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Mollusks from Wisconsinan (Pleistocene) ice-contact sediments of the Missouri Coteau in central North Dakota

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MOLLUSKS FROM WISCONSINAN (PLEISTOCENE) ICE-CONTACT SEDIMENTS OF THE MISSOURI COTEAU IN CENTRAL NORTH DAKOTA

by

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MOLLUSKS FROM WISCONSINAN (PLEISTOCENE) ICE-CONTACT SEDIMENTS OF THE MISSOURI COTEAU IN CENTRAL NORTH DAKOTA

Samuel J. Tuthill, A.B., M.S., M.A.

ABSTRACT

This thesis here abstracted was written under the direction of Frank D. Holland, Jr., and was approved by Wilson N. Laird and George C. Wheeler as members of the examining committee, of which Dr. Holland was Chairman.

Geologic and paleontologic evidence indicates that numerous mesotropic, temperate, water bodies were present while drift-covered blocks of stagnant glacier ice, emplaced during Woodfordian (late Wisconsinan, Pleistocene) time, underlay the Missouri Coteau district (approximately 50 by 300 miles in extent) in central North Dakota.

Fossil mollusks, contained in sediments deposited in contact with the stagnant ice at 40 sites, are represented by 23 species including pelecypods of the families Unionidae and Sphaeriidae and gastropods of the families Valvatidae, Hydrobiidae, Physidae, Lymnaeidae, Planorbidae, Ancylidae, Succineidae and Pupillidae. Naiad shells have provided material for five radiocarbon dates in the Missouri Coteau district which indicate that the melting of the stagnant ice may have required 2,100 years.

The fossil mollusks, as now known, do not serve as stratigraphic indices to the late Pleistocene deposits of the region, but the species composition of fossil molluscan communities dominated by the branchiate genera Valvata and Amnicola is regarded as tentative evidence of the

pre-Recent age of the Missouri Coteau sediments. The mollusks also indicate the climate of the region to have been mild and humid as early as 12,000 and as late as 8,700 radiocarbon years before the present.

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INTRODUCTION

The discovery of fossil mollusks in the drift of south-central North Dakota by three independent field parties[1] in the summer of 1961 provided valuable information for the interpretation of the glacial geology of the Missouri Coteau district (Fig. 1). Detailed investigation of the fauna at three sites was reported by Clayton (1961) and of another site by Tuthill (1961). These and 36 additional sites and their faunas are described here. Shell material from five of these has been radiocarbon dated (Fig. 20).

The drift from which the fossils were taken was deposited on stagnant ice in a belt as great as 50 miles wide, comprising the Missouri Coteau district as restricted by Lemke and Colton (1958, Fig. 1) in southern North Dakota. The presence of fossil fresh-water gastropods and pelecypods provides an excellent basis for reconstructing the ecologic conditions which prevailed during the formation of the Missouri Coteau. The pelecypods of the superfamily Unionoidea also provide material for radiocarbon dating of the sediments.

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[1]Messrs. Lee Clayton and John Bonnerville, University of North Dakota, in Logan County; Drs. Mark Rich and Harold Winters, North Dakota Geological Survey, and Mr. Charles Harnell, U. S. Geological Survey, in Stutsman County.

The large number of species (23) and the complexity of the life history of some of them, provide information about the type of community of which they were a part and are presumptive evidence for a sizeable biota not represented by fossil remains. That the molluscan fauna will provide fossil indices to geologic time is unlikely for two reasons. First, no extinct forms have been found in the drift of North Dakota. Although little detail is yet known of the Recent fauna, all of the species are still extant in some part of the state. Secondly, insufficient time elapsed during the deposition of the drift of which the fossils are a part, to expect evolutionary changes in the species and no morphologic differences between Wisconsinan specimens and Recent specimens has been observed.

Traditionally, Pleistocene time divisions have been erected on lithologic criteria which are assumed to reflect climatic conditions. Those climatic conditions which caused continental glaciers to advance and those which caused them to contract are inferred from tills and paleosols respectively. It must be remembered that these tills and paleosols are proper criteria for inferring lithologic equivalency, but they are <u>not</u> proper criteria for time correlations unless they are supported by independent time indicators such as fossil indices. However, the technique of lithologic equivalence seems usable for the larger divisions of Pleistocene time (Stages) in areas where lithologic evidence for multiple glaciations are present and well exposed. The equating of lithologies in this latter manner assumes that climatic conditions which controlled the several glaciations of the Pleistocene are known in detail and that they varied at essentially the same time across the latitudes of North America and northern Europe. The validity

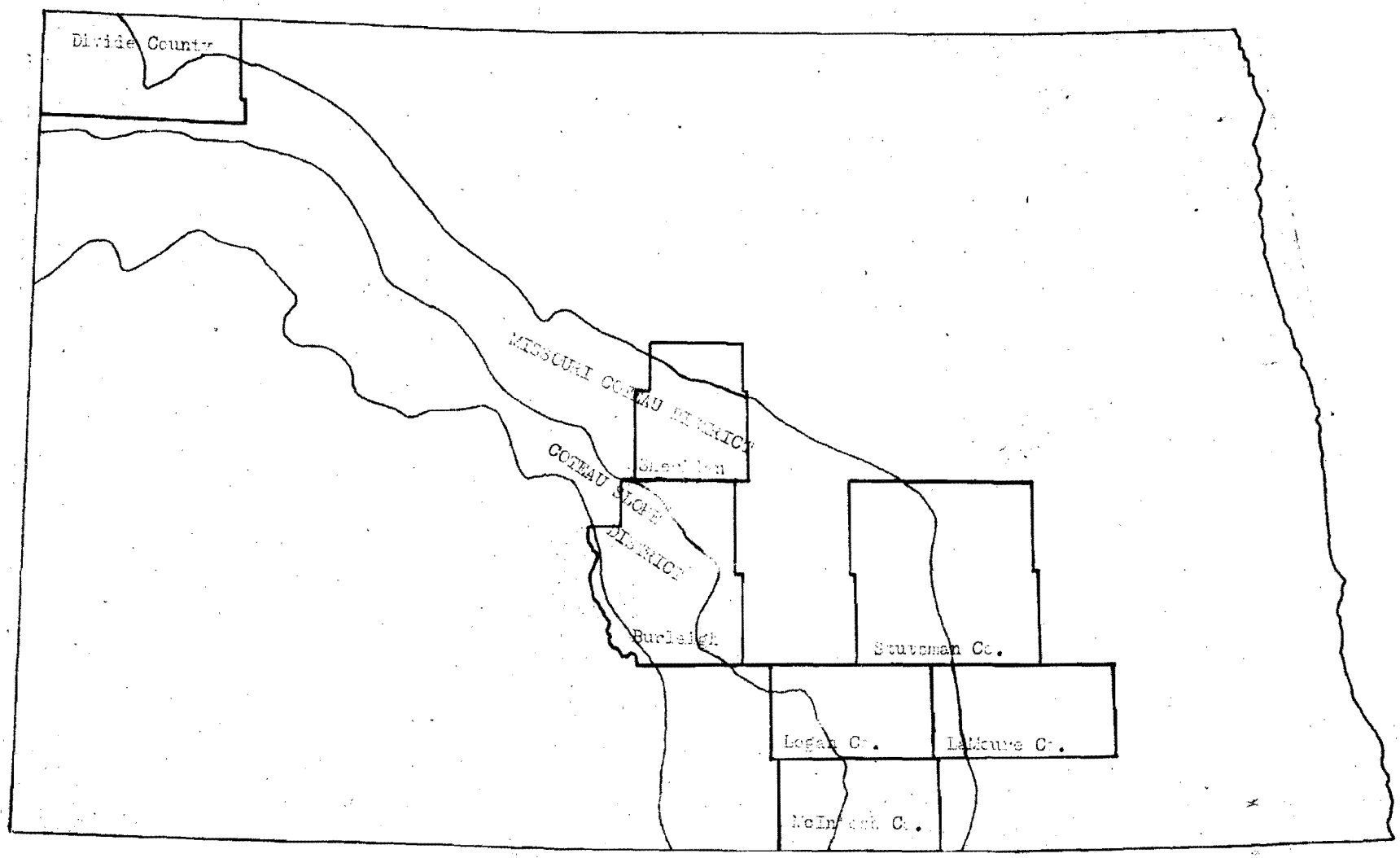


Fig. 1. INDEX MAP OF NORTH DAKOTA SHOWING THE MISSOURI COTEAU AND COTEAU SLOPE DISTRICTS AND THE AREA STUDIED. Approx. Scale 1:2,500,000.

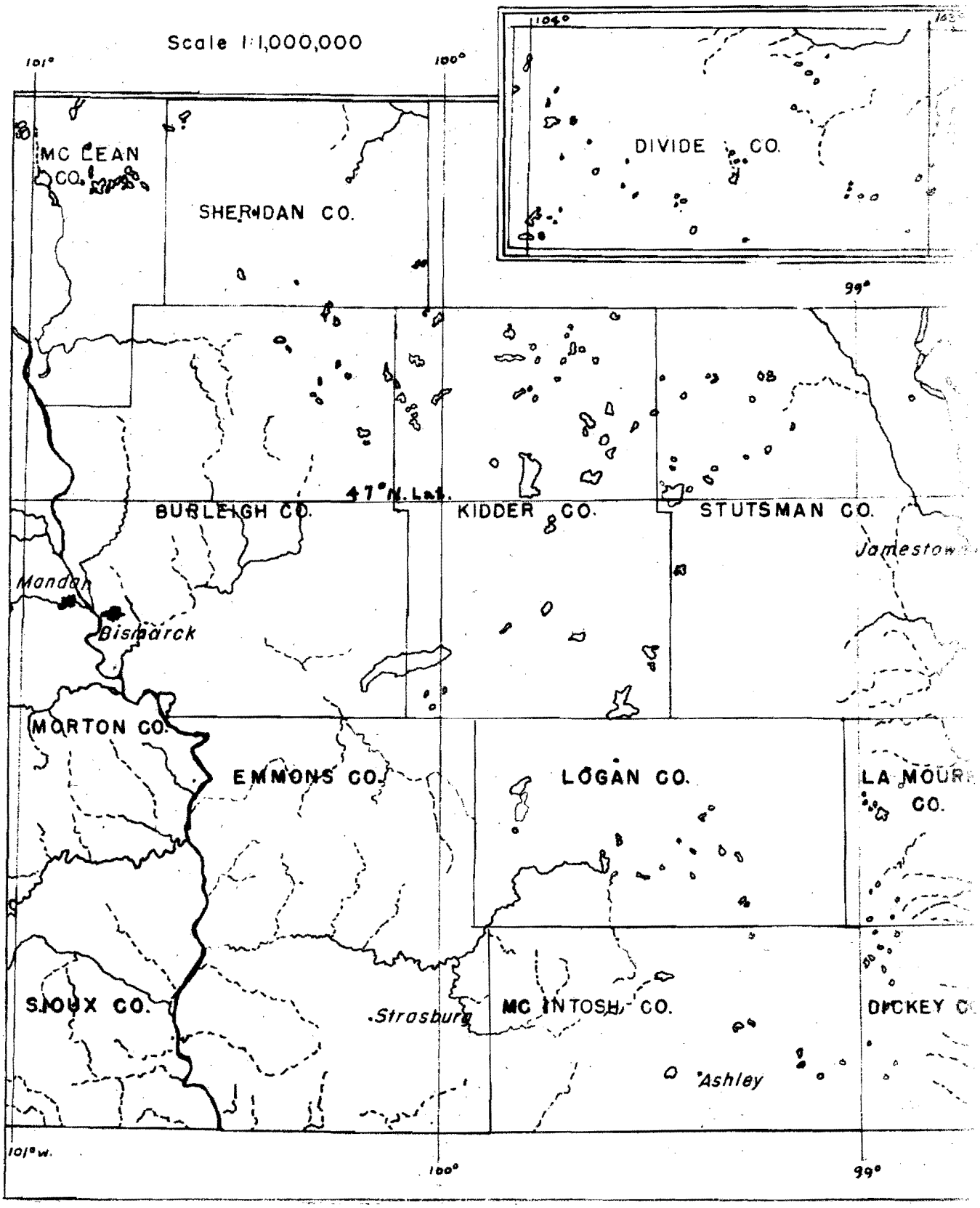


Fig. 2. MAP OF THE AREAS STUDIED SHOWING DRAINAGE PATTERN. Note integrated drainage in Coteau Slope district in western Burleigh County, Emmons County and western McIntosh County and total lack of integrated drainage in the Missouri Coteau district.

of these assumptions is not beyond question when time divisions of the order of substages are considered.

In attempting to correlate the deposits of the Missouri Cotean with deposits of the "classic" areas to the east, the method of lithologic extension fails for two reasons. The moraines of the late Pleistocene have not been traced into North Dakota with sufficient thoroughness to remove all major doubts as to the continuity of the moraines. Large gaps and local fractionation of the morainal complexes will probably never permit undisputed success in this attempt, without the support of other data. As more paleontological work is done fossil indices may contribute this necessary data, but the work reported here seems to indicate the justification of pessimism in this regard. The modern nature of the molluscan fauna of the Burnstad drift seems to preclude the hope of erecting most fossil indices for the late Pleistocene.

For these reasons I have elected to modify (Fig. 3) the classification of Frye and Willman (1960) which they erected for the Lake Michigan lobe of the Wisconsinan Stage in Illinois. Their classification has the merit of being based on radiocarbon data which is independent of lithologic and stratigraphic judgments. The assumptions implicit in the acceptance of radiocarbon time do not appear to be any more questionable or critical than those which underlie our acceptance of fossils, and the evolution that their morphology implies, as a basis for geologic time throughout the rest of the geologic column. Experience, where radiocarbon data have been employed, indicates that they are consistent and reproducible. The assumption that the $C^{14} - C^{12}$ ratio of the atmosphere, (though it might vary in time) would be uniform

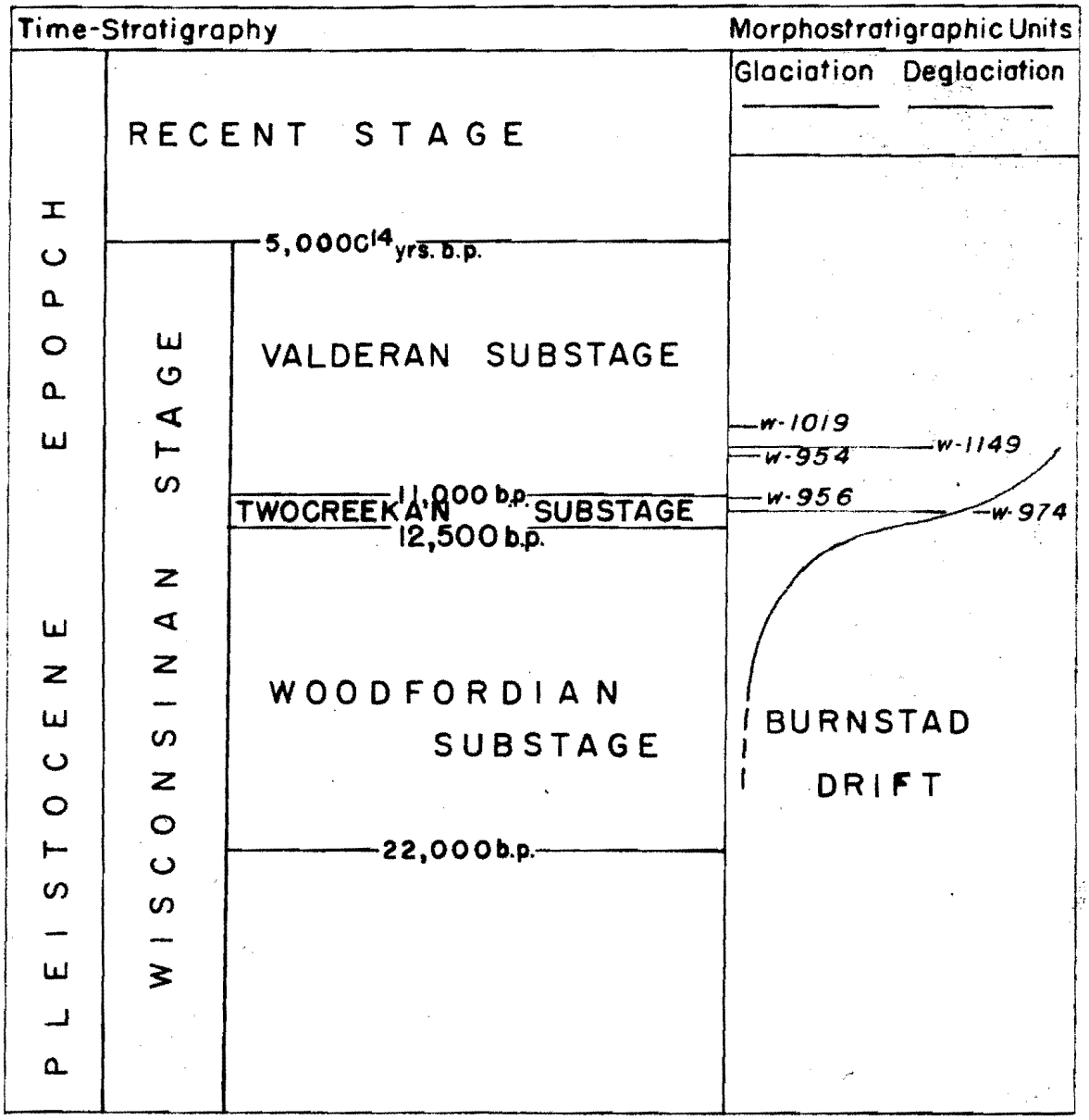


Fig. 3. CLASSIFICATION OF THE WISCONSINAN STAGE IN NORTH DAKOTA. This classification is a modification of that of Frye and Willman (1960). Substages older than the Woodfordian are not known in the Missouri Coteau district.

in the atmosphere at any given time seems more reasonable than the idea that glacial advance and retreat would vary uniformly in the dimensions of a substage across the northern hemisphere. Thus the fact that the ratio may not be the same today as it was in the past is not a critical flaw. A radiocarbon date in one area has an excellent chance of representing the same number of solar years as a similar radiocarbon date in another area despite the fact that radiocarbon years may not equal solar years.

The physiology of the assimilation of carbon by aquatic mollusks has been studied by Rubin and others (1963, p. 84-88). Their study on gastropods indicates a maximum reductional error of approximately 1000 C^{14} years is possible in dates taken from shells. If this error approximates that possible in mussel shell dates, it does not significantly alter the conclusions drawn here. Dates on wood (Meir, 1958, p. 110, W-542, on conifer wood from SW¼ sec. 25, T. 138 N., R. 71 W., 11,460 ± 300 years B.P.) in Ridder County in the Missouri Coteau district closely agrees with the dates obtained from mussel shells. With this good degree of agreement I assume that the method of radiocarbon dating of aquatic mollusk shells is valid.

I have not adopted the substage names of Frye and Willman for time divisions older than the Woodfordian because the dates obtained from the Coteau do not as yet require it.

PLEISTOCENE GEOLOGY

Wisconsinan Stage Stratigraphy:- All the faunules discussed here are from a single Pleistocene stratigraphic unit, the Burnstad Drift (as defined by Clayton, 1963, p. 62). The Burnstad Drift is a glacial morphostratigraphic unit consisting of till, outwash and lake sediments of the Burnstad and Streeter end moraines and associated dead-ice moraines, outwash plains, and ice-contact washed-drift features in south-central North Dakota. Pelecypod (unionid) shells from it have been radiocarbon dated at as little as 8,700 and as much as 11,960 years before present (see Fig. 20). The Burnstad Drift belongs to the upper part of the Wisconsinan Stage. The drift-covered stagnant ice from which the Burnstad Drift was deposited might thus have taken 2,100 years to melt. The end moraines that are composed of Burnstad Drift, deposited when the ice was active, roughly correlate with end moraine composed of Bankato Drift in Minnesota according to Clayton (1963, p. 66). The topographic features in which the fossils were found are composed of Burnstad Drift deposited in contact with the glacier ice after the ice stagnated. It correlates, in part, with the Two Creeks deposits in Wisconsin and possibly also with Valders and post-Valders deposits. The upper Burnstad Drift is thus part of Frye and Willman's (1960) Tazewellan and Valderan substages (Fig. 3), but was probably emplaced by ice which invaded North Dakota during Woodfordian time.

Ice-Contact Deposits of the Burnstad Drift:- All of the fossiliferous sediments of the Burnstad Drift are ice-contact deposits of outwash or lake sediments that resulted when sheets of glacier ice, several miles wide, stagnated. These deposits occur in a variety of

forms, including ice-walled-lake plains, collapsed lake-sediment topography, and collapsed outwash topography.

The ice-walled-lake plains are as much as 5 miles across and are bordered by outward sloping ice-contact faces. The present topography of the Cotaco is essentially the same as the glacier left it. Because the drainage of the Cotaco is completely nonintegrated, the elevated positions of the lake plains could only result from deposition in lakes that were surrounded by stagnant glacier ice. (Fig. 2). The collapsed outwash topography and collapsed-lake-sediment topography were formed during the melting of ice on which had been deposited sediments from superglacial streams and lakes (Fig. 4 and 5). The resulting collapsed outwash and lake sediment has bedding that is gently to complexly folded and faulted. Its topography has as much as 100 feet of local relief and has numerous undrained depressions, indicating that the relief is the result of collapse from stagnant ice rather than the result of stream erosion. Stream sediments are frequently found distributed over hills and depressions with no logical genetic relationship to the present topography.

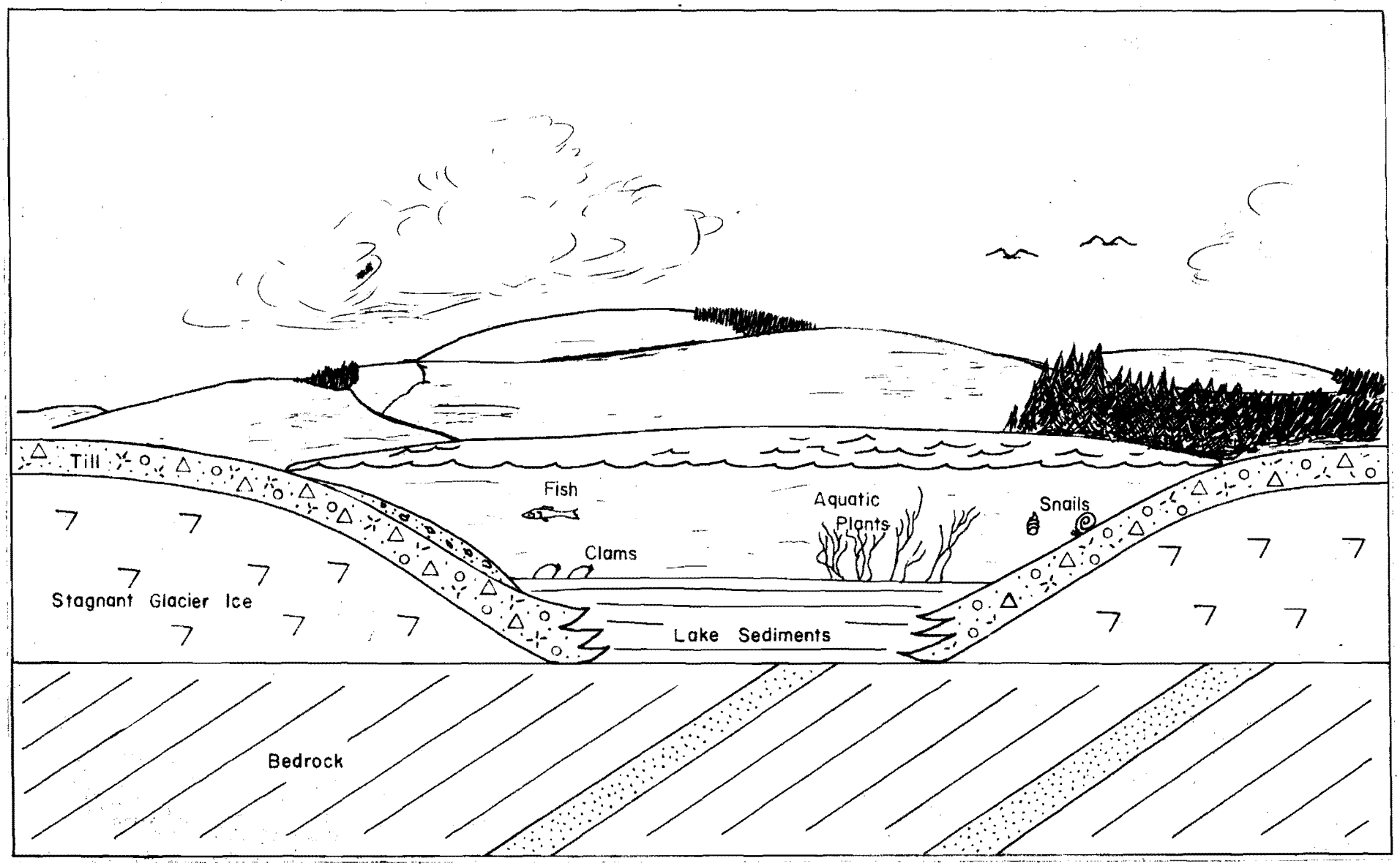


Fig. 4. SCHEME SHOWING THE MANNER IN WHICH ICE-WALLED LAKES MAY HAVE FORMED IN THE MISSOURI COTEAU DISTRICT DURING WISCONSINAN TIME. The biota is inferred from fossil remains.

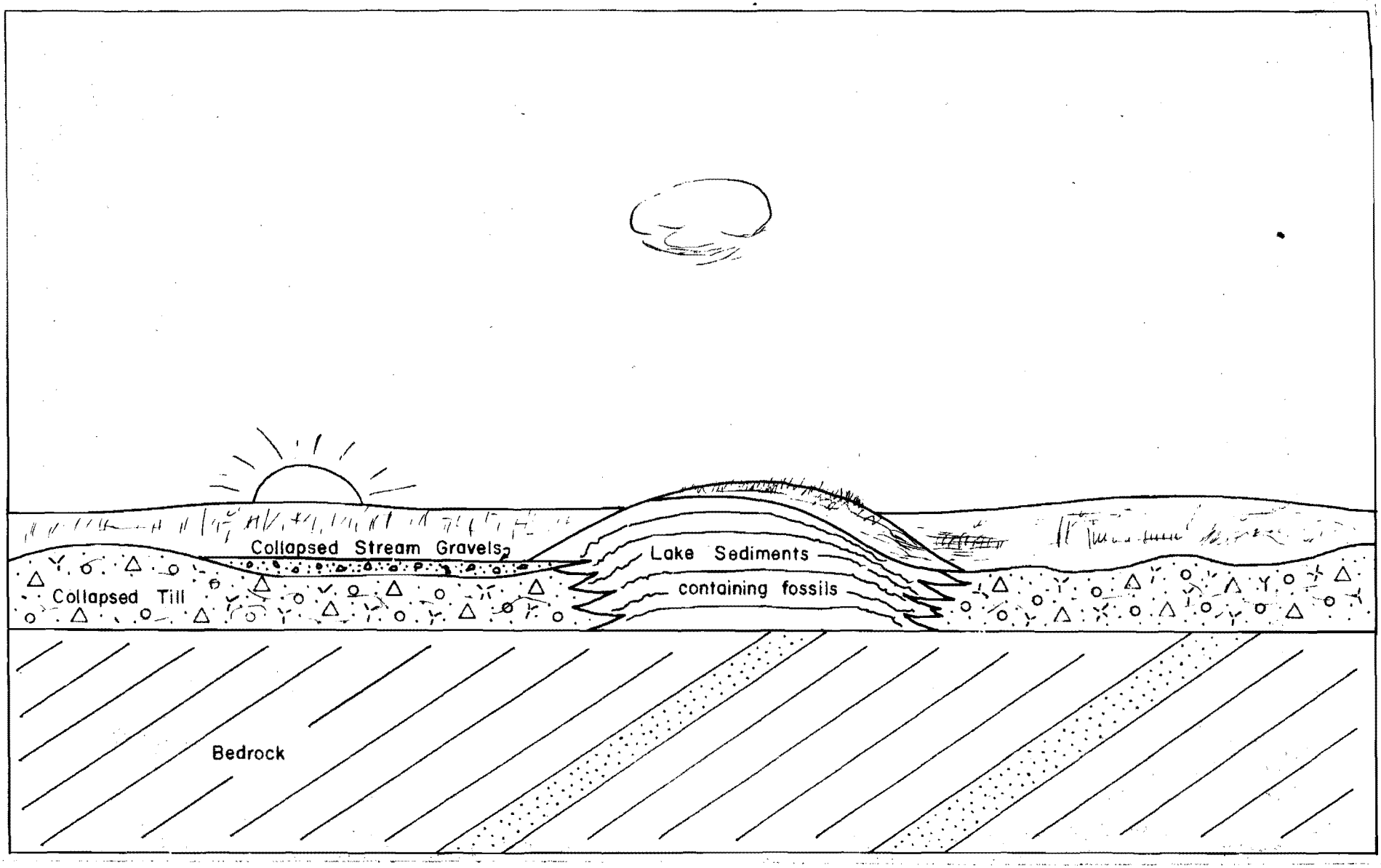


Fig. 5. SCHEMATIC DRAWING SHOWING THE RELATIONSHIP OF LITHOLOGIES AND THEIR TOPOGRAPHIC EXPRESSIONS IN THE MISSOURI COTEAU DISTRICT OF SOUTH-CENTRAL NORTH DAKOTA. The area is presently typified by a total lack of integrated drainage.

METHODS

Most of the faunules were located by geologists in the normal course of field mapping the surface geology of the state. Tailings at the entrance of badger burrows were of great assistance in locating fossiliferous sedimentary layers which were not exposed at the surface.

All sites required extensive excavation by digging a pit or trench before successful examination and sampling was possible. As a result, most of the knowledge I have is of the sediments near the surface. Nowhere was I able to sample to a depth where till or bedrock was encountered.

The fragile nature of the naiad shells necessitated a special collecting technique. The clam shells, partially exposed by excavation, were saturated with clear lacquer sprayed from a pressure bomb and allowed to dry before they were removed from the sediments. They were then removed from the sediments, again sprayed with lacquer and wrapped in tissue paper for transportation. With this technique it was possible to recover specimens in such perfect condition that they still show fibers of the ligament. The larger specimens of the genera Sphaerium, Musculium, and Lampsilis were collected from the sediments as they were encountered. All other specimens were taken in bulk samples and removed from washed samples during examination of the sediments under binocular microscope at magnifications of 10 X, 60 X, and 120 X. About one-half liter of sediments was examined from each sample and a representative fauna removed, placed in vials, identified, catalogued and placed in the collection of the University of North Dakota Department of Geology. Approximately 15,000 specimens comprise the basis of the conclusions drawn here.

At several sites, detailed descriptions of the sediments were made and sequential samples were taken (Nee Farm, Mummy Cat Slough, Rosenthal 1, Rosenthal 2, Cleveland and Schauer Farm sites). The results of the inspection of these samples for fauna and grain size of sediments are combined with the information obtained in the field and presented in graphic form in Fig. 8, 9, 13-15.

All measurements of fossils listed below were taken in the following manner:

Measurements less than 1 mm were made with an ocular grid at magnifications of 45 X, with an implied accuracy of 0.03 mm.

Measurements of 1 - 10 mm were made with an ocular grid at magnifications of 15 X, with an implied accuracy of 0.1 mm.

Measurements greater than 10 mm were made with a vernier calipers with an implied accuracy of 0.1 mm.

Shell orientation in the case of the genera Sphaerium and Pisidium follows. In Pisidium, the umbonal terminations of the lateral teeth form two points on a line of reference; shell length is the greatest distance parallel to this line in the plane of commissure, and shell height is the greatest distance normal to this line in the same plane. For Sphaerium a plane of approximate secondary symmetry can be imagined passing through the beaks and dividing the ventral margin into anterior and posterior halves; the junction of this plane and the plane of commissure forms a line of reference. Shell length for Sphaerium is the greatest distance in the plane of commissure normal to this line; shell height is the greatest distance parallel to the line. Thickness of the pelecypods was not measured because single valves were more

common than articulated ones.

Shell orientations employed in all other genera, as well as these special cases may be seen in Fig. 21.

The fragility of the specimens precluded an attempt to match disjunct valves. Articulated naiad shells were left with their contained sediments intact. The interiors of the shells were inspected through holes bored in the impregnated sediment fillings.

ACKNOWLEDGMENTS

I am indebted to several persons who facilitated the research reported here. Dr. F. D. Holland, Jr., under whose direction this thesis was written, gave freely of his time, advice, and efforts throughout the research and subsequent writing. His encouragement was in large measure responsible for my continued enthusiasm for the study. Dr. Wilson M. Laird has supported my efforts, both personally in the form of advice, parallel research participation, and encouragement and by providing support for part of the field work and the photographing of the plates, in his capacity as State Geologist. Dr. George C. Wheeler has been most helpful in assisting me to gain an understanding of the Recent molluscan fauna of North Dakota, which serves as the basis of the paleoecologic reconstructions postulated here.

Mr. Lee S. Clayton worked with me in the field from time to time. Through his own research he set the geologic scene for this study. The conversations I was privileged to have with him during the period 1960 to 1962 contributed greatly to my understanding of the Pleistocene history of the Missouri Coteau district, and this report would be far less complete were it not for his efforts. Mr. Dan E. Hansen, Geologist of the North Dakota Geological Survey, and Mr. Neil R. Sherrod, Graduate Student at the University of North Dakota, were attentive to my problem, while engaged in their own research, and their collection of fossiliferous sites in Burleigh and Divide and Sheridan Counties has extended the area of our knowledge of Wisconsinan molluscan faunas very measurably.

Mr. Miller Hansen, Assistant State Geologist, Mr. Jack Kume and Mr. Kent Nadenwald, of the North Dakota Geological Survey have contributed to the study in the form of actual assistance in the field, suggestions and criticisms and I wish to express my appreciation of their interest and efforts.

MOLLUSCA AS PALEOECOLOGIC INDICATORS

The practice of inferring ecologic and climatic conditions which existed in the past, from fossils by assuming their environmental requirements to be essentially identical with those of extant relatives, is well established and correct under the assumptions implicit in the doctrine of Uniformitarianism. In the case of the Pleistocene mollusks reported here it is most appropriate, as all of the species are extant and resident in the same general geographic region as the fossils. The ecologic differences between the present locale of the living forms and the Coteau can be regarded as the net ecologic change which has occurred between the time of the deposition of that part of the Burnstad Drift containing the fossil mollusks and the present. A discussion of this has been given by Tothill, Clayton, and Laird (1963).

Because any lotic and/or lenitic environment is composed of a variety of microhabitats which may differ from each other to a striking degree, the problem of recognizing necrocoenoses becomes central. An examination of the sediments and the population structure of the fauna usually suffices to indicate the presence or absence of a necrocoenose, but at best the conclusion is subjective. Even transported fossils, if not reworked from older rocks, can be regarded as solid paleoclimatic criteria for the general area of the Missouri Coteau.

The question of the importance of variation of numbers of specimens of one species as compared to the number of specimens of another species in a vertical sequence has been raised by LaRocque (1960, p. 141). In an area where a dense sampling pattern can be established, quantitative methods are preferrable. The faunules reported here have been treated in a semi-quantitative way as befits the manner of sampling and

the reconnaissance nature of the entire study. Exposures on the Cotaco are rare and always shallow. The presence or absence of the various species is a valid basis for conclusions about the ecologic conditions which endured, but are less precise than those permitted by a more quantitative technique.

Present knowledge of the ecology of Recent freshwater mollusks is largely limited to compilations or scattered items of information noted in conjunction with the collection of specimens. Few exhaustive ecologic studies of freshwater Mollusca have been conducted, therefore the ecologic information inferred from fossils must remain general in nature if it is to be accurate. The practice of some authors of inferring the conditions of water chemistry and specific temperature ranges is without justification at the present state of knowledge of the habitat requirements of Recent mollusks. The use of fossil communities as a basis for reconstructing climatic conditions of the Pleistocene is quite appropriate, however, in that few species have become extinct and comparable assemblages of the same species now exist in North America to guide the paleoecologist.

TYPES OF HABITATS

The sediments from which fossil mollusks have been taken indicate two basic types of sedimentary environments existed on the Missouri Coteau during late Wisconsinan time: running and standing fresh water. The last of these still exists there, but the first is totally absent. The areal distribution and thickness of lake sediments at 32 sites suggests that a considerable number of standing water environments also existed during the time the fossil mollusks lived. The high position of these lake sediments above collapsed till and outwash sediments is taken as evidence that these lakes were a part of the supraglacial drainage on the ice which deposited the Streeter and the Burnstad end moraines.

Collapsed outwash at 7 sites, containing fossils, some of which show attrition of their surfaces, presumably due to abrasion during transportation, suggest a considerable development of connecting drainage between the lakes, a feature absent from the district at the present time. The smaller number of fossiliferous sites located in outwash sediments may well be due to the greater difficulty of recognizing the presence of fossil mollusks in sand-and gravel-sized sediments.

Gastropods, reputed to be found in lakes only (e. g. Helisoma anceps and H. trivolvis) have been found in 3 of the 7 sites composed of outwash sediments and specimens of H. anceps, reputed to be a running water snail, have been found in lake sediments in 10 out of 13 sites where it was a part of the molluscan fauna. The mixing of faunas in sediments deposited by running water is to be expected.

Fossil assemblages probably reflect the settling velocity of the shells more directly than they do the biota which lived at the spot during the time of deposition of the sediments. The presence of stream-living forms in lake-laid sediments can be explained by the deposition of their shells in lakes during high water stages of the streams or by flotation.

The reliability of species as precise ecologic indicators of habitat type is not closed to question. I have reported (Tuthill and Others, 1963) successful communities of H. anceps from a lake in northwestern Minnesota which lacks inflowing or outflowing permanent streams.

For these reasons, I have assigned the various sites to one or more of the habitat types discussed below primarily on the sediment type from which the fossils were taken. The species composition at each site is in essential agreement with my assignments in that the species could be expected to have either lived in, or been carried to, the environment of deposition from an adjacent habitat more likely to have supplied the ecologic needs of the various species included in it.

Seven habitat types have been constructed as an hypothetical explanation of the aquatic environments which were probably available to the mollusks which lived on the Missouri Coteau about 9,000 to 11,500 years ago. A diagrammatic sketch of these may be seen on Fig. 6.

TYPES OF MOLLUSCAN HABITATS SUGGESTED FOR THE MISSOURI COTEAU DISTRICT DURING LATE WISCONSINAN TIME

Type 1. Backwater in Stream:- Quiet places in stream systems such as the low-velocity parts of a meandering stream or in oxbow lakes formed by meander cutoff. These were probably highly oxygenated waters with all dissolved gas content approximating equilibrium with the atmosphere. This habitat would probably have been a more or less unstable environment and the sediments would be expected to vary over a wide range of grain size and sorting in response to seasonal changes of water velocity and depth. Mixing of molluscan faunas from upstream contributions during times of high water would be expected.

Type 2. Stream:- The stream deposits, laid down in the higher velocity portions of the stream, would be expected to contain molluscan faunas with the greatest amount of mixing. Not only would shells from upstream be added to the resident fauna, but smaller shells, more easily carried by the currents, or those containing trapped gasses, would be carried away from the areas in which they lived to be deposited in quieter stretches of water. This habitat would be highly oxygenated and have a firmer substrate than the others listed here. A great variety of sediment grain size would be expected.

Type 3. Delta Top:- The delta top, formed where a stream entered a standing body of water, would contain sediments with a variety of grain size and be quite similar to that expected in habitat type 1. The greater amount of sand-sized sediments during periods of high water might alternate with silt and clay sized sediments deposited during periods of reduced water level in the drainage system. The flora would be quite different and therefore the molluscan fauna might be expected

to be dominated by pulmonates, capable of some amphibious existence. Helisoma trivolvis and various species of the family Lymnaeidae would be expected in this environment.

Type 4. Delta Front:- The delta front or slope would be typified by sediments exhibiting a variety of size, predominately in the sand range. A firm substrate and a relatively steady inflow of vegetable detritus would make this a favorable habitat for filter feeders such as the naiads. A great degree of mixing of gastropod shells would be expected in this type of environment. Shade making flora would be less likely to exist in this environment. Helisoma anceps might be expected here.

Type 5. Deep Lake:- The deep lake habitat would exist only if deep lakes were present. By deep I mean those types of standing water bodies capable of developing a thermocline rather than a lake of a specific depth. The atmospheric gas content of the hypolimnion would be reduced during the period of firmest stratification and the hypolimnion would contain branchiates only, if it contained living mollusks at all. Any molluscan community inhabiting this environment would probably be relatively unsuccessful. Shells deposited in the hypolimnion are frequently etched by organic acids if stratification endures for a protracted period. No etched shells were seen during the course of the study and it is not likely that the lakes of the Missouri Cotaau district were very deep at any time.

Type 6. Shallow Lake:- The marginal portion of the epilimnion would be expected to be relatively quiet water except in times of storms, contain abundant plant life, and contain an abundant and varied molluscan fauna. Silt- and clay-sized sediments would typify this type

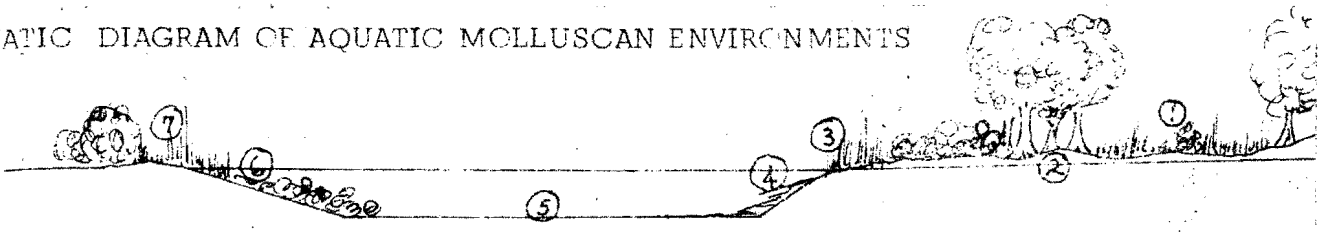
of habitat. Helisoma trivolvis might be present here and H. campanulatum would be expected along with the branchiates.

Type 7. Lake Margin:- Lake margins would be the last habitat type to be expected. The nature of this habitat would vary from beach to marsh, depending on the prevailing wind direction and the outline characteristics of the lake. The marshy type would be expected to have a sediment grain size character not unlike that of habitat types 1, or 6, and possibly 3. The presence of land snails intermixed with aquatic types would possibly indicate this type of habitat and one should expect a large number of pulmonates. The introduction of shells from habitat type 6 by wave action or from any of the other environments by flotation would not be unusual. This habitat type might be subject to great variation if fluctuations of water level were common throughout the season. The greater the fluctuation, the more distinctive this habitat type would be; and the tenuous nature of assignments to this habitat may be due to the fact that the water level in the drainages of the Missouri Coteau district were relatively stable throughout the time that molluska lived there.

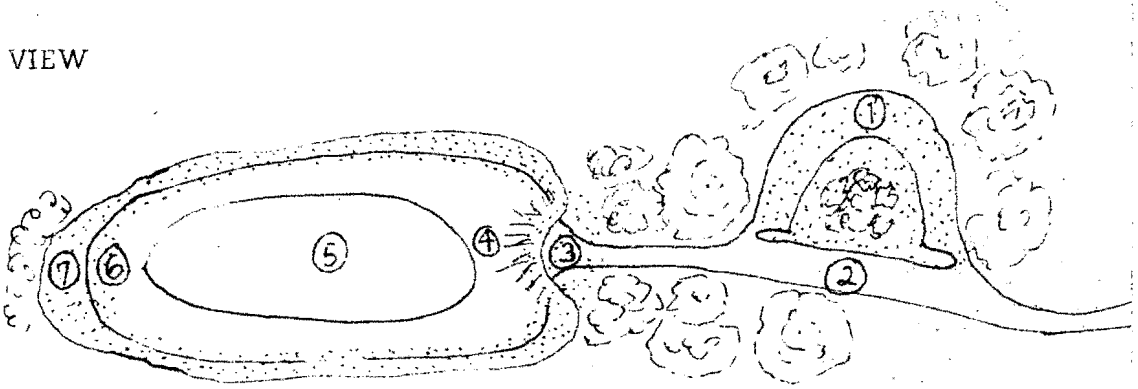
It is obvious that these habitats are gradational and the classification erected here is necessarily synthetic. Thus it is reasonable that the species composition of the fossil molluscan fauna would not be expected to provide strict criteria for the assignment of the various sites to a specific habitat site without heavy reliance on sediment type.

Table 6 shows the assignment of the sites to habitat types.

SCHEMATIC DIAGRAM OF AQUATIC MOLLUSCAN ENVIRONMENTS



CROSS-SECTIONAL VIEW



PLAN VIEW

Fig. 6. 1. Backwater in Streams- Highly oxygenated, unstable environment, mixing of fossil fauna likely.
2. Stream- Highly oxygenated, mixing of fauna from up drainage additions, great variety in grain size of sediments.
3. Delta Top- Mudflats, pulmonate fauna dominant, highly unstable environment. Mixing likely.
4. Delta Front- Relatively firm substrate (for Lake environment), shade making flora depressed, highly oxygenated branchiates dominant with naiads and Helisoma anceps.
5. Deep Lake- If thermocline present no successful population of pulmonates, branchiate forms with etched shells. If thermocline absent branchiate forms dominate, but pulmonates may be present. Mollusks less successful here than elsewhere. Oxygen content highly variable.
6. Shallow Lake- Greatest variety of species of mollusks. Oxygenated. Abundant vegetation and shade. Helisoma anceps replaced by H. trivolvis and/or H. campanulatum.
7. Lake Margin- Terrestrial snails may be mixed with aquatic pulmonates. Branchiate forms less common. May appear quite like 3 above or 1 above.

Table 1. SUMMARY OF ASSIGNMENTS OF SITES TO HABITAT TYPES

	Sites	Habitat Type							
		1	2	3	4	5	6	7	Indet.
A	Cleveland				X				
B	Schauer						X		
C	Biderman						X		
D	Schlenker						X		
E	Gutschmidt						X		
F	Brenneise						X		
G	Kroeber						X		
H	Huffmangsthall	X		X			X	X	
I	Lowenthal						X		
J	Bunny Cat						X		
K	Clear Lake						X		
L	Rosenthal 1			X			X		
M	Rosenthal 2						X		
N	Rosenthal 3						X		
O	Rosenthal 4						X		
P	Rosenthal 5		X						
Q	Antelope 1						X		
R	Antelope 2						X		
S	Nue				X				
T	Iowa 1		X	X					
U	Iowa 2						X		
V	Fedell						X		
W	Billingmeier								X
X	Field						X		
Y	Florence Lake		X						
Z	Muller 1						X		
AA	Muller 2						X		
AB	Dotlef						X		
AC	Wheelock						X		
AD	Painted Woods						X		
AE	Pelican Lake						X		
AF	Boynton						X		
AG	Teather					X	X		
AH	Neff						X		
AI	Prophets						X		
AJ	Schroeder		X				X		
AK	Silbermann		X						
AL	McClusky	X			X	X	X		
AM	Stock						X		
AN	Engele						X		
Totals	40	2	4	3	3	2	32	1	1

DESCRIPTION OF FOSSILIFEROUS SITES

The fossiliferous sites of the Missouri Coteau district have been assigned informal names. These names were derived from geographic locations (e. g. Clear Lake site because of its close proximity to Clear Lake, McIntosh County; Florence Lake because of its proximity to Florence Lake, Burleigh County, etc.), township names (e. g. Iona, Rosenthal, Huffnungsthall etc. in which the sites occur), or farm owner's names (e. g. Nue Farm site, Teather Farm site, etc.). Because of the possibility of frequent changes of ownership I have used the notations in the Platt Book in the library of the North Dakota Geological Survey as the reference for these names.

The locations of the sites are shown on individual county index maps (Fig. 7, 10, 11, 12, 16, and 18).

Stutsman County

A. Cleveland site:- The Cleveland site was studied by Tuthill (1961, p. 19-26). The site is located in the SW¼ sec. 17, T. 139 N., R. 67 W., approximately 2½ miles southwest of the village of Cleveland. Figure 8 shows the lithology of the site. The fossils were transported only a short distance, if at all. Many of the paired shells were found in sand which was overlain by gravel. Their shells were oriented in a living position and appear to have been buried rapidly; although subsequent compaction has partially crushed the valves. The fossiliferous units are of a grain size consistent with an aquatic environment most favorable for the molluscan community represented by the fossil assemblage (i. e. a slow-moving body of shallow water). Thus, I believe this

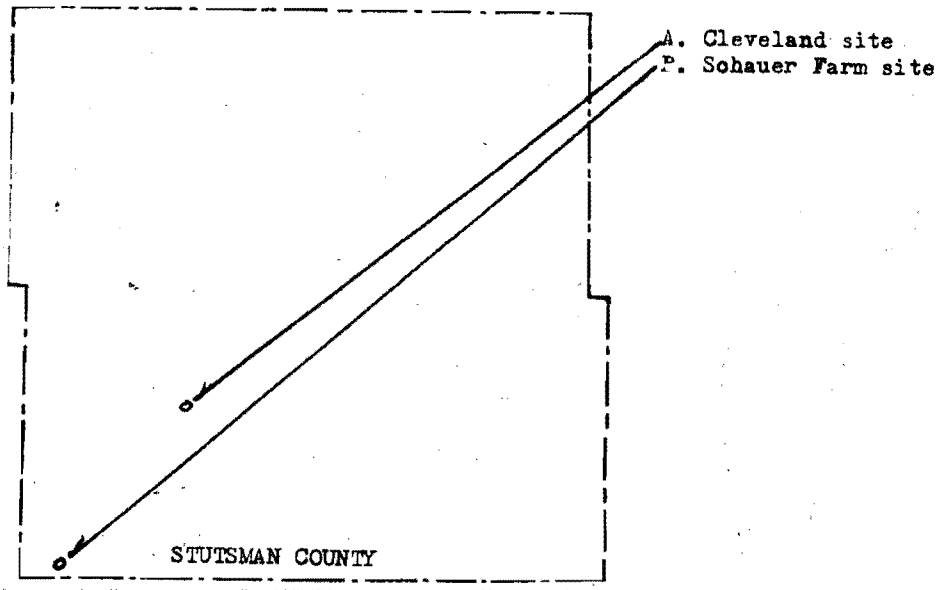


Fig. 7. [illegible] MAP OF STUTSMAN COUNTY, NORTH DAKOTA, SHOWING LOCATIONS OF [illegible] SITES.

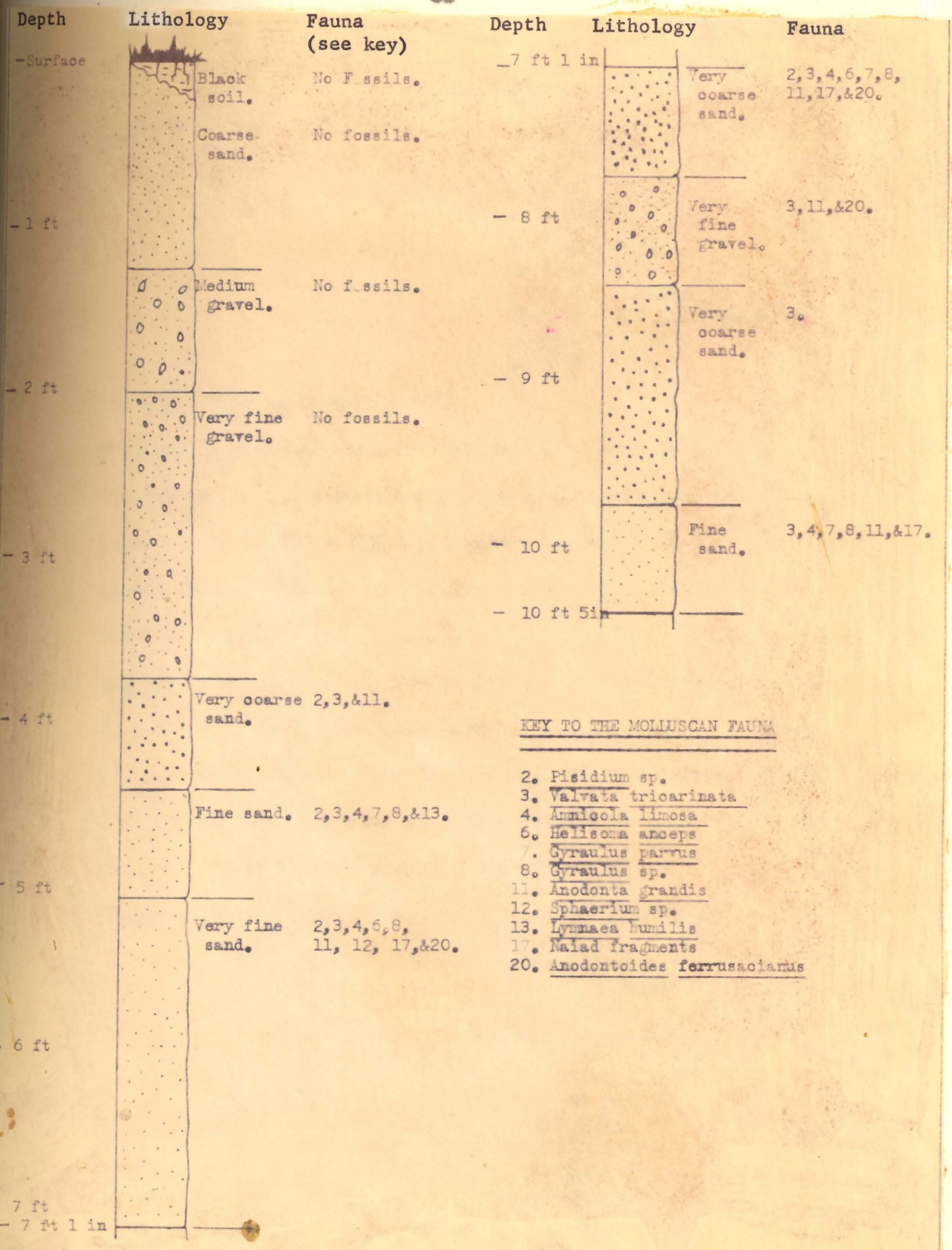


Fig. 8. LITHOLOGIC AND FAUNAL DISTRIBUTION OF MOLLUSKS IN CLEVELAND SITE (A) SW¼ sec. 17, T. 139 N., R. 67 W., Stutsman County, North Dakota.

faunule to be a succession.

Fauna:- Gastropods: Valvata tricarinata
Amnicola limosa
Lymnaea humilis
Gyraulus parvus
Gyraulus sp.
Helisoma anceps
Helisoma sp.

Pelecypods: Anodonta grandis
Anodontoides ferussacianus
Sphaerium simile
Pisidium spp.

Habitat:- Type 4, Delta Front.

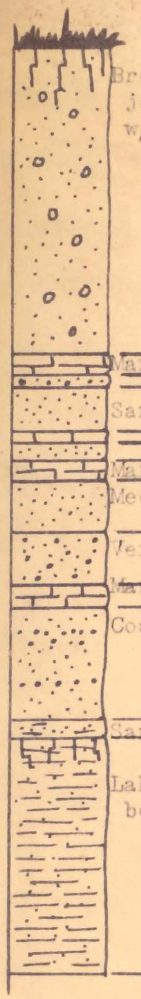
Geochronology:- Naiad shells from this site were dated by the Washington, D. C., laboratory of the U. S. Geological Survey as having lived 11,070 - 300 years before present (U.S.G.S. Sample number W-936, Rubin personal communication to Charles Hunell, U.S.G.S., Grand Forks, N. Dak.).

B. Schauer Farm site:- This site is located in the [redacted] sec. 29, T. 137 N., R. 69 W., Stutsman County. Collapsed lake sediments (Fig. 9) underlie the black soil of most of this quarter section. The samples which comprise this site were taken from an excavation. The fauna is probably a succession.

Fauna:- Gastropods: Valvata tricarinata
V. lewisi
Amnicola limosa
Lymnaea humilis
Helisoma sp.
Gyraulus parvus
Gyraulus sp.
Promenetus exacuous
Aminicola crista
Gastrocopta sp.

Pelecypods: Lampsilis radiata siliquoidea
Sphaerium sp.
Pisidium sp.

Habitat:- Type 6, Shallow Lake or Type 7, Lake Margin. The presence of Gastrocopta in the sediments of this site indicates the nearby



DEPTH	LITHOLOGY	FAUNA (see key below)
Surface	Brown gravelly soil: jointed, joint surfaces w/ clay skins.	No fossils.
1 ft	Marl	2,3,6,&8.
	Coarse to fine sand.	3,6.
	Sand w/ marl.	3 & 6.
	Marl.	3 & 6.
	Coarse sand.	3 & 6.
	Marl w/sand.	3 & 6.
2 ft	Medium to coarse sand.	2.
	Very coarse sand and granules.	2.
	Marl.	3,6,7,8,&10.
	Coarse to fine sand.	1,2,3,4,6,7,8,10,13,&17.
3 ft	Sandy silt.	2,3,4,7,8,9,10,13,&17.
	Lake clays and silts, bedded and jointed at top.	2,3,4,8,10,12,13,&19.
4 ft		

KEY TO THE MOLLUSCAN FAUNA

1. Lampsilis radiata siliquoidea
2. Pisidium spp.
3. Valvata tricarinata
4. Amnicola limosa
6. Helisoma anceps and Helisoma sp.
7. Gyraulus parvus
8. Gyraulus sp.
9. Promenetus exacuous
10. Armiger crista
12. Sphaerium sp.
13. Lymnaea humilis
17. Naiad fragments.
18. Valvata lewisi
19. Gastrocopta sp.

Fig. 9. LITHOLOGY AND VERTICAL DISTRIBUTION OF THE MOLLUSKS IN SCHAUER FARM SITE (B) SE¼ sec. 29, T. 137 N., R. 69 W., Stutsman County, North Dakota.

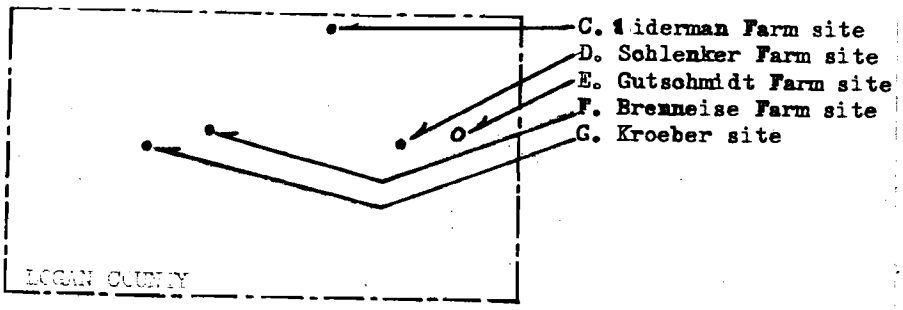


Fig. 10. INDEX MAP OF LOGAN COUNTY, NORTH DAKOTA, SHOWING LOCATIONS OF FOSSILIFEROUS SITES.

presence of terrestrial vegetation.

Geochronology:- Mated shells from the Schauer site were radiocarbon dated by the Washington, D.C., laboratory of the U. S. Geological Survey at 9,870 - 290 years before present (sample number W-954, Rubin, personal communication to Charles Hamell). This site is behind the Streeter moraine a few miles south and west of the Cleveland site. It appears that stagnant ice underlay this section of the Missouri Cotau for at least 1200 years, for the Cleveland site, 11,070 - 300 years B.P., is closer to the source of the glacier than is the Schauer farm site, 9,870 - 290 years B.P. The younger fauna lived at the Schauer site before the final melting of the ice, but this ice could not have been the product of glaciation more recent than the fauna at the Cleveland site.

Logan County

C. Biderman Farm site:- This site is located in the SW¼ sec. 9, T. 13N R., R. 69 W. The deposit is a small body of ice-contact lake clay at the south edge of a 1½ mile wide ice-contact outwash plain (Clayton, 1961, p. 15).

Fauna:-

Gastropods:	Valvata tricarinata
	Amnicola limosa
	Gyraulus parvus
	Gyraulus sp.
	Helisoma anceps
	H. campanulatum
	Succinea avara
Pelecypods:	Mated fragments

Habitat:- Type 6, Shallow Lake. The drift must have been terrestrially vegetated, because Succinea avara requires land plants and vegetable litter.

D. Schlenker Farm site:- This site is located NW¼ sec. 28, T. 135 N., R. 68 W. Ice-contact lake silts cap a hill 50 feet high at this site (Clayton, 1961, p. 14).

Fauna:- Gastropods: Amnicola limosa
Valvata tricarinata
Valvata sp.
Stagnicola caperata
Promenetus exacuous
Aplexa elodia
Helisoma campanulatum
Lymnaea humilis
Physa sp.
Pelecypods: Pisidium sp.

Habitat:- Type 6, Shallow Lake.

E. Gutschmidt Farm site:- This site is located in the NW¼NW¼NW¼ sec. 20, T. 135 N., R. 67 W., Logan County. West of the N.W. 1/4 of this section is surfaced by collapsed lacustrine sediments which are overlain by black wind-blown soil a few inches thick. Naiad shells brought to the surface by plowing were found.

A small amount of transportation of the fossils possibly occurred during deposition, but the fine grain nature of the sediments suggests that they were not carried by strong currents.

Fauna:- Gastropods: Valvata tricarinata
Amnicola limosa
Stagnicola sp.
Pelecypods: Lampsilis sp.
Naiad fragments

Habitat:- Type 6, Shallow Lake.

Geochronology:- Naiad shells from this site were radiocarbon dated at 9,000 - 300 years B.P. by the Washington, D.C., laboratory of the U. S. Geological Survey (Rubin, personal communication to Wilmon H. Baird). The Gutschmidt Farm site lies within the Streeter moraine, and the fauna lived in a lake no doubt insulated from,

but surely underlain by, glacier ice. Thus the glacier which transported the material of this part of the Burnsted Drift preexisted the fauna. This establishes a minimum age of about 9,000 C^{14} years for this part of the drift, but does not preclude the idea of the Burnsted Drift being older.

F. Brownlee Farm site:- This site is located in the NW¼ sec. 27, T. 135 N., R. 71 W. A four foot bed of marl overlying an undetermined thickness of dark gray clay comprises the site. The sediments were deposited in an irregular, partly ice-walled lake (Clayton, 1961, p. 13).

Fauna:- Gastropods:
- Valvata tricarinata
- Valvata sp.
- Amnicola limosa
- Gyraulus parvus
- Promenetus exacuous
- Armiger crista
- Helisoma trivolvis
- Lymnaea sp.

Pelecypods:
- Pisidium sp.

Habitat:- Type 6, Shallow Lake.

G. Kromber site:- This site is located in the NW cor. sec. 35, T. 135 N., R. 73 W. The bed of sediments which contains the fossil mollusks is a marl in sediments of Glacial Lake Napoleon. Clayton, (1961, p. 16) suggests that this site is probably not an ice contact deposit. It is likely that the sediments and their contained fauna are of late Wisconsinan age.

Fauna:- Gastropods:
- Valvata tricarinata
- Gyraulus parvus
- Promenetus exacuous
- Helisoma trivolvis
- Physa sp.
- Lymnaea sp.
- Armiger crista
- Lymnaea palustris

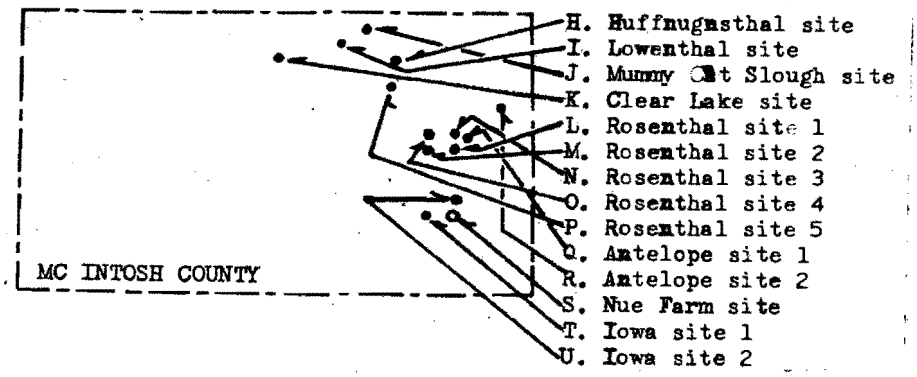


Fig. 11. INDEX MAP OF McINTOSH COUNTY, NORTH DAKOTA, SHOWING LOCATIONS OF FOSSIL BISON SITES.

		Helisoma anceps
		Gyraulus sp.
		Lymnaea humilis
		Valvata lewisi
	Pelecypods:	Pisidium sp.
		Sphaerium sp.

Habitat:- Type 6, Shallow Lake.

McIntosh County

H. Huffmanmithell site:- This site is located in the NW¼ sec. 20, T. 132 N., R. 68 W. The fossils are in marly sand and peat beds which have been distorted by the ice which deposited the Streeter Moraine. The fossils appear to have been transported after death.

Fauna:-	Gastropods:	Valvata tricarinata
		Amnicola limosa
		Amnicola sp.
		Gyraulus parvus
		Lymnaea humilis
		Lymnaea sp.
		Helisoma campanulatum
	Pelecypods:	Unio fragments
		Pisidium sp.

Habitat:- Type 1, Backwater in Stream; Type 3, Delta Top; or Type 7, Lake Margin. The lithology and topography of the surrounding area suggest that stagnant ice of the Burnstad maximum lay buried and that in the area of this site was over-ridden by an advance of the Streeter ice. This suggests that the influx of glacier ice continued well after the beginning of a warm phase of the climatic cycle.

Geochronology:- Unio shells from this site were dated by the Washington, D.C., laboratory of the U. S. Geological Survey (W-974) as 11,650 - 310 years before present (Rubin, personal communication to Wilson M. Laird). This date, coming from material which appears to have been disturbed by the ice of the Streeter advance, may suggest a maximum date for the Streeter advance of approximately

11,650 C^{14} years. This may be an extremely local situation, however, and not reflect the general advance of the Streeter ice.

I. Lemmthal site:- This site is located in a road cut in the SW¼ sec. 16, T. 132 N., R. 69 W. The exposure consists of broadly folded, bedded lake silts and clays.

The sediments are collapsed lake clays and silts which are a part of the deposits of Glacial Lake Lehr. The plain of Glacial Lake Lehr is composed of lake silts and clays which cover approximately 40 square miles in north central McIntosh County and south-central Logan County. This large plain forms the highest topography in the area, rising like a butte amid the collapsed till and outwash sediments. The presence of stagnant ice sheets under and around the deposits is indicated by the fact that all but three to four square miles at the center of the plain is underlain by collapsed lake beds. Moreover the perimeter of the plain is bordered by outward sloping ice-contact faces. The total lack of drainage development in the Coteau district precludes the idea that these outward sloping faces are erosional in origin. The fauna is a thanatocoenose, the shells being fragmented and disarticulated. One irregular pearl about 1 inch in diameter was found at this site.

Fauna:- Pelecypods: Lampsilis radiata siliquoidea

Habitat:- Type 6, Shallow Lake.

J. Bunny Cat Slough site:- Located in a steep bank on the south side of the slough from which it takes its name, this site is in the NW¼ sec. 14, T. 132 N., R. 69 W. Figure 12 shows the lithology

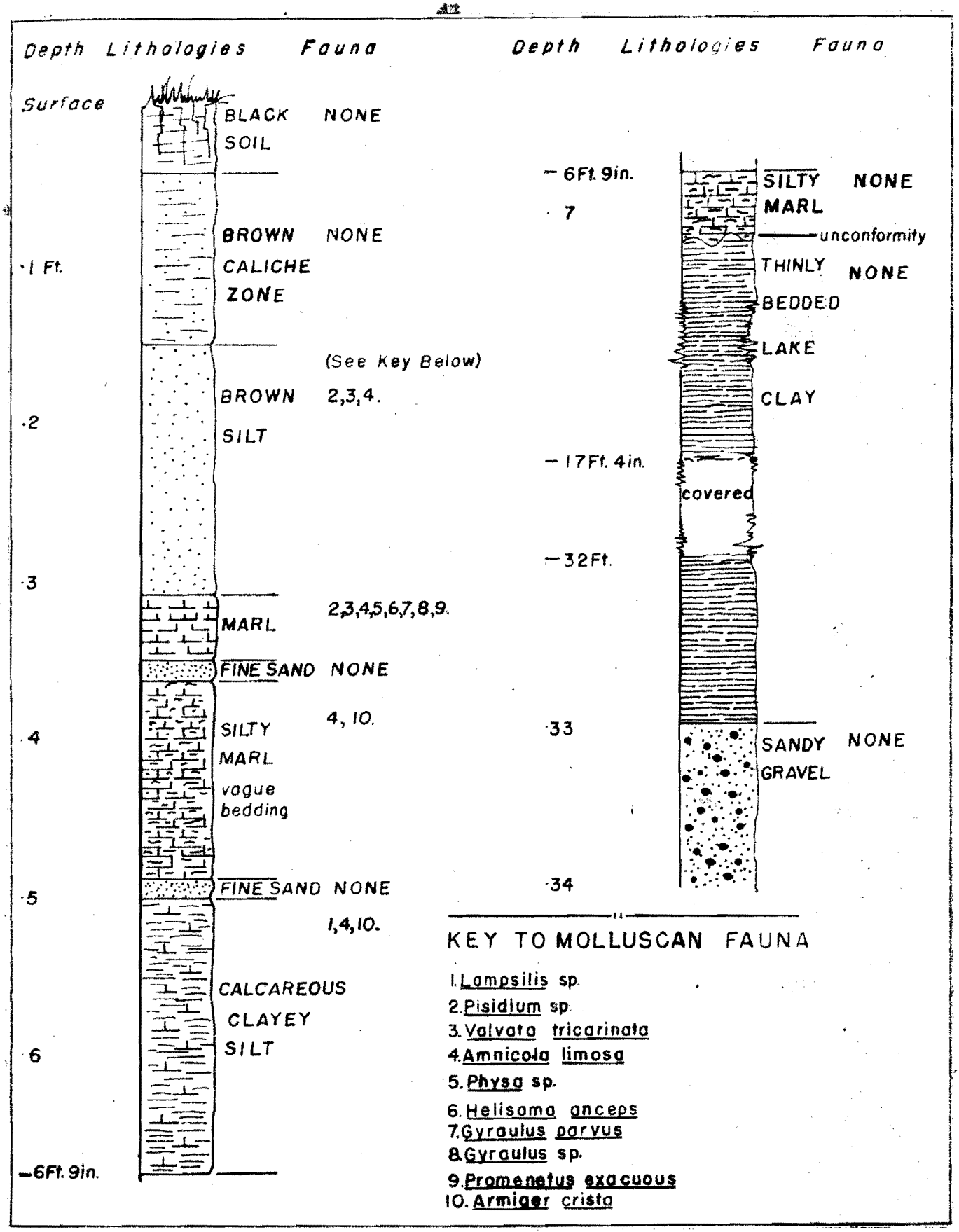


Fig. 12. LITHOLOGY AND VERTICAL DISTRIBUTION OF MOLLUSKS IN MUDDY CAT SLOUGH SITE (J) [illegible] sec. 14, T. 132 N., R. 69 W., McIntosh County, North Dakota.

of the exposure. The entire sequence is composed of beds of sands, lake silts and clays. An unconformity separates the beds of the upper 8 feet from the lower beds which are unfossiliferous and strongly contorted. An auger sample taken approximately 150 yards north of the site in the bottom of the present day slough contained 1/4 feet of decayed vegetable matter with shells of Anisus bryanerus, Lymnaea humilis, Sphaerium sp., and Gyraulus sp.; 1 foot of buff, unfossiliferous lake silts and clays resembling those in the base of the site; overlying at least 2½ feet of pebbly outwash. The present slough depression is a large kettle hole.

Fauna:-

Gastropods:	Valvata tricarinata
	Amnicola limosa
	Physa sp.
	Hallesma arctica
	Gyraulus parvus
	Gyraulus sp.
	Promenetus umbilicatus
	Armiger crista
Pelecypods:	Unio fragments
	Pisidium sp.

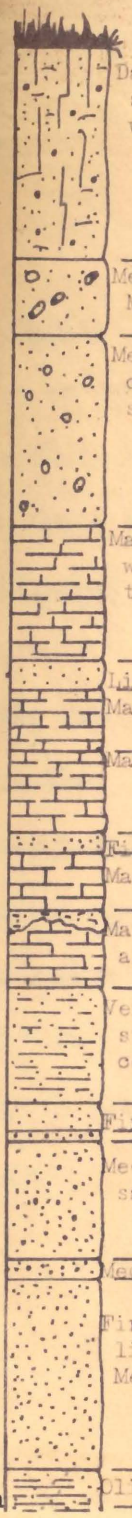
Habitat:- Type 6, Shallow Lake. The fauna represents a biocoenose. The sterile lower beds which lie below the unconformity probably represent deposition during the time, after stagnation of the ice, before the drift insulated the bodies of water and the drainage channels sufficiently to permit turbidity to be reduced and solar elevation of the water temperature to occur. Thus there are two habitats represented in this site. The lower one was a cold, probably turbid lake which received melt water from supergleial streams which were in contact with the ice. The upper 8 feet represent a permanent seasonally temperate body of water.

K. Clear Lake site:- This site is located in the SE¼ sec. 21, T. 132 N., R. 70 W. A marl layer in poorly bedded lake silts comprises the lithology of the site. All of the fossils were found in the marl. The exposure is approximately 30 feet above the present level of Clear Lake, but it is inside the depression which forms the basin for the lake. For this reason the idea that the sediments are Recent in age, having been deposited during a time when the level of Clear Lake was higher, cannot be discounted. The presence of unionids and aquatic snails, while inconsistent with the present condition of the molluscan community of the lake, is not inconsistent with those which would be expected during a pluvial cycle on the Coteau.

Fauna:- Gastropods: Valvata tricarinata
Amnicola limosa
Amnicola sp.
Gyraulus parvus
Promenetus exacuous
Aplexa elata
Helisoma anceps
H. campanulatum
Pelecypods: Lampsilis sp. (fragments, probably L. radiata siliquoidea

Habitat:- Type 6, Shallow Lake.

L. Rosenthal site 1:- This site is located in the NE¼ sec. 36, T. 131 N., R. 60 W. Sand, silt, and clay in beds which dip 14° toward the north in a road cut comprise this site. The numbering of the sites under the name of Rosenthal is intended to indicate only the geographic proximity of these separate sites. All of the fossils except those found in peat and marl layers appear to be transported. Fig. 13 shows the lithology and the vertical distribution of the fauna. The sediments were deposited in a high level lake behind the



DEPTH	LITHOLOGY	FAUNA (see key below)
Surface	Dark brown soil, sandy w/ pebbles.	3 & 17.
-1 ft	Medium sand to Medium gravel.	No fossils.
	Medium to coarse sand.	17.
-2 ft	Marly clay w/ peat at top.	2,3,4,7,11,&17.
	Limonitic medium sand.	No fossils.
	Marl w/ peat.	3.
-3 ft	Marl w/ root concretions.	2.
	Fine sand.	2.
	Marl.	2.
	Marl w/ silt at top.	17.
-4 ft	Very fine silt w/ root concretions.	17.
	Fine sand.	17.
	Medium sand.	17.
	Medium to coarse sand.	17.
-5 ft	Medium sand.	17.
	Fine-bedded limonitic Medium sand.	No fossils.
-6 ft		
-6 ft 4 in	Olive-gray silt.	4,6,&17.

KEY TO THE MOLLUSCAN FAUNA

2. Pisidium spp.
3. Valvata tricarinata
4. Amnicola limosa
6. Helisoma anceps
7. Gyraulus parvus
11. Anodonta grandis
17. Naiad fragments.

Fig. 13. LITHOLOGY AND VERTICAL DISTRIBUTION OF MOLLUSKS IN ROSENTHAL SITE 1 (L) NE¼ sec. 36, T. 131 N., R. 68 W., McIntosh County, North Dakota.

Streeter moraine.

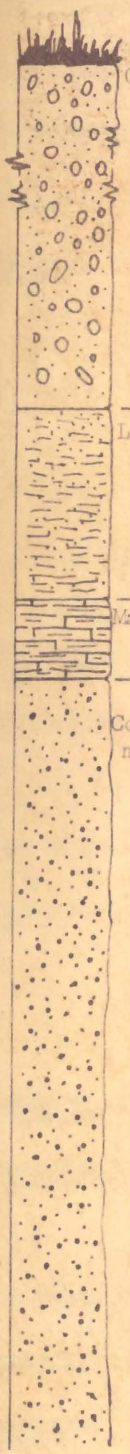
Fauna:- Gastropods: Valvata tricarinata
Valvata lewisi
Valvata sp.
Amnicola limosa
Amnicola sp.
Helisoma anceps
Gyraulus parvus
Pelecypods: Anodonta grandis
Pisidium sp.
Naiad prisms and fragments

Habitat:- The peat layer and the marl layer represent Type 3, Delta Top or Type 6, Shallow Lake. The balance of the sediments represents habitats higher in the drainage and therefore best fit habitat Type 4, Delta Front.

N. Rosenthal site 2:- This site is located in the NE¼ sec. 34, T. 131 N., R. 68 W. Lake silts, clays, and outwash comprise the lithology of this site (see Fig. 14). The marl bed which contains most of the fossils, dips 9.5° to the north. This bed can be traced across the entire one-half section and appears to be distorted but no exposure exists where folds can be clearly seen. Like Rosenthal site 1 the sediments were deposited in a high level lake behind the Streeter moraine. Except for being let down, the fossils were all untransported and are a necrocoenose.

Fauna:- Gastropods: Valvata tricarinata
Valvata lewisi
Amnicola limosa
Helisoma anceps
Gyraulus parvus
Gyraulus sp.
Promenetus exacuous
Lymnaea humilis
Pelecypods: Anodonta grandis
Sphaerium sp.
Pisidium sp.
Naiad fragments

Habitat:- Type 6, Shallow Lake.



KEY TO THE MOLLUSCAN FAUNA

2. Pisidium spp.
3. Valvata tricarinata
4. Amnicola limosa
6. Helisoma anceps
7. Gyraulus parvus
8. Gyraulus sp.
9. Promenetus exacuous
11. Anodonta grandis
12. Sphaerium sp.
13. Lymnaea humilis

Fig. 14. THE LITHOLOGY AND VERTICAL DISTRIBUTION OF MOLLUSKS IN ROSENTHAL SITE 2 (N) N½ sec. 34, T. 131 N., R. 68 W., McIntosh County, North Dakota.

E. Rosenthal site 3:- This site is located in the SE¼ sec. 25. T. 131 N., R. 60 W. Lake clays, silts, and marls in a road cut 5½ feet below the crest of a small hill comprise the site. The sediments are probably related to those encountered at Rosenthal sites 1 and 2.

Fauna:-	Gastropods:	Valvata tricarinata Amnicola limosa Helisoma trivolvis Gyraulus parvus Gyraulus sp. Promenetus exacuous Lymnaea humilis Physa sp.
	Pelecypods:	Anodonta grandis Lampsilis radiata siliquoidea Pisidium sp.

Habitat:- Type 6, Shallow Lake.

G. Rosenthal site 4:- This site is located in the NW¼ sec. 27, T. 131 N., R. 60 W. Marl in disterted lake clays and silts comprise the site.

Fauna:-	Gastropods:	Valvata tricarinata Amnicola limosa Gyraulus parvus Lymnaea humilis
	Pelecypods:	Pisidium sp.

Habitat:- Type 6, Shallow Lake.

F. Rosenthal site 5:- This site is located in the NE¼ sec. 6, T. 131 N., R. 60 W. An undetermined thickness of sand underlying 11½ feet of outwash gravel contains a few fossil mollusks. They all appear to have been transported.

Fauna:-	Gastropods:	Valvata tricarinata Amnicola sp. Gyraulus parvus
	Pelecypods:	Naiad fragments

Habitat:- Type 2, Stream.

Q. Antelope site 1:- This site is located in the NW¼ sec. 30, T. 131 N., R. 67 W. Nonstratified to poorly stratified lake sediments in a 4 by 20 foot road cut comprise this site. A light brown fossiliferous layer overlies a darker brown unfossiliferous part of the exposure.

Fauna:- Gastropods: Valvata tricarinata
Valvata lewisi
Amnicola limosa
Gyraulus parvus
Gyraulus sp.
Lymnaea sp.
Promenetus umbilicatus
Helisoma anceps

Habitat:- Type 6, Shallow Lake.

R. Antelope site 2:- This site is located in the NW¼ sec. 16, T. 131 N., R. 67 W. The exposure consists of about 4 feet of pebbly outwash above 1 to 1½ inches of medium grained sand, above 1 to 1½ inches of yellow fossiliferous marl, above at least 3½ feet of lake clays and silts.

Fauna:- Gastropods: Valvata sp.
Gyraulus sp.
Promenetus umbilicatus
Amnicola limosa
Physa sp.
Pelecypods: Pisidium sp.

Habitat:- Type 6, Shallow Lake.

S. Nue Farm site:- The Nue Farm site is located in a road cut 0.2 miles north of the SE cor. sec. 36, T. 130 N., R. 68 W., about 11.5 miles E. of Ashley. Thin bedded collapsed outwash sand and gravels contain the fossils. This site has produced the most abundant and varied fauna of Pleistocene mollusks of any so far studied in North Dakota. Most of the unionids were found as articulated valves in living positions. A lithologic column is shown on Figure 15.

The fauna is a neoecocenose which inhabited an environment much

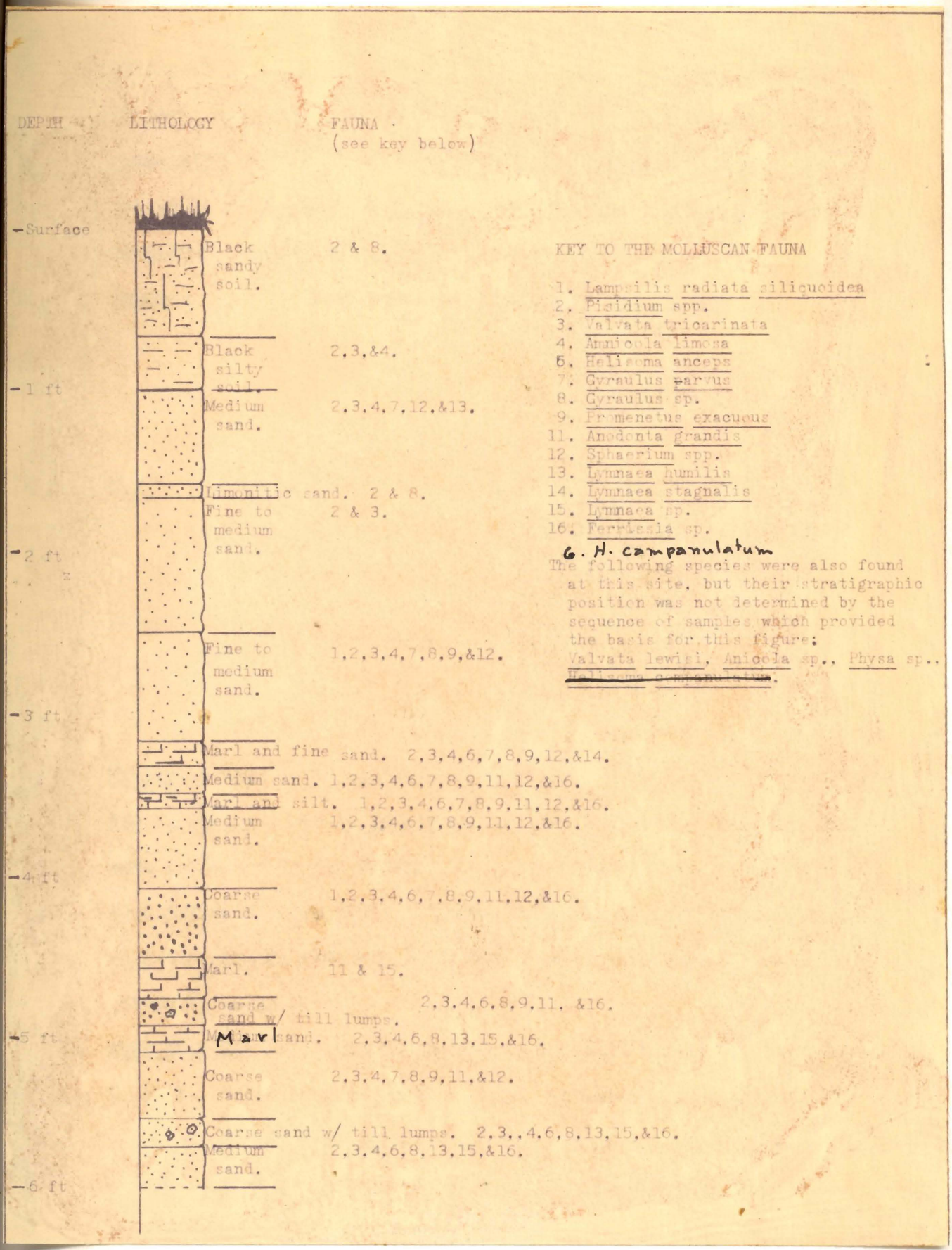


Fig. 15. THE LITHOLOGY AND VERTICAL DISTRIBUTION OF MOLLUSKS IN NUE FARM SITE (S) SE¼ sec. 36, T. 130 N., R. 68 W., McIntosh County, North Dakota.

like that of the Cleveland site (A). Some postmortem concentration of the gastropods may have occurred, but the naiad population was certainly not transported any significant distance. Lymnaea stagnalis and the Helisoma species probably occupied micro-habitats peripheral to the lotic-lenitic environment of the naiads.

Fauna:-

Gastropods:
Valvata tricarinata
Valvata lewisi
Amnicola sp.
A. limosa
Lymnaea stagnalis
L. humilis
Lymnaea sp.
Physa sp.
Helisoma anceps anceps
H. anceps
Gyraulus parvus
Gyraulus sp.
Promenetus exacuous
Armiger crista
Ferrissia sp.

Pelecypods:
Anodonta grandis
Lampsilis siliquoidea
Sphaerium spp.
Pisidium spp.
Naiad fragments

Habitat:- Type 4, Delta Front.

Geochronology:- Lampsilis radiata siliquoidea shells from this site were dated by the Washington, D.C., laboratory of the U. S. Geological Survey as having lived 9,620 - 350 C^{14} years before present (U.S.G.S. Sample number W-1149, Rubin personal communication to Wilson M. Laird).

T. Iowa Site 1:- This site is located in the SE¼SE¼ sec. 34, T. 130 N., R. 68 W., McIntosh County, in a field approximately 12 feet N. of the road and 330 feet north of the S.E. corner of the section. A gravel body shows through the soil in an elongate sinuous band extending across the field in a general direction of N. 30° E.

Snails were observed in this gravel and in the sandy soil adjacent to it. Lake clays with faint bedding still discernible were encountered at 2½ feet depth. The fauna here reported came from these lake clays. Loam site 1 is grouped with loam site 2 because of geographic proximity only.

Fauna:- Gastropods: Valvata tricarinata
Amnicola limosa
Helisoma anceps
Gyraulus parvus
Gyraulus sp.
Promenetus exacuous
Lymnaea humilis

Habitat:- Type 2, Stream or Type 3, Delta Top.

U. Loam site 2:- Loam site 2 is located in SW¼SW¼ sec. 25, T. 130 N., R. 68 W., McIntosh County. The fossils occur in lake silts which exhibit poor or no bedding. This site may well be associated with the loam 1 and Rue Farm sites.

Fauna:- Gastropods: Valvata tricarinata
Amnicola limosa
Lymnaea cf. L. humilis
Gyraulus sp.
Pisidium sp.

Habitat:- Type 6, Shallow Lake.

LaMoure County

V. Podell Farm site:- This site is located 12 feet below the surface of an intermittent slough depression in the NW¼ sec. 14, T. 135 N., R. 66 W. Mr. Robert Podell, owner of the land, discovered wood and associated mollusk shells in a peat zone at approximately 12 feet depth while trying to dig a watering hole for his stock. I visited this site in April of 1963, but was unable to view the excavation because it was under water. Fortunately Mr. Podell had saved

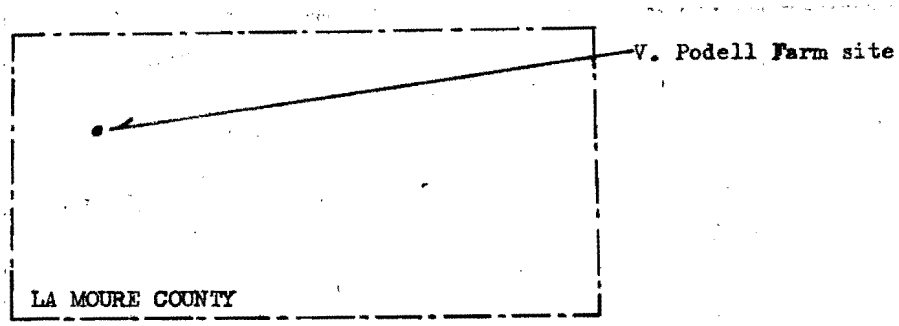


Fig. 16. INDEX MAP OF LAMOURE COUNTY, NORTH DAKOTA, SHOWING THE LOCATION OF THE PODELL FARM SITE.

samples of the wood and peat and the fauna reported below was taken from these samples. The situation which he describes appears to be very much like that described by Moir (1958, p. 108-114). The wood was identified as tamarack according to Mr. Elmer L. Worthington, Woodland Consultant, U. S. Department of Agriculture, Soils Conservation Service, Mandan, North Dakota (personal communication to Frank Schulte, Jud, North Dakota).

Fauna:- Gastropods: Hallesum trivolvis
Lymnaea palustris
Lymnaea humilis
Lymnaea stagnalis
Promenetus exacuous
Physa sp.
Gyraulus parvus
Gyraulus sp.
Amnicola sp.

Habitat:- Type 6, Shallow Lake or Type 7, Lake Margin.

Burleigh County

The following sites were discovered and collected by D. E. Hansen, geologist on the staff of the North Dakota Geological Survey. I am responsible for the identification of the fossils and any conclusions drawn from them.

N. Hillingmeier Farm site:- This site is located in the NW¼ sec. 12, T. 144 N., R. 75 W. The single fossil recovered was contained in silty marl taken from dead-ice moraine of the Harvestad Drift.

Fauna:- Gastropods: Gyraulus parvus
Gyraulus sp.
Pelecypods: Sphaerium sp.

Habitat:- Indeterminate. The marl and silt suggest a well oxygenated pond. Two occurrences of mollusean fossils are insufficient to provide a basis for conclusions other than that seasonally

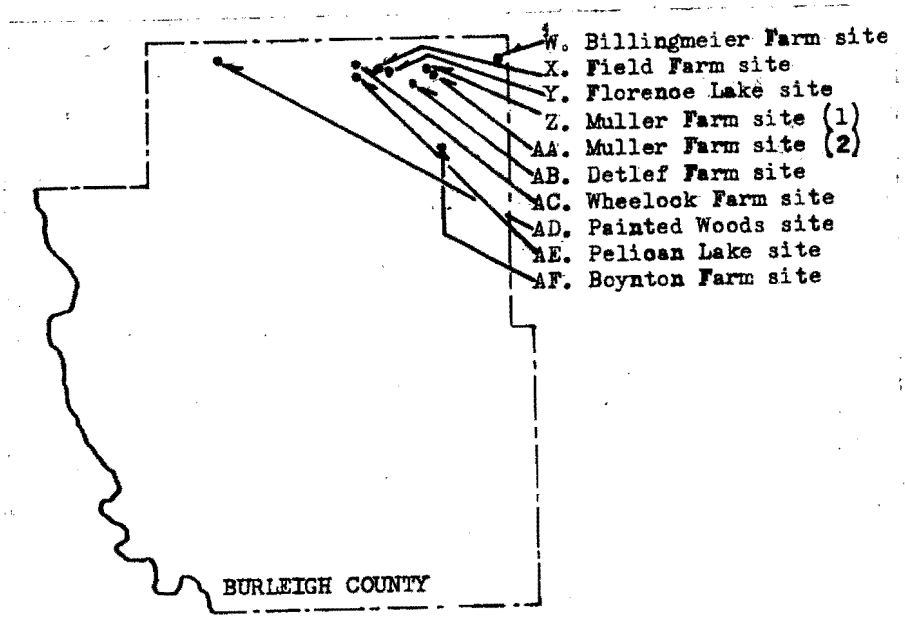


Fig. 17. INDEX MAP OF BURLEIGH COUNTY, NORTH DAKOTA, SHOWING LOCATIONS OF THE FOSSILIFEROUS SITES.

temperate water was present at one time.

X. Field Farm site:- This site is located in the NE¼SE¼ sec. 17, T. 144 N., R. 76 W. It is in stagnation features of the Barnstad Drift.

Fauna:- Gastropods: Valvata tricarinata
Amnicola limosa
Helisoma anceps
Gyraulus parvus
Pelecypods: Pisidium sp.

Habitat:- Type 6, Shallow Lake.

Y. Florence Lake site:- This site is located in NW¼NW¼ sec. 17, T. 144 N., R. 76 W., in collapsed outwash in front of the Streeter Moraine of the Barnstad Drift.

Fauna:- Gastropods: Valvata tricarinata
Amnicola limosa
Lymnaea humilis
Helisoma campanulatum
H. anceps
Gyraulus parvus
Promenetus exacuous

Habitat:- Type 2, Stream.

Z. Muller Farm site 1:- This site is located in the NE¼NE¼ sec. 14, T. 144 N., R. 76 W., 0.25 miles west of N.E. section corner. The fossils were enclosed in silts from the Barnstad Drift.

Fauna:- Gastropods: Valvata tricarinata
Amnicola limosa
Lymnaea sp.
Gyraulus parvus
Gyraulus sp.
Promenetus exacuous
Pelecypods: Pisidium sp.

Habitat:- Type 6, Shallow Lake.

AA. Muller Farm site 2:- This site is located 0.25 miles south of the section corner of NW¼NW¼ sec. 14, T. 144 N., R. 76 W., in collapsed

outwash sediments of the Burnstad Drift.

Fauna:- Gastropods: Valvata tricarinata
Lymnaea sp.
Helisoma anceps
Gyraulus parvus
Gyraulus sp.
Amnicola crista
Pelecypods: Pisidium sp.
Naiades (fragments probably of Lampsilis radiata siliquoidea

Habitat:- Type 6, Shallow Lake. Although the aquatic pulmonates are very numerous, V. tricarinata forms an important part of the fauna. Thus permanent water was undoubtedly present throughout the time that the fauna lived. Vegetation, both marginal and aquatic, was probably present and the waters were temperate during the warm season.

AB. Detlef Farm site:- This site is located in the NE¼NW¼ sec. 22, T. 144 N., R. 76 W., 0.6 miles west of Highway 14 in collapsed outwash in front of the Streeter Moraine of the Burnstad Drift.

Fauna:- Gastropods: Valvata tricarinata
Amnicola limosa
Lymnaea sp.
Helisoma campanulata
Gyraulus sp.
Promenetus umbonatus

Habitat:- Type 6, Shallow Lake.

AC. Shacklock Farm site:- This site is located 0.6 miles south of the section corner in the NW¼SW¼ of sec. 11, T. 144 N., R. 77 W., in dead-ice moraine of the Burnstad Drift.

Fauna:- Gastropods: Valvata tricarinata
Amnicola limosa
Lymnaea cf. L. humilis
Helisoma campanulatum
H. anceps
Gyraulus parvus
Gyraulus sp.
Promenetus cf. P. umbonatus
Pelecypods: Pisidium sp.

Habitat:- Type 6, Shallow Lake.

AD. Painted Woods site:- This site is located 0.7 miles east of the NW cor. sec. 12, T. 144 N., R. 79 W., in dead-ice moraine of the Burnsted Drift.

Fauna:-		
	Gastropods:	Valvata tricarinata
		Amnicola limosa
		Physa cf. P. gyrina
		Helisoma anceps
		H. antrosa
		Gyraulus parvus
		Gyraulus sp.
		Promenetus exacuous
		Armiger crista
	Pelecypods:	Sphaerium spp.
		Pisidium spp.

Habitat:- Type 6, Shallow Lake.

AE. Pelican Lake site:- This site is located in the NW¼SW¼ sec. 13, T. 144 N., R. 77 W., in marl on the edge of a kettle in dead-ice moraine.

Fauna:-		
	Gastropods:	Valvata tricarinata
		Gyraulus sp.
	Pelecypods:	Pisidium spp.

Habitat:- Type 6, Shallow Lake. Marl suggests standing, clear, permanent water bodies. The fauna although it is small and simple supports this idea.

AF. Royston Farm site:- This site is located 0.5 miles south of NE cor. sec. 19, T. 143 N., R. 75 W., in dead-ice moraine of the Burnsted Drift.

Fauna:-		
	Gastropods:	Valvata tricarinata
		Amnicola limosa
		Helisoma anceps
		Gyraulus parvus
		Gyraulus sp.
		Promenetus exacuous
		Armiger crista
	Pelecypods:	Pisidium spp.

Habitat:- Type 6, Shallow Lake.

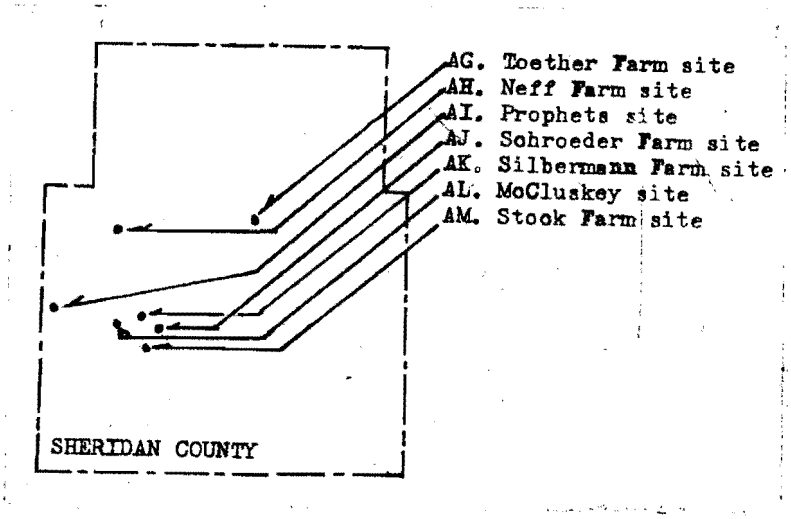


Fig. 18. INDEX MAP OF SHERIDAN COUNTY, NORTH DAKOTA, SHOWING LOCATIONS OF THE FOSSILIFEROUS SITES.

Sheridan County

The following sites were discovered and collected by R. E. Sherrod, graduate student at the University of North Dakota and Temporary Geologist for the North Dakota Geological Survey during the summer of 1962. I am responsible for the identification of the fossils and any conclusions drawn from them.

AG. Teather Farm site:- This site is located 0.4 miles south of NE cor. sec. 13, T. 148 N., R. 76 W. The site is composed of lake sediments, mostly clay sized, at the east edge of the Missouri Coteau district. No lake outline is visible so presumably these sediments are collapsed.

Fauna:- Gastropods: Gyraulus sp.
Valvata tricarinata

Habitat:- The sediments suggest Type 6, Shallow Lake, or Type 5, Deep Lake. The fauna is too small to offer information other than the presence of permanent, clear water in the area.

AH. Neff Farm site:- This site is located 0.6 miles west of SE cor. sec. 19, T. 148 N., R. 77 W. A single fragmentary gastropod was found in a well defined, ½ mile diameter body of collapsed lake sediments surrounded by high-relief dead ice moraine.

Fauna:- Gastropod: One fragment

Habitat:- Type 6, Shallow Lake. The geology of the area suggests a freshwater pond in an ice basin. The fauna is not significant to reconstruct the ecology at the site, save to indicate conditions, somewhere in the superglacial drainage system, which could support mollusks.

AI. Prophets site:- This site is located 0.2 miles south and 0.2 miles

east of NE cor. sec. 29, T. 147 N., R. 78 W. The sediments were collected from a tailings pile beside a cattle watering dugout. The dugout is in a depression between high, well defined ridges near the summit of the Lincoln Valley moraine in the Prophets Mountains. The mollusks were taken from rhythmically bedded, clayey lake sediments. Recent sloughs occupy most of the depressions in the area.

Fauna:- Gastropods: Gyraulus parvus
Armiger crista
Lymnaea humilis
Lymnaea sp cf. L. palustris
Pelecypods: Pisidium spp.

Habitat:- Type 6, Shallow Lake.

Remarks:- The sediments also contain excellently preserved fossil fish of the families Catostomidae (suckers) and Cyprinidae (dace and chub). The molluscan fauna lacks branchiate forms and may be Recent in age. The site is receiving further study by Sherrod (1963). The fish are being studied by Drs. Robert Miller and Teruya Uyeno of the University of Michigan. The latter kindly supplied the tentative identifications. Their age (i. e. early Recent or Wisconsinan) has not yet been established.

MJ. Schroeder Farm site:- This site is located 0.4 miles north of SE cor. sec. 34, T. 147 N., R. 77 W. The sediments which contain the fossil mollusks are in dead ice moraine at the edge of a collapsed outwash plain.

Fauna:- Gastropods: Valvata tricarinata
V. lewisi
Gyraulus parvus
Gyraulus sp.
Promenetus exacuous
Pelecypods: Pisidium spp.

Habitat:- Type 2, Stream, or Type 6, Shallow Lake.

AK. Silbernagel Farm site:- This site is located 0.4 miles north of SE cor. sec. 26, T. 147 N., R. 77 W. The fossiliferous sediments are at the edge of a body of collapsed outwash sediments.

Fauna:- Gastropods: Valvata tricarinata

Habitat:- Type 2, Stream.

AL. McClusky site:- This site is located 0.2 miles south of NE cor. sec. 31, T. 147 N., R. 77 W. The sediments containing the fossil mollusks are clay and are a part of a body of dead ice moraine. No definable lake outline was observed by Mr. Sherrod at this site.

Fauna:- Gastropods: Valvata tricarinata
Gyraulus sp.
Pelecypods: Pisidium spp.

Habitat:- Type 1, Backwater, Type 4, Delta Front, Type 5, Deep Lake, or Type 6, Shallow Lake.

AM. Stock Farm site:- This site is located 0.5 miles south of NW cor. sec. 15, T. 146 N., R. 77 W. The sediments are in dead ice moraine and the fossils are contained in clayey silt. No definable outline of a body of lake sediments was observed by Mr. Sherrod.

Fauna:- Gastropods: Amnicola cf. A. limosa
Valvata tricarinata
Gyraulus parvus
Gyraulus sp.
Pelecypods: Pisidium spp.

Habitat:- Type 6, Shallow Lake.

Divide County

Mr. Hansen discovered and collected a fossiliferous site in Divide County. The site described below is interesting as it shows the geographic range in North Dakota of the fossiliferous ice-contact

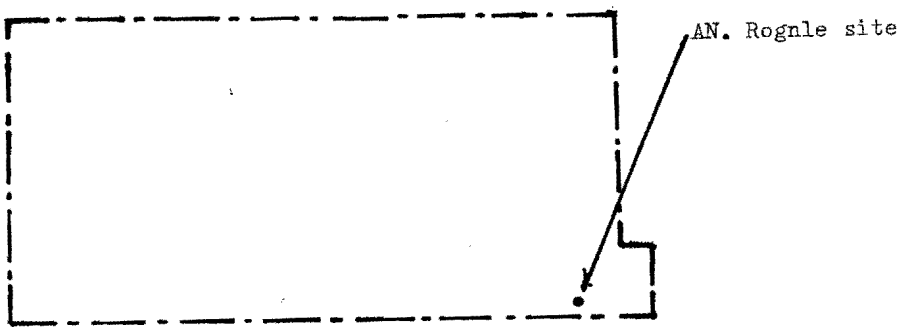


Fig. 19. INDEX MAP OF DIVIDE COUNTY, NORTH DAKOTA, SHOWING LOCATION OF THE ROGNLE FARM SITE.

faunas associated with the Missouri Coteau. Divide County is in the extreme northwestern corner of North Dakota. While not yet fully studied, the Missouri Coteau is known to maintain its character of high relief and low relief dead-ice moraine from Dickey County in the southeast to Divide County in the northwest and it is probable that the conditions postulated from the examination of the sediments and fossils reported here from the southern part of the Coteau are typical of the entire Missouri Coteau district.

AM. Reznic Farm site:- This site is located in the [illegible] sec. 34, T. 160 N., R. 96 W., very near the Divide-Williams County boundary, about 26 miles south of the Canadian boundary. The sample was collected from a road-cut near the boundary of collapsed lake and collapsed outwash sediments. The sediments from which samples were taken is 2 feet thick. A thin surface soil zone is developed on the top of this body of sediments and the unit overlies a medium-grained sand unit of unknown thickness, but small areal extent. The drift is of either late Wisconsinan or early Recent age and is as yet unnamed.

Fauna:- Gastropods: Valvata tricarinata
Lymnaea humilis
Gyraulus parvus
Promenetus exacuous
Helisoma trivolvis
Pelecypods: Pisidium sp.

Habitat:- Type 3, Delta Top; Type 4, Delta Front; or Type 6, Shallow Lake.

No. species/site	Gastropoda sp.	Succinea sp.	Ferrissia sp.	Helisoma anceps anceps	Helisoma anceps multivolvis	Helisoma trivolvis	Amnicola sp.	Cyraulus parvus	Cyraulus sp.	Lymnaea caperata & L. humilis modelli	Lymnaea palustris	Lymnaea stagnalis	Physa sp.	Unionacea	Anodonta sp.	Valvata lewisi tuberculata	Valvata sincera sincera	Pisidium sp.	Sphaerium sp.	Unidentified	Unidentified	Unidentified	Unidentified
11				C				A	A	R				A			A		C	R	X		R	C
14	R			R			R	A	A	R				A		R	A	R	A	R	X	C		
9		R		R	C			C	C					C		R	A				X			
10					R		C	A		R			R	A		R	A	C	C					
5									R					R			R				X	C		
8							R	A		C				R		C	A	C	R					
13				R		R	R	A	A	R	R		R			R	A	R	C	R				
8					R			C		R				R	R		C		C		X			
2																					X	R		
10				R			R	A	A	A			C	A			A	A	A		X			
9				R	R		R	A					R	R			A	C			X			
9				R				R						C	R	R	C		R		X			C
11					R			C	C	R				A		R	A	R	A	R	X			C
11						R		A	C	C			R	A			A	R	C			R		C
6								A	C	R				A			A		C					
3															R		R				X			
8				R				A	R	R			R	A		R		C						
6							R		R				R			R		C	R					
19			R		R	R	R	A	C	R		C	R	A	R	R	A	C	R	R	X	A		C
7				R				R	R	R				R			R		R					
5									R	R				R			R		R					
9						A	C	C	R	C	A	A	C					A						
1								R																
7				X				X	X					X			X		X	X				
7				X	X			X		X				X			X	X						
7								X	X	X				X			X	X	X					
9				X			X	X	X	X							X		X		X	X		
6					X				X	X				X			X	X						
9				X	X			X	X	X				X			X	X	X					
11				X	X		X	X	X				X	X			X	X	X	X				
3									X								X		X					
8				X			X	X	X					X			X	X	X					
2									X								X							
1					ONE Gastropod Fragment																			
4							X	X		X									X					
6								X	X							X	X	X	X					
1																	X							
3									X								X		X					
5								X	X					X			X		X					
6						X		X		X							X	X	X					
	1	1	1	15	10	5	13	29	27	22	2	2	9	25	4	11	33	20	27	7	13	6	1	

CONCLUSIONS

The conclusions which logically issue from this type of study are of two types: first, the organisms are presumptive evidence for ecologic conditions; and secondly, the conditions inferred in one provide the basis for secondary conclusions with respect to evaluations of geologic time and the correlation of sediments.

The reconnaissance nature of this investigation precludes all but the grossest generalities. To postulate details of the aquatic environment and its chemical composition and physical condition is an over-extension of our knowledge of the ecologic limits of the various species of molluscs. General climatic conditions can be suggested and comparisons with regions currently supporting similar molluscan communities can be safely made.

From rather limited studies of the Recent molluscan fauna of the Missouri Coteau (Tuthill and Laird, 1963) a slight, but significant difference in the species composition appears to exist. The Recent faunas are strongly dominated by the pulmonate genera Physa, Lymnaea and Gyraulus, whereas the Wisconsinan faunas were strongly dominated by the prosobranchiate genera Valvata and Amnicola. This suggests the greater permanency of water bodies during Wisconsinan time. A more humid climate would be the logical cause for greater permanency of aquatic environments than now exists. All species found in the fossil faunas are found in bodies of water in the Coteau Slope district which adjoins the Missouri Coteau district on the west and which forms the eastern drainage slope of the Missouri River in the area. The operculates are present in the Coteau Slope, but do not dominate there. Thus the faunal differences are assessable only by an evaluation of

molluscan communities rather than by species composition differences caused by local extermination or actual evolutionary extinction.

The nearest area known to support molluscan faunas essentially identical to the Wisconsinan faunas is northwestern Minnesota (Tuthill, Clayton, and Laird, in press). The climatic differences between this part of Minnesota and the Missouri Coteau district in North Dakota are very slight. The most significant apparent difference seems to be that the Minnesota locality is in an area having a surplus with respect to precipitation-evapotranspiration relationships, whereas the Missouri Coteau is an area of deficiency (Thornthwaite, 1948). This difference, slight though it be, has far reaching effects on ecologic conditions in the two areas. The chemistry of the lakes in the two areas responds very directly to this ratio of precipitation vs. evapotranspiration.

The geology of the Missouri Coteau clearly indicates a dynamic situation where thick drift cover conserved buried ice blocks for long periods of time. Collapse of sediments, draining of ponds and lakes and deflection of river and stream courses would be expected to occur with greater frequency than under more usual conditions. The amount of dynamic drainage change could not have been very great, however, because the dominance of fossil molluscan communities by gill-bearing operculates suggests clear water. That mollusk-supporting bodies of clear water could endure in the terminal ice of a stagnant glacier has been proved by studies I am conducting in the area of the Martin River Glacier, Alaska. Although most of the glacier melt water there is carried away by turbid streams and many polar lakes of turbid water exist, a significant number of clear-water, temperate lakes exist

in the lee of the stagnant terminus and are rendered essentially insulated from the ice by approximately 10 feet of drift. It seems likely from the fossil evidence as well as the geologic evidence that an analogous situation existed on the Missouri Cotese during late Wisconsinan time.

The faunas taken from sediments having a clearly lenitic environment of deposition tempt the worker to draw conclusions about climatic changes through the time of deposition. The hazards of doing this are obvious from a consideration of the probable instability of the environments. As mentioned above the causes for marked changes in a lenitic or a lotic environment would be legion. To assume that faunal changes, which do indeed exist in vertical sequences, represent climatic change only, is to ignore these special conditions of an ice-cored landform as well as problems of dispersal, possible succession, and grain-size selection in sedimentation (i. e. postmortem transportation and sorting of shells because of settling velocity differences).

The actual amount of oxygen, carbon dioxide, nitrate, etc. dissolved in the waters of the Wisconsinan aquatic environments cannot be inferred from the species composition of the molluscan fauna at the present time. There is no doubt that the conditions of the water were not unlike Recent waters containing essentially the same faunas (i. e. northwestern Minnesota), but mere specific inferences decrease the accuracy of paleoecologic conclusions at the present time.

A sizable additional biota can be inferred from the fossil assemblage. Confidence in the probable presence of this biota is relatively high, but it should be noted that particular elements of this biota are the product of presumptive evidence; the actual genera and species

mentioned may have been replaced by others which would complete the community equally well.

The unionids, as previously mentioned, require fish of the families Percidae or Centrarchidae in their glochidial stage. Many of the interiors of the shells of Anodonta grandis exhibit small (about 0.5mm high and 0.75mm dia.) pearl blisters. These are similar to the blisters formed over the eggs of mites of the genus Unionicola Haldeman 1842 in living specimens. Lampsilis radiata siliquoidea and probably species of Anodonta too, frequently are hosts for the trematodes Cotylogaster lasiensis and Aspidogaster conchicola. The mucous coat of the mantle frequently contains various species of Vorticella as well as the protists Conchophthirus curtus and C. anodontae. The oligochaete worm Chaetogaster limnaei is frequently found in unionid valves where it feeds on the various parasites. Normal predators of unionids today are muskrats, raccoons, mink, water fowl, turtles and man. It is conceivable that some or all of these were present during late Wisconsinan time. Aquatic as well as marginal vegetation was present in some form as a basis of the diet of the clams.

The gastropod fauna suggests the possible presence of the plant genera, Potamogeton, Nymphaea, Nelumbo, Castalia, Limnaia, Myriophyllum, Elodea, Typha, Cladophora, Spirogyra, and Vaucheria, if present floral associates of the various species of snails in the mid-continent are also typical for late Wisconsinan time.

Chronology, the constant concern of the paleontologist, is complicated by the fact that none of the species of the fossil assemblage is extinct nor even locally exterminated. The community, as discussed above, may eventually prove to be useful for age determinations. At

present the sediments in the Missouri Coteau district which contain molluscan faunas dominated by the genera Valvata and Amnicola are tentatively used to assign it a Wisconsinan age.

Actually the snails are providing the most information for assessments of age. They have been used for the determination of radiocarbon age of five sites (Gutzahnidt Farm site - M-956, 9,000-300; Rue Farm site - M-1149, 9,620-350; Schauer Farm site - M-954, 9,870-290; Cleveland site - M-956, 11,070-300; and Huffaungsthall site - M-974, 11,650-310, see Fig. 20). These dates are too few in number to provide the basis for a formal time-classification for use in North Dakota. They do suggest a pattern of events and are intimately associated with paleoecologic interpretations. Fig. 20 shows the chronologic relationships of these five sites graphically. A modification of a portion of Frye and Willman's (1960) classification, proposed for the Michigan lobe in Illinois is shown on Fig. 3. As this classification is based on radiocarbon time, rather than lithologic extensions, I regard it as being at least germane if not of enduring value in the area studied.

If the distribution of these five dates proves to be a reflection of the situation which actually exists, mollusks may have lived in the aquatic environments of the Missouri Coteau during the latter part of Tazewellian time, been locally exterminated (possibly by some aspect of climate) during early Valderan time and then returned during a latter part of that time. The drift of the Missouri Coteau in its entirety resulted from sedimentation of material transported into the area during Woodfordian and/or Tazewellian time. Both the Cleveland and the Huffaungsthall sites (the oldest) are inside the Streeter Moraine of the Burnsted Drift. The existence of younger faunas outside the Streeter

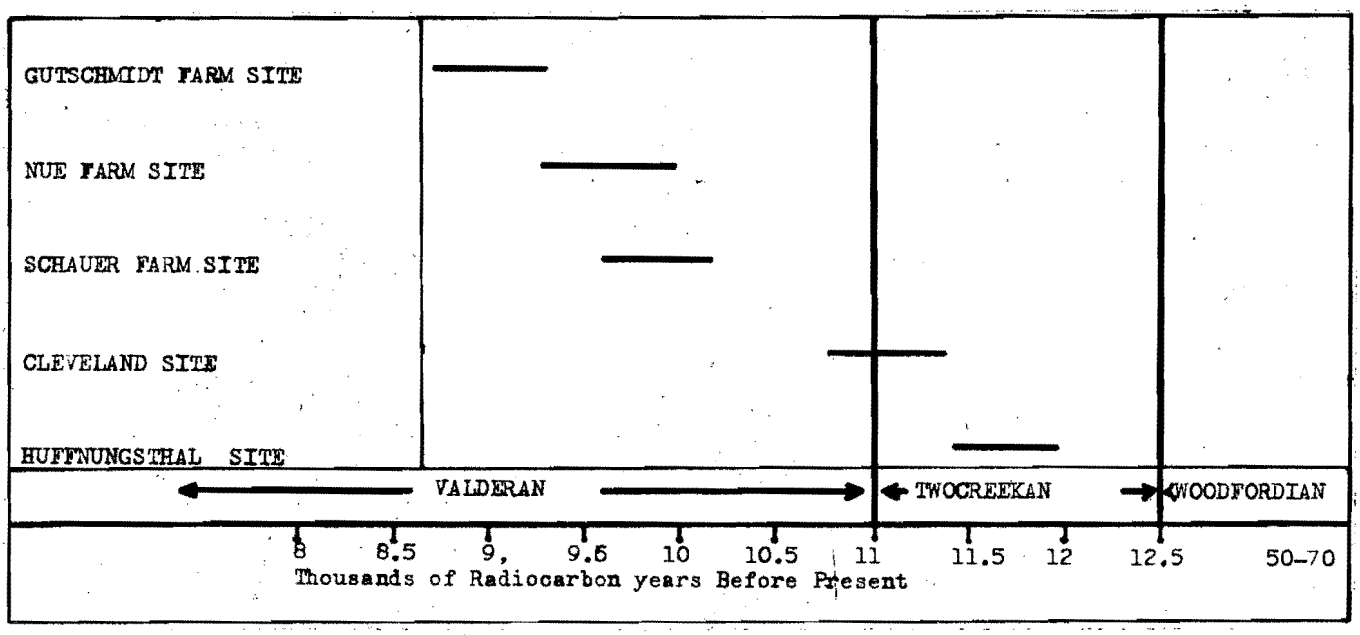


Fig. 20. DISTRIBUTION OF RADIOCARBON DATES FROM MOLLUSK SHELLS IN RELATION TO THE LATE PLEISTOCENE TIME DIVISIONS.

Moraine, but inside the Durnstad Moraine (g. g., Nue Farm sites) does not establish the maximum age of the outer part of the Durnstad Drift.

All of the sites which have been radiocarbon dated (Fig. 20) except the Schauer Farm site lie on the proximal side of the Streeter Moraine. The Schauer Farm site is in sediments on the distal side of the Streeter Moraine but on the proximal side of the Durnstad Moraine. Thus it would appear that the latest date which could be assigned to the Streeter advance would be that of the Huffmangthall site (i. g. 11,650 ± 350 C^{14} yrs. B.P.). Clayton (1963, p. 65) states that the sediments at the Huffmangthall site are lake sediments which were incorporated in end moraine of the Streeter Moraine. If this is true, and the topography and sedimentary structures at the site strongly support Clayton's contention, the Cleveland site provides a more conservative date for the latest date of the Streeter advance (i. g. 11,070 ± 300 C^{14} years B.P.). The Cleveland site could not have been formed during active advance of the ice which emplaced the portion of the Durnstad Drift sheet which is proximal to the Streeter Moraine, but must have formed prior to the complete wasting of the stagnant ice.

Thus the Streeter ice advanced into Logan County after 11,650 ± 350 C^{14} yrs. B.P. and had stagnated in Stutsman County before 11,070 ± C^{14} yrs. B.P.

The collapsed nature of most of the sediments which surface the Missouri Coteau does indicate the conservative nature of melting, possibly having required 2,100 years for the ice underlying the Missouri Coteau to melt.

These studies suggest the value of continuation of the work and the extension of investigation to both the north and the south, as

fossil mollusks should eventually provide criteria for more reliable correlation of glacial sediments than the techniques of lithologic equivalency will allow, as well as possible details of late Pleistocene climate.

DESCRIPTIVE PALEONTOLOGY

In this section a partial synonymy is given which is designed to indicate the concepts of the various species with which I believe the material from the Missouri Coteau district compares. I have not included original citations because I have not seen most of them. The purpose of this investigation is paleoecologic and not primarily taxonomic. A brief description of the fossil material, including measurements of representative specimens, Geologic age of the material described, and records of occurrence are also given. The records of occurrence are given by a letter which refers to the site and a number which is the catalogue number under which the specimen or specimens is curated in the University of North Dakota Department of Geology collection.

The following meanings are assigned to the terms; very small, small, medium, and large:

Pelecypods: Very small = less than ½ cm.
Small = greater than ½ cm to 2 cm in greatest dimension.
Medium = greater than 2 cm to 10 cm in greatest dimension.
Large = greater than 10 cm in greatest dimension.

Gastropods: Very small = less than 2 mm in greatest dimension.
Small = greater than 2 mm to 5 mm in greatest dimension.
Medium = greater than 5 mm to 10 mm in greatest dimension.
Large = greater than 10 mm in greatest dimension.

The descriptive terminology of Cox (1960, p. 106-126) is used for gastropods in this section.

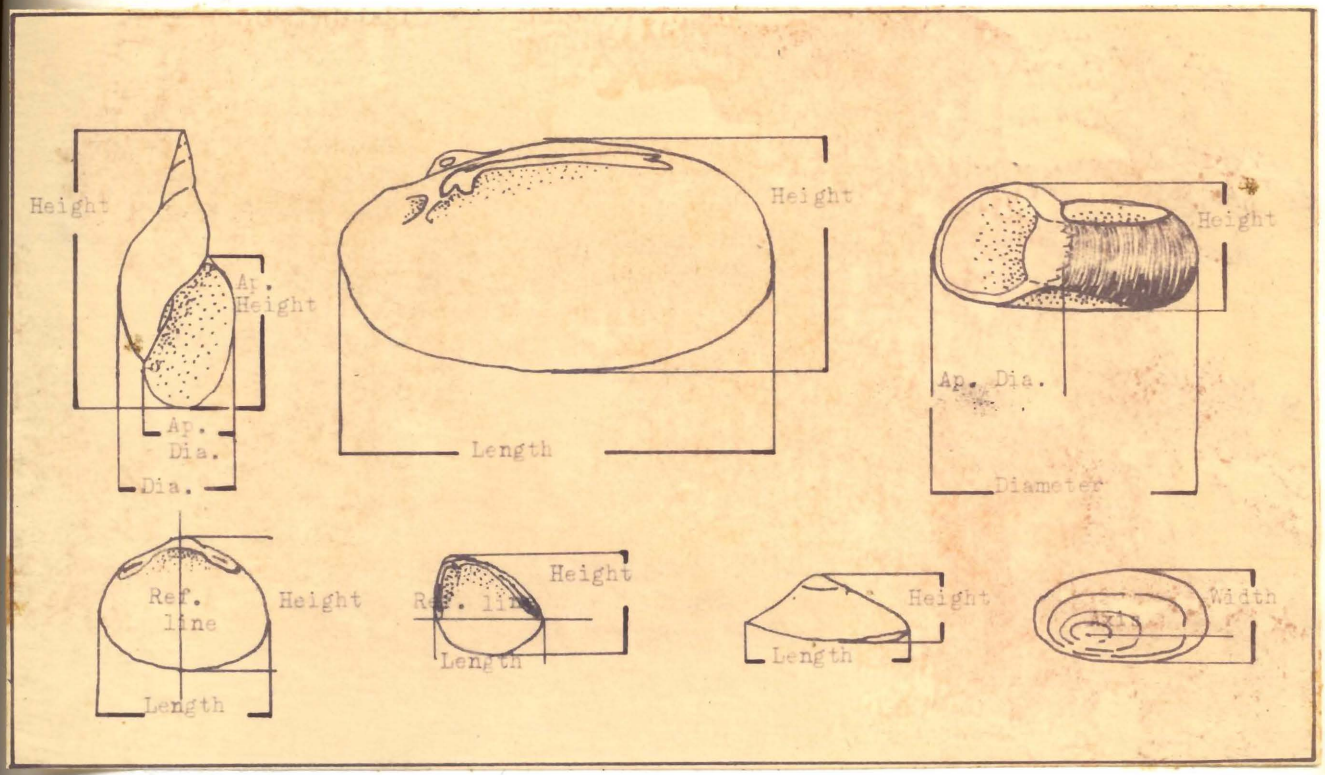


Fig. 21. DIAGRAM OF SHELL ORIENTATIONS USED IN MEASURING OF SPECIMENS.

Systematic List Of Molluscs

Class PELECYPODA
  Order EULAMELLIBRANCHIA
    Superfamily NAIADAE
      Family UNIONIDAE
        Anodonta grandis Say, 1829.
        Anodontoides ferussacianus (Lea), 1834.
        Lasmigona radiata alligenidea (Barnes), 1823.
  Order TELEODESMACEA
    Family SPHAERIIDAE
        Sphaerium spp.
        Pisidium spp.
Class GASTROPODA
 Subclass STREPTONEURA
  Order MESOGASTROPODA
   Superfamily VALVATACEA
    Family VALVATIDAE
        Valvata tricarinata (Say), 1817.
        Valvata lewisi Currier, 1868.
   Superfamily RISSOACEA
    Family HYDROBIIDAE
        Amnicola limosa (Say), 1817.
        Amnicola sp.
 Subclass EUTHYNEURA
  Order BASOMMATOPHORA
   Superfamily LYMNAEACEA
    Family LYMNAEIDAE
        Lymnaea palustris (Muller), 1774.
        Lymnaea humilis (Say), 1822.
        Lymnaea stagnalis (Linne), 1758.
   Superfamily ANCYLACEA
    Family ANCYLIDAE
        Ferrissia sp.
    Family PLANORBIDAE
        Gyraulus parvus (Say), 1817.
        Gyraulus sp.
        Promenetus umbilicatus (Say), 1821.
        Armiger crista (Linne), 1758.
        Helisoma trivolvis (Say), 1817.
        Helisoma anceps (Menke), 1830.
    Family PHYSIDAE
        Physa sp.
  Order STYLOMMATOPHORA
   Suborder ORTHURETHRA
    Superfamily PUPILLACEA
    Family PUPILLIDAE
        Gastrocopta sp.
   Suborder HETEROURETHRA
    Superfamily SUCCINEACEA
    Family SUCCINEIDAE
        Succinea avara (Say), 1824.

Anodonta grandis Say, 1829

Pl. 2 Fig. 1

(1) Anodonta grandis Say. Bull. 1908, Harriman Alaska Series, v. 13, p. 129-130. Baker, 1928a, Wisconsin Geol. Nat. Hist. Survey Bull. 70, pt. 2, p. 152-155. van der Schalie, 1938, Mich. Univ. Mus. Zool. Misc. Publ. 40, p. 50-52.

Description of the fossil material:- Medium; relatively thin shelled; produced in the area of the beaks; rounded anterior margin; length approximately twice height; posterior margin, usually broken, narrowing to a rounded point; beak with concentric double-looped ridges; no teeth.

UND #	Valve	Height (mm)	Length (mm)	
			broken	posterior
3207-1	Right	4.37	"	"
3207-2	Right	5.00	"	"
3195	Left	4.77	"	"
3205-1	Left	4.79	"	"
3205-2	Left	5.30	"	"
3205-3	Left	5.25	"	"
3197	Left	3.84	"	"
3212	Articulated Left and right	2.88	5.13	

Occurrence:- A. 3222, 3522; L. occurs; S. 3391, 3392; N. 3217; S. 3195, 3197, 3201, 3207, 3212, 3214.

Geologic Age:- Late Wisconsinan.

Remarks:- Anodonta grandis in conjunction with the other unionids is important presumptive evidence for fish of the families Centrarchidae and Percidae, species of which serve as hosts for the glochidia of the clams. A. grandis feeds only on vegetable detritus (Howard, 1922, p. 63-89) thus suggesting abundant aquatic vegetation; the respiratory method (gills) of this species requires relatively clear water. During the first two years of this study a search for fossil remains of fish

in the Missouri Cotean sediments was fruitless, but Mr. M. S. Sherrod (1963) has found specimens of both of 2 fresh-water fish (see Prophets site AI) in collapsed lake sediments in Sheridan County.

Anodontoides ferrussacianus (Lea), 1834

(1) Anodontoides ferrussacianus (Lea). Baker, 1928a, Misc. Geol. Nat. Hist. Survey Bull. 70, pt. 2, pl. 175, pl. 67, fig. 3, 4, 7. Pl. 75, fig. 305. Van der Schalie, 1938, Mich. Univ. Mus. Zool. Misc. Publ. 40, p. 32, 56.

Description of fossil material:- Medium, thin shelled, elliptical (margins broken); beak sculpture of single-looped, concentric bars; without hinge teeth; beaks anterior and slightly prosocline.

Occurrence:- A. 3223.

Geologic Age:- Late Wisconsinan.

Remarks:- This species is differentiated (in the shell) from small Anodonta grandis by the beak sculpture according to Baker (1928a, 177). In A. grandis the beak has concentric, raised loops or bars which have one or more deflection toward and away from the apex so as to form small adapical "V" in each loop. A. ferrussacianus does not have these deflections and the loops are arranged concentrically. The shells assigned to this species were broken at the margins, but sufficient material was present to support the conclusion made from an examination of the beaks to permit a good degree of confidence in the identification.

Lampsilis radiata siliquoidea (Barnes), 1823.

Pl. 2 Figs. 5-7

(1) Lampsilis siliquoidea (Barnes). Baker, 1928a, Misc. Geol. Nat. Hist. Survey Bull., 70, pt. 2, p. 270, pl. 89, fig. 5-8, pl. 90, fig. 1. van der Schalie, 1938, Mich. Univ. Mus. Zool. Misc. Publ. 40, p. 67, fig. 23.

Description of fossil material:- Medium to large, moderately thick shelled; elliptical, 1½ times as long as high, smooth, female with angular posterior ventral margin and greatest height in posterior ⅓; beak sculpture of several fine wavy bars which loop apically at their ends; beaks anterior and slightly prosocline; two lateral teeth in left valve, one in right valve; pseudocardinal teeth ragged, left valve containing the larger. Growth-interruption lines regular and not strongly raised.

UNO #	Valve	Height (mm)	Length (mm)	Sex
3279	Right	6.00	broken	Male
3279	Left	6.03	12.10	Male
3280	Right	5.51	9.18	Female
3196	Right	4.49	8.45	Male
3196	Left	4.59	8.65	Male
3200	Right (art.)[2]	broken umbone	10.43	Male
3200	Left (art.)	5.80	10.35	Male
3204-1	Left	4.08	broken posterior	Female
3204-2	Left (art.)	5.14	broken posterior	Male
3204-2	Right (art.)	4.74	broken posterior	Male
3204-3	Right	4.56	8.45	Male
3204-4	Left	4.57	broken anterior	Male
3204-5	Right	4.27	posterior broken	Female
3204-6	Right	5.13	9.15	Female
3204-7	Right	5.24	posterior broken	Female
3198	Right	5.98	10.6 broken anterior	Male
3199-1	Right (art.)	4.53	7.83	Female
3199-1	Left (art.)	4.54	7.79	Female
3199-2	Left	4.46	7.90 posterior broken	Male

[2]The abbreviation art. means the valves were articulated and therefore measurements are slightly different than would be obtained from single valves.

3502	Left (art.)	4.53	0.16	Female
3502	Right	4.58	0.19	Female

Occurrence:- B. 3646, 3647; I. 3215; M. 3218; S. 3194, 3196, 3198, 3199, 3200, 3202, 3203, 3204, 3206, 3208, 3210, 3211, 3213, 3216, 3219, 3279, 3280, 3281, 3282, 3283.

Geologic Age:- Late Wisconsinan.

Remarks:- Shell fragments have been found at sites: A, C, E, H, J, L, N, P and K. It is possible that these fragments, often nothing more than prisms, are reworked from older sediments. It is more likely, however, that these fragments are from Pleistocene molds, but the possibility that they are from Cretaceous marine pelecypods cannot be ignored.

Sphaerium spp.

Pl. 2 Fig. 2

Description of fossil material:- Small, thin-shelled, oval to triangulate, beaks central, anterior and posterior halves approximately symmetrical in external appearance, cardinal and lateral teeth present, prosopon of fine concentric ridges. Many shells have a raised apical portion of the valve which usually have concentric growth-interruption lines.

UNO #	Height (mm)	Length (mm)
3572-1	.64	.83
3572-2	.62	.80
3301	.94	1.26
3521-1	1.24	1.68
3521-2	1.25	1.67

Occurrence:- A. 3521; B. 3596; S. 3233, 3252, 3264, 3572, 3503; M. 3374; X. 3135; AD. 3179, 3183, 3187.

Geologic Age:- Late Wisconsinan.

Remarks:- The purpose of this research was to assess the paleoecology of the Wisconsinan sediments of the Missouri Coteau. The taxonomy of the Sphaeriidae awaits major revision, therefore ecologic inferences based on species of this family are subject to great error. For this reason their occurrence has been noted, but they have not been thoroughly studied as yet.

Pisidium spp.

Pl. 1 Fig. 21

Description of fossil material:- Very small; approximately as high as long. Nepionic valve not distinguishable in prosopes; beaks eccentric with respect to a plane normal to the plane of commissure and parallel to the line of greatest height; lateral teeth present.

UND #	Height (cm)	Length (cm)
3220-1	.072	.077
3220-2	.072	.077
3220-3	.048	.056
3220-4	.063	.070
3220-5	.073	.080
3220-6	.076	.080
3220-7	.054	.061

Occurrences:- A. 3516; B. 3592, 3609, 3619, 3626, 3635, 3637, 3642; D. 1765; E. 3605; F. 1781; G. 3469, 3582; H. occurs; J. 3414, 3418, 3428; L. 3341, 3350; M. 3375, 3376, 3379, 3383; N. 3400; O. 3360, 3366; R. 3449; S. 3220, 3230, 3243, 3250, 3264, 3273, 3291, 3300, 3308, 3326, 3332, 3573; U. 3561; X. 3133; Z. 3140; AA. 3150; AC. 3151; AD. 3186; AE. 3162; AF. 3129, 3120; AI. 6154; AJ. 6166; AL. 6159; AM. 6172.

Geologic Age:- Late Wisconsinan.

Remarks:- The state of the taxonomy of this group awaits major

revisions. As in the case of Subcarinum, I have not attempted specific assignment of Platidiscus because they will not offer a satisfactory basis for paleoecologic reconstruction until they can be confidently identified and are widely collected.

Valvata tricarinata (Say). 1817.

Pl. 1 Figs. 14,16.

(1) Valvata tricarinata (Say). Walker, 1902, Nautilus, v. 15, p. 121-122, fig. 1-4. Dall, 1905, Harriman Alaska Series, v. 13, p. 121, fig. 93. Baker, 1928, Wisconsin Geol. Nat. Hist. Survey Bull. 70, pt. 1, p. 16, pl. 1, fig. 1-3. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, pl. 15, fig. u.

(2) Valvata tricarinata normanfana Walker. Baker, 1928, op. cit. p. 16, pl. 1, fig. 4.

Description of fossil material:- Small; about 3½ whorls; turbinate, dextral, orthostrophic, carinate with 1, 2, or 3 carinae or noncarinate, whorl profile circular, first two whorls involute, subsequent whorls evolute, suture at middle carina; nucleus without carinae or ornamentation, sunken below next whorl; surface shiny and with thread transverse lines at former aperture positions; aperture circular, operculate, without a callus; narrow infundibulate umbilicus.

UNM #	No. of Whorls	Shell Height (mm)	Shell Diameter (mm)	Aperture Height (mm)	Aperture Diameter (mm)	Umbilicus Diameter (mm)
3284-1	3 1/2	3.0	4.4	2.1	1.9	0.9
3284-2	3 1/2	3.2	4.0	2.0	1.8	1.0
3284-3	3 1/2	3.0	3.8	1.9	1.7	1.0
3284-4	3 1/2	2.5	4.2	1.9	1.6	1.2
3284-5	3 3/4	3.4	4.6	2.2	2.0	1.1
3284-6	3 1/4	2.7	3.8	1.9	1.8	0.7
3284-7	2 3/4	1.7	2.5	1.2	1.2	0.5
3284-8	3 1/2	2.6	4.1	1.9	1.8	1.1
3284-9	3 1/2	2.4	3.6	1.8	1.6	0.8
3284-10	3 1/2	2.9	3.8	1.8	1.6	0.8
3284-11	3	2.0	3.0	1.4	1.4	0.6

3284-12	2 1/2	1.6	2.5	1.3	1.3	0.4
3284-13	3	1.9	2.9	1.3	1.3	0.5
3284-14	3 1/2	2.5	3.5	1.7	1.6	0.5
3570-1	3 1/4	2.7	3.7	1.8	1.6	0.7
3570-2	3	1.8	3.1	1.3	1.3	0.8
3570-3	3	1.9	3.3	1.4	1.3	1.0
3570-4	3	2.6	3.5	1.6	1.7	0.7
3570-5	3	2.1	3.4	1.4	1.5	0.8

Occurrences:- A. 3509; B. 3587, 3607, 3618, 3623, 3630, 3639, 3645; C. 1776, 3599; D. 1767; E. 3644; F. 1788; G. 3579, 3465; H. 3541; J. 3411, 3417, 3426, 3442; K. 3485; L. 3442, 3352; M. 3367, 3381, 3378; N. 3403; O. 3556, 3565; P. 3478; S. 3231, 3246, 3251, 3265, 3277, 3295; 3299, 3307, 3322, 3323, 3329, 3570; T. 3284; U. 3562; X. 3134; Y. 3173; Z. 3138; AA. 3149; AB. 3168; AC. 3159; AD. 3185; AF. 3124, 3116; AG. 6157; AJ. 6160; AK. 6162; AL. 6160; AM. 6173.

Geologic Age:- Late Wisconsinan.

Valvata lewisi Currier, 1960

Pl. 1 Fig. 15

Valvata lewisi Currier. Ball, 1905, Alaska Harriman Series, p. 128, fig. 94. Baker, 1920. Wisconsin Geol. Nat. Hist. Survey Bull. 70, pt. 1, p. 25-29, pl. 1, fig. 28-30.

Description of fossil material:- Small; about 3½ whorls; turbinate, dextral, orthostrophic, advolute, without carinae, sutures impressed; surface with coarser transverse lines than in the ecarinate form of V. tricarinata: nucleus unornamented, rising above next whorl; aperture circular, operculate, without a callus; moderately narrow umbilicus.

USNM #	No. of	Shell Height (mm)	Shell Diameter (mm)	Aperture Height (mm)	Aperture Diameter (mm)	Umbilicus Diameter (mm)
3568-	3 1/2	3.7	4.7	2.3	2.1	1.0
3385-1	3 3/4	2.9	4.2	1.8	1.8	1.0
3385-2	3 3/4	3.6	4.3	1.8	1.7	1.0
3385-3	3 3/4	3.7	4.5	2.1	2.1	1.0
3385-4	3 1/2	2.7	3.6	1.8	1.7	0.8

Occurrences:- B. 3591, 3614; L. 3354; C. 3586; N. 3568; Q. 3451; S. 3568; AJ. 6167.

Remarks:- This species is quite rare in the collections from the Pleistocene sediments of the Missouri Cotaux and is not, therefore, a significant taxon in reconstructing the paleoecology of the sites where it is found.

Amnicola limosa (Say), 1817

Pl. 1 Figs. 18, 19

(1) Amnicola limosa (Say). Dall, 1905, Harriman Alaska Series, v. 13, p. 117, fig. 84. Baker, 1920, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 93, pl. 1-6.

(2) Amnicola limosa porata (Say). Baker, 1920, op. cit., p. 98, pl. 6, fig. 7 & 8.

(3) Amnicola limosa parva (Lea). Baker, 1920, op. cit., p. 102, pl. 6, fig. 12-14. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, pl. 15, fig. t.

(4) Amnicola limosa superiorensis Baker. Baker, 1920, op. cit., p. 101, pl. 6, fig. 9-11, pl. 7, fig. 22, 23.

(5) Amnicola leightoni Baker. Baker, 1920, op. cit., p. 120, pl. 6, fig. 34-39.

(6) Amnicola (Amnicola) limosa (Say). Berry, 1943, Michigan Univ. Mus. Zool. Misc. Publ., 37, p. 23, pl. 1, fig. 1.

Description of fossil material:- Small; 4½ whorls; conoheidal, globular, orthostrophic, slightly involute; nucleus elevated above next whorl, smooth or minutely granular; surface with transverse thread costellae, finer and more widely spaced spiral lines; narrow umbilicus exposes only the last whorl; aperture cordate operculate.

UND #	No. of Whorls	Shell Height (mm)	Shell Diameter (mm)	Aperture Height (mm)	Aperture Diameter (mm)
3569-1	4 1/2	4.3	3.6	2.3	1.9
3569-2	4 1/2	4.6	3.8	2.6	2.0
3569-3	4 1/2	4.3	3.4	2.2	1.8

3569-4	4 1/2	4.0	3.4	2.1	1.8
3569-5	4	3.2	2.4	1.7	1.4
3569-6	4	3.1	2.4	1.8	1.4
3569-7	3 1/2	3.6	3.0	2.0	1.7
3569-8	4	4.2	3.5		broken
3569-9	4	4.0	3.3	2.1	1.8
3569-10	4	4.0	3.0		broken

Occurrences:- A. 3510; B. 3580, 3608, 3622, 3636; C. 1771; D. 1759; E. 3651; F. 1777; H. present; J. 3505, 3410, 3422, 3427, 3441; K. 3479; L. 3343, 3354; M. 3371, 3382; N. 3401; O. 3359, 3364; Q. 3454, 3551; S. 3292, 3293, 3225, 3226, 3227, 3235, 3241, 3260, 3271, 3306, 3327, 3569; T. 3286; U. 3560; X. 3192; Y. 3176; Z. 3137; AB. 3167; AC. 3158; AD. 3191; AF. 3125; AR. 6176.

Geologic Age:- Late Wisconsinan.

Remarks:- The Wisconsinan mollusks of the Missouri Cotean district are not perceptibly different in shell form from Recent specimens I have seen. One exception to this statement is suggested by shells of the family Hydrobiidae. Amnicola leightoni Baker, 1920, was named for Pleistocene specimens from Ohio. The characters outlined by Baker (1920, p. 125, 1921, p. 23, and 1928, p. 119-121), for this species fit the specimens listed as Amnicola limosa (Say), 1817, in this report. It is my opinion that Baker's species merely represents a portion of the species A. limosa and is synonymous with the latter. The A. limosa specimens I have seen from the Illinois Geological Survey Museum compare favorably with the specimens of A. leightoni from the same collections. Baker identified all of the material in the Illinois Geological Survey Museum collections and I believe that his assignment of specimens to A. leightoni is merely a fractionation of a group which is known to very greatly in shell form. Dr. Elmer G. Berry of the Laboratory of

Parasitic Diseases, National Institute of Allergy and Infectious Disease, Bethesda, Maryland, has identified specimens from the Nuo Farm site (S) as A. limosa (personal communication).

Physa sp.

Pl. 1 Figs. 12, 13.

Description of fossil material:- Small to medium; 4 whorls stout-fusiform, sinistral, orthostrophic; moderately convoluta with the body whorl abutting pervious ones, last whorl comprises about 90 per cent of shell height; shell very thin, very fine thread transverse lines in former aperture positions; aperture large and ovate, with a distinct parietal callus; cryptomphalous.

UNO #	No. of Whorls	Shell Height (mm)	Shell Diameter (mm)	Height of Last Whorl (mm)	Aperture Height (mm)	Aperture Diameter (mm)
3420-1	4	5.1	3.5	4.7	4.0	2.2
3420-3	3 1/4	3.5	3.3	3.2	3.0	1.4
1764-1	4	6.6	4.1	5.8	5.0	2.3
3444	2	1.5	1.0	1.4	1.2	0.4

Occurrences:- C. 3597; D. 1764; G. 3580; J. 3420, 3430; N. 3398; R. 3444; S. 3320; AD. 3181.

Geologic Age:- Late Wisconsinan.

Remarks:- Most of the shells from the Missouri Cotean sediments appear to be immature specimens and lack sufficient characteristics for specific assignments. Identification of the species of this genus is beset with hazards because of the great morphologic variation of the taxon, presumably, in response to ecologic conditions. Physa is one of the genera of freshwater snails most able to endure generally adverse conditions. It is one of the most common of the genera of the Recent

snail fauna of the Missouri Coteau. Its rarity, therefore, in Wisconsinan molluscan communities is not easy to interpret. Ecologic pressure from other species of mollusks may be a logical explanation. Its rarity is not a statistical factor. The tendency for the shells to uncoil when dried and the large size of the body whorl may account for its scarcity in that it is extremely fragile and may be more poorly preserved.

Lymnaea palustris (Muller), 1774.

(1) Stagnicola palustris jolietensis (F. C. Baker). Baker, 1928, Misc. Geol. and Nat. Hist. Survey Bull. 70, pt. 1, p. 220, pl. 13, figs. 23-26.

(2) Stagnicola palustris elodes (Say). Baker, ibid., p. 212, pl. 13, figs. 3-7, 9-13.

(3) Lymnaea palustris (Muller), Hubendick, 1951, Kungl. Svensk. Vetenskad. Handl., ser. 4, v. 3, p. 84, 85, 119-122, figs. 190, 191, 195-203, fig. 303, b, m, and v (only).

Description of fossil material:- Large; 5 whorls, last whorl less than ½ total height, shoulders lacking, expansion of later whorls regular; cryptomphalous; columnar fold weakly developed; not operculate; protoconch of fine transverse threads, some specimens malformed in last whorl.

No. of Whorls	Shell Height (mm)	Shell Diameter (mm)	Aperture Height (mm)	Aperture Diameter (mm)
5	18.3	9.0	8.7	6.5

Occurrences:- G. 3580; V. 7201; Al. 6153.

Geologic Age:- Late Wisconsinan.

Lymnaea stagnalis (Linne) 1758

Pl. 1 Fig. 11

(1) Lymnaea stagnalis jugularis Say. Baker, 1928, Mus. Geol. Nat. Hist. Survey Bull. 70, pt. 1, p. 198-204, Pl. 11, fig. 6, 9, 10, 12 and 13 (only), Pl. 12, 4 (only).

(2) Lymnaea stagnalis (Linne). Habendich, 1951, Kungl. Svenska Vetenskapsakademiens Handlingar, Band 3, no. 1, p. 118-119, fig. 300 (E & F only).

Description of fossil material:- Large; 5-6 whorls, last whorl more than ½ total height, adapical shoulder on last ½ whorl, (shoulders rounded, spire attenuated, expanding rapidly in last whorl;), cryptomphalous; columellar fold well developed; not operculate.

UMD #	No. of Whorls	Shell Height (mm)	Shell Diameter (mm)	Aperture Height (mm)	Aperture Diameter (mm)
3209-1	6 1/2	44.1	22.6	25.5	14.3
3209-2	6	17.9	12.4	15.4	10.0
3209-3	6	30.6	15.9	17.7	9.9

Occurrences:- S. 3240, 3209.

Geologic Age:- Late Wisconsinan.

Remarks:- The fragility of the shells found at the Nun Farm site (S) precluded collection of many whole specimens. Many specimens were seen in the sediments during excavation of this site, only a few of which could be collected. Despite the small number of specimens in the collection, there seems little doubt that at one time during the existence of the aquatic environment at this site, Lymnaea stagnalis was a successful member of the molluscan community.

L. stagnalis shells were seen in the sediments of the Podell Farm site (V), but collection of whole specimens was impossible.

Lymnaea humilis Say, 1822

Pl. 1 Figs. 9, 10.

(1) Lymnaea humilis Say, 1822, Jour. Acad. Nat. Sci. Phila., v. 2, p. 378. Dall, 1905, p. 73, fig. 50. Hubendick, 1951, Kungl. Svenska Vetenskapsakademiens Handlinger, Band 3, No. 1, p. 126, 180, fig. 308 (g and h only). Tuthill, Clayton, and Laird, 1963, Amer. Midl. Nat. (in press).

(2) Fossaria galbana (Say), 1928, Baker, Wisconsin Geol. Nat. Hist. Survey Bull. 70, pt. 1, p. 304-305, pl. 18, fig. 4i (only).

Description of fossil material:- Medium, 4-5½ whorls; attenuated, dextral, orthostrophic, slightly involute, strongly shouldered, abapical profile of each whorl narrower in diameter than adapical profile, body whorl about 2/3 of height; narrowly to moderately umbilicate; transverse fine lines on all whorls except nuclear whorl and subsequent ½ whorl, whorls increase in diameter regularly, no callus; subrectangular, oblong-ovate aperture height always greater than ½ shell height in unbroken specimens, aperture with a slightly recurved parietal lip partially constricting umbilicus; not operculate.

UND #	No. of Whorls	Shell Height (mm)	Shell Diameter (mm)	Aperture Height (mm)	Aperture Diameter (mm)
3511-1	5	6.3	3.5	3.6	1.8
3511-2	5	6.0	3.1	3.1	2.0
3511-3	5	6.0	3.4	3.5	2.1
3511-4	4 1/2	5.6	3.2	2.9	1.8
3511-5	5	6.2	3.2	3.2	2.0
3511-6	5	6.8	broken	3.3	broken
3511-7	4 1/2	5.8	2.9	2.9	1.9
3511-8	4	5.8	2.9	3.0	1.8
3511-9	4	3.3	2.0	1.7	1.2
3567-1	5 1/4	7.4	3.8	4.1	2.4

Occurrences:- A. 3511; B. 3611; C. 3600; D. 1762; G. 3584; H. occurs; M. occurs; O. 3361; S. 3567, 3290, 3564; T. 3177; Z. 3142; AA. 3145; AB. 3166; AC. 3153; AI. 6152.

Geologic Age:- Late Wisconsinan.

Remarks:- The species of the genus Lymnaea (in the sense of Hubendick, 1951, or the family Lymnaeidae in the sense of Baker, 1928a) are composed of groups which exhibit a wide variety of shell form. On the basis of neontologic as well as morphometric criteria, Hubendick (1951, p. 126-128) has grouped the following taxa into the species [L.] humilis: Galbana Say, [L.] peteskeyensis Walker, [L.] obrussa decampi Streng, [L.] dalli, Baker, [L.] caperata Say, [L.] umbilicata Adams, [L.] cyclostoma Walker, [L.] parva Lea, [L.] parva storkii Baker, [L.] omasecensis Baker, [L.] dalli Baker, [L.] pilsbryi Hemphill, [L.] ferruginea Haldeman, [L.] humilis modicella Say, [L.] humilis rustica Lea and [L.] obrussa Say. It is beyond the power of the paleontologist to create taxa having as great a range of shell morphology as Hubendick has created. Because I regard the criteria available to Hubendick, as probably more indicative of natural breeding populations I accept his revision. The shells reported here are apparently of the forms designated in the synonymy only.

Gyraulus parvus (Say), 1817

Pl. 1 Figs. 4-6.

(1) Planorbis (Torquis) parvus Say. Dall., 1905, Alaska Harriman Series, v. 13, p. 95.

(2) Gyraulus parvus (Say). Baker, 1928, Wisconsin Geol. Nat. Hist. Survey Bull. 70, p. 1, p. 374, pl. 23, fig. 27-31, & 39. Taylor, 1960, U. S. Geol. Survey Prof. Paper 337, p. 58, pl. 4, fig. 1-13, 17, 18.

Description of fossil material:- Small; 3½-4 whorls, pseudo-planispiral, dextral, advolute, shoulders rounded, abapical profile of

whorl slightly more obese than the adapical profile; surface ornamented with fine transverse costellae which occupy former aperture positions; nucleus sunken below subsequent whorls and unornamented; very wide apical and abapical umbilicuses, all whorls visible from either apical or abapical view; aperture deflected abapically except in shells with less than 3¼ whorls, forms a 45° angle with the axis of coiling, not operculate, without a callus.

UND *	No. of Whorls	Shell Height (mm)	Shell Diameter (mm)
3574-1	3 1/2	0.9	2.7
3574-2	3 1/2	0.9	2.9
3574-3	4	1.4	4.2
3574-4	3 1/2	0.9	2.9
3574-5	3 1/2	1.1	3.1

Occurrences:- A. 3512; B. 3610, 3621, 3634; C. 1772, 3598; D. 1766; E. 3652; F. 1788; G. 3466, 3578; H. 3540; J. 3424; K. 3486; L. 3340; M. 3370, 3386; N. 3397; O. 3358; Q. 3452, 3548; S. 3229, 3238, 3247, 3262, 3303, 3324, 3574; T. 3288; U. 3122; Y. 3174; Z. 3139; AA. 3147; AC. 3157; AD. 3188; AF. 3130, 3117; AI. 6151; AJ. 6163; AM. 6170.

Geologic Age:- Late Wisconsinan.

Remarks:- The specimens assigned to this species were distinguished largely on the basis of their having a wide adapical and abapical umbilicus, slightly excentric whorl profile, and the downward deflection of the last ¼ whorl in larger specimens and the tendency toward this deflection in shells not yet fully developed. Specimens of a similar form and size, but lacking the above characters with the exception of the wide umbilicus, have been designated as Gyraulus sp. It is quite possible that these latter specimens are merely a group of shell forms within the species G. parvus. The matter is receiving further study.

Promenetus exacuous (Say), 1821

Pl. 1 Fig. 7

(1) Planorbis (Menetus) exacuous (Say). Dall, 1905, Harriman Alaska series, v. 13, p. 91.

(2) Menetus exacuous (Say). Baker, 1928, Wisconsin Geol. Nat. Hist. Survey Bull. 70, pt. 1, p. 361, pl. 23, fig. 1-5.

(3) Promenetus exacuous exacuous (Say). Baker, 1945, Molluscan Family Planorbidae, p. 182.

Description of fossil material:- Small; 4 whorls; pseudoplanispiral, dextral, orthostrophic, discoidal shoulder of last whorl terminates in an acute angle, involute, nucleus below next whorl and unornamented; aperture ovate, without a callus, frequently broken away; surface cancellate threads; moderately wide apical and abapical umbilicus exposes all whorls.

UND #	No. of Whorls	Shell Height (mm)	Shell Diameter (mm)	Abapical Umbilicus Diameter (mm)
3249-1	3 1/2	1.4	4.4	---
3239-2	4	2.0	6.7	---
1794-1	3 1/2	1.4	4.2	1.4
1794-2	3 1/2	1.4	4.3	1.2
1794-3	3 1/2	4.4	1.3	1.0
1794-4	3	1.0	2.6	0.9
1794-5	3 1/4	1.1	3.9	1.0
1794-6	3 1/4	1.0	3.6	0.8
3232-1	3	1.1	3.0	0.7
3232-2	3	1.0	2.8	0.8

Occurrences:- B. 3616; D. 1794; F. 1782; G. 3585, 3467; J. 3413, 3425; K. 3482; M. 3372, 3380; N. 3309; Q. 3456, 3549; R. 3446; S. 3232, 3244, 3249, 3261, 3325, 3575; T. 3286; Y. 3175; Z. 3143; AB. 3169; AC. 3152; AD. 3189; AF. 3115, 3126; AJ. 6166.

Geologic Age:- Late Wisconsinan.

Armiger crista (Linne) 1758

Pl. 1 Fig. 8

(1) Planorbis (Armiger) crista (Linne). Dall, 1905, Harriman Alaska series, v. 13, p. 96.

(2) Gyraulus crista (Linne). Baker, 1928, Misc. Geol. Nat. Hist. Survey Bull. 70, pt. 1, p. 385-387, fig. 164.

(3) Armiger crista (Linne). Baker, 1945, Mell. Nam. Planorbidae, p. 78, pl. 76, fig. 6. Edmondson, 1959, Ward and Whipple's Fresh-water Biol., p. 1128, fig. 43, 17.

Description of fossil material:- Very small; 2-2½ whorls; pseudo-planispiral, dextral, apex flat, adapical profile angulate and interrupted by regularly spaced nodes which arise in thickened growth-interruption ridges; adapical profile rounded; surface ornamented with fine radial lines and ridges; the thickness of which varies in individuals; nucleus with spiral lines; sutures deeply impressed; umbilicus deep and wide; not operculate; without a callus.

UND #	No. of Whorls	Shell Height (mm)	Shell Diameter (mm)	No. of Nodes on Shell Peryphery
1760-1	2 1/2	0.4	1.4	18
1760-2	2 1/4	0.3	1.0	10
3318	2 1/4	0.4	1.2	16

Occurrences:- B. 3590, 3615, 3629; D. 1760; F. 1785; G. 3506, 3464; J. 3406; K. 3008; S. 3318; AA. 3144; AD. 3190; AF. 3119, 3128; AI. 6150.

Geologic Age:- Late Wisconsinan.

Helisoma trivolvis (Say) 1817.

(1) Planorbis (Pierosoma) trivolvis (Say). Dall, 1905, Harriman Alaska Ser., v. 13, p. 80, fig. 68, 69.

(2) Helisoma trivolvis (Say). Baker, 1928, Wisc. Geol. Nat. Hist. Survey, Bull. 70, pt. 1, p. 330, pl. 20, fig. 1-13, 33, 23. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, pl. 16, fig. V.

(3) Helisoma (Pierosoma) trivolvis (Say). Taylor, 1960, U. S. Geol. Survey Prof. Paper 337, p. 59.

Description of fossil material:- Large; 1½-2 whorls (immature specimens); pseudoplanispiral, sinestral, adapical carinae, adapical profile rounded; nucleus and first 1 to 1½ whorls sunken below subsequent whorls; sutures deep; coarse radiating threads on all whorls save the nucleus; aperture roundly lunate and recurved slightly, not expanded greatly, a distinct callus; umbilicus small, all whorls visible.

Occurrences:- C. 1795; F. 1779; N. 3402; Q. 3550.

Geologic Age:- Late Wisconsinan.

Remarks:- All specimens were fragmentary, therefore no measurements are available.

Helisoma companulatum (Say), 1821

Pl. 1 Fig. 1.

(1) Planorbis (Planorbella) companulatus Say. Dall, 1905, Alaska Harriman Ser., v. 13, p. 90, fig. 70.

(2) Helisoma companulata (Say). Baker, 1928, Wisc. Geol. Nat. Hist. Survey, Bull. 70, pt. 1, p. 345, pl. 21, fig. 1, 2, 4, 5, 8, 9, 13, and 14.

(3) Helisoma companulatum (Say). Baker, 1945, Moll. Fam. Planorbidae, pl. 108, fig. 1-12, 14-17 (only); pl. 109, 1-6.

(4) Helisoma companulatum ferrissi F. C. Baker. Baker, 1945, Moll. Fam. Planorbidae, pl. 108, fig. 18-34.

Description of fossil material:- Medium; 5 whorls; planispiral, sinestral; whorl angulate at adapical shoulder through third whorl,

rounded thereafter, no carinae; surface with strong, regularly spaced transverse costae at former aperture positions; aperture strongly campanulate, last 1/8 of whorl expanded; parietal callus; narrow, deep umbilicus, nucleus and subsequent 2 whorls depressed.

UND #	No. of Whorls	Shell Height (mm)	Shell Diameter (mm)	Aperture Height (mm)	Aperture Diameter (mm)
3002	4 1/2	4.2	8.3	---	---
3565	5	5.8	11.4	5.0	4.6

Occurrences:- D. 1763; H. 3543; K. 3002; S. 3565; Y. 3171; AB. 3164; AC. 3154; AD. 3182.

Geologic Age:- Late Wisconsinan.

Helisoma anceps (Menke), 1830

(1) Planorbis (Helisoma) bicarinata Say. Dall, 1905, Harriman Alaska series, v. 13, p. 87, fig. 64.

(2) Helisoma antrosa (Conrad). Baker, 1928, Wisconsin Geol. Nat. Hist. Survey Bull., 70, pt. 1, p. 317, pl. 19, 8-5. Frye and Leonard, 1952, Kansas Geol. Survey Bull., 99, pl. 15, fig. y. Tuthill, Clayton, and Laird, 1963, Amer. Midl. Nat. (in press).

(3) Helisoma anceps (Menke). Taylor, 1960, U. S. Geol. Survey Professional Paper 337, p. 58, 59.

Description of fossil material:- Medium to large; 3 to 3½ whorls; planispiral, sinestral; whorl profile biangulate, apical angulation forms an inward sloping ramp and in central whorls a carina, abapical angulation more acute than the apical one and forms an infundibulate umbilicus and a carina; nucleus small and visible from both above and below, unornamented; whorls with transverse costae at former aperture positions; umbilicus moderately wide, apical umbilicus shallow, all whorls visible in apical and abapical views; aperture campanulate, parietal callus.

UND #	No. of Whorls	Shell Height (mm)	Shell Diameter (mm)	Aperture Height (mm)	Aperture Diameter (mm)
3267	3 1/2	7.0	12.7	6.0	7.2
3571-1	3 1/2	4.6	8.0	4.0	4.6
3571-2	3 1/2	4.3	7.7	3.8	4.4
3571-3	3	3.3	5.5	2.5	3.3

Occurrences:- A. 3514; B. 3624; C. 1774; G. 3581; J. 3421; K. 3481; L. 3343; M. 3384; S. 3239, 3254, 3268; T. 3267; X. 3131; Y. 3172; W. 3148; AC. 3155; AD. 3180; AF. 3123; 3114.

Geologic Age:- Late Wisconsinan.

Remarks:- All of the specimens of H. sucsus found during this study appear to be smaller than specimens of the same species to be found on the Coteau and elsewhere in the central United States today.

Ferrissia cf. F. tarda (Say), 1865

(1) Ferrissia tarda (Say). Baker, 1928, Wisc. Geol. and Nat. Hist. Survey Bull. 70, pt. 1, p. 399-401, pl. 26, fig. 6-9, text fig. 171.

Description of the fossil material:- Very small, patelliform, apex eccentric to right and rear; concentric thread lines centering on apex (posterior margin broken).

UND #	Height (mm)	Width (mm)	Length (mm)
3256	0.5	1.0	1.4

Occurrence:- S. 3256.

Geologic Age:- Late Wisconsinan.

Remarks:- Only one specimen of the genus Ferrissia has been recovered from sediments of the Missouri Coteau. This may be due to the frail nature of this form and the unavoidable roughness of handling attendant to wet sieving.

Succinea avara (Say), 1824

(1) Succinea avara Say. Dall, 1905, Harriman Alaska Ser., v. 13, p. 57, fig. 39, Pilsbry, 1948, Acad. Nat. Sci. Phila., Mono. 3, v. 2, pt. 2, p. 837, fig. 455. Leonard, 1950, Kansas Univ. Paleo. Contrib., art. 3, p. 23, pl. 4, fig. 6. 1952, Kansas Univ. Paleo. Contrib., art. 4, p. 23, pl. 2, fig. 6.

Description of fossil material:- Medium; very thin, 3 whorls; width about 3/4 of height; aperture 2/3 of height, oval, no callus; surface ornamented with wrinkled lines in former aperture positions.

Occurrence:- C. 1796.

Geologic Age:- Late Pleistocene.

Remarks:- The assignment of members of the family Succindeidae to species on shell criteria alone is not possible with any degree of certainty. The shells seen seem to best satisfy the characters given for Succinea avara. The genus is extremely common in the Missouri Coteau district at present and the possibility that these specimens are included by contamination is raised by the striking paucity of terrestrial snail shells in the 40 sites reported here. Mr. Clayton, the collector of this site, has suggested the possibility that contamination of the sample may have occurred during collection. Succinea is, however, known to have occurred on the Great Plains throughout the Wisconsinan Stage and earlier (Leonard, 1950, p. 23, 24; 1952, p. 23, 24; Taylor, 1960, p. 78) so that its presence in Burnstad Drift is not anomalous.

Gastrocopta sp.

Description of fossil material:- Very small; relatively thick, 6 whorls, narrowly perforate; cylindrical; columellar lamella fused

with parietal lamella forming an inverted Y in aperture, lower and outer aperturel margin broken away.

Occurrence:- B. 3594.

Geologic Age:- Late Pleistocene.

Remarks:- The genus Gastrocopta is represented in the Missouri Cotaux district at present by at least 3 species. It is possible that the specimens of Gastrocopta from this site are included by contamination.

with parietal lamella forming an inverted Y in aperture, lower and outer apertural margin broken away.

Occurrence:- B. 3594.

Geologic Age:- Late Pleistocene.

Remarks:- The genus Gastrocopta is represented in the Missouri Coteau district at present by at least 3 species. It is possible that the specimens of Gastrocopta from this site are included by contamination.

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PLATE 1

Fig. 1. Helisoma campanulatum (Say). Clear Lake site (K), approx. 3, 7 X, (UND 3002).

Figs. 2, 3. Helisoma anceps (Menke). Clear Lake site (K), approx. 5 X, 2. apical view, 3. abapical view.

Figs. 4-6. Gyraulus parvus (Say). Nue Farm site (S), 4. approx. 6.3 X, apical view, 5. approx. 7.4 X, abapical view, 6. approx. 7.4 X, apertural view, (UND 3574-3).

Fig. 7. Promenetus exacuous (Say). Schlenker Farm site (D), approx. 6.8 X, (UND 1794-1).

Fig. 8. Armiger crista (Linne). Nue Farm site (S), approx. 7.5 X, (UND 3318).

Figs. 9, 10. Lymnaea humilis (Say). 9. Nue Farm site (S), approx. 4.6 X, (UND 3567-1), 10. Cleveland site (A), approx. 5.7 X, (UND 3511-7).

Fig. 11. Lymnaea stagnalis (Linne). Nue Farm site (S), approx. 1.4 X, (UND 3209-3).

Figs. 12, 13. Physa sp. 12. Mummy Cat Slough site (J), approx. 7.0 X, (UND 3420-3), 13. Schlenker Farm site (D), approx. 5.7 X, (UND 1764-1).

Figs. 14, 16. Valvata tricarinata (Say). 14. Iowa site 1 (T), approx. 5 X, (UND 3284-5), 16. Nue Farm site (S), approx. 8.5 X, (UND 3570-3).

Fig. 15. Valvata lewisi Currier. Rosenthal 2 site (M), approx. 4.9 X, (UND 3385-2).

Fig. 17. Amnicola sp. Nue Farm site (S), approx. 8 X, (UND 3493).

Figs. 18, 19. Amnicola limosa (Say). Nue Farm site (S), 18. approx. 5 X, (UND 3569-1), 19. approx. 4.2 X, (UND 3569-4).

Fig. 20. Ferrissia sp. Nue Farm site (S), approx. 6 X, (UND 3256).

Fig. 21. Pisidium sp. Nue Farm site (S), approx. 2.3 X, (UND 3220-5).

Plate I.


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PLATE 2

Fig. 1. Anodonta grandis Say. Nue Farm site (S), approx. 1.3 X, (UND 3207-1).

Figs. 2, 4. Sphaerium sp. 2. Nue Farm site (S), approx. 3.8 X, (UND 3301), 4. Cleveland site (A), approx. 4.2 X, (UND 3521-1).

Fig. 3. Pearl from naiad. Lowenthal site (I), IX, (UND 3336).

Figs. 5-7. Lampsilis radiata siliquoidea (Barnes). Nue Farm site (S), 5. female, right valve, showing produced posterior and posterior-ventral margins typical of this sex in this species, approx. 1.2 X, (UND 3241); 6. articulated valves of male showing excellent preservation of shell and ligament fibers, approx. 0.7 X, (UND 3279); 7. male, left valve, approx. 0.8 X, (UND 3213-1).

Plate 2.

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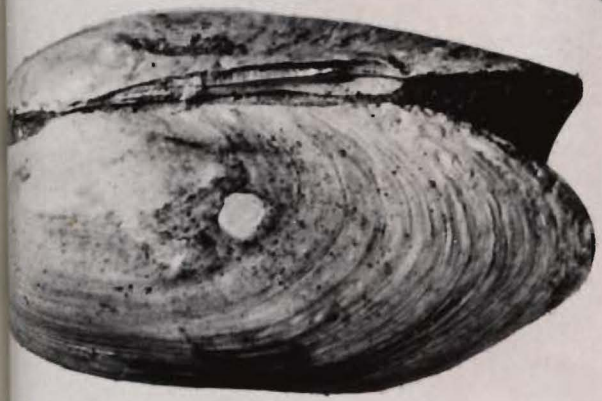

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