 N., R. 54 W., about 1 mile south-southeast of Anselm, Ransom Co., N. Dak.; July 25, 1966. Station, 111 river miles above mouth. Station described and collecting of mollusks by A. M. Cvancara and A. C. F. Hung. Stream bottom primarily medium to coarse pebbly sand; adjacent to bridge primarily a sandy gravel with boulders up to 0.8 m in diameter; along banks fine to medium muddy sand surfaced with up to 3 mm clayey silt. Stream width average about 19 m. Maximum depth about 1.3 m, generally 0.7 to 1 m. Stream bottom examined from 87 m below bridge to 185 m above it for 1 1/4 hours. Mussels collected primarily by feeling bottom with feet. Channel well shaded by trees. Rooted aquatics uncommon to rare. No algae noted. About 106 mussels collected per hour.

Station 24 (A 168).--Sheyenne River where crossed by north-south gravel road, NW1/4 sec. 8, SW1/4 sec. 5 and SE1/4 sec. 6, T. 135

N., R. 52 W., 8 1/2 miles south of Leonard, Richland Co., N. Dak.; September 9, 1966. Station, 82 river miles above mouth. Stream bottom primarily reddish-brown fine to medium sand; generally firm. Bottom sample taken 4 m below bridge, 2 m from right bank at depth of 0.8 m on September 30, 1966. Particle size analysis, as follows: gravel, 7%; sand, 84%; silt, 6%; clay, 3%. Stream 17.5 m wide at bridge with maximum depth of 1.5 m. Water flow moderate. Stream bottom examined from 105 m below bridge to 274 m above it for 2 hours. Channel partially shaded by trees. No aquatics noted. About 5 mussels collected per hour.

Station 25 (A 110).--Sheyenne River where crossed by north-south earth road along section line common to sections 22 and 23, T. 136 N., R. 51 W., about 7 miles west-northwest of Walcott, Richland Co., N. Dak.; July 25, 1966. Station, 66 river miles above mouth. Station described and collecting of mollusks by A. M. Cvancara and A. C. F. Hung. Stream bottom primarily medium sand with occasional silty clay "pellets" up to 6 mm in diameter. Along banks, primarily very fine muddy sand surfaced with about 3 mm clayey silt. Bottom sample taken 1 m below bridge, 12 m from left bank at depth of 0.7 m on September 30, 1966 by R. D. Norby. Particle size analysis, as follows: gravel, 3%; sand, 84%; silt, 9%; clay, 4%. Average width of stream about 19 m. Maximum depth probably 1.3 m with average of 1 m. Stream bottom examined from 52 m below bridge to 332 m above it for 5/6 of an hour.

Mussels collected primarily by feeling bottom with feet. Channel well shaded by trees. No rooted aquatics noted. Filamentous algae uncommon to rare on fallen branches. About 4 mussels collected per hour.

Station 26 (A 111).--Sheyenne River where crossed by east-west gravel road along section line common to sections 24 and 25, T. 138 N., R. 50 W., about 1 1/2 miles southwest of Horace, Cass Co., N. Dak.; July 26, 1966. Station, 36 river miles above mouth. Station described and collecting of mollusks by A. M. Cvancara and A. C. F. Hung. Stream bottom primarily very fine muddy sand; middle of channel not seen. Bottom sample taken 2 m above bridge, 2 m from left bank at depth of 0.8 on September 30, 1966 by R. D. Norby. Particle size analysis, as follows: sand, 57%; silt, 41%; clay, 2%. Average stream width 14.5 m. Maximum depth at bridge 2.1 m. Area 1.7 to 2 m examined along left bank from 87 m below bridge to 172 m above it for 2/3 of an hour. Mussels collected primarily by feeling bottom with hands. Fair to good shading of channel by trees. Rooted aquatics uncommon. No algae noted. About 3 mussels collected per hour.

Section 27 (A 108).--Sheyenne River where crossed by east-west gravel road along section line common to sections 18 and 19, T. 140 N., R. 49 W., about 3 3/4 miles southwest of Harwood, Cass Co., N. Dak.; July 23, 1966. Station, 17 river miles above mouth. Station described and collecting of mollusks by A. M. Cvancara and A. C. F. Hung. Stream bottom primarily very fine to fine muddy sand; more muddy along

banks and surfaced with up to 6 mm clayey sandy silt. Bottom soft along banks and firm toward middle of channel. Average stream width 17.5 m. Maximum depth probably 1.7 m; generally 1.2 to 1.4 m. Area 1.7 to 2 m examined along banks from bridge to 221 m above it for 5/6 of an hour. Mussels collected primarily by feeling bottom with hands. Fair to good shading of channel by trees. Rooted aquatics uncommon to rare. No algae noted. About 8 mussels collected per hour.

APPENDIX B

DESCRIPTION OF SHEYENNE RIVER SECTIONS

General.--Mud, as used in the descriptions, is a wet or dry mixture of silt and clay.

Relative abundance of each fossil species is indicated by: A = abundant, C = common, U = uncommon, and R = rare.

A

Kathyrn Section 1

Cutbank exposure on right bank of Sheyenne River, about 450 yds. above bridge on road common to secs. 2, 3, 10, 11, T. 137 N., R. 58 W., about 1 1/2 miles north of Kathryn, Barnes Co., N. Dak.; June 14, 1966.

Unit	Description	Feet
top of section		
9	Partially concealed, probably soil.	6
8	Sandy mud, sand fine to medium; gray brown, weathering light gray; sorting poor. Sand mainly quartz, but much limonite and hematite present. Undulating bedding. Particle size analyses: sand, 24%; silt, 46%; clay, 30%. Fossils	0.3

collected: Amnicola cf. A. limosa (R), Ferrissia sp. (R), Vallonia sp. (R).

7	Sandy mud, gray; sorting fair.	1.4
6	Sandy mud, sand fine to coarse; similar to unit 8. Particle size analysis: sand, 43%; silt, 34%; clay, 22%. Fossils collected: Sphaerium sp. (U-R), Amnicola cf. A. limosa (U-R), Ferrissia sp. (R), Succinea sp. (R), Vallonia sp. (U-R).	0.3
5	Similar to unit 7.	1.5
4	Sandy mud, sand fine to medium; similar to unit 8. Particle size analysis: sand, 28%; silt, 45%; clay, 27%. Fossil collected: Lampsilis ventricosa (R).	0.4
3	Similar to unit 7.	1.4
2	Sandy mud, sand medium; similar to unit 8. Particle size analysis: gravel, 2%; sand, 44%; silt, 33%; clay, 21%. Fossils collected: Anodonta grandis (R), Anodontoides ferussacianus (R), Sphaerium sp. (A-C), Amnicola cf. A. limosa (C), Ferrissia sp. (R), Physa sp. (R), Succinea sp. (R), and Zonitoides ? sp. (R).	0.8
1	Sandy mud; similar to unit 7. Particle size	0.4

analysis: sand, 16%; silt, 54%; clay, 30%.

1a	Concealed by slump, probably same as unit 1.	5.8

B

Anselm Section

South road cut exposure of delta or terrace sediments on west edge of bridge, north edge NE1/4 sec. 32, T. 135 N., R. 54 W., about 4 miles south of Anselm, Ransom Co., N. Dak.; section measured by A. M. Cvancara, June 7, 1966.

Unit	Description	Feet
top of section		
3	Concealed portion, probably soil.	4.1
2	Sand, fine to medium, becoming coarser toward bottom; sorting good. Particle size analysis on sample taken 2.2 feet from top of unit: sand, 68%; silt, 20%; clay, 12%. Analysis on sample taken 3-6 inches above base of unit which contained mussels: gravel, 5%; sand, 84%; silt, 7%; clay, 4%. Fossils collected: Lampsilis siliquoidea (C), Sphaerium sp. (U), Amnicola cf. A. limosa (R).	5.6
1	Pebble gravel sand, sand medium to coarse and pebbles 2-3 cm in diameter.	4.7

1a	Concealed till? Till occurs just below base of unit 1 (fide Dr. J. A. Brophy, N. Dak. State Univ., June 7, 1966).	31.2

C

Lisbon Section 1

Cutbank exposure on left bank of Sheyenne River, about 400 yds. above bridge, NW1/4 sec. 32, T. 134 N., R. 55 W., about 4 1/2 miles southeast of Lisbon, Ransom Co., N. Dak.; July 27, 1966.

Unit	Description	Feet
top of section		
4	Sand, very fine, reddish-brown, sorting good.	1.6
3	Pebble gravel sand. Sand fine to coarse, light brownish gray, quartz predominant; sorting fair. Particle size analysis: gravel, 21%; sand, 64%; silt, 10%; clay, 5%. Fossils collected: Fusconaia flava (U-C), Amblema costata (R), Quadrula quadrula (R), Anodonta grandis (R), Strophitus rugosus (U), Ligumia recta latissima (U), Lampsilis siliquoidea (U), L. ventricosa (R), Sphaerium sp. (A), Pisidium sp. (U), Amnicola cf. A. limosa (A), Helisoma antrosa (R), H. trivolvis (R), Menetus ? sp. (R),	1.0

Gyraulus sp. (R), Physa sp. (R), Succinea sp. (R), Cionella sp. (R), and Vallonia sp. (R).

2	Sand, fine to coarse, mainly medium, brownish gray, quartz predominant; sorting good. Particle size analysis: gravel, 1%; sand, 82%; silt, 12%; clay, 5%. Fossils collected: Quadrula quadrula (R), Ligumia recta latissima (R), Sphaerium sp. (C), Pisidium sp. (U), Amnicola cf. A. limosa (C), Succinea sp. (R), Vallonia sp. (U), and Helicodiscus sp. (R).	0.8
1	Concealed, probably sand similar to above units.	4.0

D

Lisbon Section 2

Cutbank exposure on left bank of Sheyenne River, about 500 yds. above bridge, NW1/4 sec. 32, T. 134 N., R. 55 W., about 4 1/2 miles southeast of Lisbon, Ransom Co., N. Dak.; July 27, 1966.

Unit	Description	Feet
top of section		
4	Concealed, probably sand similar to units below.	3.3
3	Muddy sand, very fine to medium, mainly fine, light brownish gray, quartz predominant; sorting	2.2

good. Particle size analysis: sand, 60%; silt, 27%; clay, 13%. Fossils collected: Fusconaia flava (R), Amblema costata (R), Lasmigona complanata (R), Strophitus rugosus (R), Ligumia recta latissima (U), Lampsilis siliquoidea (U), L. ventricosa (R), and Amnicola cf. A. limosa (R).

2 Muddy sandy pebble gravel, particles to 2 cm, sand mainly fine and coarse (essentially no medium), reddish brown to gray; sorting poor. Sand quartz but much limonite and hematite present. Particle size analysis: gravel, 39%; sand, 14%; silt, 29%; clay, 18%. Fossils collected: Fusconaia flava (U), Amblema costata (U), Quadrula quadrula (R), Lasmigona complanta (R), Anodonta grandis (U), Strophitus rugosus (C), Lampsilis siliquoidea (C), L. ventricosa (C), Sphaerium sp. (A), Pisidium sp. (U), Amnicola cf. A. limosa (A), Helisoma antrosa (U), H. trivolvis (R), Physa sp. (R), and Succinea sp. (R). 0.8

1 Muddy sand, very fine to fine, brownish gray; sorting good. 2.3

E

Kathyrn Section 2

Cutbank exposure on left bank of Sheyenne River, about 700 yds. above bridge common to secs. 2, 3, 10 and 11, T. 137 N., R. 58 W., about 1 1/2 miles north of Kathyrn, Barnes Co., N. Dak.; June 14, 1966.

Unit	Description	Feet
top of section		
3	Concealed by slump, probably primarily soil.	8.0
2	Sandy mud near top grading to a pebbly muddy sand near bottom. Pebbles up to 1-2 cm, sand fine to very coarse, reddish brown near top with limonite and hematite grading to light brownish gray with much quartz near bottom. Particle size analysis on sample 3 in. below top of unit: gravel, 6%; sand, 35%; silt, 35%; clay, 24%. Analysis on sample 3 in. above bottom of unit: gravel, 15%; sand, 59%; silt, 18%; clay, 8%. Fossils collected: Lasmigona complanata (R) and Vallonia sp. (R).	2.0
1	Sandy mud, dark gray, weathers gray; sorting poor.	4.4

F

Cooperstown Section

Cutbank exposure on right bank of Sheyenne River, about 120 yds. below bridge, SW1/4 sec. 3 and NW1/4 sec. 10, T. 145 N., R. 58 W., about 5 miles southeast of Cooperstown, Griggs Co., N. Dak.; September 5, 1966.

Unit	Description	Feet
top of section		
10	Soil.	6.0
9	Sandy mud, dark gray, weathers gray, sand fine to medium; sorting poor.	1.0
8	Muddy sand, fine to very coarse, brownish gray, much black hematite and limonite; sorting poor. Undulating bedding. Particle size analysis: gravel, 10%; sand, 48%; silt, 28%; clay, 14%. Fossils collected: Lampsilis siliquoidea (R), Sphaerium sp. (U), Amnicola cf. A. limosa (U), and Helisoma trivolvis (R).	0.6
7	Sandy mud; similar to unit 9.	0.8
6	Muddy sand, medium to coarse, brownish-gray, uncommon pebbles up to 1-2 cm, undulating bedding; sorting poor.	0.6

5	Sandy mud; similar to unit 9.	0.8
4	Sandy mud, sand fine to very coarse, brownish-gray, much black hematite and limonite, common pebbles up to 1-2 cm; sorting poor. Particle size analysis: gravel, 25%; sand, 32%; silt, 28%; clay, 15%. Fossils collected: Anodonta grandis (R), Anodontoides ferussacianus (R), Strophitus rugosus (U), Lampsilis siliquoidea (R), L. ventricosa (R), Sphaerium sp. (A), Pisidium sp. (R), and Amnicola cf. A. limosa (A).	0.6
3	Sandy mud; similar to unit 9.	0.8
2	Sandy mud, sand fine to very coarse, brownish gray, much black hematite and limonite, common pebbles up to 1-2 cm; sorting poor. Particle size analysis: gravel, 17%; sand, 33%; silt, 32%; clay, 18%. Fossils collected: Anodonta grandis (U), Anodontoides ferussacianus (R), Strophitus rugosus (U), Lampsilis siliquoidea (C), L. ventricosa (U), Sphaerium sp. (A), Pisidium sp. (R), Amnicola cf. A. limosa (C), Lymnaea sp. (R), Ferrissia sp. (R), Succinea sp. (R).	0.6
1	Muddy sand, fine to medium, gray; sorting fair.	2.2

LEGEND

HIGHEST STRANDLINE OF LAKE AGASSIZ

DELTA OF LAKE AGASSIZ

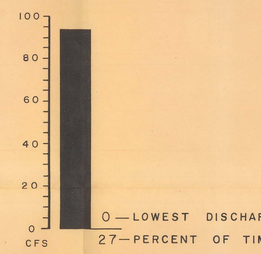
FOSSIL SITE

GAGE STATION

LIVE MUSSELS

NO LIVE MUSSELS

AVERAGE DISCHARGE (in cubic feet per second)

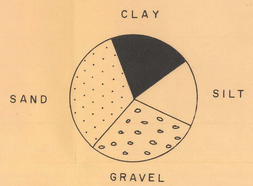


0 — LOWEST DISCHARGE

27 — PERCENT OF TIME OF NO FLOW

DISCHARGE VALUES ARE FOR WATER CALENDER YEARS 1956 – 1965 (OCT. 1, 1955 — SEPT. 30, 1965)

* Discharge values for gage station 587 are for Water Calender Years 1957 – 1966



5 0 5 10 15 20 MILES

SCALE 1:250,000

PLATE 1